Geology based f_0 model of New England

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Abstract

In this research, we develop a statistical f_0 model of New England using a database of 1627 measurements sub-divided by 1) geologically-based sub-region and 2) surficial geology. We first clip the surficial geology to each sub-region and then subdivide the f_0 dataset by the surficial geology within each subregion. We then calculate statistics of each unit's f_0 distribution and assign those statistics to their respective sub-region geologic unit polygon. We do this for every sub-region, and then merge the dataset back together, developing a generalized map of expected f_0 values in New England. We then discuss the relationship between f_0 and the more commonly used site response variable Vs30 and argue that f_0 is advantageous for regional-scale studies because it contains both depth and shear wave velocity information and can be collected cheaply and at scale.

Dataset

We begin our analysis by looking at the undivided dataset. Figure 1 shows the complete f_0 database – a combination of data collected in the field and compiled from other researchers. Figure 2 shows a digital elevation model of New England for reference and to discuss future addition of geomorphology into the model. Figure 3 shows the surficial geologic map the we developed for New England by combining the state scale maps and reducing the number of classified units. Figure 4 shows the sub-regions that we defined by elevation and geologic history. Most of the land in the study is classified as till and is contained within the general New England subregion.

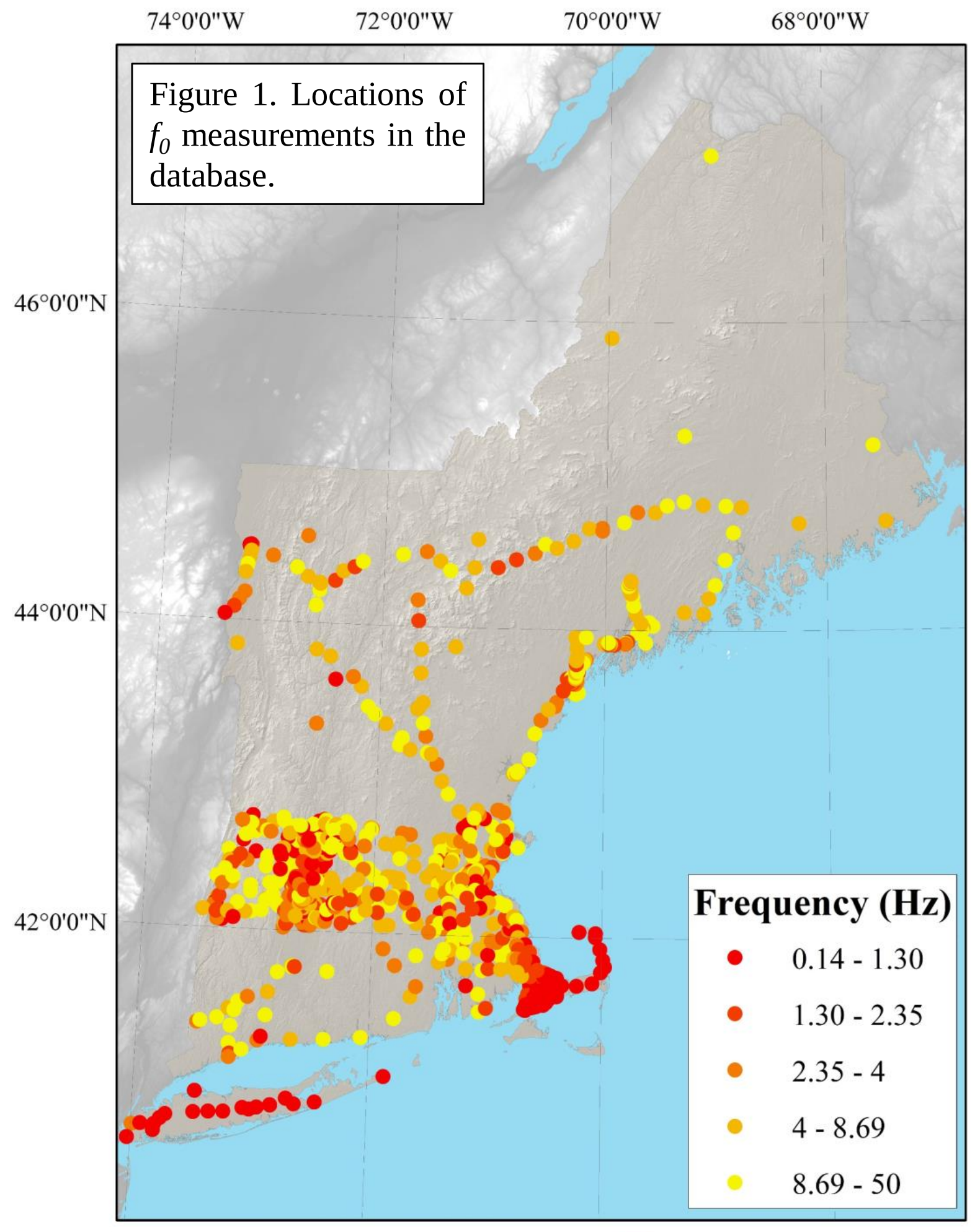


Figure 1. Locations of f_0 measurements in the database.

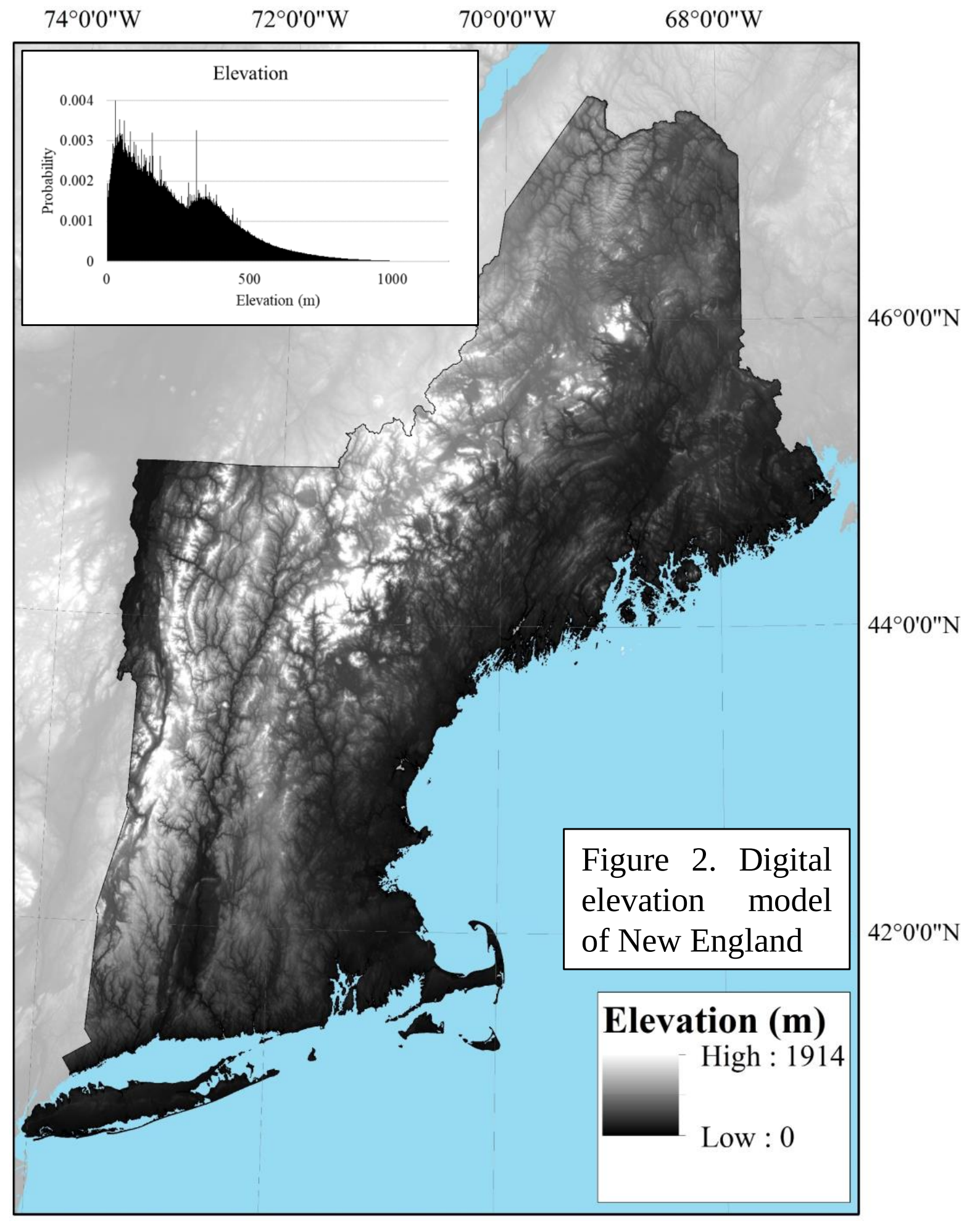


Figure 2. Digital elevation model of New England

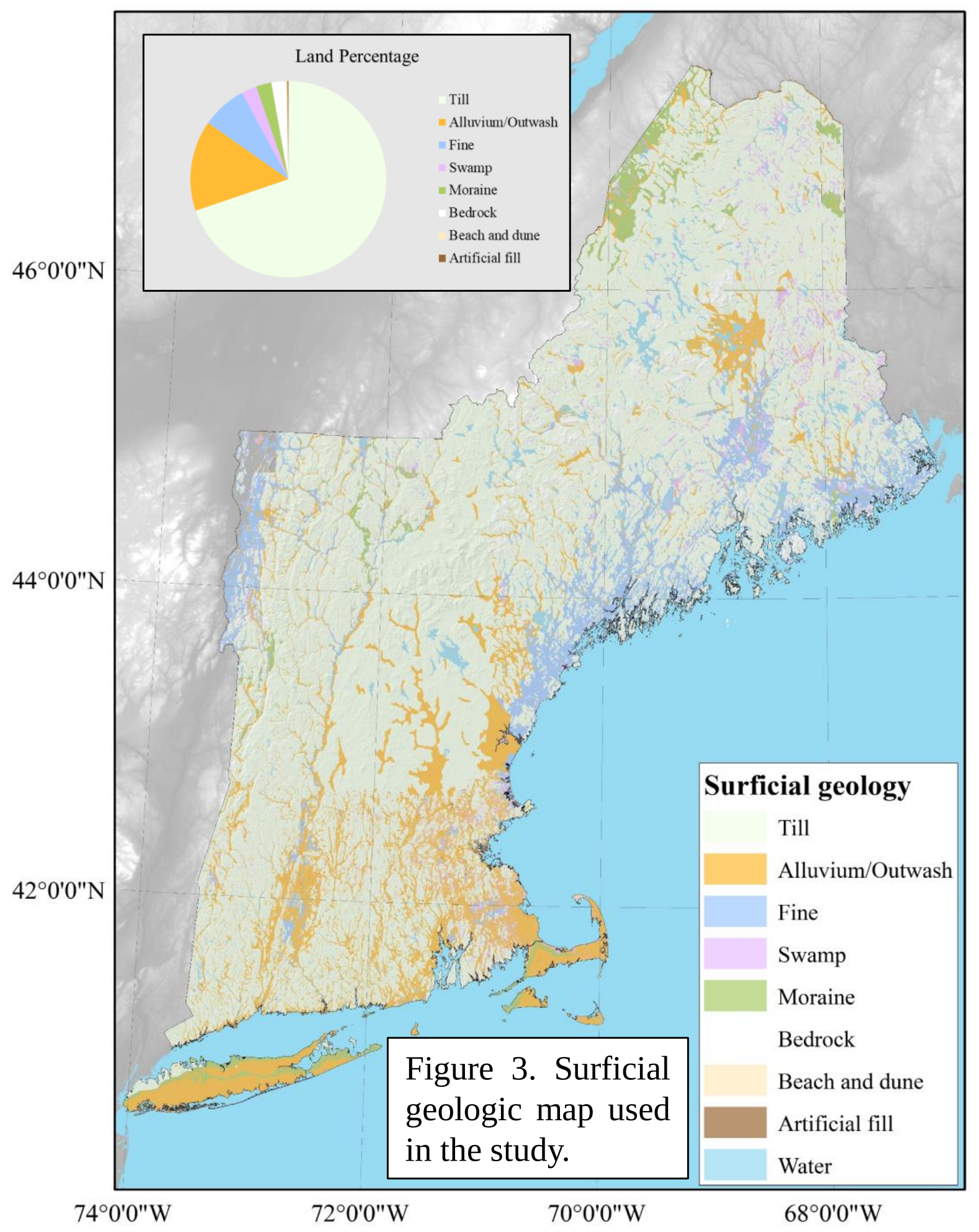


Figure 3. Surficial geologic map used in the study.

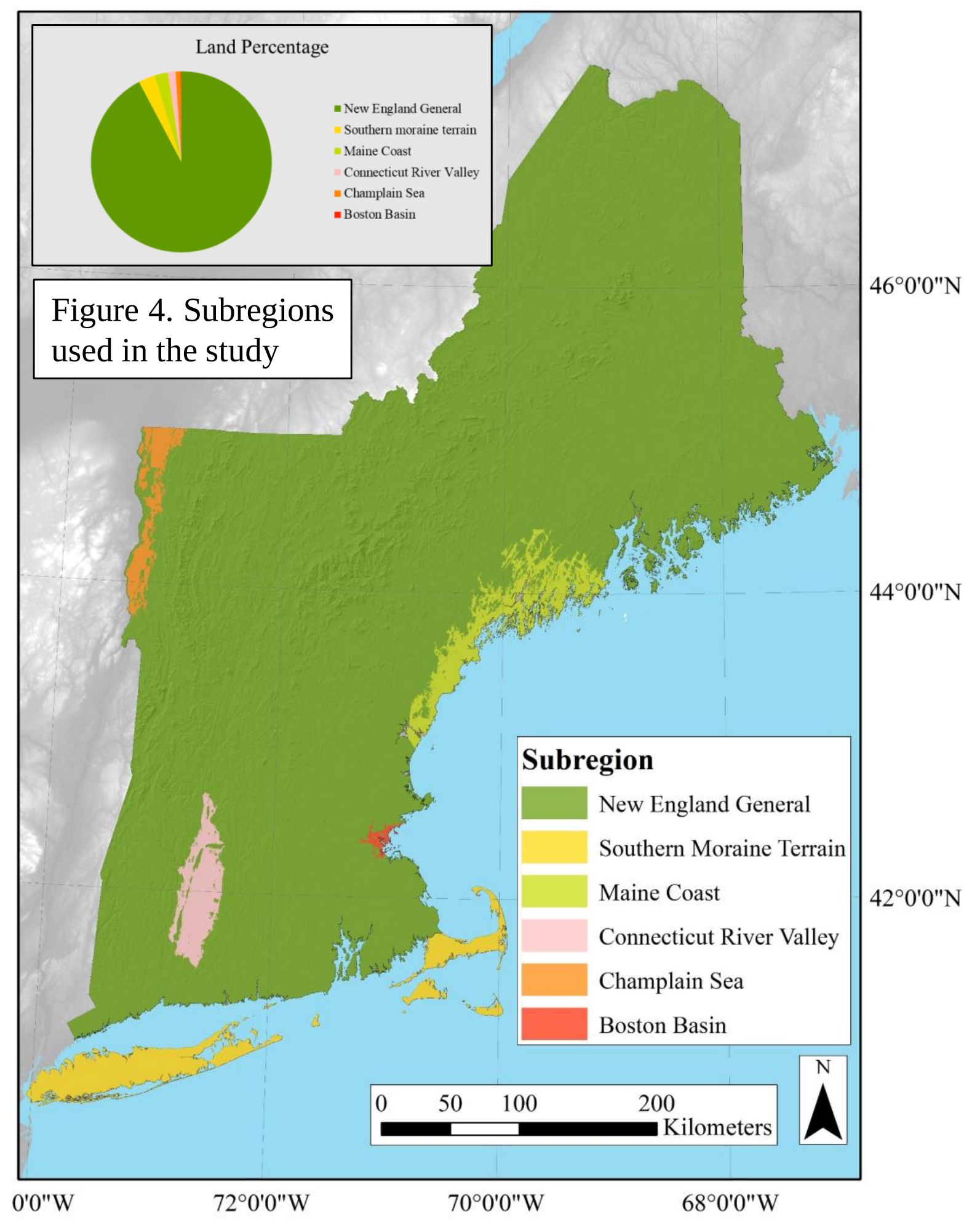


Figure 4. Subregions used in the study

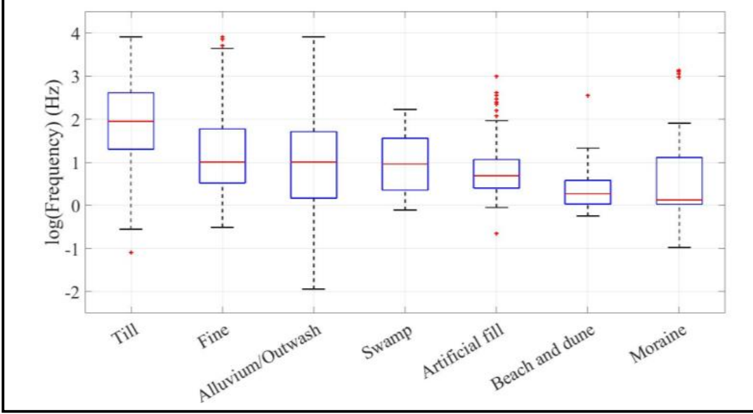


Figure 5. The distributions of f_0 within each surficial geologic unit of figure 3.

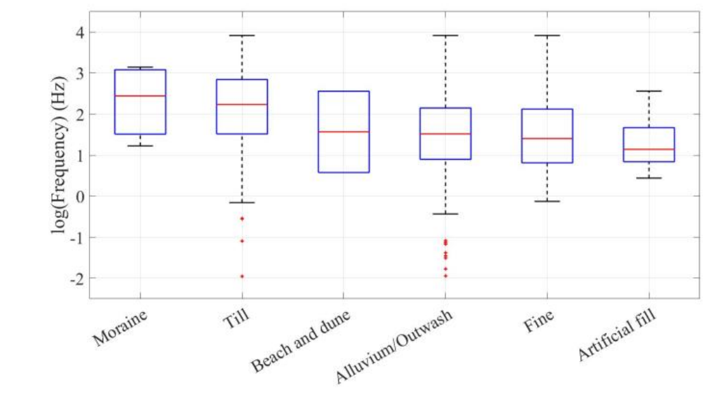


Figure 6. The distributions of f_0 within the New England subregion in figure 4.

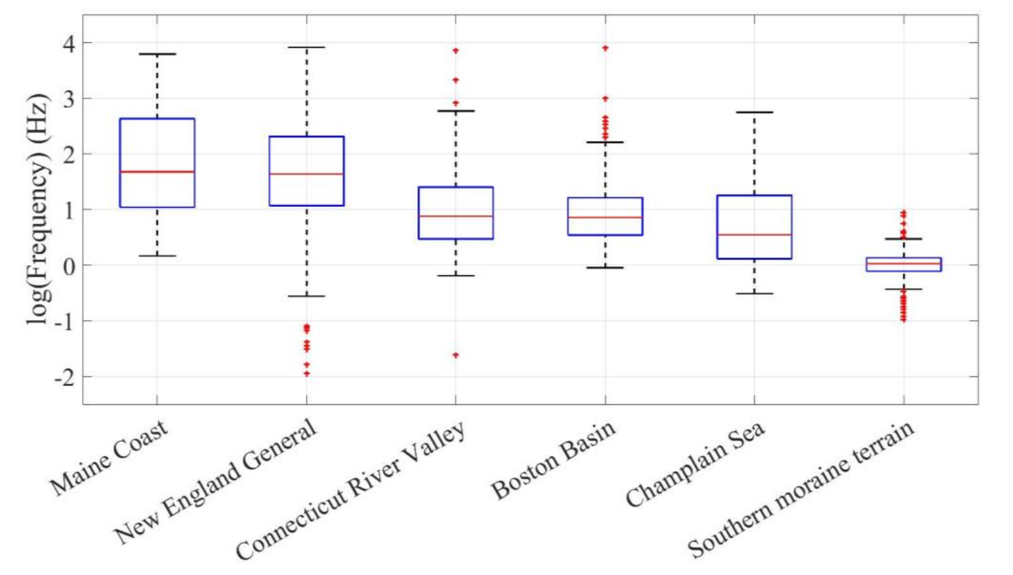


Figure 7. The distributions of f_0 within each New England subregion in figure 4. There appear to be 3 groups of medians with the southern moraine terrain consistently having the lowest of f_0 values

Boston Basin

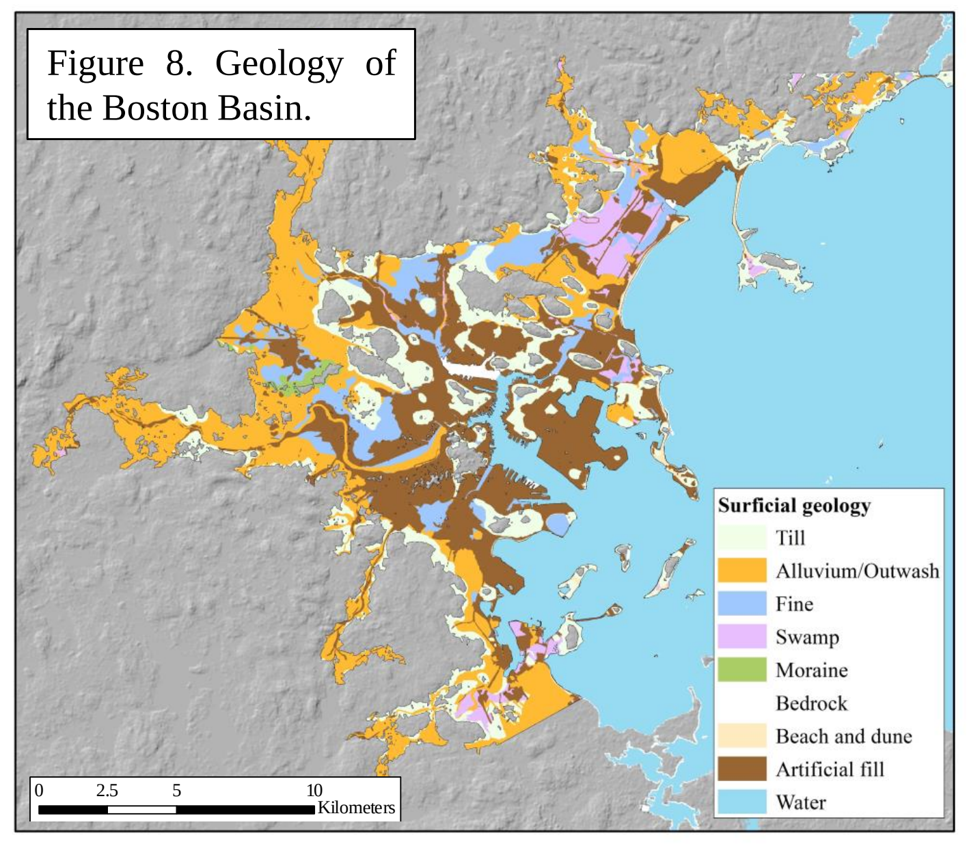


Figure 8. Geology of the Boston Basin.

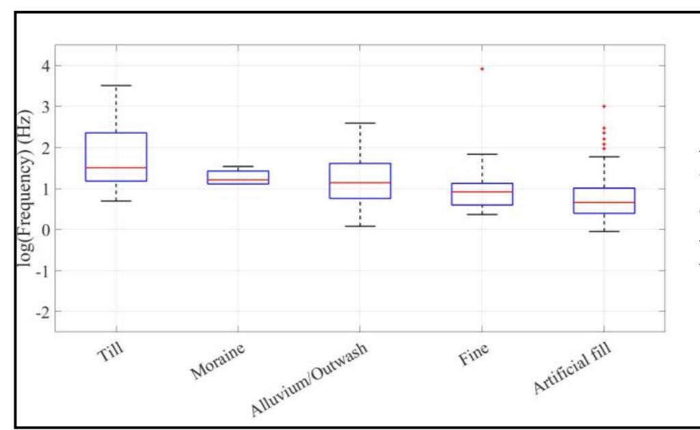


Figure 9. Distributions of f_0 within the Boston Basin sub-region

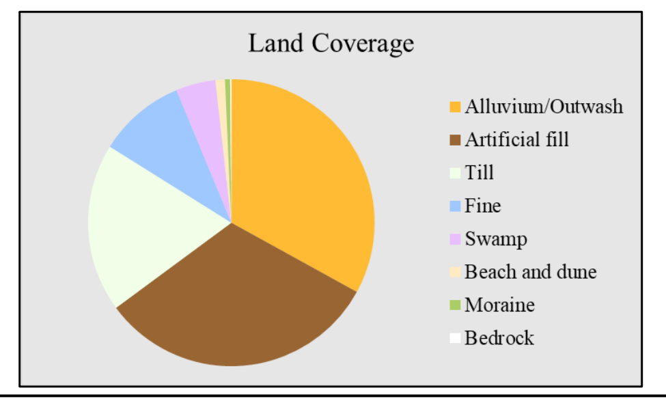


Figure 10. Proportion of land area of each geologic unit within the Boston Basin

The Boston Basin contains significant deposits of artificial fill from centuries of land development as well as fine glaciomarine clay deposited after the last glaciation period. Additionally, the Charles and Mystic River flood plains contain deep deposits of unconsolidated alluvium. As a result, much of the city subsurface is deep, has low velocities and, on average tends to have lower f_0 values than New England as a whole. There are drumlins within the basin limits with higher frequencies classified as till (figure 9).

Maine Coast

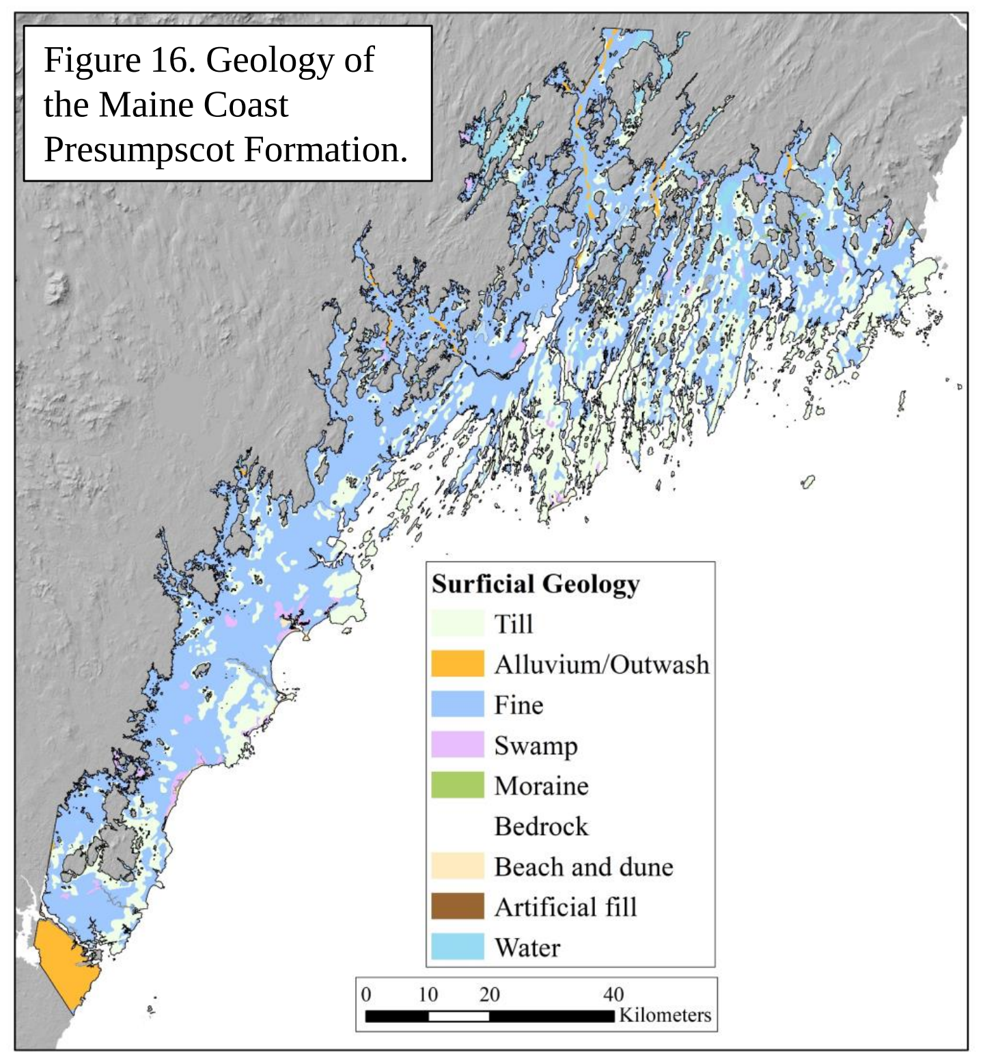


Figure 16. Geology of the Maine Coast Presumpscot Formation.

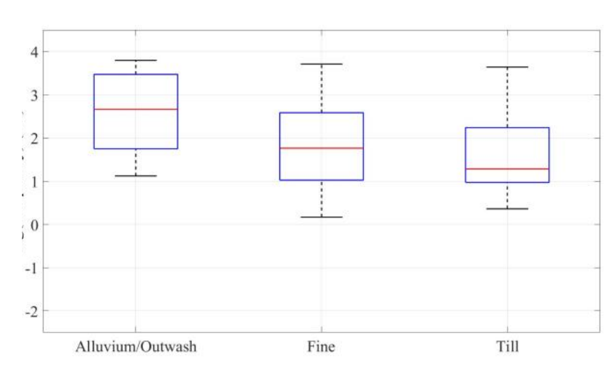


Figure 17. Distributions of f_0 within the Maine Coast sub-region

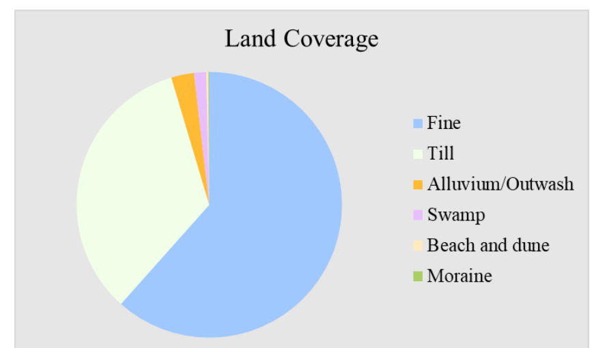


Figure 18. Proportion of land area of each geologic unit within the Maine coast sediments

Like the Champlain Sea and the Boston Basin, the Maine Coast is composed of glaciomarine clay – the Presumpscot Formation. Unlike the other two areas, however, we found less evidence for deep deposits of the unit, with consistently higher f_0 values within the unit, perhaps due to erosion of the clay.

Connecticut River Valley

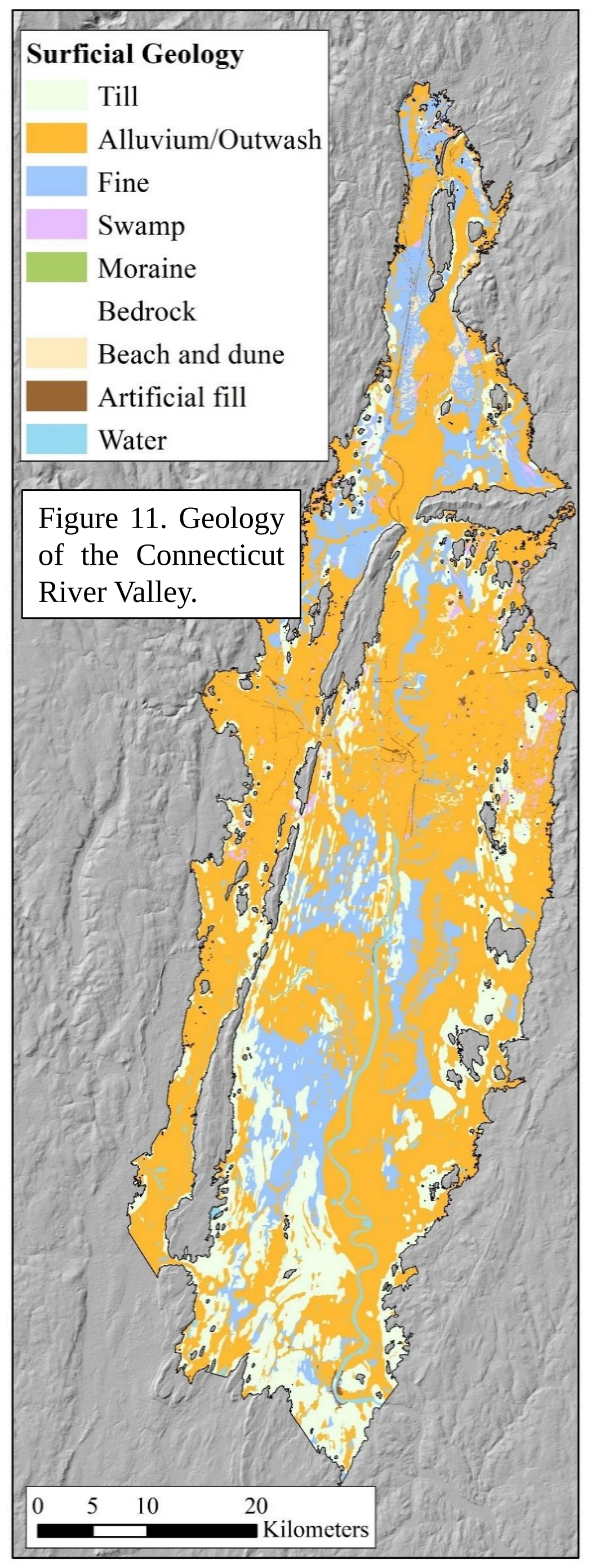


Figure 11. Geology of the Connecticut River Valley.

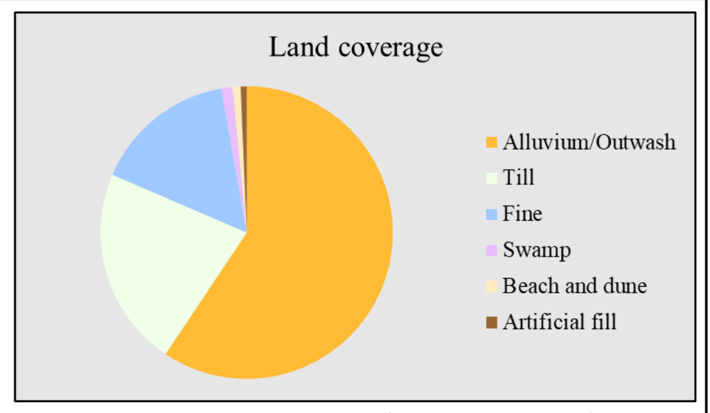


Figure 12. Proportion of land area of each geologic unit within the Connecticut River Valley

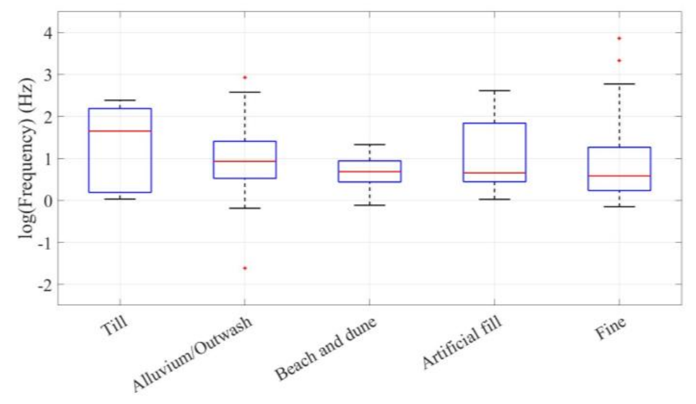


Figure 13. Distributions of f_0 within the Boston Basin sub-region

The CRV contains flood plain alluvium from the Connecticut River and fine deposits from Glacial Lake Hitchcock, both in higher percentages than the New England average. It tends to have f_0 values between 1 and 3.5 Hz, low for New England, but not as low as in the Southern Moraine Terrain.

Champlain Sea

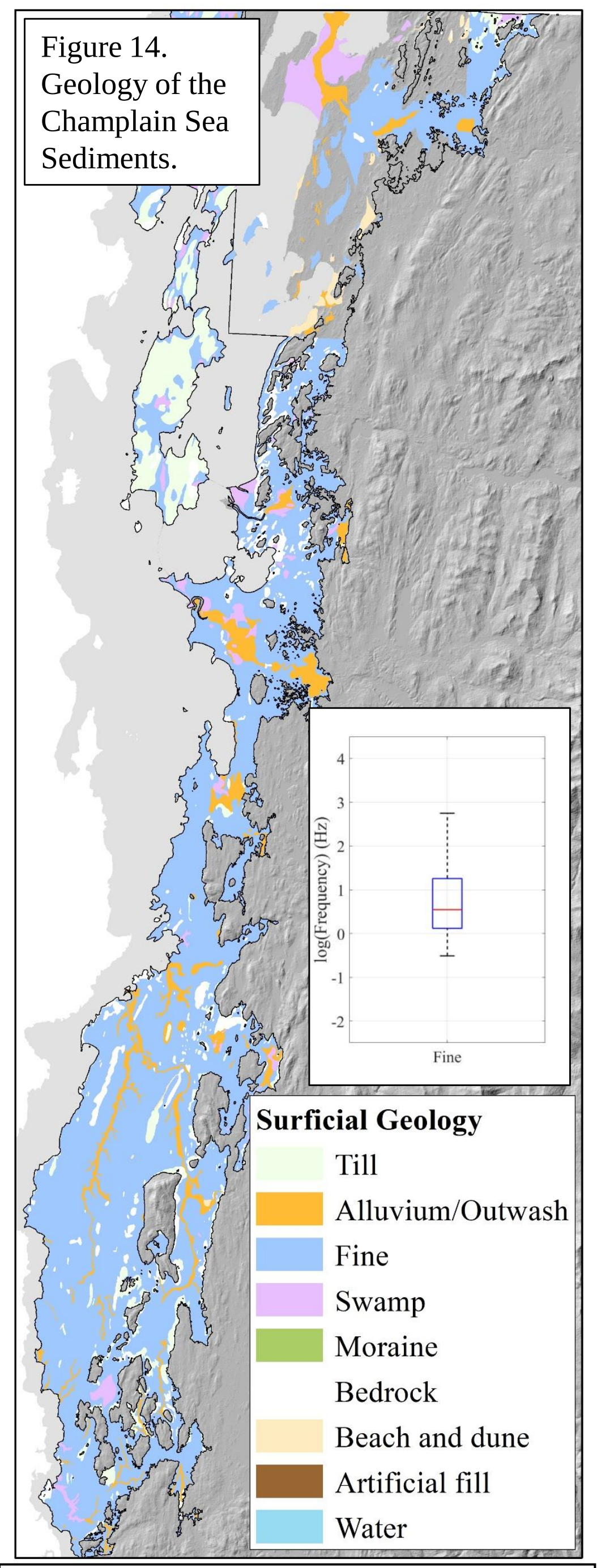


Figure 14. Geology of the Champlain Sea Sediments.

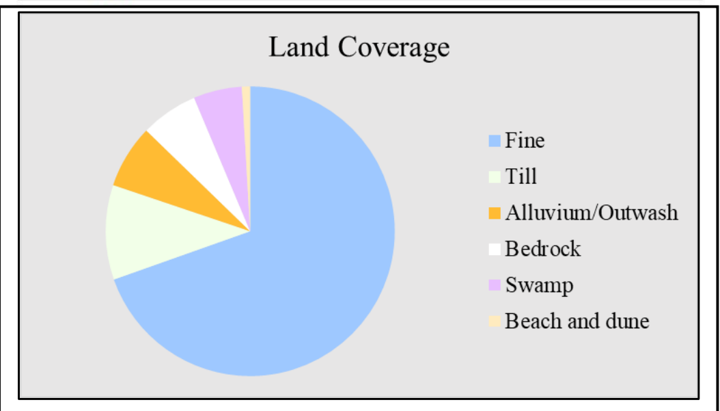


Figure 15. Proportion of land area of each geologic unit within the Champlain Sea Sediments

The Champlain Sea sediments are almost entirely classified as fine and tend to have low frequencies. The deposit makes up most of the low land adjacent to the Champlain Sea, deposited below the ancient high-water line.

Southern Moraine Terrain

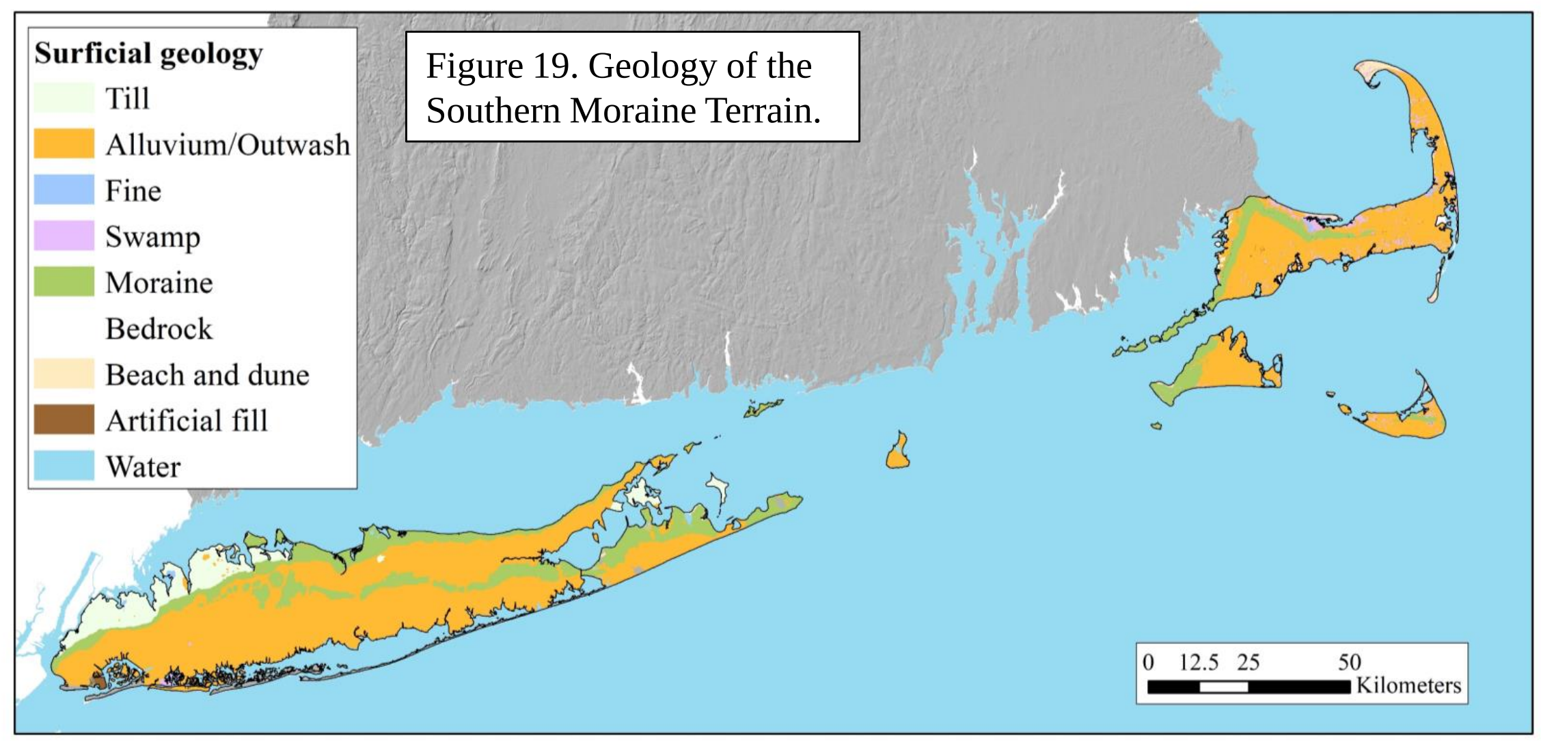


Figure 19. Geology of the Southern Moraine Terrain.

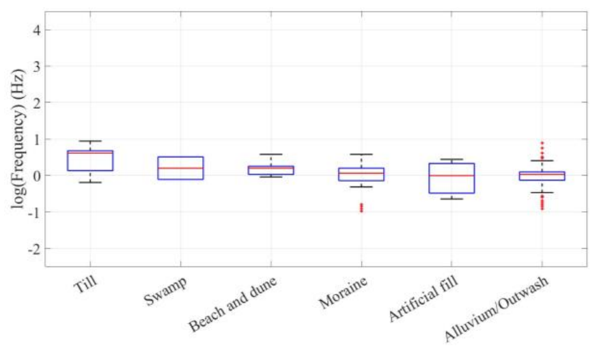


Figure 20. Distributions of f_0 within the Southern Moraine Terrain

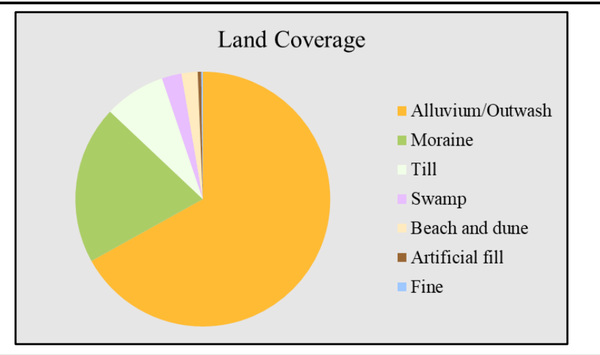


Figure 21. Proportion of land area of each geologic unit within the Southern Moraine Terrain

The Southern Moraine Terrain containing the Cape and Long Island is the simplest of the subregions as it has consistently low f_0 values within a narrow range. This pattern is nearly independent of geology and is instead likely driven by large-scale bedrock sloping towards the southeast.

Discussion/Conclusion

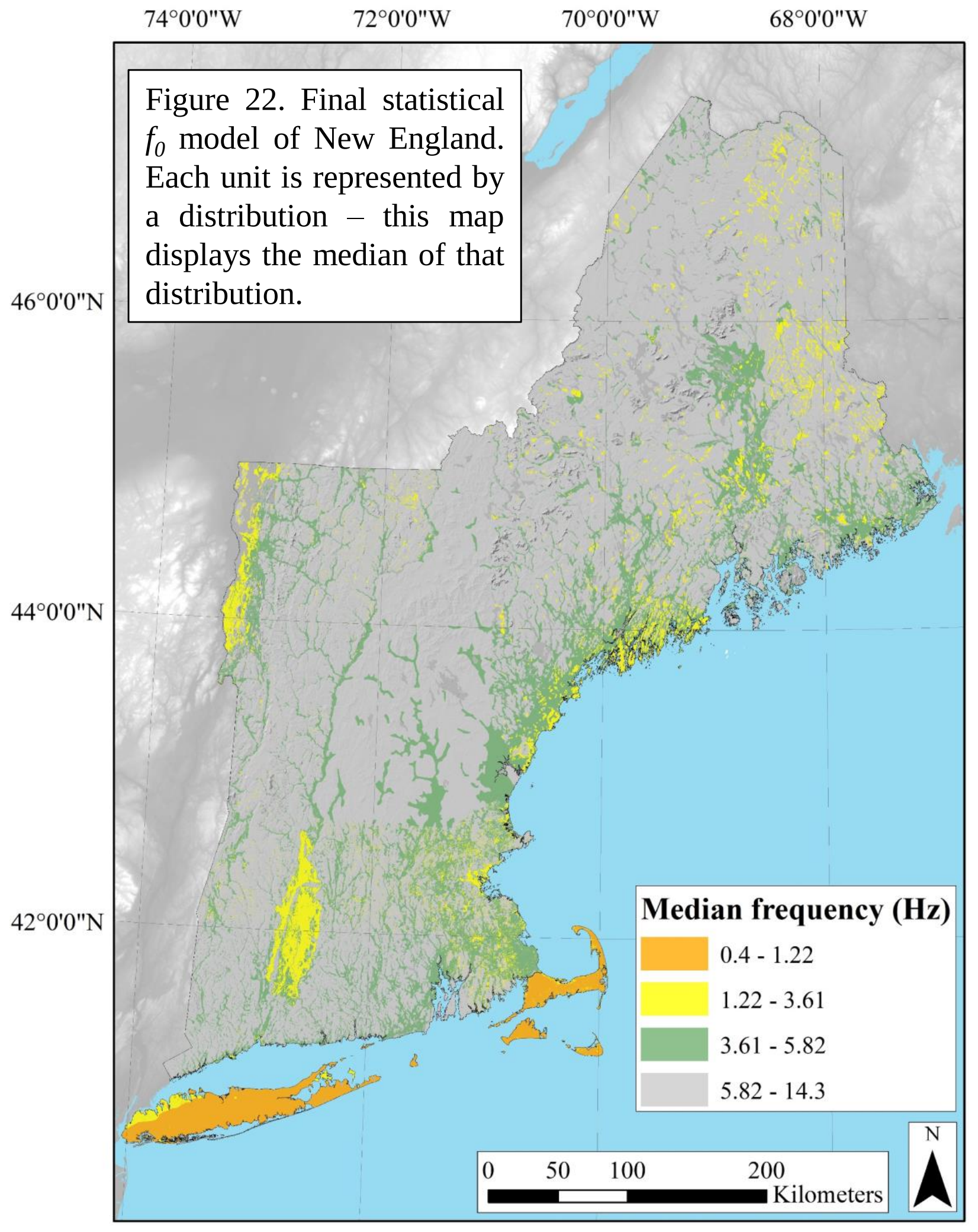
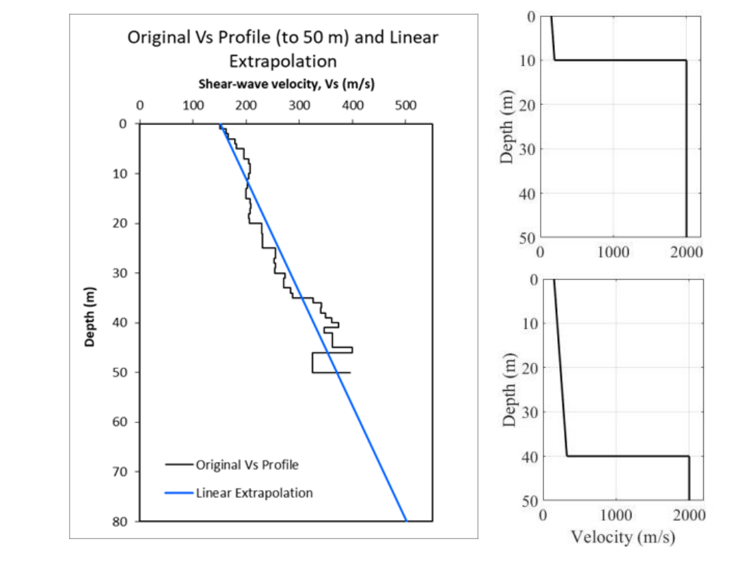


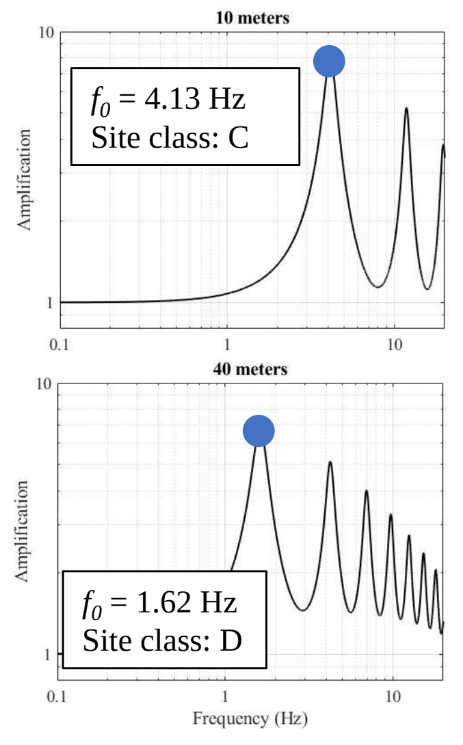
Figure 22. Final statistical f_0 model of New England. Each unit is represented by a distribution – this map displays the median of that distribution.

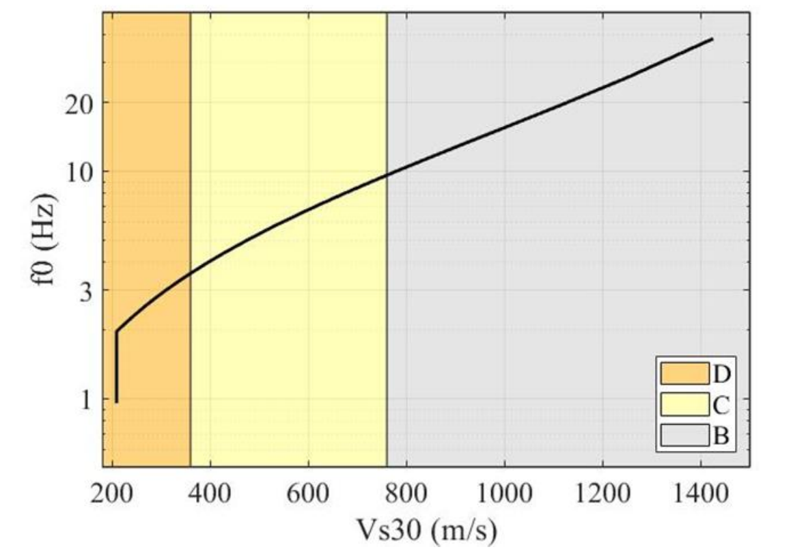
In our study, the lowest frequency region, and therefore the deepest, is the Southern Moraine Terrain (figure 22). It also has the least amount of f_0 variability and is therefore the easiest to model. Following the Southern Moraine Terrain with higher frequencies is the Champlain Sea, the Connecticut River Valley and the Boston Basin. The Connecticut River Valley is mostly flood plain alluvium from the Connecticut River with some fines deposited by Glacial Lake Hitchcock. Both the Boston Basin and the Champlain Sea are predominantly fine deposits of glaciomarine clay, The Boston Blue Clay and Champlain Sea Sediments, respectively. Finally, the Maine Coast, though also containing mapped glaciomarine deposits has similar frequencies to the rest of New England indicating that despite the low velocity of the clays, the deposits are likely to be shallower than the deposits in the other regions that we identified.

By using f_0 we can collect more data than we would using a measure like Vs30. Despite the non-uniqueness of the output - a difference in frequency can be attributed to a change in depth, velocity or both - f_0 does a good job identifying amplifiable geologic deposits that require further exploration and allows us to make a first approximation at ranking their depths and velocities. With either depth or velocity information in addition to frequency - with a nearby borehole or a velocity profile - it is possible to get a very clear picture about the general site response behavior of a soil unit of interest.

f_0 to Vs30-based site class relationship







Given a uniform, laterally homogenous velocity profile, one can plot S-wave fundamental resonance against Vs30, thus relating f_0 to site class

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