Using ShoreZone to Model Suitable Forage Fish Spawning Habitat in the Gulf Islands

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Introduction

Forage fish are those species that are prey for larger fish, birds and marine mammals, including many commercially important species. They support important marine food webs and are therefore important species for management and conservation. Two species of forage fish, Pacific Sand Lance (*Ammodytes hexapterus*) and Surf Smelt (*Hypomesus pretiosus*), are found in British Columbia waters and use intertidal beaches for spawning. This use of the intertidal makes these populations more vulnerable as they are more likely to come into conflict with anthropogenic uses of that zone. This makes it important that suitable spawning beaches are identified so they can be properly managed.

The purpose of this project is to build on previous exercises comparing ShoreZone data to known forage fish spawning beaches to determine which ShoreZone attributes are associated with those beaches. The intent is to build a model that can reasonably predict suitable forage fish spawning beaches for management and planning purposes where ground survey data does not currently exist and to help direct future ground-based research. This project takes the results from those previous studies and applies the suggested model to five of the southern Gulf Islands in British Columbia where both ShoreZone mapping and ground survey data exist. The results of that model were then compared to the existing ground surveys in the Gulf Islands and the resulting data was used to refine the model.

Data Sources in the Gulf Islands

The ShoreZone coastal imaging and habitat mapping protocol was initially developed and tested in the southern Strait of Georgia in 1979 (Howes *et al*., 1994). It was initially conceived as an oil spill planning and response tool, but has been used for many other purposes over time. The fundamental basis of ShoreZone is using oblique, low-altitude imagery to segment a digital shoreline into relatively homogenous units using a standardized protocol (see Cook *et al*., 2017 for the most recent version of that protocol). These units are then divided into relatively homogenous across-shore components which describe different aspects of the beach. Figure 1 shows an example of this segmentation with the beach on the right of the figure having a sand and pebble storm berm in the high intertidal and a beach face with cobble over sand/pebble in the mid to low intertidal.

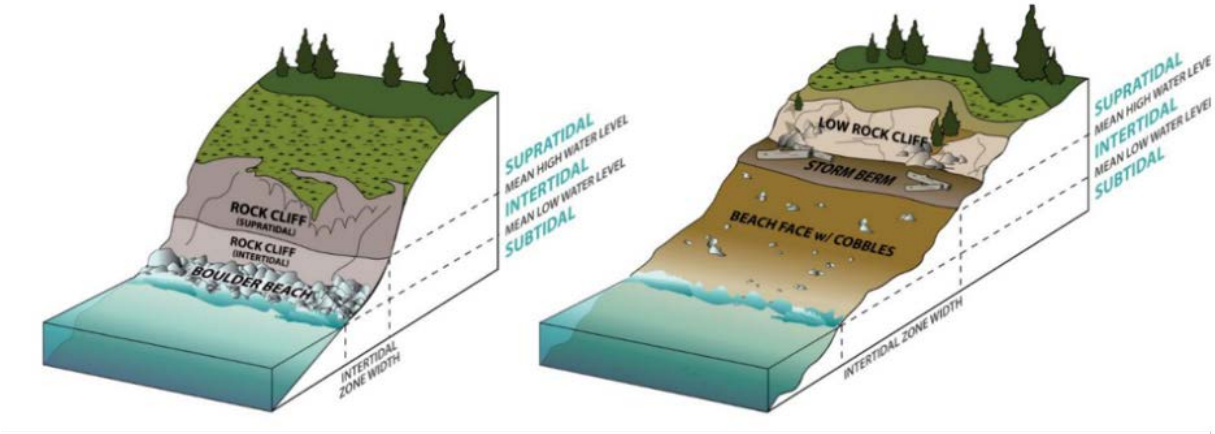

Figure 1. Across-shore zones and components on a steep (left) and moderately inclined (right) shoreline.

The very first ShoreZone imaging survey was completed around Salt Spring, Gabriola and Galiano Islands in 1979. This imagery was mapped for physical attributes but not biological as they had not yet been developed for ShoreZone at that point. Also, still photos had not yet become part of the imaging protocol so those islands only had video imagery. All of the southern Gulf Islands were re-imaged in 2004 except Galiano Island, which was re-imaged in 2006 (Figure 2). Video and 35mm photos were taken for both surveys. Portions of the imagery was re-mapped in 2007 (Salt Spring, North and South Pender, and Mayne Islands) with Thetis Island re-mapping completed in 2010 (Figure 3). This re-mapping included the biological attributes (Biobands, Biological Wave Exposure and Habitat Class).

The Gulf Islands also have a robust forage fish spawning ground survey dataset. The data is all publicly available through the Islands Trust Fund website at http://www.islandstrustfund.bc.ca/initiatives/marineconservation/foragefish.aspx. This data spans the southern Gulf Islands, the northern Gulf Islands and the Islands in Howe Sound. These ground surveys collected sediment samples on potentially suitable beaches for grain-size analysis. Statistical analysis was used to compare the grain-size distribution to that of known forage fish spawning beaches in BC and Washington State (de Graaf, 2017; de Graaf, 2014; de Graaf, 2013). Based on this analysis, the beaches surveyed were classed as suitable or not suitable spawning habitat. The surveys did not include embryo sampling so these beaches cannot be confirmed as spawning sites, although some spawning surveys have also been conducted in the area. For the purposes of this study, it is assumed the ground survey data provides a more complete picture of the amount and distribution of suitable forage fish spawning habitat in the study area.

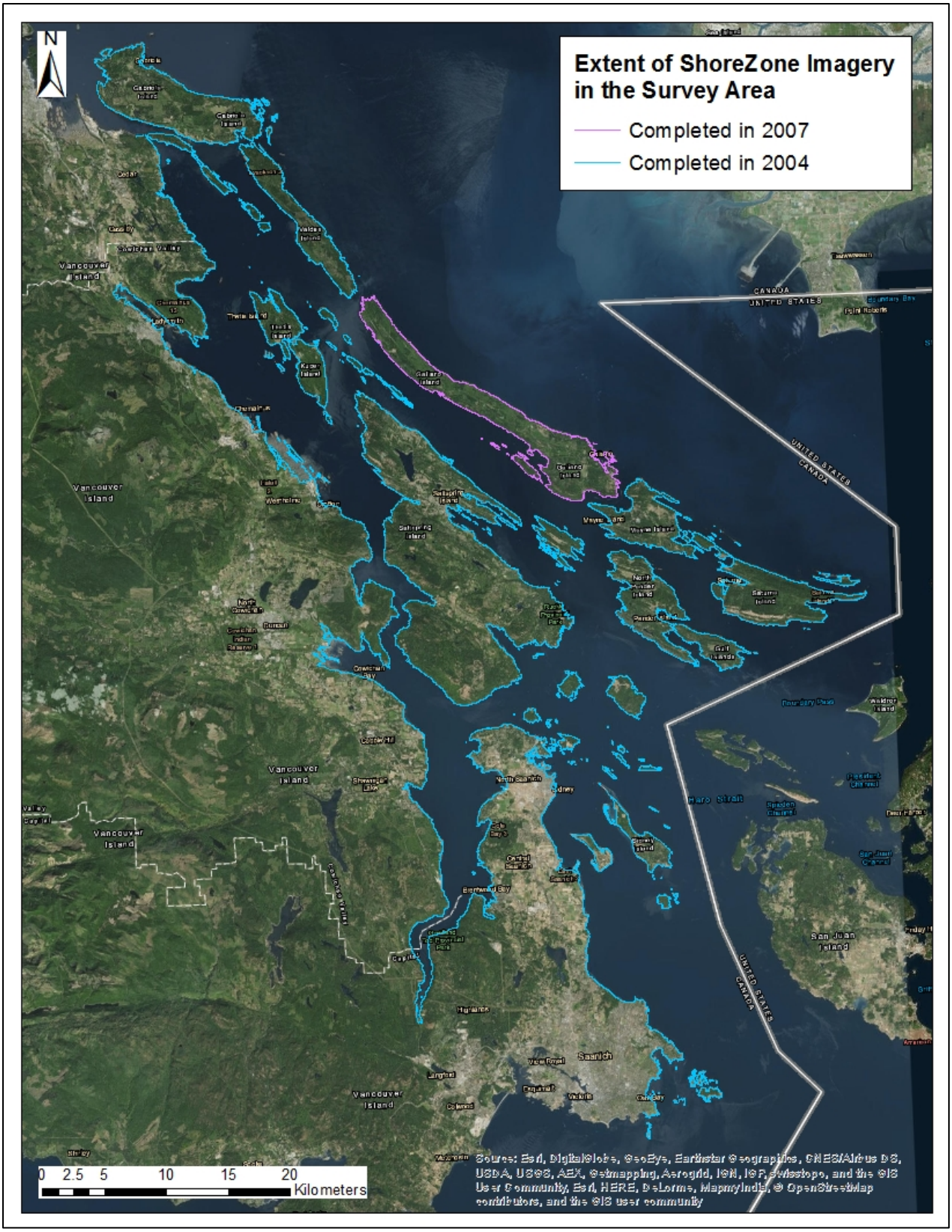

Figure 2. ShoreZone imagery extent and chronology in the southern Gulf Islands.

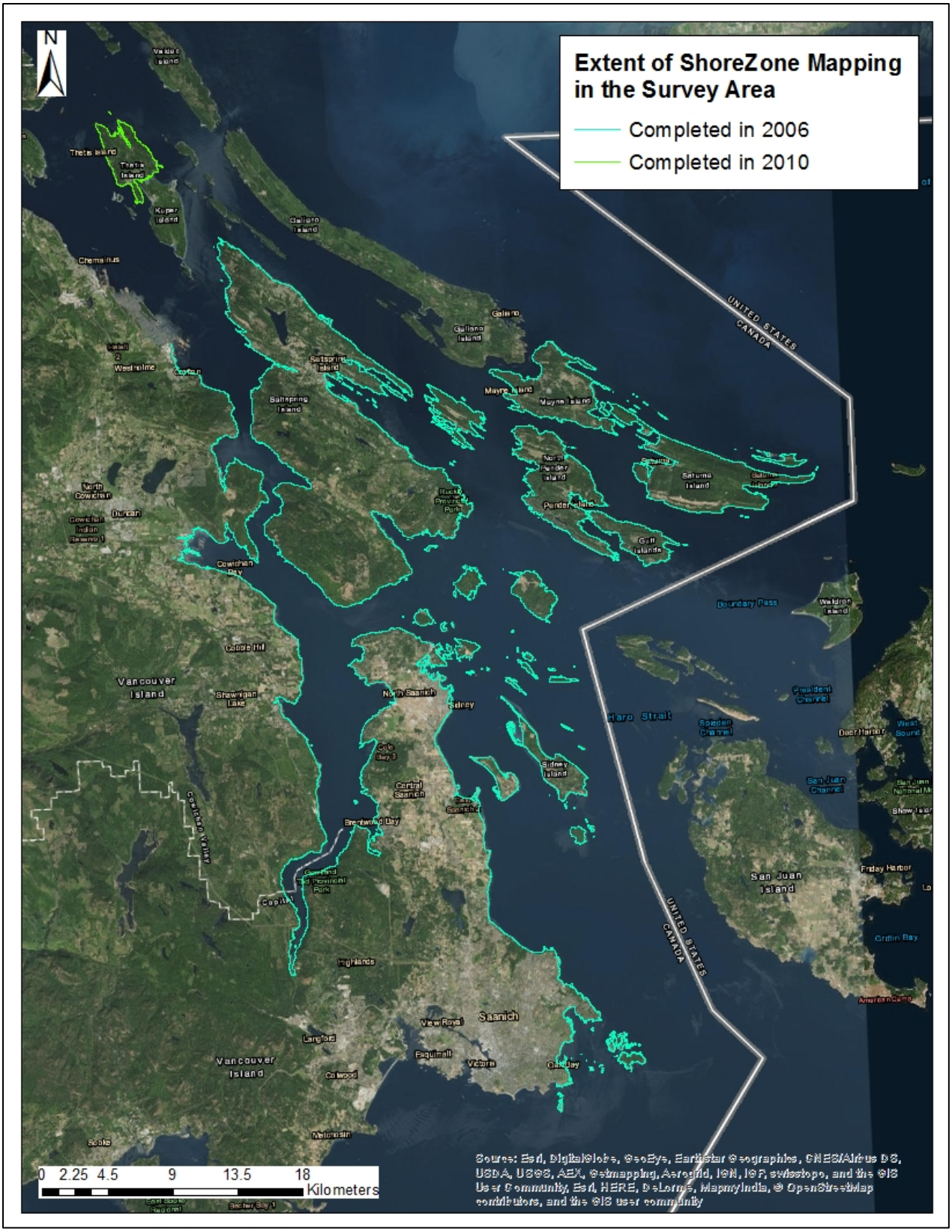

Figure 3. ShoreZone re-mapping extent and chronology in the southern Gulf Islands.

Development of the ShoreZone Suitable Forage Fish Spawning Habitat Model

The ShoreZone protocol's detailed description of the physical and biological attributes of the shoreline make it a good tool for modelling species and habitat distribution. Often this is done by combining it with more detailed, directed data set such as ground surveys conducted with a specific goal in mind. One such data set is the forage fish beach spawning inventory that has been conducted by the Washington State Department of Fish and Wildlife for more than 2 decades in Puget Sound (http://wdfw.wa.gov/conservation/research/projects/marine_beach_spawning/). However, this program only identifies known spawning sites for Pacific Sand Lance (Ammodytes hexapterus) and Surf Smelt (Hypomesus pretiosus), but since not all beaches have been inventoried it does not include potential spawning sites. Since ShoreZone imagery and mapping also exists along the entire coast of Washington State (Berry *et al*., 2004), Coastal and Ocean Resources was contracted by the Washington Department of Natural Resources to both identify the attributes in the ShoreZone dataset consistently associated with known beach spawning sites in Puget Sound and to use that data to model potentially suitable sites that had not been inventoried or were not currently being used as active spawning sites (Harper and Borecky, 2003). The results of that study are summarized in Table 1. The table combines the results for Sand Lance and Surf Smelt, although they were analyzed separately in the report, because the results were not significantly different between the two species. Eelgrass was also included as potentially linked to distribution of known Sand Lance spawning habitat; however, it was not associated with known Surf Smelt spawning habitat so was not included here as the correlation was not as strong as the other attributes.

Table 1. The ShoreZone attributes commonly associated with known forage fish beach spawning sites in Puget Sound and that were used as a predictive model for suitable spawning sites (after Tables 17 and 19 in Harper and Borecky, 2003).

Attribute Type	Values (with ShoreZone Codes)
Upper Intertidal (B1) Form	Beach face (Bf) **OR** Beach berm (Bb)
Upper Intertidal (B1) Material(s)	Sand and pebble (Csp) **OR** Sand (Cs) **OR** Pebble and Sand (Cps) **OR** Cut logs over Sand and Pebble (At/Csp) **OR** Cut logs over Pebble and Sand (At/Cps) **OR** Cut logs over sand and gravel (At/Csg) **OR** a veneer of pebble over sand (Cp/Cs) **OR** a veneer of pebble and cobble over sand (Cpc/Cs)
Exposure	Protected (P) **OR** Semi-Protected (SP)

This predictive model was applied to five of the Gulf Islands in British Columbia: Salt Spring Island, North and South Pender Islands, Mayne Island and Thetis Island. These islands were chosen because they have both newer ShoreZone imaging and mapping and forage fish ground survey data (Figure 4).

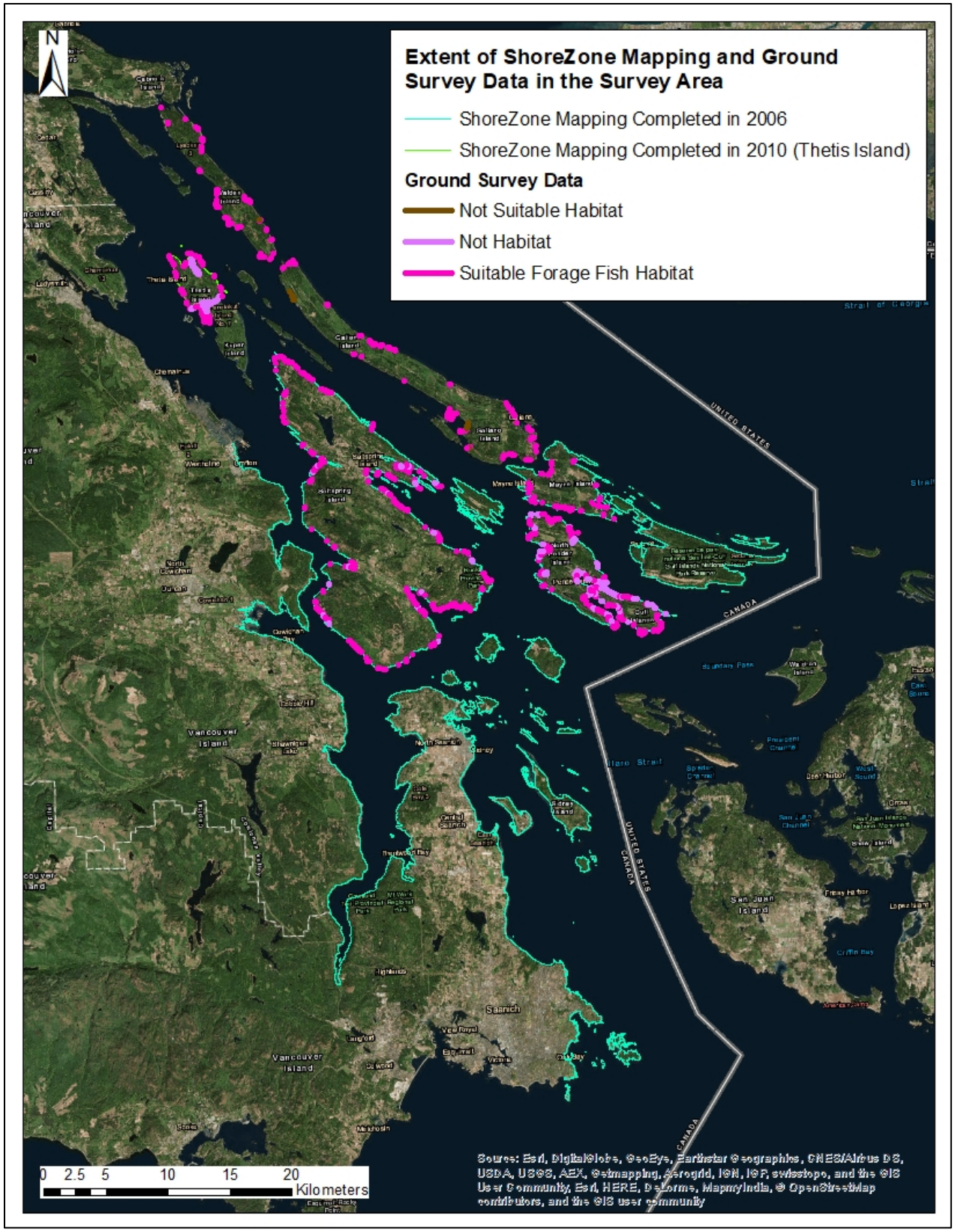

Figure 4. Survey area in the Gulf Islands with both newer ShoreZone imaging and mapping and total coverage of forage fish suitable spawning habitat ground survey data.

The results of the initial model was compared to the ground data collected on Salt Spring Island to determine how accurate it was in predicting suitable forage fish spawning sites. Of the 771 ShoreZone units mapped on Salt Spring Island, 133 were captured by this initial model (17.3%). The ground survey data identified 186 suitable beaches for forage fish spawning. When the ShoreZone units in the model were compared to the ground data, a number of discrepancies were noted. When the ground data that was NOT captured by the initial model was analyzed, a number of similarities were noted. The main issue appeared to be that small pocket beaches that existed within larger ShoreZone units were not captured by the model because they were not the primary upper intertidal Form or Material in the unit. Another issue was that, due to the large number of codes that can be used to describe a beach, there were many beaches considered suitable during the ground survey that were classified as Platforms rather than Beaches in the data set and so were not included in the model. These Platforms (which are considered rock-dominated features in ShoreZone) generally were bedrock with a veneer of sediment in places that was obviously thick enough for forage fish spawning. It was also noted that Cobble was a commonly occurring Material on many suitable beaches not captured by the initial model. Taking this information into account, the model was refined as shown in Table 2.

Table 2. The ShoreZone attributes included in the refined (final) predictive model for suitable forage fish spawning beaches in the Gulf Islands.

Attribute Type	Values (with ShoreZone Codes)
Upper Intertidal (B1) Form	Not specified (all upper intertidal (component B1) Forms included)
Upper Intertidal (B1) Material(s)	Any combination of Sand, Pebble and Cobble Materials. The possible combinations are in ShoreZone are: Bcf, Cs, Csp, Cps, Ccsp, Ccps, Cspc, Cscp, Cpsc, Cpcs */Cs, */Csp, */Cps, */Ccps, */Ccsp, */Cpcs, */Cpsc, */Cspc, */Cscp Cs/*, Csp/*, Cps/*, Ccsp/*, Ccps/*, Cspc/*, Cscp/*, Cpsc/*, Cpcs/*
Exposure	Very Protected (VP) **OR** Protected (P) **OR** Semi-Protected (SP)

*Indicates a non-specific Material code

This model was run on the primary Material codes for the upper intertidal (B1) zone and the units captured were defined as Continuous suitable forage fish habitat. It was also run on the secondary and tertiary material codes for the upper intertidal (B1) zone and the units captured were defined as Patchy suitable forage fish habitat, as these were likely pockets of suitable sediment or pocket beaches that exist within a large unit. Figures 5 to 10 show the results of the final model on the five Gulf Islands with the ground survey data. The detailed comparison of the model with the ground survey data are presented in the next section.

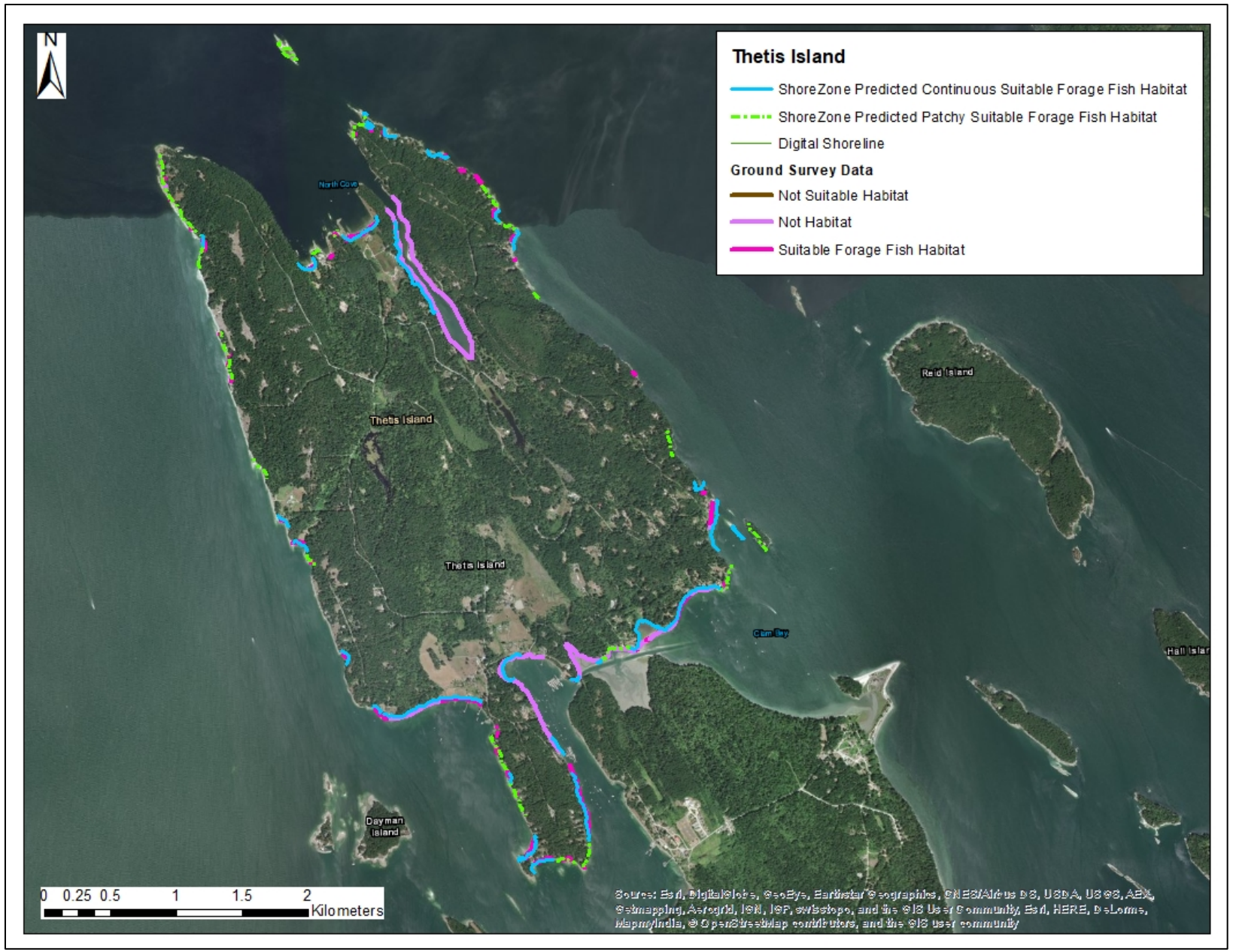

Figure 5. The ShoreZone suitable forage fish spawning habitat final model results with the ground survey data for Thetis Island.

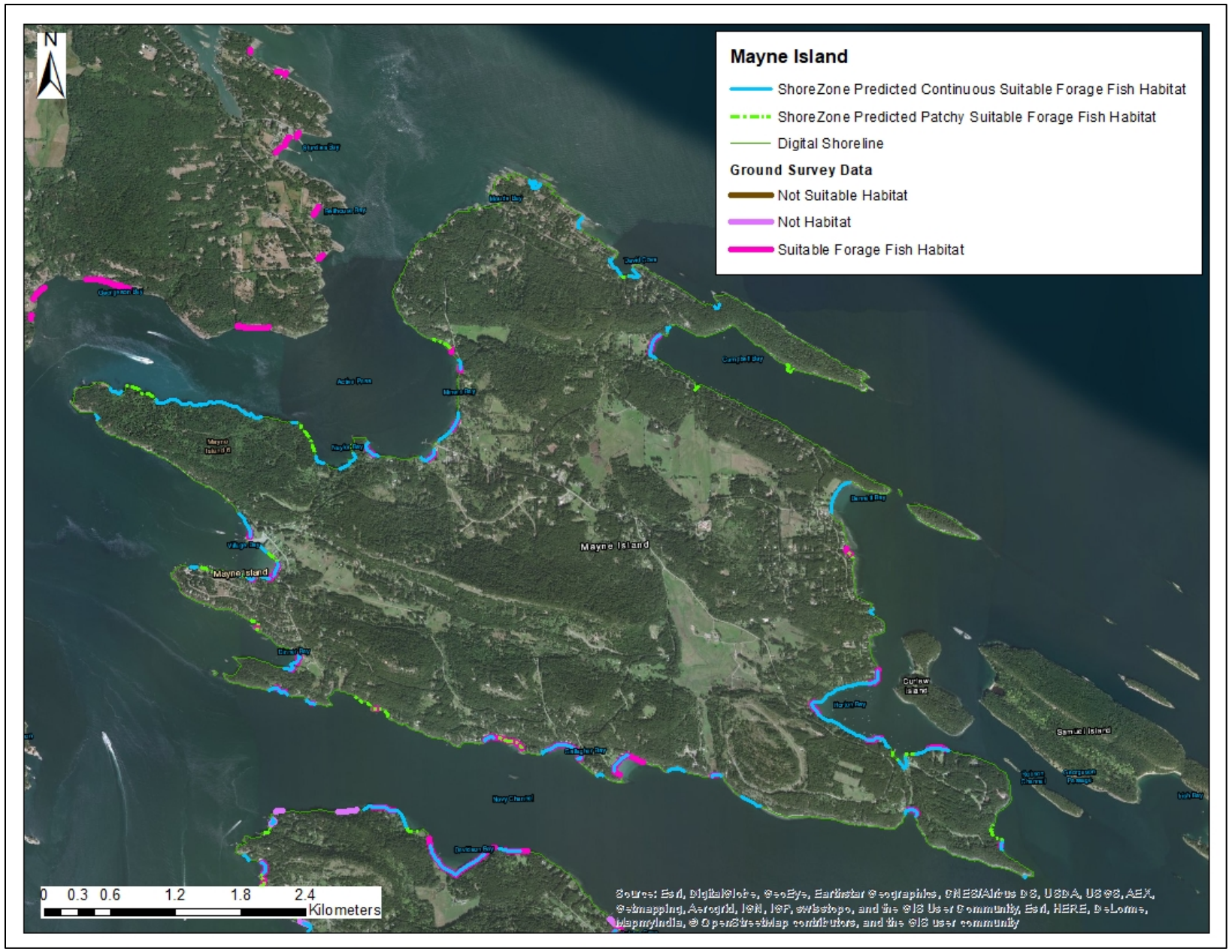

Figure 6. The ShoreZone suitable forage fish spawning habitat final model results with the ground survey data for Mayne Island.

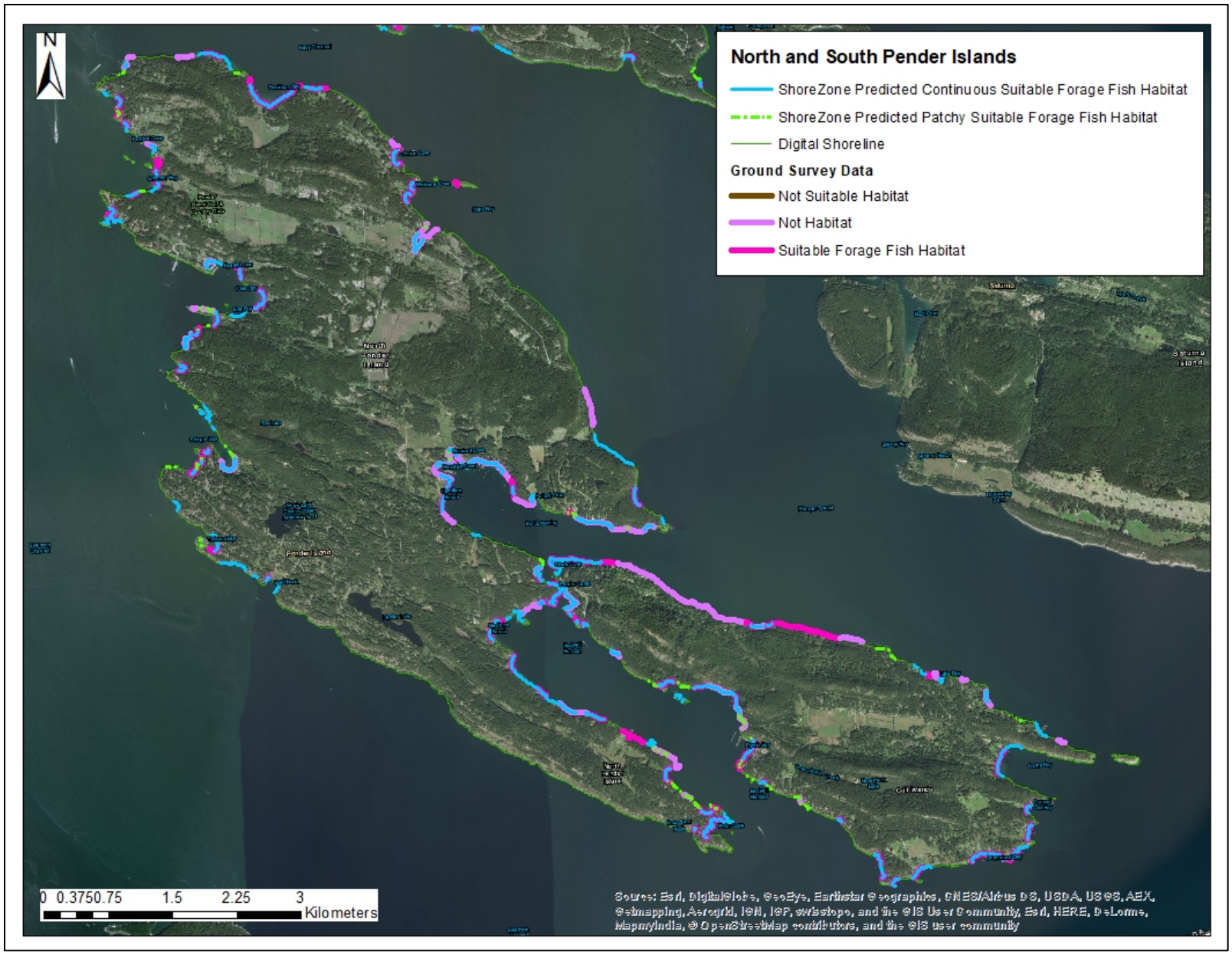

Figure 7. The ShoreZone suitable forage fish spawning habitat final model results with the ground survey data for North and South Pender Islands.

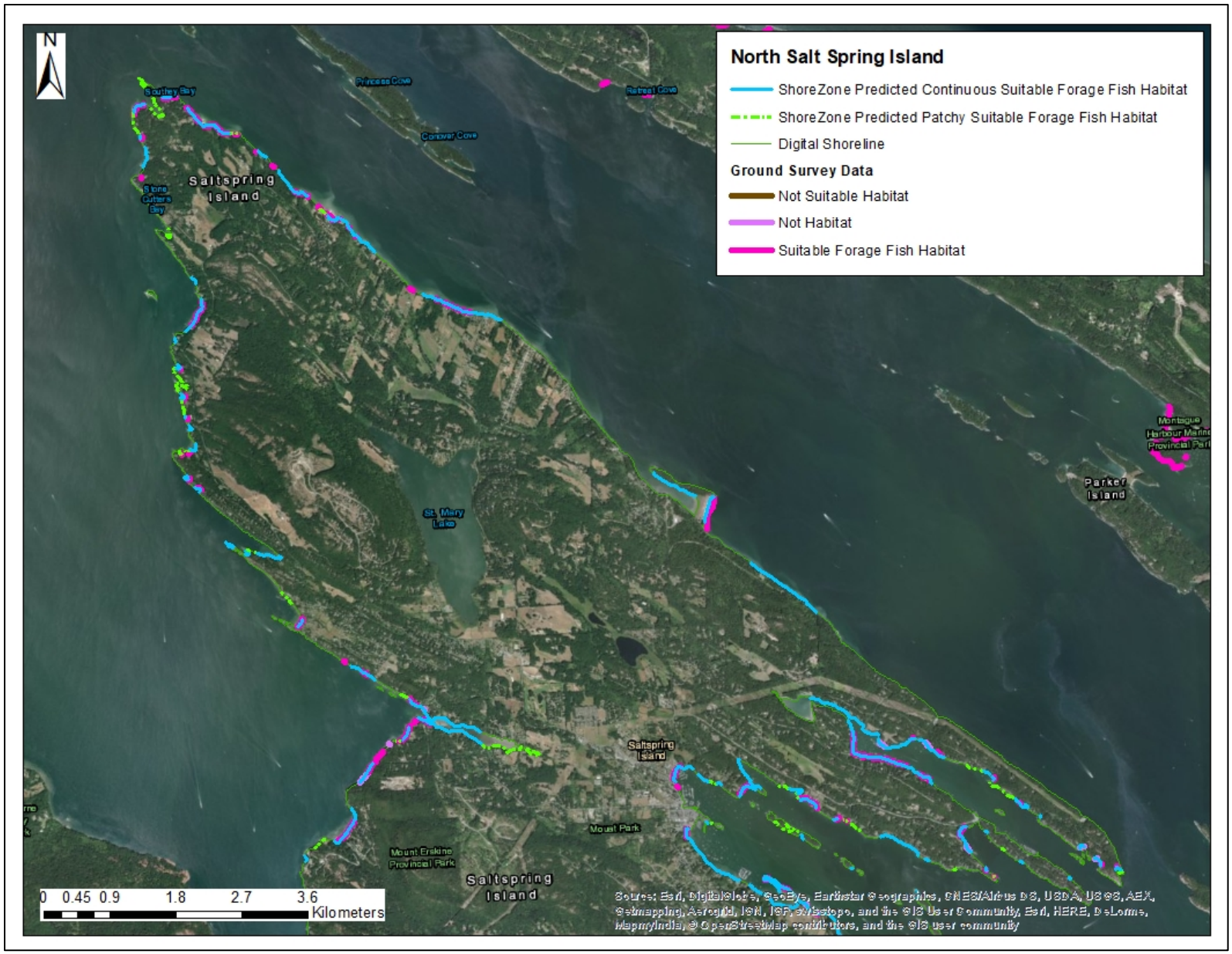

Figure 8. The ShoreZone suitable forage fish spawning habitat final model results with the ground survey data for the northern portion of Salt Spring Island.

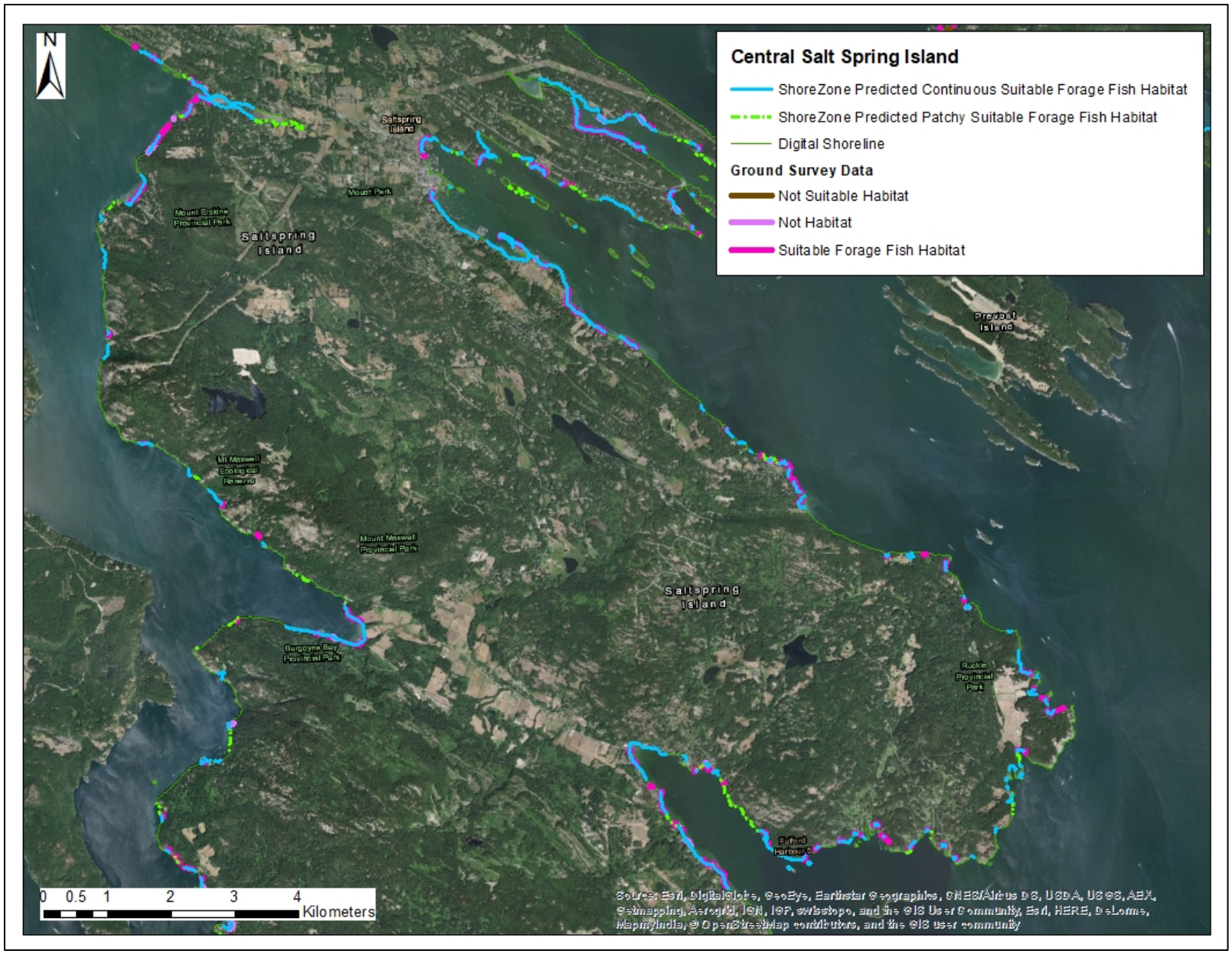

Figure 9. The ShoreZone suitable forage fish spawning habitat final model results with the ground survey data for the central portion of Salt Spring Island.

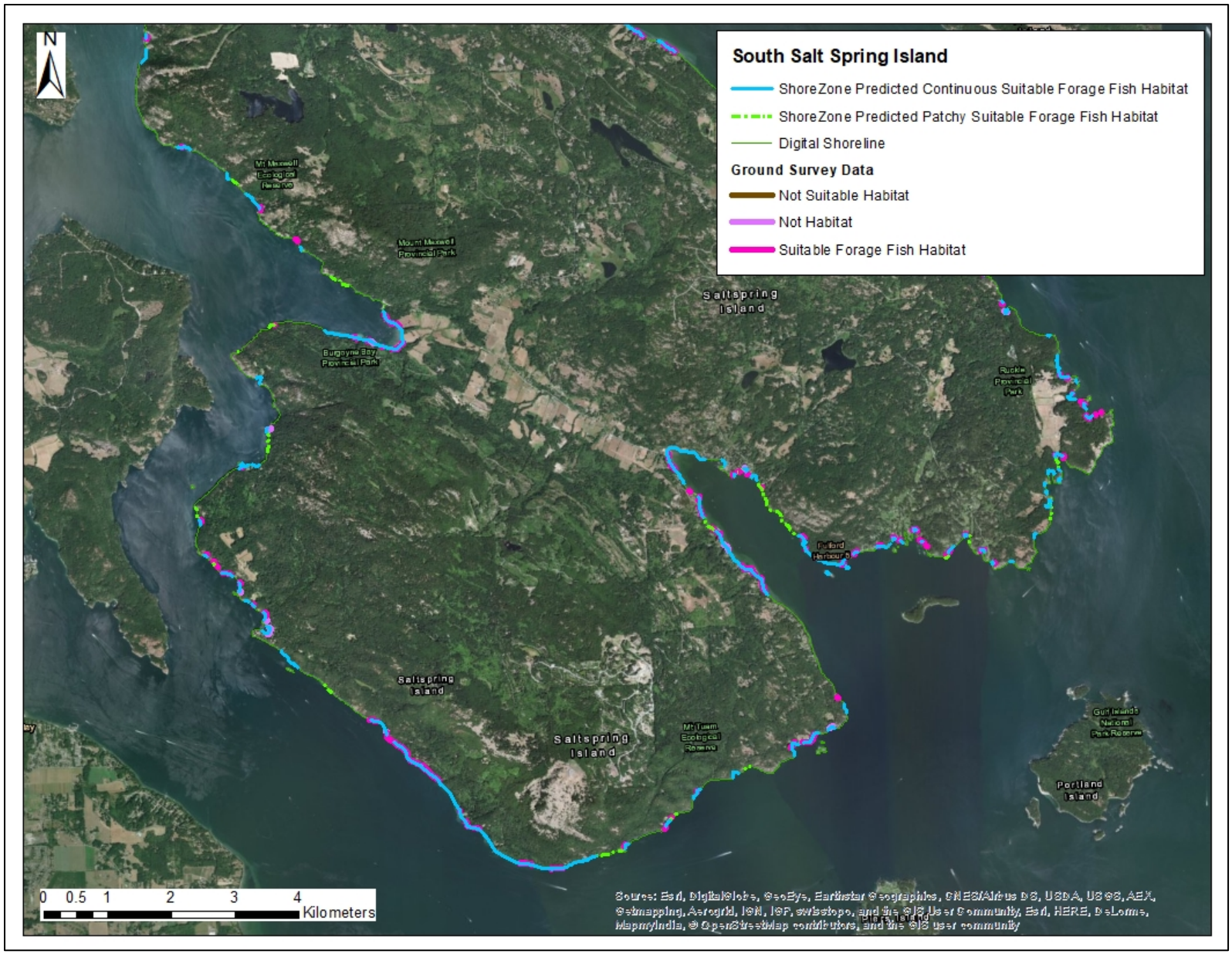

Figure 10. The ShoreZone suitable forage fish spawning habitat final model results with the ground survey data for the southern portion of Salt Spring Island.

Final Model Analysis

The final predictive ShoreZone model results were compared to the ground survey data for each of the five Gulf Islands. The main issue in this comparison was that the ground survey digital shoreline data did not always match the digital shoreline the ShoreZone data was classified on. We explored 'snapping' the ground survey data to the ShoreZone digital shoreline in order to compare the two sets of data; however, there were significant enough differences between the two that we decided it could potentially introduce too many errors in the comparison. So the comparison was done visually by going through each ShoreZone unit and determining if there was full or partial overlap between the unit and the ground survey data. The assumption underlying this comparison was that a lack of ground survey data in a given unit indicated the shoreline was NOT suitable habitat. This is likely a good assumption as the reports from the Gulf Islands indicate near total coverage of that shoreline (de Graaf, 2017). If the team did not take sediment samples from a beach, it was assumed they had visually assessed it as not being suitable either from the ground or from a boat. There may be a limited number of units for which that assumption is not valid. The ground data was then compared to the ShoreZone model results and it was determined if there was a match between the model and the ground survey data. The results are presented in Table 3 and Figure 5.

Table 3. The results of the comparison between the ShoreZone final predictive suitable forage fish model and the ground survey data for the ShoreZone units in the study area.

ShoreZone Model Prediction	Ground Data Comparison	Match/Mismatch Between ShoreZone and Ground Data	Number of Units
Continuous Spawning Habitat	Continuous Spawning Habitat	Match	187
	Patchy Spawning Habitat*	Partial Match	100
	No Suitable Spawning Habitat	Mismatch	263
Patchy Spawning Habitat	Continuous Spawning Habitat	Partial Match	10
	Patchy Spawning Habitat	Match	39
	No Suitable Spawning Habitat	Mismatch	87
No Suitable Spawning Habitat	Continuous Spawning Habitat	Mismatch	20
	Patchy Spawning Habitat	Mismatch	41
	No Suitable Spawning Habitat	Match	853
		Total ShoreZone Units	1600

*The 'Patchy' designation as used here indicates less than 50% of the ShoreZone unit overlapped with a beach identified as suitable by the ground survey, so 'patchy' in this regard only refers to the distribution of the predicted spawning habitat within the ShoreZone unit. The ground data itself did not use this terminology to classify beaches.

Overall, there was a good match between the ShoreZone model and the ground survey, with 74.3% of the units having at least a partial match with the results of the ground survey. Where there was a mismatch with the ground survey data (25.7% of the units), the ShoreZone model over predicted the presence of suitable forage fish spawning habitat in 21.9% of the units and under predicted it in 3.8% of the units.

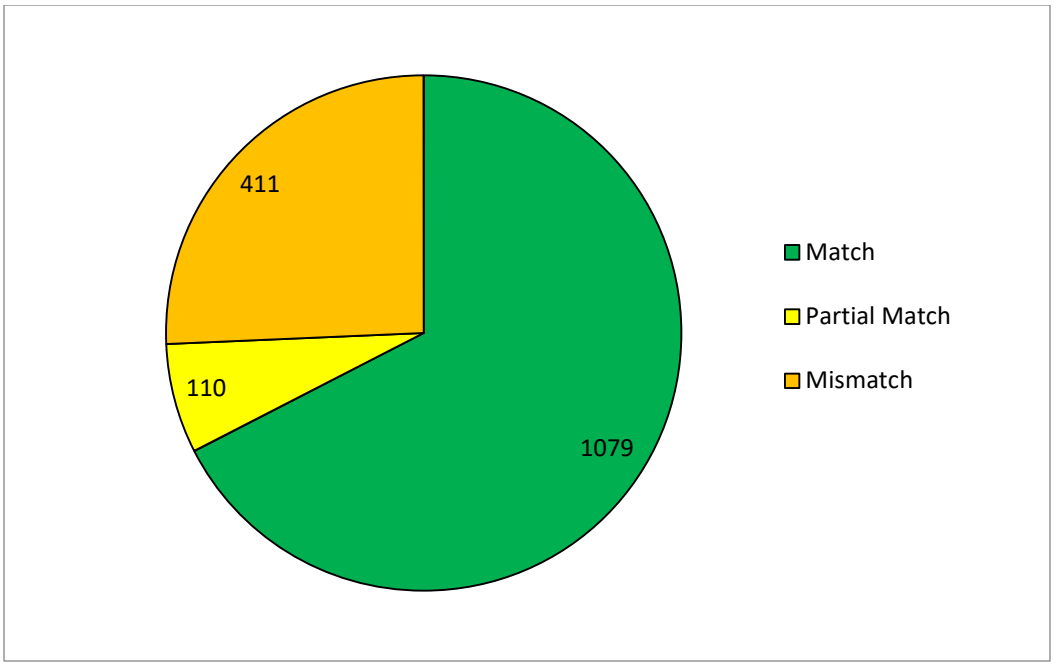

Figure 5. Summary of the comparison of the ShoreZone final model to the ground survey data by number of units in each category.

Acknowledgements

This project was enriched by the insight and experience of Pam Thuringer (Independent Contractor), Scott Northrup (Hemmera), Phillip Dionne (Washington Department of Fish and Wildlife), Brian Emmett (Archipelago Marine Research) and Ramona de Graaf (Sea Watch Society). Many thanks to Kate Emmings (Islands Trust) and the Islands Trust for providing access to the ground survey data in the Gulf Islands. Also thanks to Kalen Morrow (Coastal and Ocean Resources) for updating and QAQCing the BC ShoreZone dataset provided by Carol Ogbourne at GeoBC, and for providing invaluable GIS support. Thanks as well to Simone Behrens (Coastal and Ocean Resources) for meticulously comparing the final model to the ground data.

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Appendix

Digital Attachments:

ShoreZone Final Model Shapefiles:

- SSIPendersMayne_ContinuousFFHab
- SSIPendersMayne_PatchyFFHab
- Thetis_ContinuousFFHab
- Thetis_PatchyFFHab

BC ShoreZone Geodatabase (original geodatabase provide by GeoBC, this one has been formatted and QAQC'd by Coastal and Ocean Resources):

- BC_ShoreZone_Original_GDB_08nov17.gdb