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Habitat Availability and Population Size on the Island of Newfoundland

American Marten (*Martes americana atrata*)

Report prepared under contract by Brian J. Hearn, Ph.D. with support from Adam Durocher

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AUTHORS

Dr. Brian Hearn (retired Canadian Forest Service) was contracted by the Department of Fisheries, Forestry and Agriculture in 2018 to develop a population estimate for American Marten on the Island of Newfoundland and to assist the Wildlife Division in revising a draft species status report for the Committee on the Status of Endangered Wildlife in Canada for the population. Adam Durocher with the Atlantic Canada Conservation Data Centre provided significant support to Dr. Hearn during the development of the population estimate and the revisions to the status report. Mr. Durocher ran the models and developed all the maps contained within the report. Shelley Moores, Shelley Garland and Lesley Sullivan of the Wildlife Division reviewed, edited and formatted the document, and updated with new information since its initial completion in 2020.

EXECUTIVE SUMMARY

The Newfoundland Marten (*Martes americana atrata)*, endemic to the island of Newfoundland, is a geographically-isolated and genetically-distinct subspecies of the American Marten (*M. americana)* (Kyle and Strobeck 2003). Currently, the Newfoundland Marten is listed as Vulnerable under the Newfoundland and Labrador Endangered Species Act (ESA). Utilizing the available provincial forest inventory, and the Marten Occupancy Model (MOM) developed for application in Newfoundland by Fuller et al. (2006, 2007) we modelled and spatially mapped habitat suitability, and calculated potential and actual population size, for marten on the island of Newfoundland. Overall, we assessed approximately 75% of the island (83,020 km^2) as to its suitability for marten habitat. The remainder of the island was not modelled due to the lack of a landcover inventory that was readily compatible with the MOM marten model; this excluded area included both national parks. Marten appear to be recapturing parts of their historical range, notably the Baie Verte Peninsula, Stephenville area, and forested areas in southcentral Newfoundland. We estimated that the assessed area has the potential to support in excess of 4,000 adult resident marten (adult breeding population). Currently, we estimate that approximately 70% of the higher "quality" marten habitat (≥ 60% probability of occupancy) is in use by marten, translating into an actual marten population estimate of between 2,494-2,773 adult resident marten. An additional 60 marten are estimated to be resident in the two national

parks. Total actual marten population size would be higher if juvenile and non-resident marten, as well as marten occupying areas of the island not assessed in this analysis, are included.

It is important to note that while this most recent population estimate is significantly higher than those previously reported for Newfoundland Marten it is not directly comparable to past estimates of marten abundance, which were based on limited empirical data. By contrast, this modelling exercise benefited from the availability of a significant body of scientific research, additional field data on local marten occurrence, and the availability of the marten habitat model. Further, local conditions potentially affecting marten, e.g., habitat availability, prey resources, incidental mortality, are felt to have improved considerably over the last several decades and are no doubt contributing factors to the noted increase in the estimated population size. Nevertheless, like all modelling efforts designed to assess natural systems, our estimates have stated assumptions and uncertainties. Assumptions and other data or knowledge constraints that could affect these estimates both positively and negatively are provided in the later discussion section of the report. Further research and management efforts for marten in Newfoundland should focus on knowledge and/or data gaps to improve our ability to manage this designated species. The results of this analysis was used by the Government of Newfoundland and Labrador to inform the 2022 COSEWIC assessment for the Newfoundland Marten.

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INTRODUCTION

The Newfoundland Marten (*Martes americana atrata)* is a geographically-isolated and genetically distinct subspecies of the American marten (*M. americana)* (Kyle and Strobeck 2003). In addition, the Newfoundland marten is one of only 14 mammals which are endemic to the island of Newfoundland (Dodds 1983). Previously classified by the Committee of the Status of Endangered Wildlife in Canada (COSEWIC) as *Endangered* (COSEWIC 2000), then assessed as Threatened (COSEWIC 2007), the Newfoundland Marten is currently assessed as Special Concern (COSEWIC 2022).

The decline of the Newfoundland Marten both in population size and spatial distribution began in the early 1900's (Bergerud 1969, Snyder 1984, Snyder and Bissonette 1987, Thompson 1991, Forsey et al. 1995) and coincided with widespread declines of American Marten and Fisher (*Martes pennant)* populations throughout North America via overexploitation (Aldous and Mendall 1941, Burt 1946, Yeager 1950, de Vos 1951, Quick 1956, Hagmeier 1956, Dodds and Martel 1971, Gibilisco 1994, Strickland and Douglas 1981, Krohn et al. 1994, Stickland 1994). A similar history of decline was also documented for other game and furbearers in Newfoundland during this period: the Newfoundland Wolf (*Canis lupus beothucus)* was extirpated between 1910 and 1923 (Allen and Barbour 1937); beaver (*Castor canadensis)* were nearly eliminated (Cameron 1958, Payne 1975). Further, caribou (*Rangifer tarandus),* lynx (*Lynx canadensis)* and otter (*Lutra canadensis)* populations were so severely reduced that the Newfoundland government closed the harvest seasons (Dodds 1983). Thereafter, the marten

population on the island continued to decline for the next several decades. Consequently, trapping for marten was prohibited beginning in 1934 and is still in effect currently (Forsey et al. 1995).

By the mid 1950's, the distribution of marten in Newfoundland was essentially restricted to the inaccessible areas of mature and overmature timber remaining on the island (Bergerud 1969) where forest harvesting was absent, human access was limited, and exploitation by trappers and residents snaring for Snowshoe Hare (*Lepus americana)* was prevented by poor access. Understandably, with little additional knowledge about the relative importance of other factors limiting marten population recovery, the restricted association of Newfoundland Marten to overmature forest, coinciding with the expanding harvest of mature and overmature forest, was interpreted by natural resource managers as the most probable explanation and principal reason for the continual decline of marten (Bergerud 1969, Thompson 1991, Thompson and Curran 1995, Forsey et al. 1995, Sturtevant and Bissonette 1997, Bissonette et al. 1997).

Synder and Hancock (1985) produced the first population estimate for Newfoundland Marten. Using live-trapping data from Synder (1984), and marten occurrence data based on a trapper questionnaire (Hancock et al. 1985), they estimated that there were between 630-875 on the island. Notably, the total island-wide population of marten was also felt to be restricted to the Pine Marten Study Area (PMSA) in western Newfoundland and that no subpopulations were resident elsewhere on the island; the PMSA was a provincially-designated wildlife reserve

established in 1972 for the protection of the Newfoundland Marten (Synder and Hancock 1985).

Forsey et al. (1995) produced the second population estimate for Newfoundland Marten and reported that the marten population had declined to only 300 animals. This second island-wide estimate included what was believed to be a remnant marten population in Terra Nova National Park. Forsey et al.'s estimate was based on the earlier density estimate of 0.26 marten/km^2 calculated by Bissonette et al. (1988) and the assumption that the island-wide habitat supply for marten was ≤ 600 km^2 of "prime" habitat. At that time, "prime" habitat for Newfoundland Marten was considered to be restricted to 80+ year-old conifer forest (Thompson 1984). Further, these authors suggested that 60-80-year-old conifer forest was marginal habitat and capable of supporting marten at only one-third of the density (0.08 marten/km^2) of "prime" habitat. They further supposed that all other forest types were unsuitable for habitat for Newfoundland Marten. More recent research on the habitat associations of marten on the island suggests that these earlier habitat definitions were too restrictive and overly conservative (Gosse et al. 2005, Hearn 2007, Hearn et al. 2010).

In 2007, Schmelzer (reported in COSEWIC 2007) produced the third population estimate for Newfoundland Marten. She utilized data on a range of area-specific density estimates, marten occurrence data, and the recently-developed marten habitat occupancy model (Fuller et al. 2006) to estimate four alternative estimates of the island-wide marten population. She calculated that the island-wide marten population, including both juvenile and adult marten, was between 438 – 852 animals (Table 1). Her estimate utilized the latest published and

unpublished research and empirical data on marten occurrence, spatial ecology, habitat associations, and habitat supply modeling, e.g., Gosse et al. 2005, Hearn et al. 2005, Fuller 2006, Fuller et al. 2006. Most importantly, this last estimate provided the first population estimate for Newfoundland Marten based on a rigorous and stepwise methodology.

In recognition of increased observations of marten on the landscape and the impending COSEWIC assessment for Newfoundland Marten started in 2017, this project was initiated to develop a new marten population estimate. Subsequently, in 2019, this report was initiated to update information on the population and to complete the draft COSEWIC report. Specifically, the objectives of this project were:

1) Using the Marten Occupancy Model (MOM) developed by Fuller et al. (2006, 2007), map marten habitat availability and "potential" population levels for each of the 18 Forest Management Districts (FMD) on the island;
2) Utilizing the marten location database maintained by the Department of Fisheries, Forestry and Agriculture– Wildlife Division (WD), unpublished data, and any supplementary information and expert opinion available, develop procedures to estimate the current spatial distribution (occurrence) of marten on the island, and;
3) Using the products developed above, estimate the current size of the Newfoundland Marten population.

Table 1. The island-wide population estimate for Newfoundland marten produced by Schmelzer as reported in COSEWIC (2007). Final population numbers range from 438 to 852 based on two alternate methods and various assumptions. Population estimates include both juvenile and adult age classes (COSEWIC 2007). The island-wide area of occupancy for marten in 2007 was estimated as 23,383 km^2. Detailed methods are described in COSEWIC (2007).

		Method 1		Method 2	
	Area (km^2)	Mean	High	Mean	High
Main River	2,177	117	190	94	153
Terra Nova Area	2,829	55	102	47	80
LGL/RIL[1]	6,232	310	481	237	368
St. Georges	590	16	16	14	14
Peripheral[2]	11,555	63	63	46	46
Totals	23,383	561	852	438	661

Marten densities assumed to vary considerable among areas and between Method 1 and 2; densities ranged 22-fold from 0.004 to 0.087 marten / km^2 among estimates.

[2] Little Grand Lake - Red Indian Lake Area.

[3] Densities in Peripheral Areas which was ~ 50% of the total area assessed was assumed to be 20% of that in high-density areas, i.e., Main River and LGL/RIL.

CAVEAT

Over the last decade, our understanding of the spatial ecology, habitat associations, and population parameters of marten on the island of Newfoundland has improved considerably (Gosse et al. 2005, Hearn et al. 2005, Fuller 2006, Fuller et al. 2006, 2007, Hearn 2007, Hearn et al. 2010). The development of the Marten Occupancy Model (MOM) by Fuller et al. (2006, 2007) provided a spatially-explicit model for a landscape-level habitat assessment and population estimation. In addition, the MOM model provides a functional link to other quantitative models utilized in the province by various resource agencies, i.e., wood-supply modeling, environmental assessment of proposed harvesting plans, and/or energy corridors. Nevertheless, all ecological models and related decision-support tools are simplifications of ecological systems. And while, in principle, models provide a structured and objective approach to assessment and decision-making, their development and application regularly requires the use of assumptions and/or expert opinion.

Accordingly, in consultation with the Senior Manager of Research for the NL Wildlife Division we developed a modelling approach that we judged was objective, methodologically repeatable, based on best-available information, and compatible with other landscape planning tools in use in the province. We document the assumptions used herein and discuss potential uncertainties in our estimates and/or modeling approach. Further, we highlight areas where we feel our current understanding of the ecology of the Newfoundland Marten, and our modelling and assumptions and data sources need to be improved; however, such work is outside the scope and timelines for this project. Finally, while we offer recommendations and

interpretations of the analyses, the application of the results reported herein rests with the management agency.

METHODS

As noted, for forest management purposes, the island portion of the province is divided into 18 Forest Management Districts (FMD) therefore we used the FMD as the appropriate unit for our analyses. However, this approach required us to develop methods to deal with two inherent issues related to the spatial and temporal variation in the forest inventory available across the 18 districts.

Landcover

Initially, we developed landcover maps for each of the 18 FMD using the Provincial Forest Inventory (PFI). However, the PFI was originally established to serve as a landcover classification to support the forest industry. Accordingly, when originally developed the PFI program was focused on the more productive land base on the island, hence, areas of the province that were not of significant interest to the forest industry were not inventoried. As a consequence, forest inventory information was either not available for portions of the island or was outdated. Similarly, compatible PFI data was not available for the two national parks (Figure 1). Furthermore, the PFI is interpreted from aerial photography collected over a 10-year inventory cycle, i.e., ca. 10% of the province is inventoried annually (Anonymous 1991). Consequently, the PFI is actually a mosaic where the actual year of inventory can vary by over a decade among the various forest management districts.

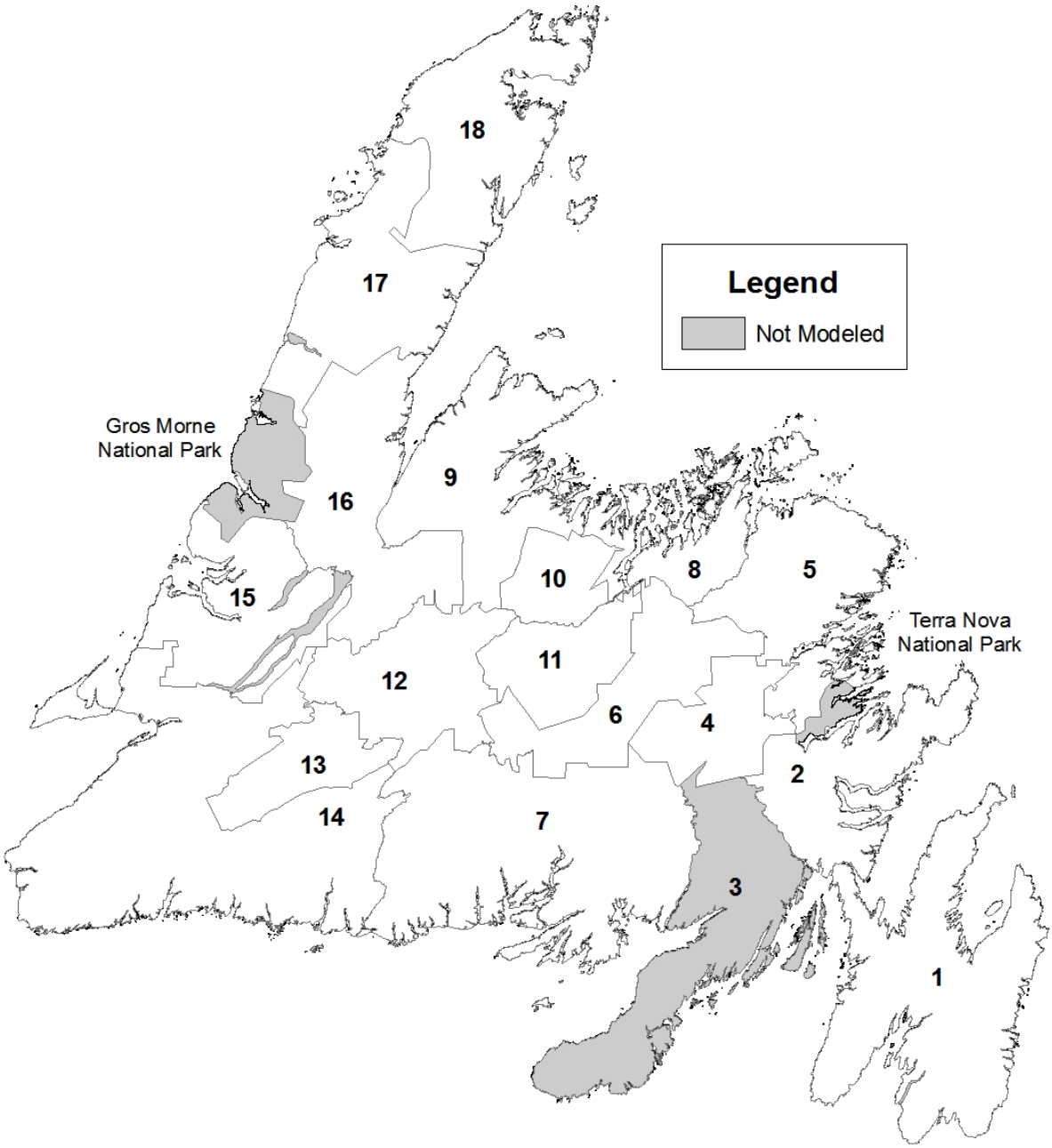

Figure 1. Spatial location and configuration of the 18 Forest Management Districts modeled for marten habitat availability. FMD 3 and both national parks were not modelled for marten habitat suitability or to estimate population size.

To account for this 10+ year temporal difference, for FMDs where the forest inventory was outdated, we advanced the forest growth by increasing stand height for all stands occupying sites with a site quality index of medium or better based on local growth and yield equations. This approach was used by Hearn et al. (2005) for their habitat selection analysis, and subsequently by Fuller et al. (2005, 2006) in the development of the marten habitat model. Fortunately, forest harvesting data is updated annually so the current available inventory does incorporated all cut block information up to January 2019. Additionally, due to the limitations in our GIS modelling platform (e.g., maximum number of simultaneous computer calculations and system memory, limited network performance) whenever necessary we apportioned the FMD into several smaller areas and combined the modelling results from these units to report at the FMD level.

Marten Location Database

For the past 40+ years, the NL Wildlife Division has maintained a database of all Newfoundland Marten locations (MLD) recorded for the island. Locational data categories included: live trapping locations, sightings, accidental trapped marten captured in rabbit snares or traps, radio-collar locations from research studies (e.g., Gosse et al. 2005, Hearn 2007, Hearn et al 2010), locations from hair-snagging studies, bait station tracks, and locations of road-killed marten. We used the MLD as the best-available information on the current spatial distribution of marten on the island, i.e., area currently occupied (Figures 2-7).

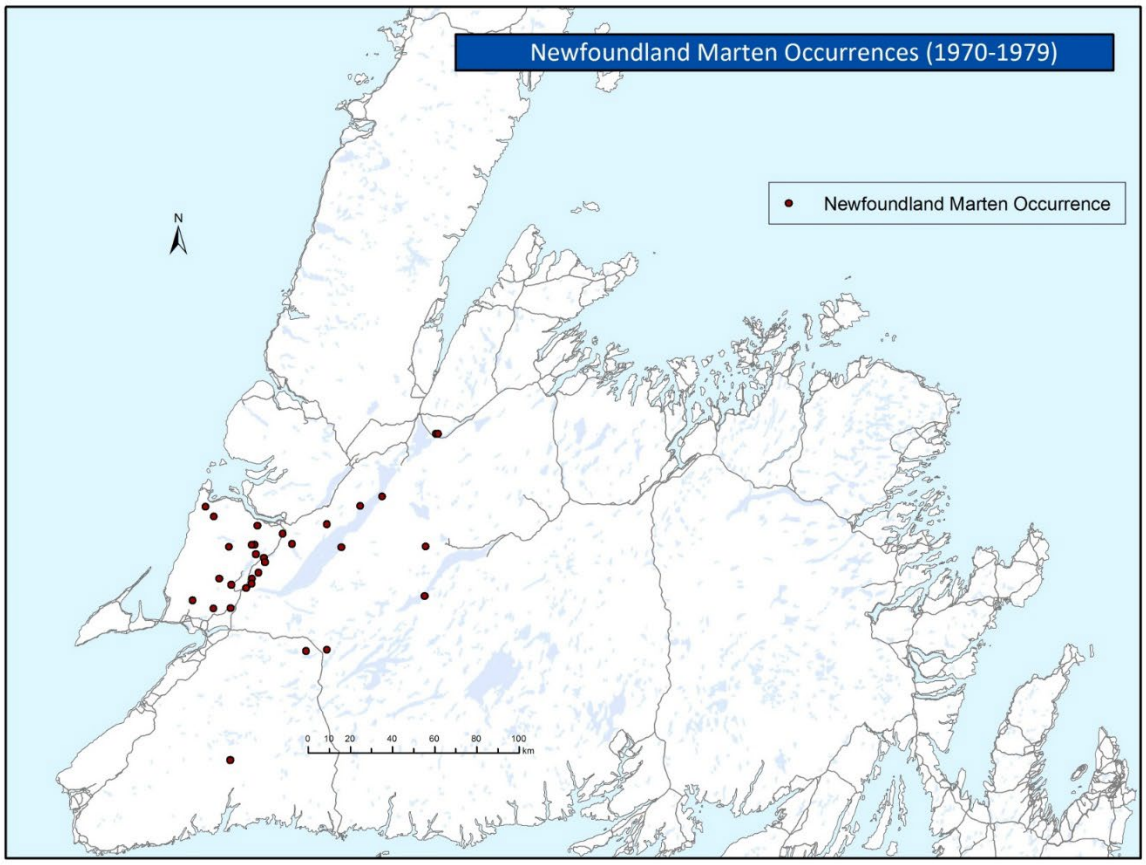

Figure 2. Marten location data for the island of Newfoundland, 1970-1979.

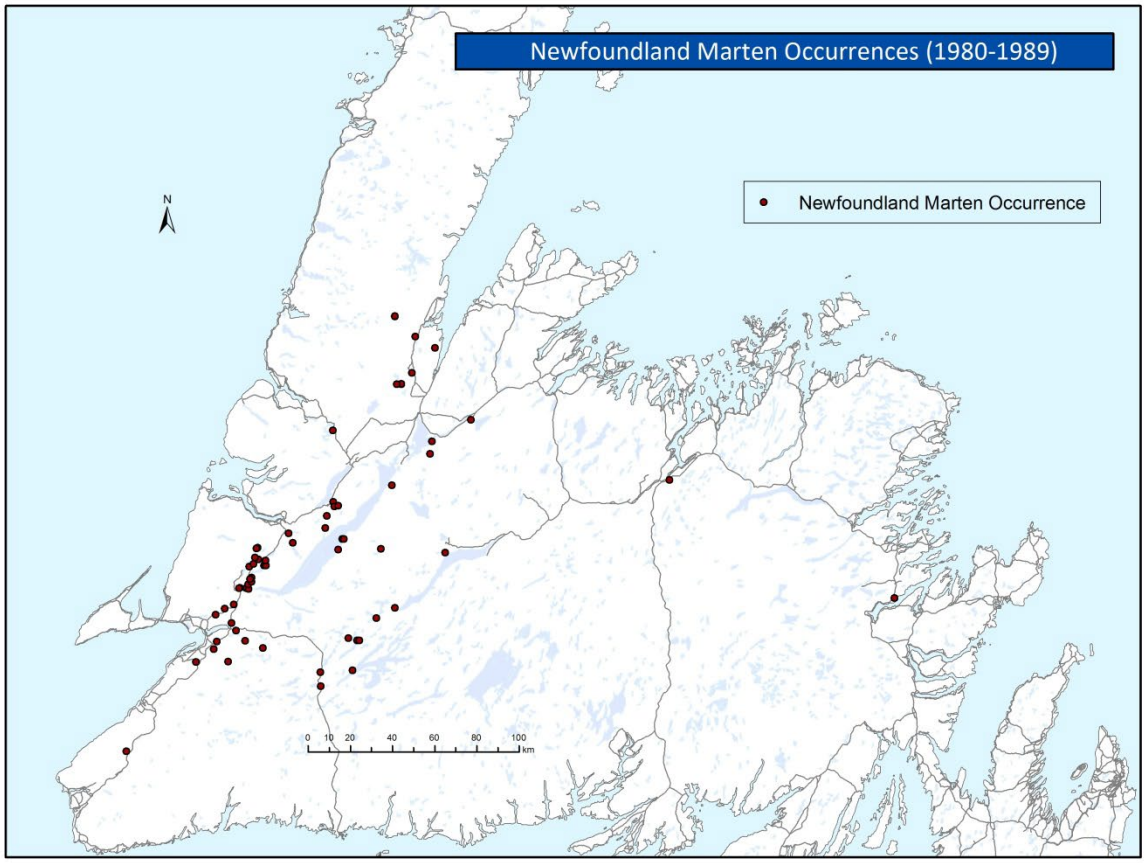

Figure 3. Marten location data for the island of Newfoundland, 1980-1989.

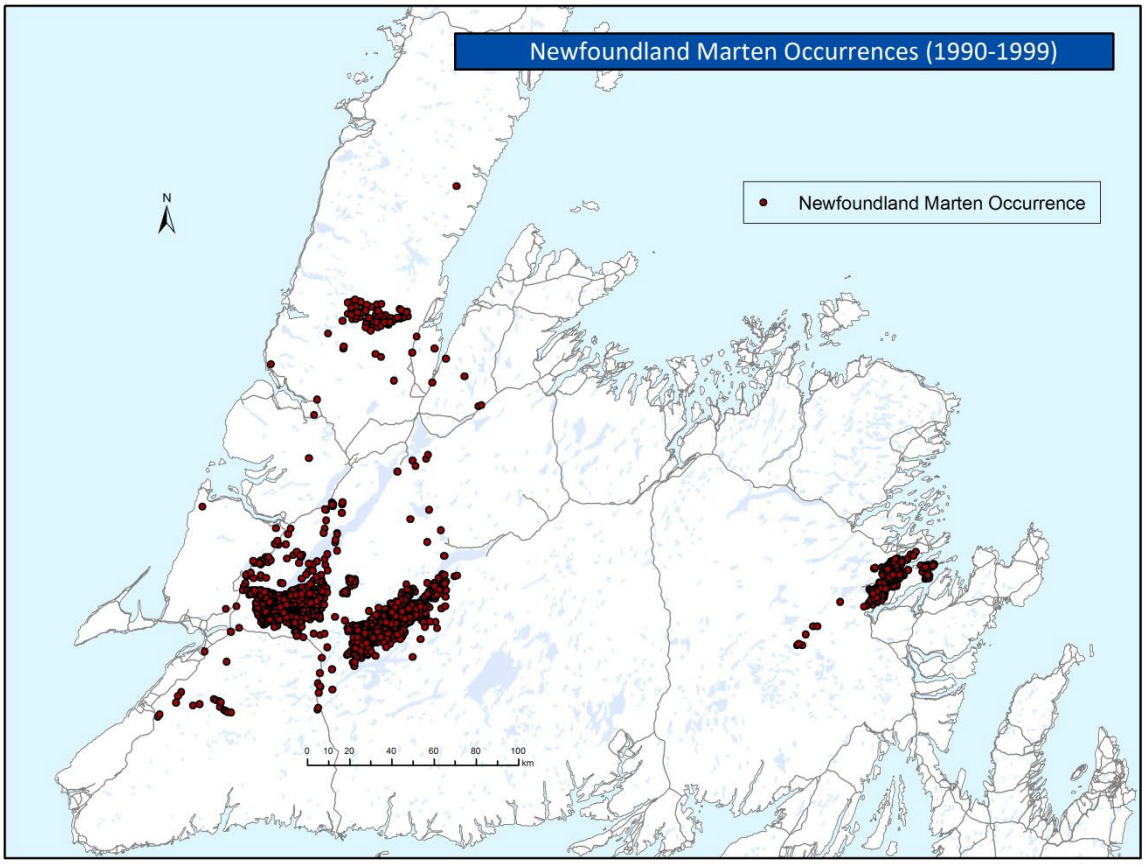

Figure 4. Marten location data for the island of Newfoundland, 1990-1999.

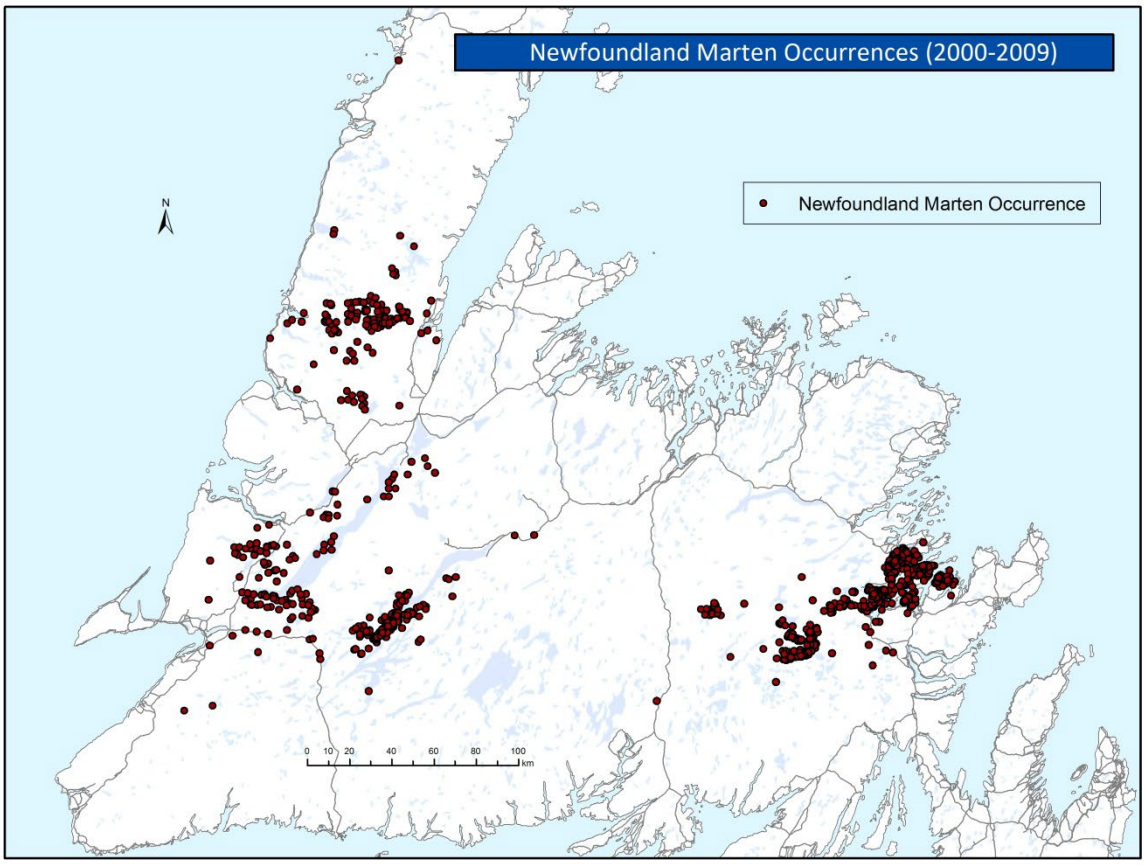

Figure 5. Marten location data for the island of Newfoundland, 2000-2009.

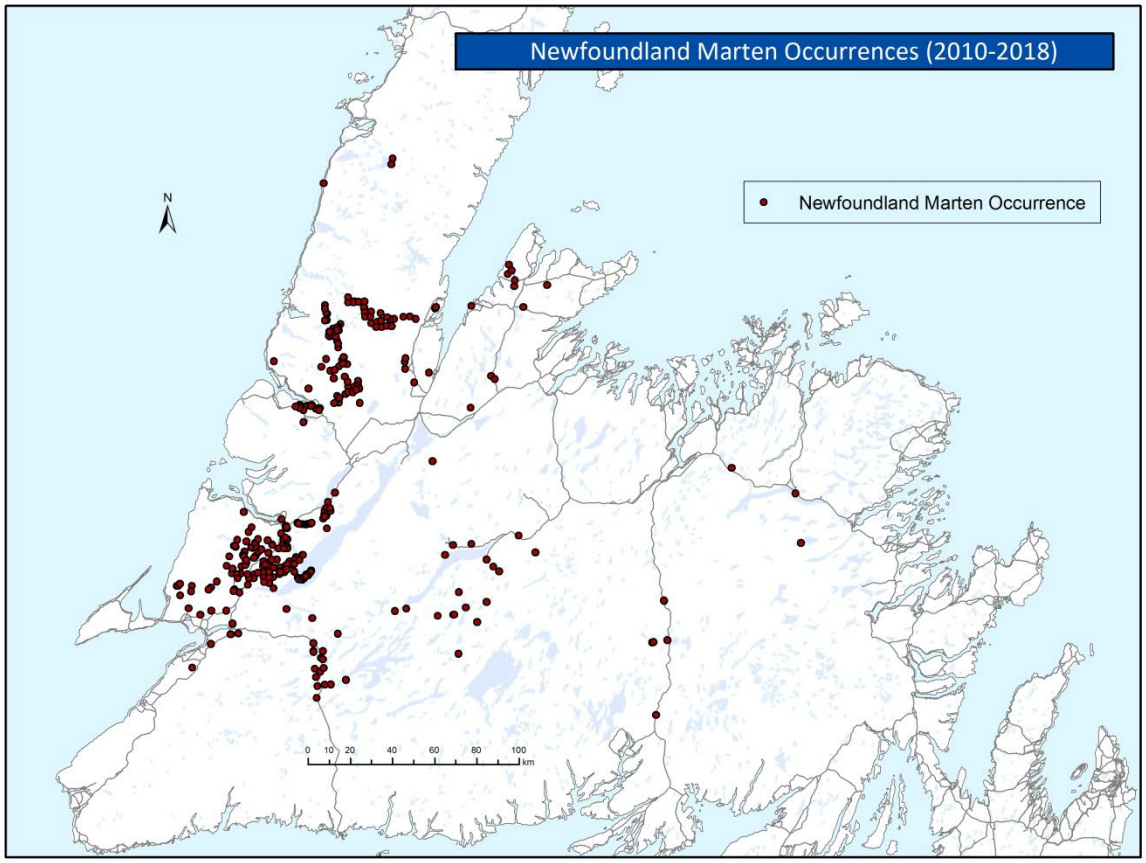

Figure 6. Marten location data for the island of Newfoundland, 2010-2018.

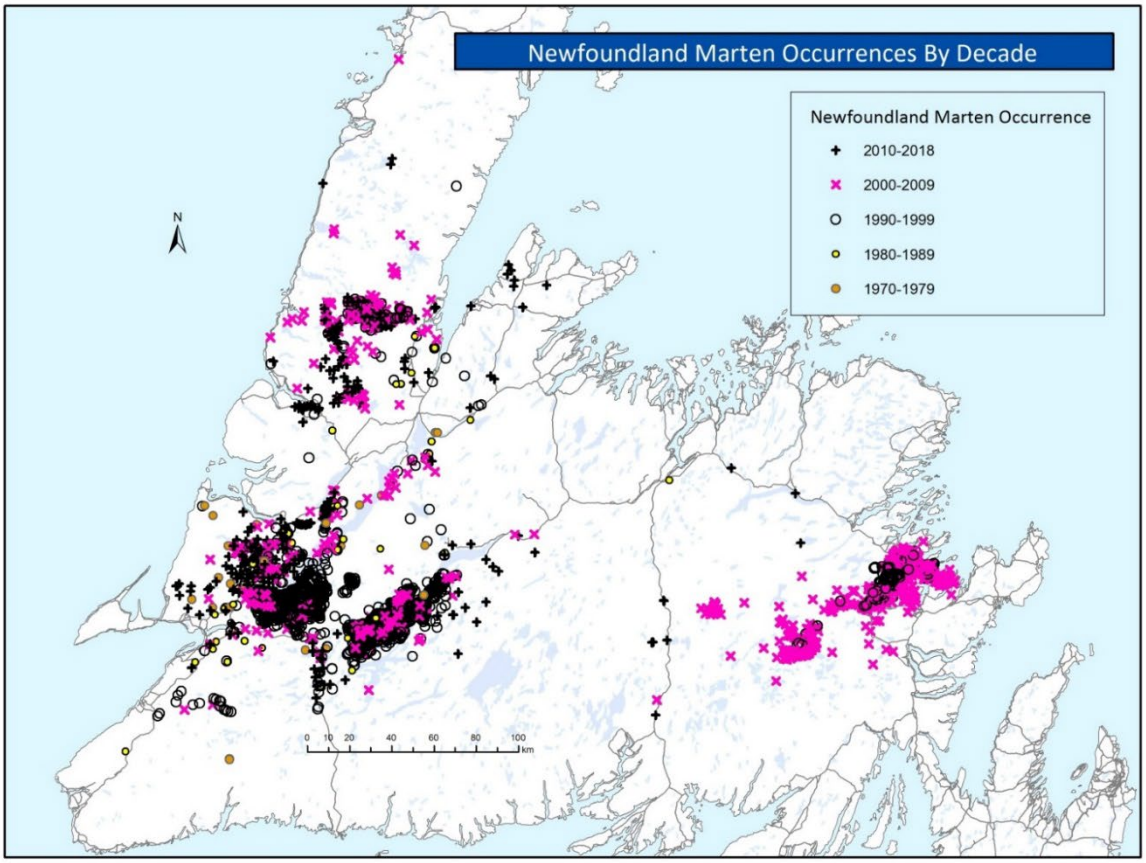

Figure 7. All locations in the marten location database mapped by decade, 1970-2018.

Marten Occupancy Model

Briefly, the MOM (Fuller et al. 2006, 2007) assesses the probability that an area can support an adult, resident female marten based on the surrounding landcover as mapped by the PFI. Initially, the PFI provides a detailed landcover map of > 100 possible landcover types based on various characteristics, e.g., species, stand height, crown-closure classes. To begin, MOM simplifies the PFI into an "interim" landcover of 12 marten habitat classes. This "interim" landcover map is further simplified into a binomial classification as either suitable or unsuitable habitat for marten. These suitable and unsuitable habitat types were derived from a multi-scale habitat selection analysis conducted by Hearn et al. (2005) and subsequently refined by Fuller et al. (2006, 2007). In general, unsuitable habitat types for marten in Newfoundland are water, bog and barren, scrub, recently (≤ 5-yrs) cut stands, and medium height (6.6-12.5 m tall) conifer stands, with ≤ 50% canopy closure (Table 2). In-depth descriptions of the methods used to determine suitable and unsuitable habitat types utilized by the MOM modeling platform are provided in Fuller (2007), Fuller et al. (2006, 2007), Hearn (2007), and Hearn et al. (2005, 2010).

Fuller et al. (2006, 2007) developed MOM using an information-theoretic approach (Burnham and Anderson 1998) to evaluate the relationship between home-range occupancy and various habitat characteristics, i.e., habitat composition and spatial configuration. Their analysis concluded that marten occupancy was most strongly influenced by a single variable, i.e., the amount of suitable habitat within the home range. They further reported that other landscape characteristics (habitat patch size and characteristics) were far less influential in determining whether a marten occupied an area. Based on this analysis, MOM uses a logistic

Table 2. Marten habitat classes utilized to define suitable and unsuitable habitat types for Newfoundland Marten (Hearn et al. 2005, 2010), Hearn (2007), Fuller (2006), Fuller et al. (2006, 2007). Habitat class general descriptions derived from the provincial forest inventory (Anonymous 1991).

Habitat Class	General Description
Bog / Barren	Open, generally treeless bogs, and rock and soil barrens
Recent Cuts	Recent (≤ 5 years) cutovers; some snag retention, and residual patches of hardwood and unmerchantable softwood
Scrub	Unmerchantable softwood patches ≤ 6.5 m; generally low productivity sites
Regenerating Stands	Young conifer regeneration with height ≤ 6.5 m and canopy closure ≥ 75%
Precommercially Thinned Stands	Closed canopy (> 50%) conifer stands, 20-30 years old (7-17 years post thinning); typical density of 1500 stems/ha
Medium Open Softwood	Medium height (6.6-12.5 m) conifer stands with canopy closure ≤ 50%
Medium Closed Softwood	Medium height (6.6-12.5 m) conifer stands with canopy closure > 50%
Tall Open Softwood	Tall (+ 12.6 m) conifer stands with canopy closure ≤ 50%
Tall Closed Softwood	Tall (+ 12.6 m) conifer stands with canopy closure > 50%
Insect-killed Stands	Primarily tall (+ 12.6 m) insect-killed conifer stands with little (< 25%) canopy closure; understory typically softwood (*Abies balsamea)* regeneration

regression-based habitat model to predict and map the probability of occurrence for an adult female marten (Figure 8; Table 3) as a function of the percent of suitable habitat in the home range (Figure 9).

Successively, MOM then converts the marten probability map into an estimate of "potential" density of adult female marten, i.e., occupiable territories, by generating a fishnet grid (squares) with marten home-range size (8-km^2) squares (Figure 10); 8-km^2 was the median home-range size of adult resident female marten (see Hearn 2007; Table 3) after being adjusted for intrasexual home-range overlap (Fuller et al. 2007). All home-range size squares are assessed as to overall probability of occupancy using the Zonal statistics tool within ArcGIS and each potential home-range square is given an average probability of occupancy. These home-ranges can be grouped and spatially mapped into user-defined classes according to minimum amount of habitat within a home-range size square, e.g., ≥ 35, ≥ 40% suitable habitat, for any study area of interest. Each simulated home range is further assessed by MOM for other spatial-statistic thresholds to determine if the simulated home-range is suitable for marten occupancy, e.g., the amount of young forest (i.e., PCT, Recent Cuts + Regenerating Forest) within each home range cannot exceed ≥ 38%; the minimum amount of mature forest is 24%. Home-range squares not meeting these criteria are eliminated as suitable for occupancy by marten. These screening criteria were developed by Fuller et al. (2007) based on the habitat composition of 88 (44 females; 40 males) home ranges of adult (≥ 1-yr) resident marten documented by Hearn (2007). Criteria and methods used to model home-range size and spatial location, and residency of adult marten, are fully outlined in Hearn et al. (2005).

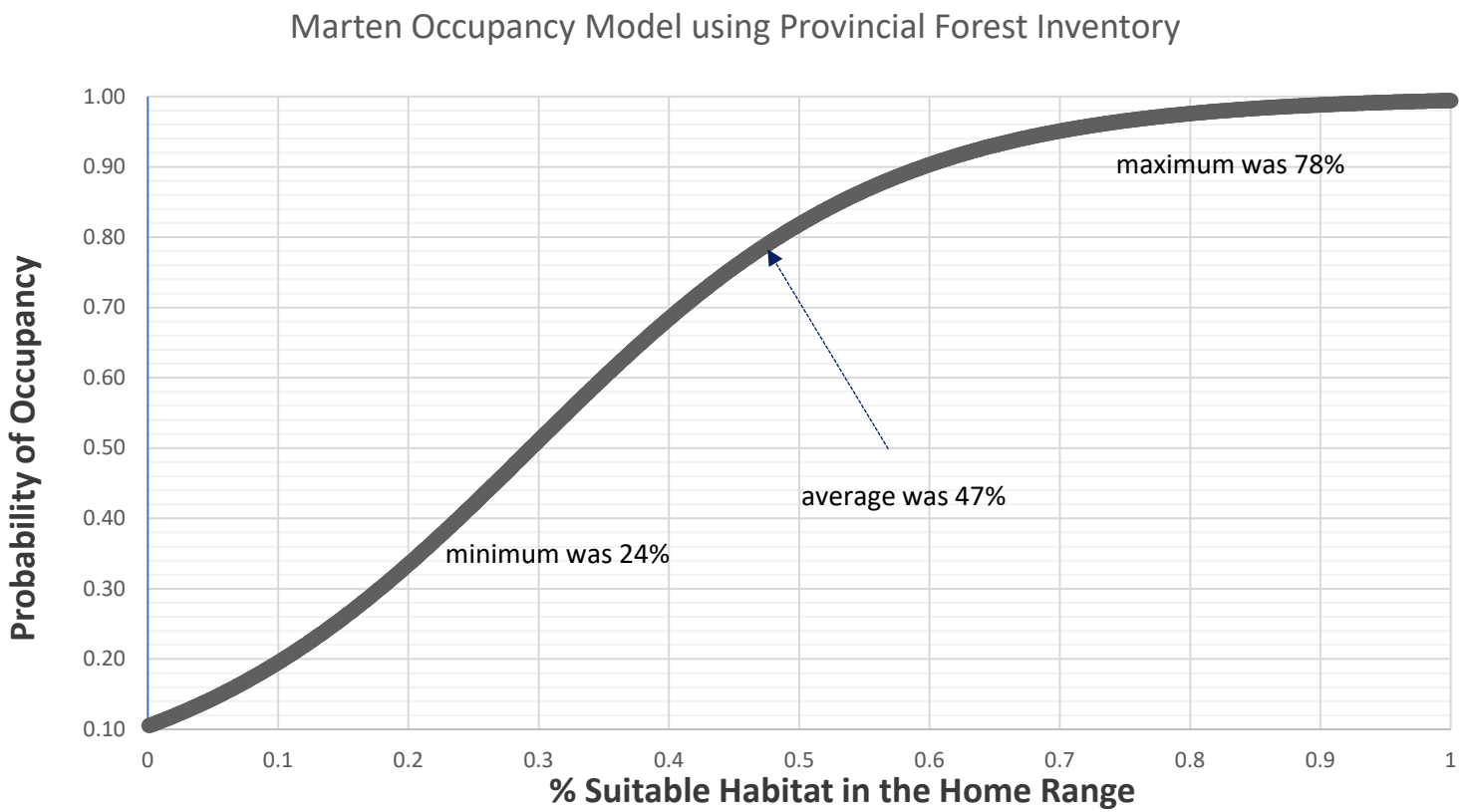

Figure 8. Marten probability of occupancy as a function (logistic regression) of the percent of suitable habitat in the home range. This logistic regression was based on the amount of suitable habitat in home ranges of 84 adult resident marten (Hearn et al. 2005, Fuller et al. 2005) versus the habitat composition of home-range size areas not known to support a resident marten (Fuller 2006). Average amount of suitable habitat in these ranges was 47% (range = 24-78%). Further, 82% of adult resident marten had ≥ 35% suitable habitat whereas 18% had between 24% and 34% suitable habitat.

Table 3. Probability that an adult marten would occupy a home-range size area (8-km^2) at various levels of suitable habitat availability within the home range; tabular data generated from logistic regression depicted in Figure 9. By explanation, the regression predicts that the probability of a marten occupying a home range area comprised of 35% suitable habitat is approximately 60%

% Suitable Habitat Available in the Home Range Area	Probability that an adult marten would occupy the area
25%	42.0%
30%	51.1%
35%	60.1%
40%	68.4%
45%	75.7%
50%	81.8%
55%	86.6%
60%	90.3%
65%	93.1%
70%	95.1%
75%	96.5%
80%	97.6%
85%	98.3%
90%	98.8%
95%	99.2%
100%	99.4%

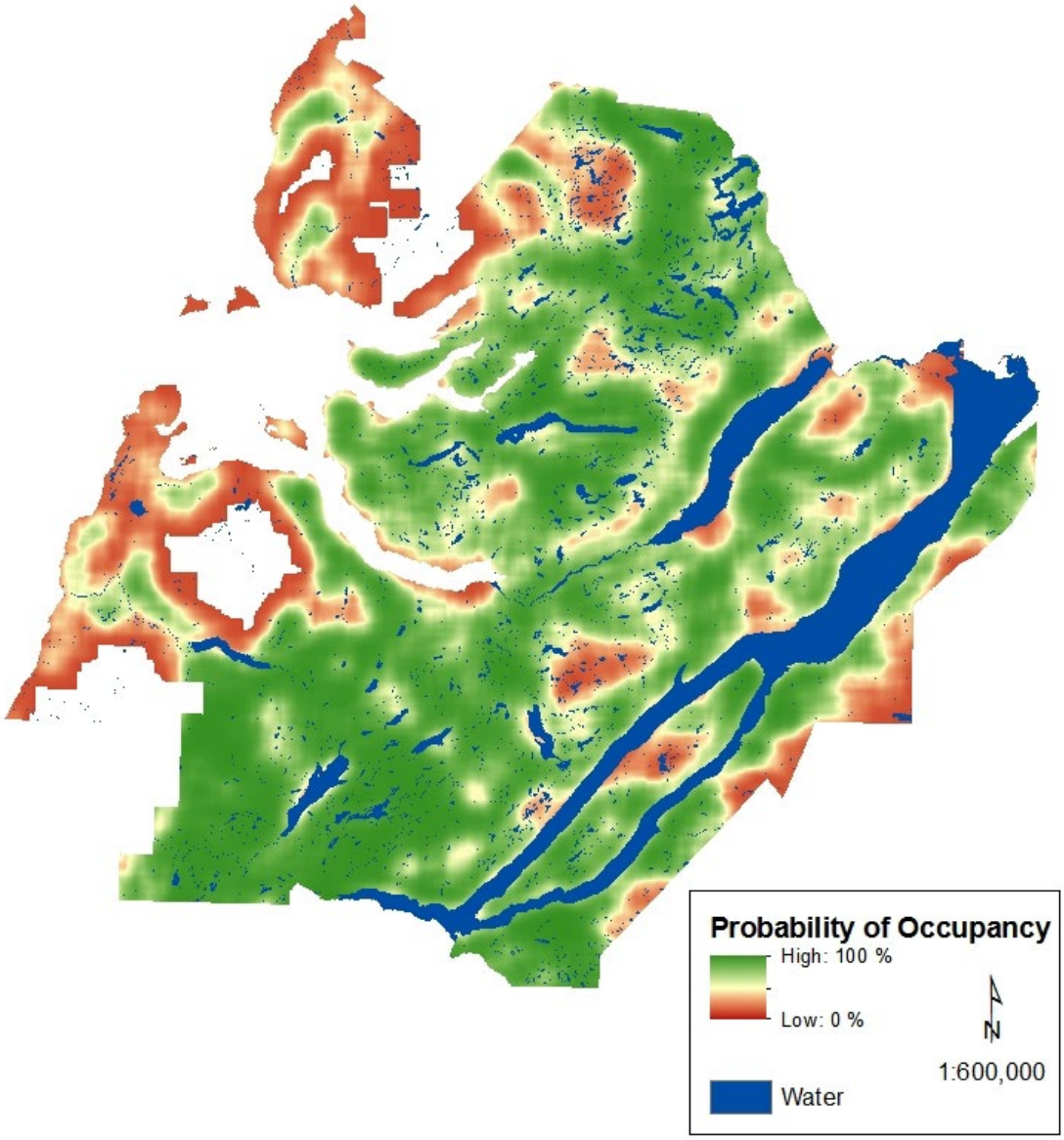

Figure 9. Results of the marten occupancy model for Forest Management District 15.

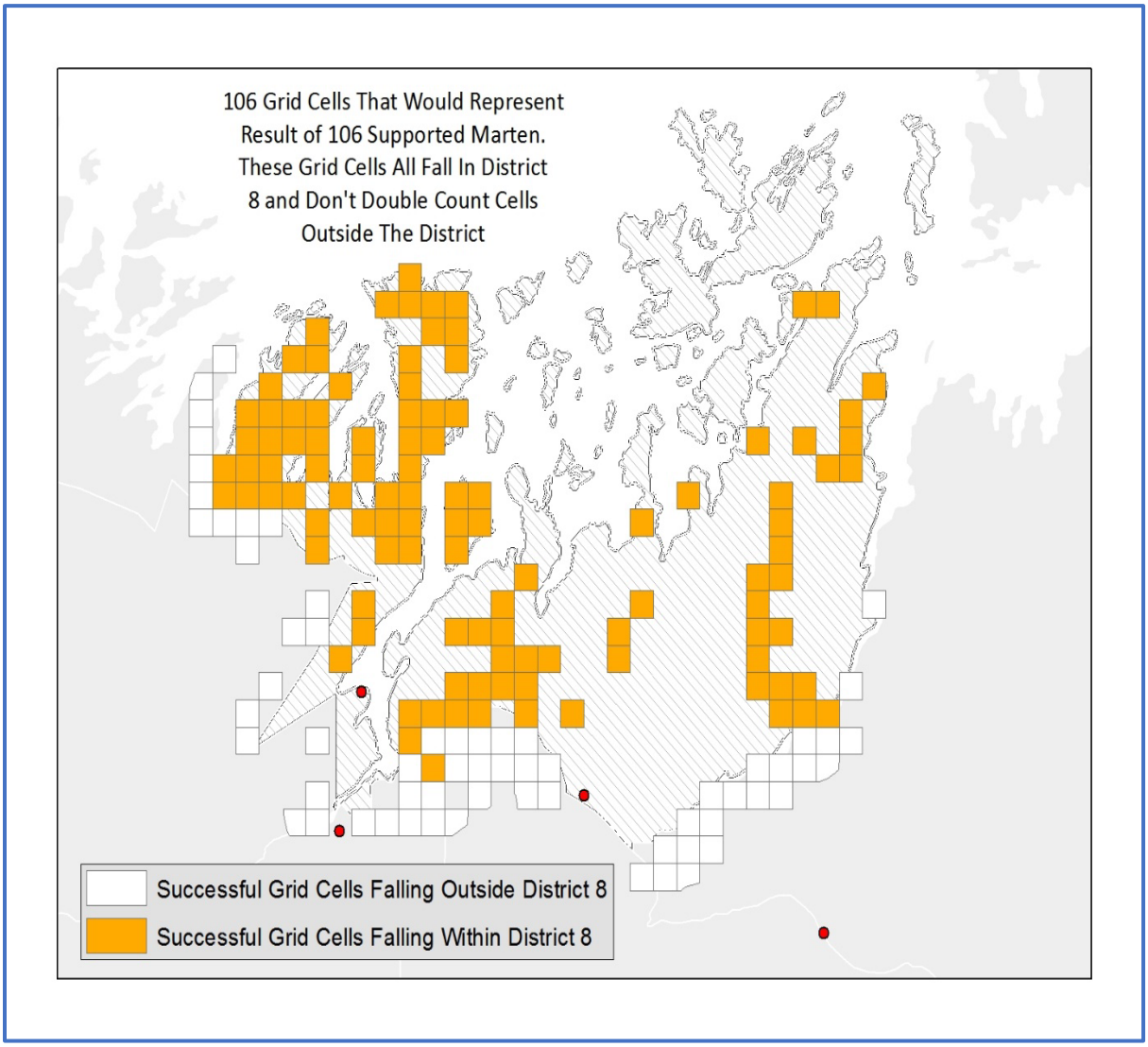

Figure 10. Fishnet grid use by Marten Occupancy Model overlaid on Forest Management District 8 indicating successful grids, i.e., simulated 8-km^2 marten home-ranges that have ≥ 35% suitable habitat available.

Potential Marten Population Estimate

To estimate the potential marten population size, we ran MOM for each of the forest management districts at two levels of suitable habitat availability: 1) home ranges in the FMD with ≥ 35% suitable habitat; versus 2) home ranges with ≥ 40% suitable habitat. These % habitat suitability levels (model defaults) correspond to approximately 60% and 68% probability that a marten would occupy a home range comprised of 35% or 40% suitable habitat, respectively. We chose to run the model at these two habitat suitability levels based on the empirical field data used to develop the model, i.e., the average amount of suitable habitat in the home ranges of 84 adult resident marten reported by Fuller et al. (2006, 2007) was 47% (range = 24-78%). Based on the cumulative distribution of the data used to build MOM, 18% of marten home ranges had < 35% suitable habitat and 82% had ≥ 35% suitable habitat. MOM calculates a population estimate by summing all home ranges on the landscape that meet the default % suitable habitat threshold set for the analyses. In fact, the final estimate of the number of adult female marten an area can support is the average of 9 separate model iterations during which the fishnet grid overlaying the landscape is shifted slightly between each iteration. Fuller et al. (2007) reported that the estimated number of potential home ranges that could be supported stabilized after only 4 iterations.

Actual Marten Population Estimate

To calculate the actual number of adult resident female marten an area could support, we clipped the FMD area based on the marten locational database. We used only marten locations collected since 1990 and buffered each point by 20 km. We then restricted the

application of our MOM results to count only marten territories within the FMD that were inside this 20 km buffered radius of the known marten location. We set 1990 as the cut-off year for filtering the marten location database to utilize the more recent data and to exploit the large amounts of marten location data collected during the most intensive marten research period of the mid- to late 1990's. However, based on Figures 2-7, we suspect that including all marten locations recorded in the database would not have changed the results of the analysis significantly due to the substantial overlap between the current estimated distribution of marten on the island and the marten locations recorded prior to 1990. In reality, the current spatial distribution of marten on the island is undoubtedly increasing; unfortunately, however, the quantity of locational data collected annually has decreased over the last several decades primarily due to reduced research and survey efforts. We chose to use a 20-km radius around all known marten locations as a reasonable estimate of the potential of the surrounding areas (high-probability marten habitat) to be occupied by marten; this distance is well within the observed movement distance of Newfoundland Marten based on empirical field data (Gosse et al. 2005, Hearn 2007, Hearn et al., unpublished field data).

We did not discard marten locations where the age of the animal was either unknown e.g., track stations, hair snagging data, or location was from a juvenile animal. Our assumption here is that a dispersing juvenile would become resident in areas mapped as high probability of occupancy if no territorial adult was resident. Dispersing juveniles have been noted to displace territorial breeding females that are oftentimes energetically depleted and in poor body condition postpartum (D. Harrison, University of Maine, pers. comm.).

We developed our methods and modelling procedures based on the best-available information from published research and unpublished data. In summary, our step-by-step approach (with transitional steps) was to:

1. Develop landcover maps for each of the 18 FMD:
    a. Update the provincial forest inventory for all FMD with dated inventory;
    b. Apportion the FMD whenever required to deal with computer modelling capabilities;
    c. Eliminate districts (or portions) where inventory was outdated or unavailable.
2. Run MOM for each of the FMD on the island:
    a. Calculate the potential number of marten that could be supported for each of the 18 FMD at two levels of habitat suitability, i.e., 35% and 40% suitable habitat within the home-range size assessment.
3. Using the provincial marten location database (MLD), determine areas of the province currently supporting marten:
    a. Finalize the subset of this data to map current marten distribution;
    b. Develop methodologies to objectively group and encompass marten occurrence data thus our estimates of where marten currently occur on the island.
4. For each of the 18 FMD, rerun the MOM model on the subsection of the FMD estimated in Step (3b) above to calculate the actual population size of marten on the island.

RESULTS

Landcover

Forest inventory was largely available for 17 of the 18 FMD on the island (Table 4). Only 5.6% of FMD 3 has been inventoried, and no marten locations are known for this district thus we excluded it from the analysis. No PFI is available for either of the two national parks in the province (combined area of 2,280 km^2), so these areas were also excluded. Similarly, forest inventory information is available for only 26% of FMD 7 and the available inventory information is dated. However, the inventoried portion of FMD 7 that was available represented an area of over 3,000 km^2, and further, marten are known to be present in this portion of the FMD (Appendix 6). Consequently, we included FMD 7 in our analysis. For the remaining 16 forest management districts, inventory was available for an average of 94% of the district but inventory availability ranged from a low of 56.8% (FMD 14) to 100% (FMDs 4, 6, 8, 10, 11, 12, and 15). Overall, we evaluated 83,020 km^2 (74.6%) of the island as to marten habitat suitability, potential population size, and actual population size.

The actual year of aerial photography (hence forest inventory) for the 17 districts we assessed ranged from 1970 to 2011. Therefore, we advanced forest stand age (hence stand height) for 8 of the 16 FMD which represented approximately 40% of the area we assessed, following the methods outlined in Hearn (2007) and Fuller et al. (2006, 2007). After this temporal adjustment, the weighted (based on area inventoried and modelled in km^2) average time stamp for the landcover across the 17 districts was 2014 (range 2008-2015). Henceforth,

the habitat availability, and population estimates reported herein reference conditions on the island around 2014-2015.

Table 4. Summary statistics and information on the provincial forest inventory available for the 18 forest management districts (FMD) on the island of Newfoundland.

FMD	Area (km^2)	% of Island	PFI year of actual photography	Projected PFI year[3]	Inventoried area (km^2)	% of FMD inventoried
1	9,747	8.8	2009	2019	7,986	81.9
2	4,814	4.3	2005	2015	4,808	99.9
3[4]	6,848	6.2	2006	n/a	380	5.6
4	3,016	2.7	2005	2015	3,016	100.0
5	5,774	5.2	2005	2015	5,768	99.9
6	4,527	4.1	2006	2016	4,527	100.0
7	12,404	11.1	1970	n/a	3,237	26.1
8	2,817	2.5	1999	2009	2,816	100.0
9	6,248	5.6	2011	2021	6,222	99.6
10	1,991	1.8	2011	2021	1,991	100.0
11	2,988	2.7	2003	2013	2,988	100.0
12	4,857	4.4	2003	2013	4,856	100.0
13	2,593	2.3	2003	2013	2,371	91.4
14	15,155	13.6	2010	2020	8,613	56.8
15	5,625	5.1	2001	2011	5,625	100.0
16	6,858	6.2	2007	2017	6,773	98.8
17	6,468	5.8	2008	2018	5,917	91.5
18	6,266	5.6	2008	2018	5,499	87.8
Terra Nova & Gros Morne National Parks[2]	2,280	2.0	n/a	n/a	n/a	n/a
Total Area	111,278				79,776	

[3] Projected PFI year indicates that the stand height was advance one height class to account for growth since aerial photography interpretation.
[4] Excluded from analysis; only 5.6% of FMD 3 is inventoried; PFI unavailable for both national parks.

Potential Marten Population Estimate

We estimated that the potential number of adult female home ranges that could be supported on the portion of the island for which we had available forest inventory information (83,020 km^2) was 2,004 marten when the model was constrained to a 35% habitat suitability threshold (Table 5). Accounting for males, the total adult resident marten population would be double or 4,008 adult resident marten. This number might alternatively be described as potential adult breeding segment of the marten population. Restricting the model to require home-ranges areas to contain at least 40% suitable habitat would reduce the carrying capacity of the inventoried landcover on the island to 1,794 adult female marten or a total marten population of ca. 3,600 marten. Additional potential home ranges would be available in suitable habitat within both national parks and the remaining portion of the island which was not modelled. These animals are not included in this estimate of potential number of marten that could be supported island-wide. This estimate appears plausible given that the historical record indicated that 3,580 pelts were exported from the island in 1763 (COSEWIC 2019).

Table 5. Potential number of adult female home ranges (8-km^2) that could be supported in the inventoried portion of each of the Forest Management Districts (FMD), at 2 levels of habitat availability, i.e., ≥ 35% or ≥ 40% of suitable habitat. Estimates are based on the forest inventory information available for each FMD and not the total area in the district, e.g., FMD 7 is 12,404 km^2 but only 3,237 km^2 (26.1%) is inventoried (see Table 4 for details on forest inventory availability per FMD).

FMD	Inventoried Area Portion of the District (km²)	Minimum amount of habitat in home range = 35%	Minimum amount of habitat in home range = 40%
1	7,986	86	57
2	4,809	124	109
3[5]	n/a	n/a	n/a
4	3,016	32	28
5	5,768	85	74
6	4,527	75	70
7	3,237	51	46
8	2,817	112	90
9	6,222	164	146
10	1,991	34	30
11	2,988	40	34
12	4,857	150	116
13	2,371	38	29
14	8,613	178	172
15	5,625	308	283
16	6,774	244	239
17	5,917	185	176
18	5,500	149	141
Total Resident Adult Females		2,004	1,794
Total Resident Population		4,008	3,588

[5] Excluded from analysis. No forest inventory available; no marten locations known for district.

Actual Marten Population Estimate

Marten have been recorded in 15 of the 18 FMD on the island (Figure 7). No marten locations have been recorded for the Burin Peninsula (FMD 3) or the northernmost regions of the Northern Peninsula (FMD 18). Similarly, no marten have been observed or captured in FMD 1 (Avalon Peninsula). However, partially verified information (genetic testing of hair snag samples) is suggesting that marten may now be present in the easternmost portion of the Avalon Peninsula. Nonetheless, given that there are no other marten locations recorded east of the beginning of Avalon Isthmus we conservatively judged it more appropriate to consider that currently marten do not occupy any portion of the province east of the Avalon Peninsula Isthmus (Figure 11). Therefore, the total number of resident females estimated to occupy territories on the remaining portion of the island having at least 60% probability of occurrence for marten is 1,386 animals. Accounting for males, the total breeding population would be estimated at 2,773 marten (Table 6). Restricting our population estimate to count only home-range areas with ≥ 40% suitable habitat (68% probability of occurrence) would only reduce the number of marten estimated to be occurring in these same areas by approximately 10% (total population size of 2,495 adult marten; Table 5). Thus, our best estimate of the total adult breeding population for the portion of the island was assessed (ca. 75%) ranges between 2,495-2,773 adult resident marten.

Table 6. Estimated actual adult resident marten on 83,020 km^2 of the island of Newfoundland by Forest Management District (FMD) based on 35% suitable habitat availability within home-range size areas (8-km^2). Marten spatial distribution within each FMD based on known occurrence data and a 20 km buffer surrounding each known location.

FMD	Adult Female Population Estimate at 35% suitable habitat	Total Adult Population Estimate (Males and Females)
1[6]	0	0
2	93	186
3[7]	n/a	n/a
4	27	54
5	54	108
6	52	103
7	23	46
8	33	66
9	80	161
10	22	43
11	27	55
12	135	270
13	33	66
14	128	255
15	288	576
16	220	441
17	171	342
18[1]	0	0
Total Marten Population Estimate	1386	2773

[6] No marten occurrence data recorded for FMD 1 or FMD 18 suggesting that presently marten do not occur in these districts.

[7] FMD 3 was not modelled due to lack of forest inventory; no marten occurrence recorded for FMD 3.

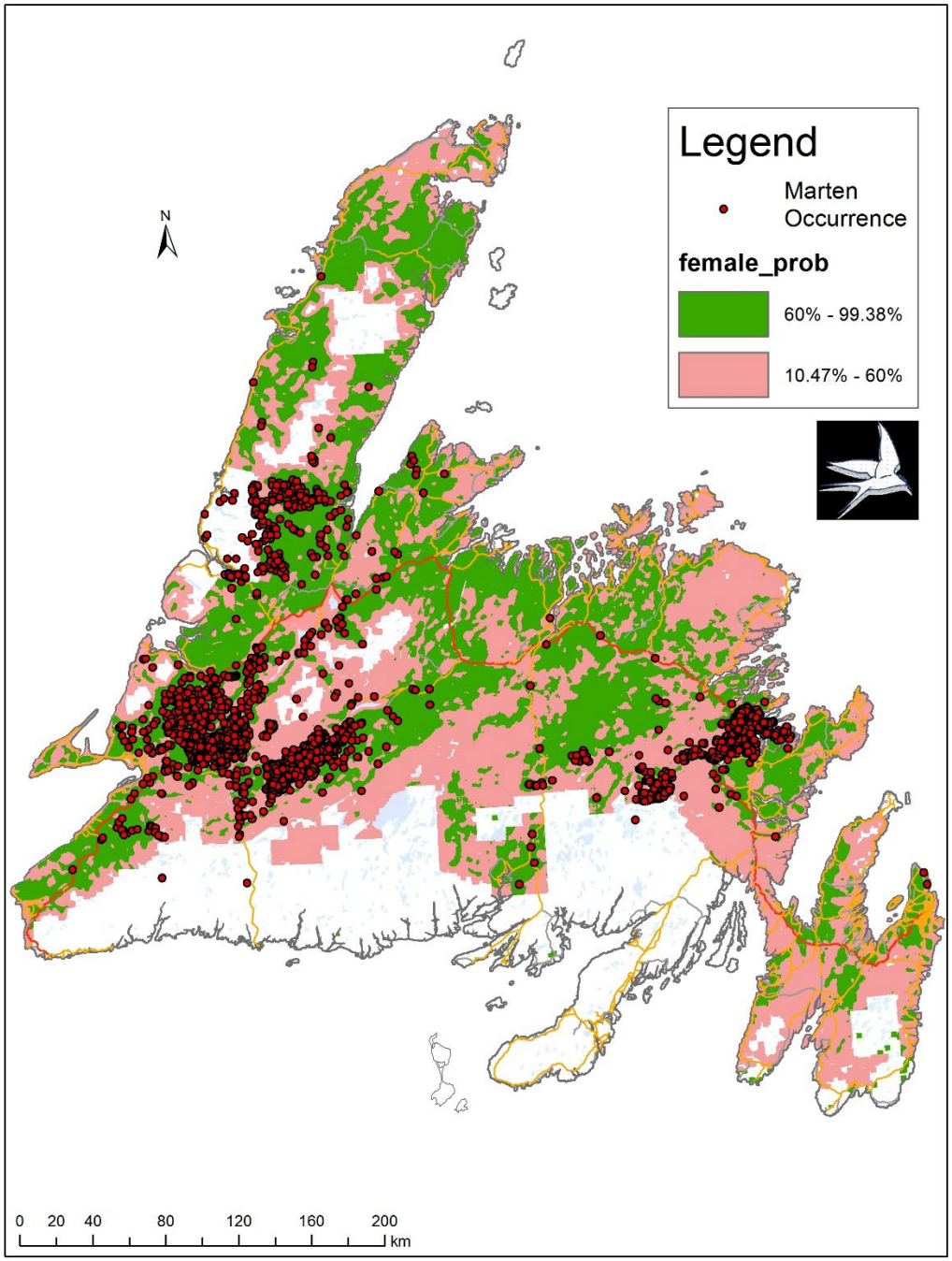

Figure 11. All marten locations recorded on the island between 1990-2018 overlain on the total area of the province assessed. Green areas highlight habitat with ≥ 60% probability of occupancy by marten based on the underlying landcover.

The most recent information on marten abundance in the two national parks (COSEWIC 2019) is suggesting approximately 30 marten in each of the two national parks, or a total of 60 additional marten. These marten are in addition to the total adult resident marten of 2,495-2,773 estimated above.

CONCLUSIONS AND MANAGEMENT CONSIDERATIONS

Empirical data and anecdotal observations of marten in Newfoundland are strongly suggesting that the Newfoundland Marten population has undergone considerable recovery over the last several decades. Marten appear to be recapturing parts of their historical range, notably the Baie Verte Peninsula, Stephenville area, and forested areas in southcentral Newfoundland. Currently, we estimate that the adult resident population of Newfoundland Marten is between 2,495-2,773 adult resident marten. This estimate assumes that marten are resident within a 20-km radius of known marten observations in all home-range size areas with 35-40% suitable habitat (60-68% probability of occurrence). We could argue that the higher population estimate based on the ≥ 35% suitable habitat is an appropriate and still slightly conservative value based on the fact that 18% of the adult resident marten that supplied data to build our predictive models occurred in areas with < 35% suitable habitat (Fuller et al. 2006, 2007).

Our current population estimate indicates that the Newfoundland marten has shown significant population growth since the COSEWIC population assessments of 1995 and 2007. We strongly suspect that this increase is the result of at least two interacting issues. Firstly, we

suspect that several of the previous population estimates for Newfoundland Marten were overly conservative and based on precautionary assumptions given the concern for this listed species that was predominant when these earlier population assessments were completed. Thus, the significant increase we note in the overall marten population estimated is explained in part by differences in assessment methods.

Secondly, the marten population in Newfoundland is increasing in spatial distribution and recapturing historical range, consequently the population size has undoubtedly increased. This population growth is likely being driven by several positive changes (and interactions) in the ecological circumstances for marten in Newfoundland. Several of these positive changes are noted below:

- Accidental snaring and trapping mortalities are likely decreasing following the introduction of best management practices over the last decade to reduce incidental take of marten; further, the Newfoundland population of snares and trappers is likely diminishing as older residents discontinue this recreational activity while fewer younger individuals engage in these traditional activities;
- Forest harvesting levels have reduced over the last decades resulting in a decrease in the amount of forest harvested annually; this reduction in forest harvesting is a confounded positive effect as it reduces the amount of marten habitat that is immediately removed while also reducing human access and opportunities for snaring and trapping;

- Red-backed Vole (*Myodes gapperi*) expansion across the island over the last 2 decades is likely improving marten demography by increasing available prey biomass, which in turn, is likely improving marten fecundity and adult juvenile survival;
- Unpublished field data suggest that marten territories may be smaller now than in the past, seemingly a direct response to improvements in small mammal prey biomass following the introduction of the Red-backed Vole; smaller home range requirements for resident marten would increase marten densities on the landscape.

Future assessments of the population status of the Newfoundland Marten would benefit from an applied research and management program aimed at reducing the uncertainties intrinsic to a population assessment such as this one. In particular, the continuation of passive hair-snagging surveys would improve our understanding of where marten occur and would improve our ability to map habitat occupancy and estimate population size. Future hair snagging surveys could be focused in areas having significant amounts of contiguous suitable habitat that currently are not known to be occupied by resident marten, e.g., FMD 18 (see attached Appendices). Research into current marten spatial requirements might be considered to test whether Newfoundland Marten home-ranges have decreased in response to the island-wide establishment of the Red-Backed Vole and such information should then be used to adjust future modelling efforts. Translocations of marten appear unnecessary to advance recovery of the population at this time but might be considered to speed recovery

in areas with significant amounts of suitable habitat that are disjunct from currently occupied areas, e.g., Avalon Peninsula. Such an effort would provide a very positive conservation and public stewardship opportunity for the province. Finally, the availability of a spatially-explicit population assessment tool such as the Marten Occupancy Model should be integrated into other spatially-explicit assessments, in particular forest harvest planning. Such an approach would proactively reduce natural resource management conflicts.

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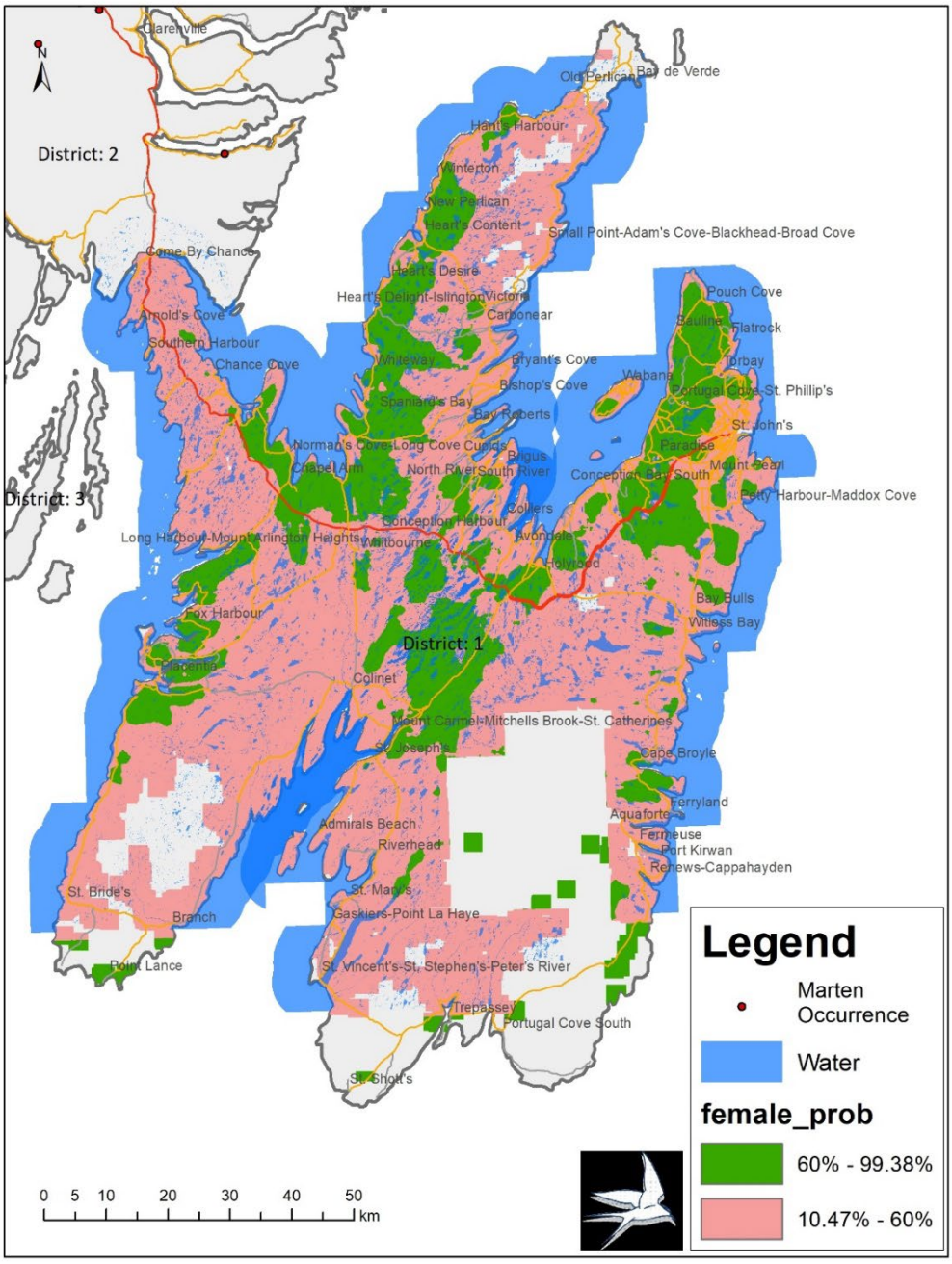
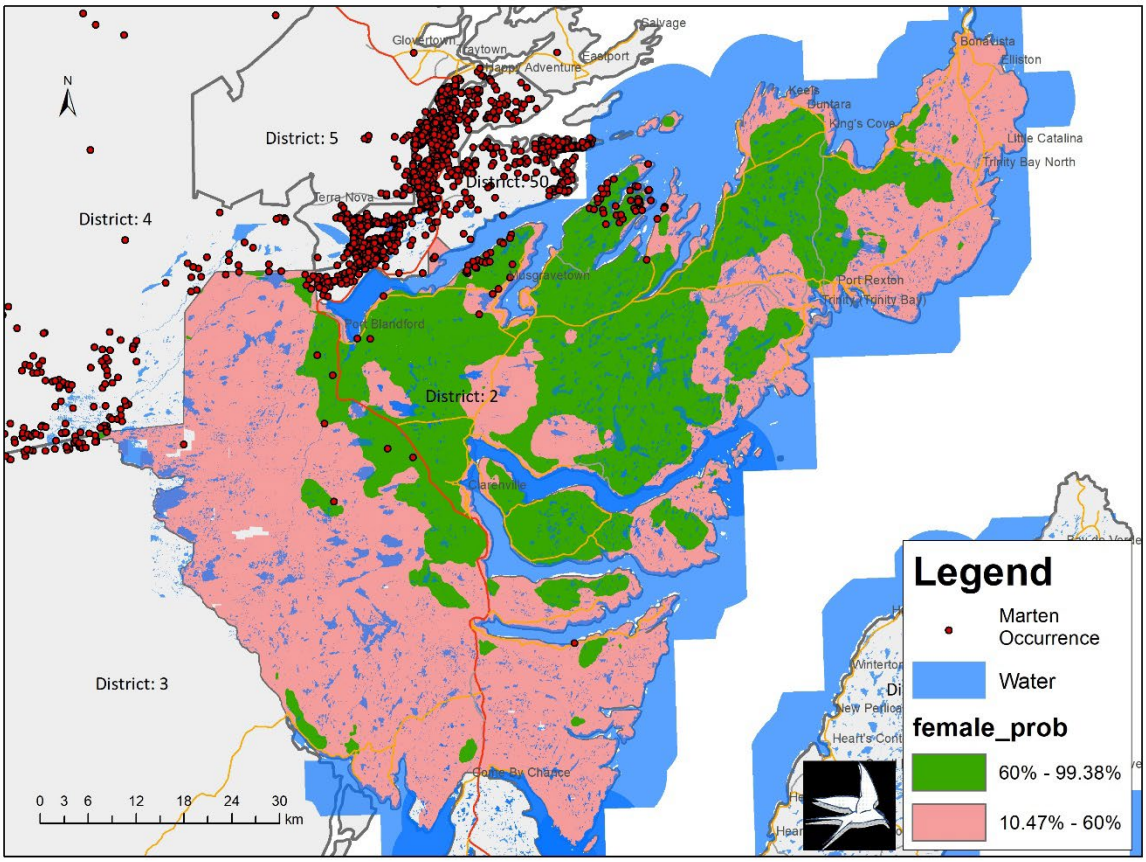
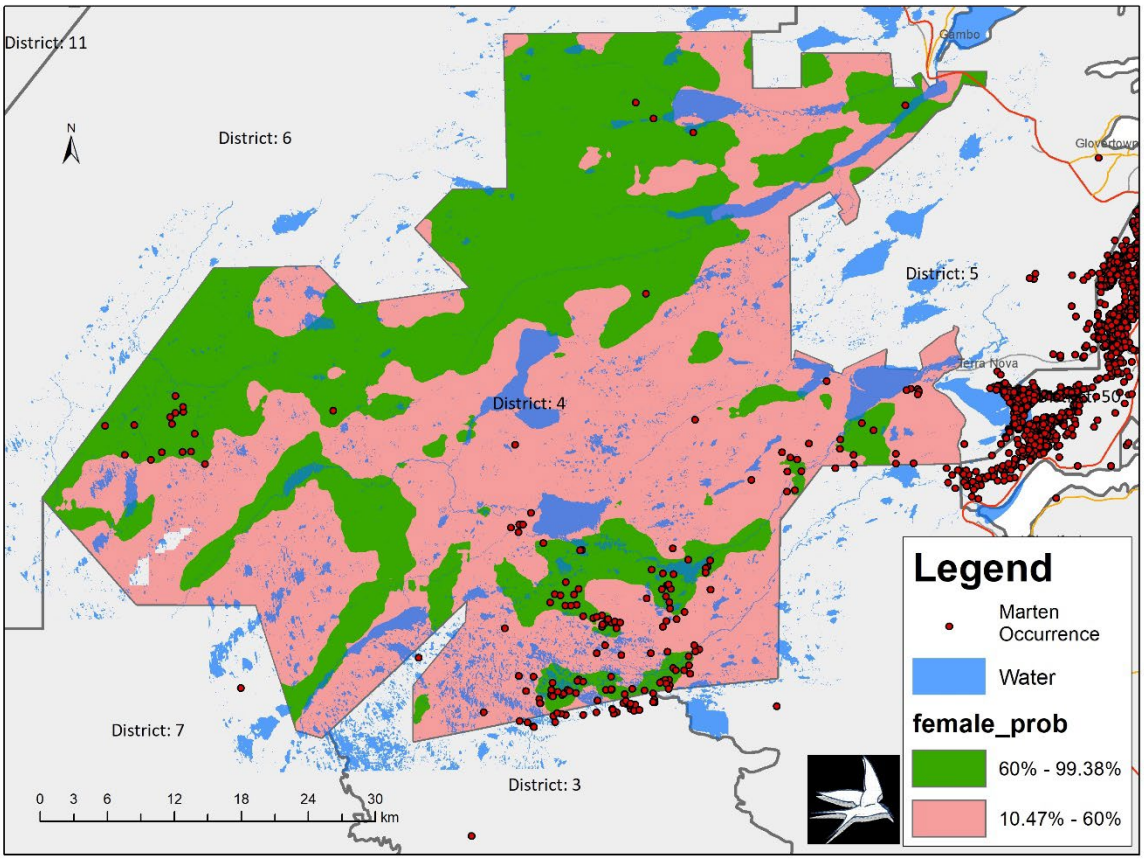
APPENDICES: MARTEN HABITAT WITH ≥ 60% PROBABILITY OF OCCURRENCE FOR EACH OF THE FOREST MANAGEMENT DISTRICTS ON THE ISLAND OF NEWFOUNDLAND.



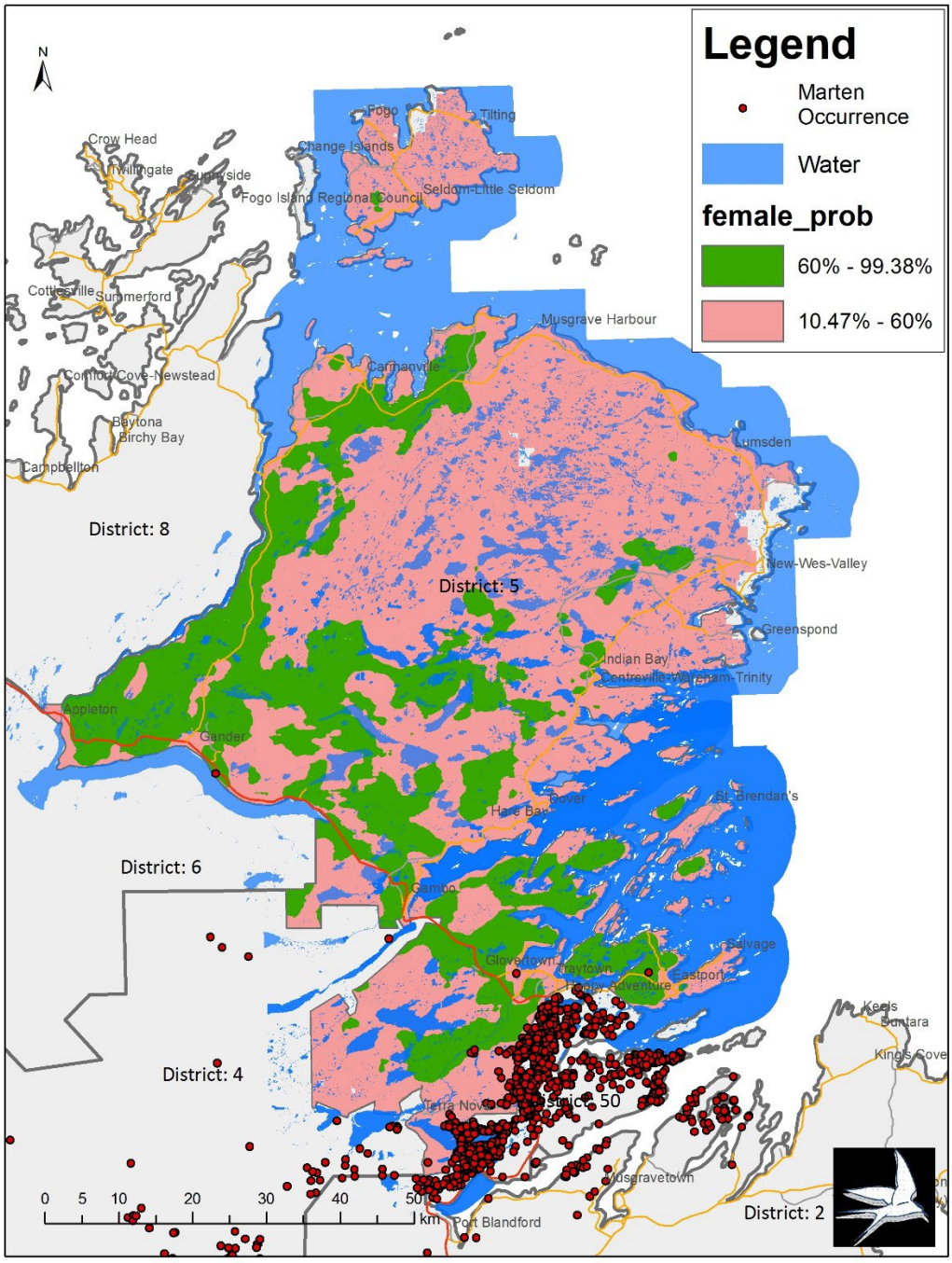
APPENDIX 1. MARTEN HABITAT IN FM1 WITH ≥ 60% PROBABILITY OF OCCUPANCY



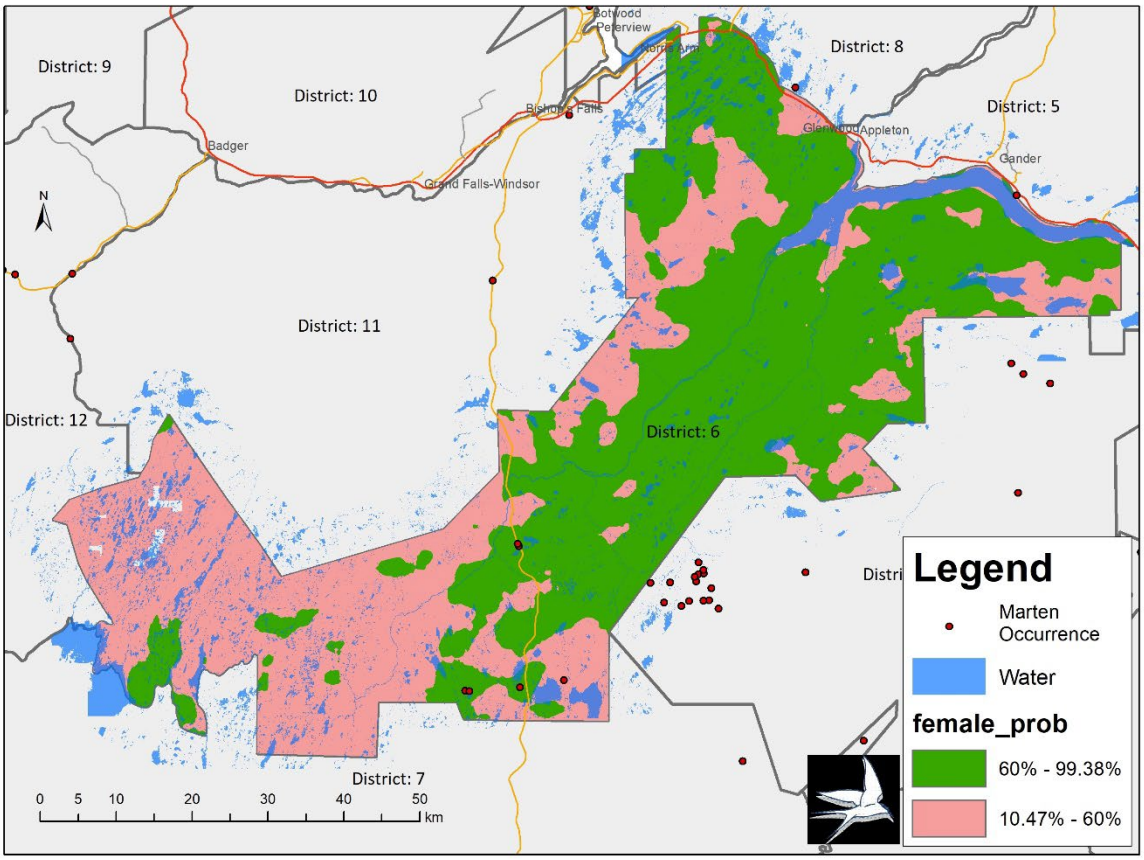
APPENDIX 2. MARTEN HABITAT IN FMD 2 WITH ≥ 60% PROBABILITY OF OCCURRENCE



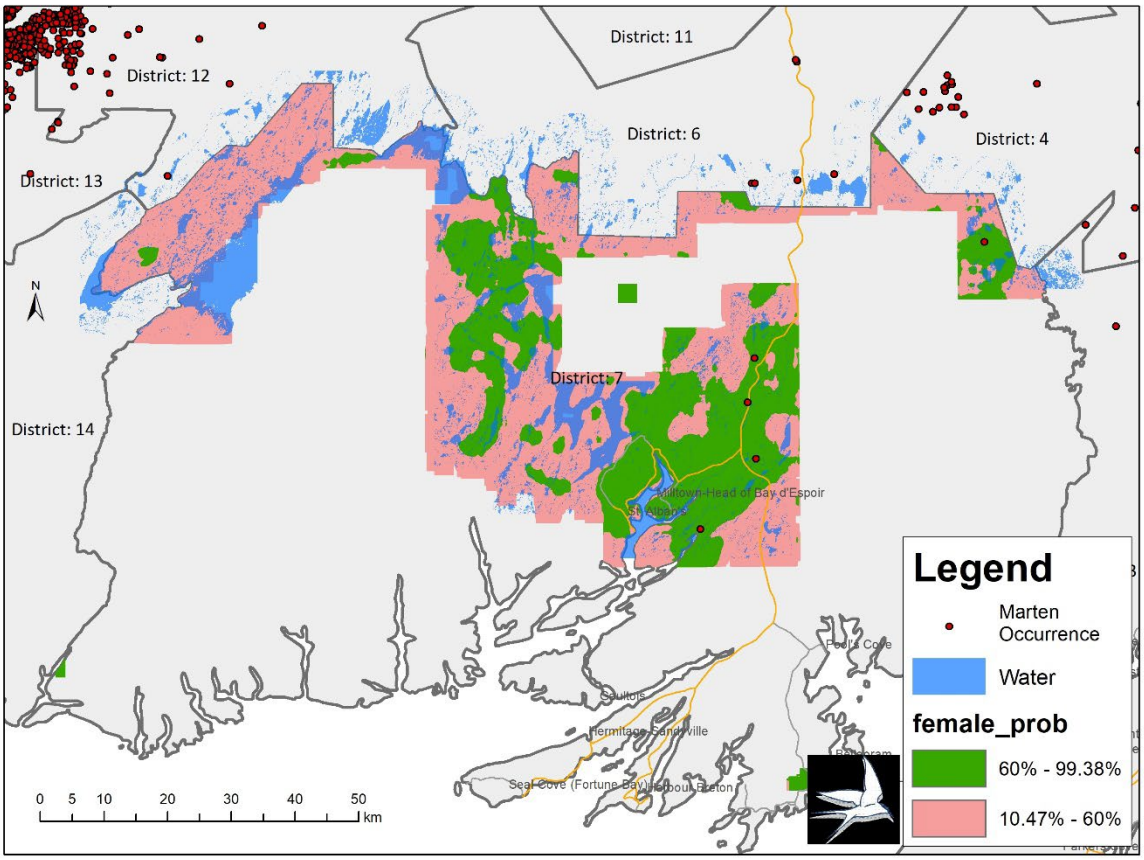
APPENDIX 3. MARTEN HABITAT IN FMD 4 WITH ≥ 60% PROBABILITY OF OCCURRENCE



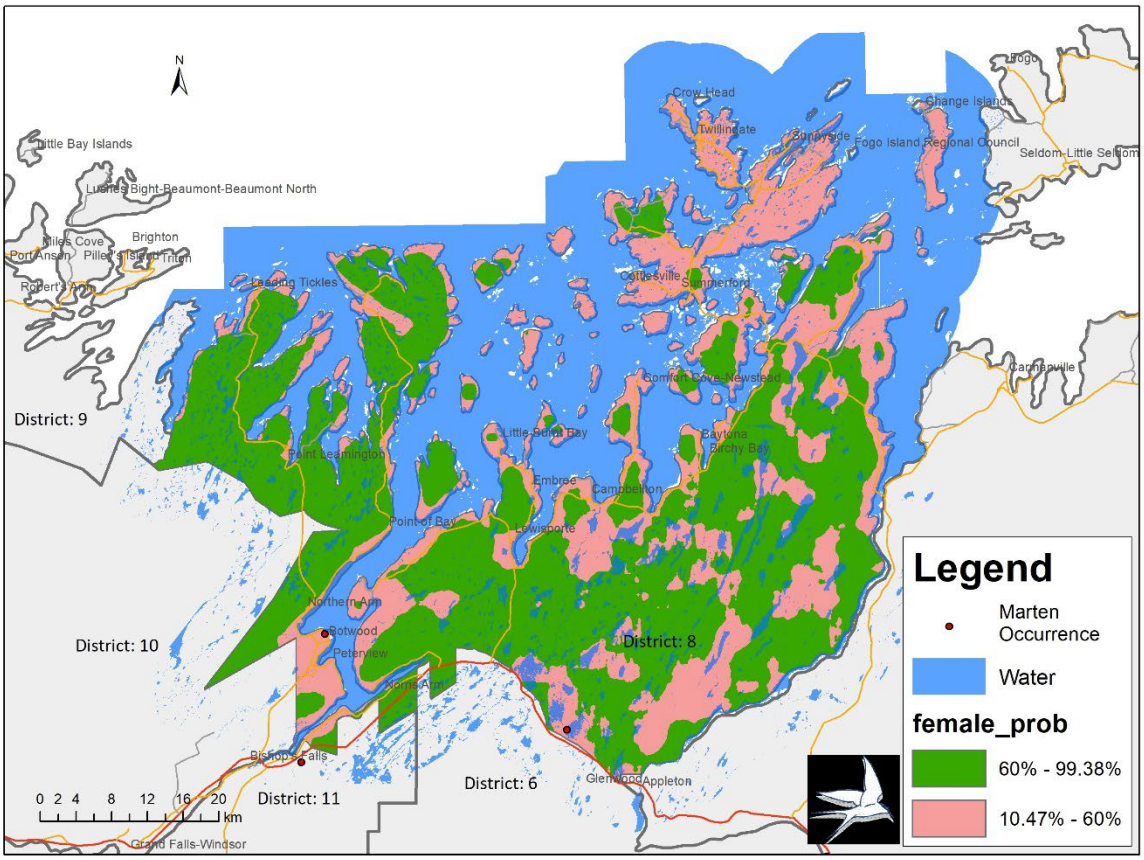
APPENDIX 4. MARTEN HABITAT IN FMD 4 WITH ≥ 60% PROBABILITY OF OCCURRENCE



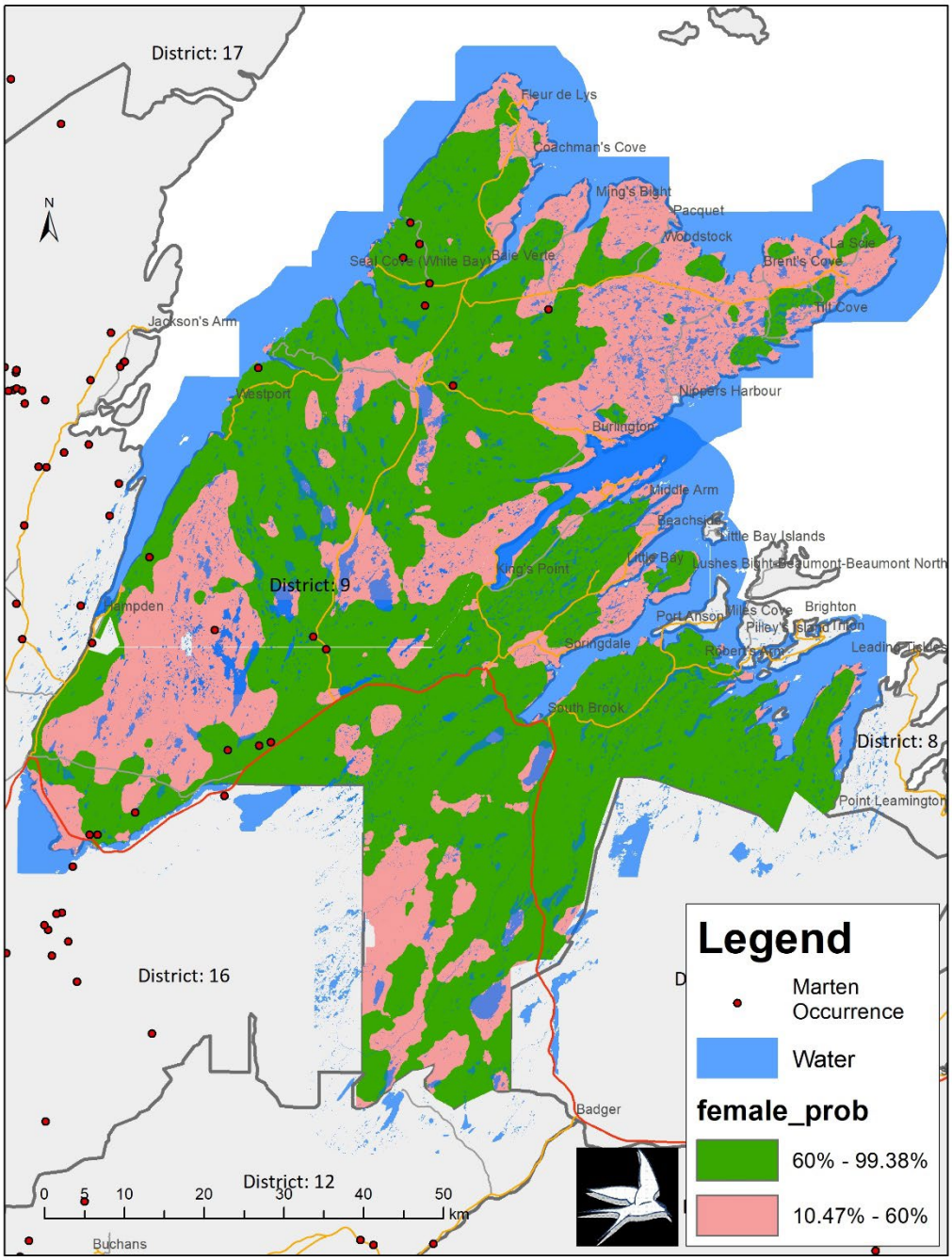
APPENDIX 5. MARTEN HABITAT IN FMD 6 WITH ≥ 60% PROBABILITY OF OCCURRENCE



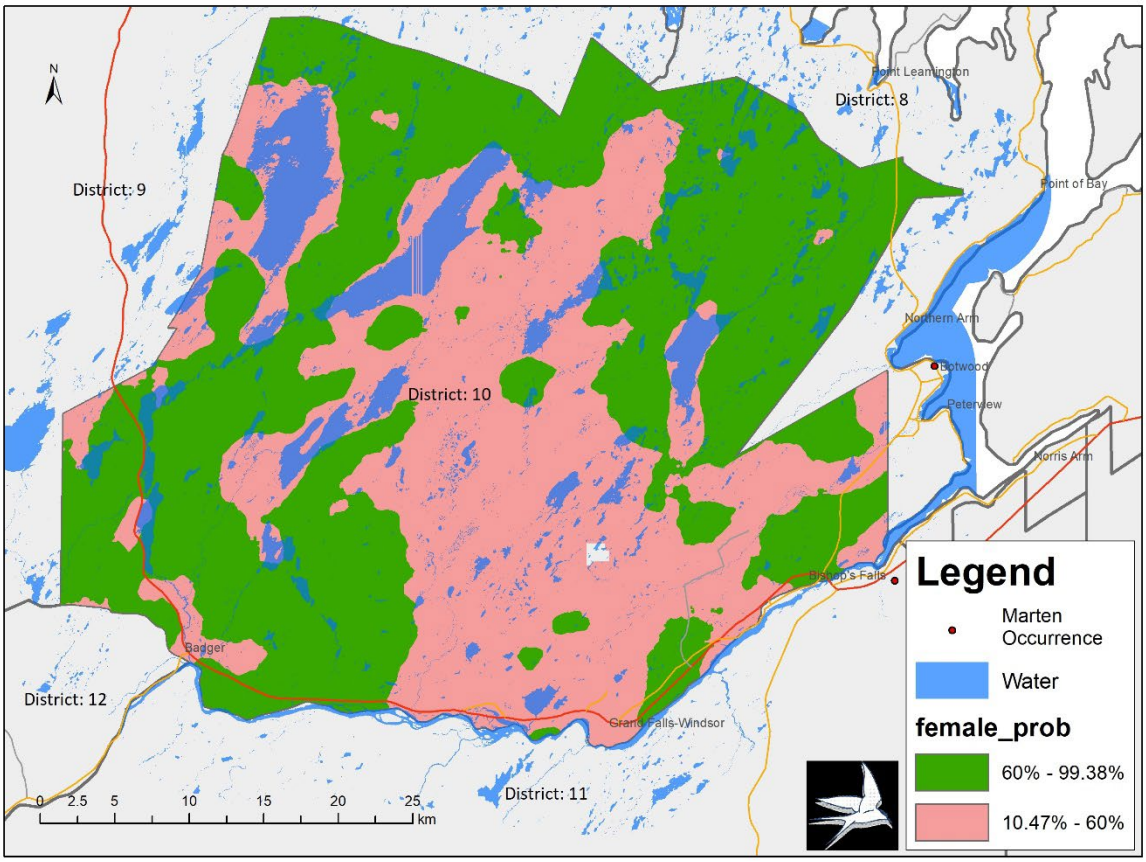
APPENDIX 6. MARTEN HABITAT IN FMD 7 WITH ≥ 60% PROBABLIITY OF OCCURRENCE



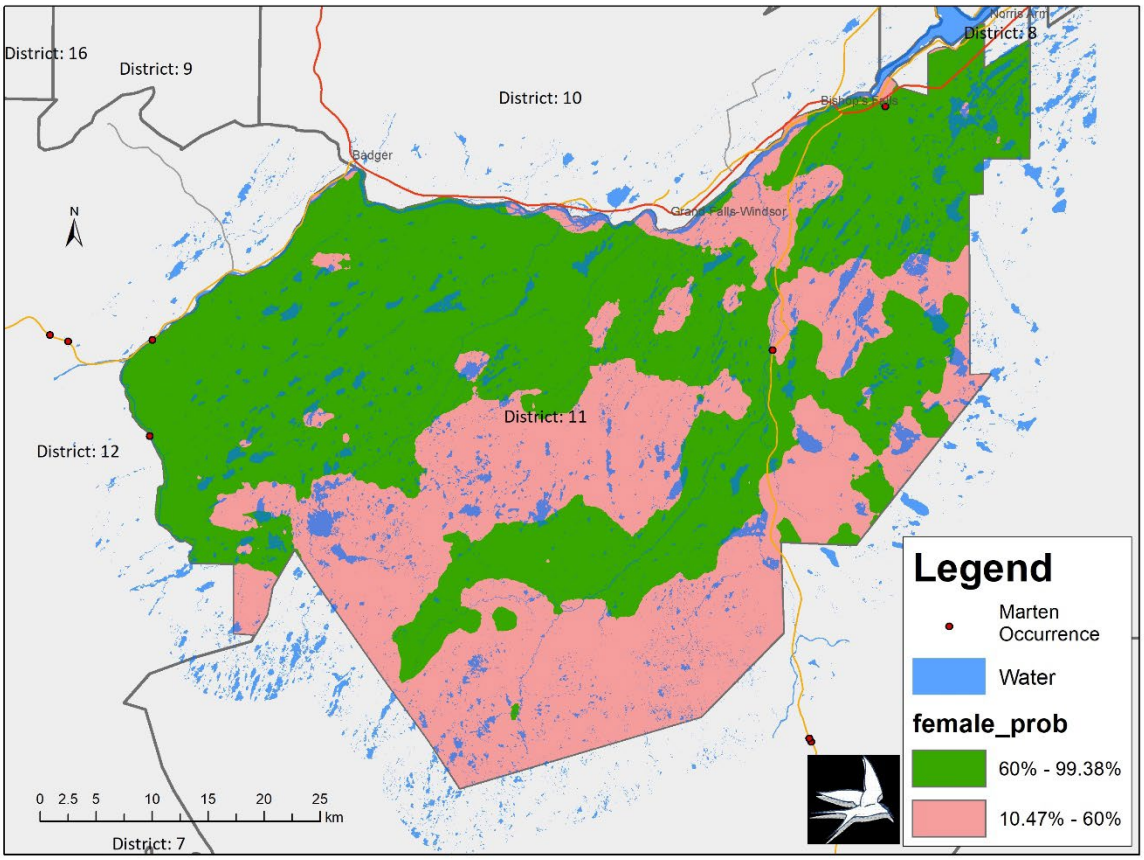
APPENDIX 7. MARTEN HABITAT IN FMD 8 WITH ≥ 60% PROBABILITY OF OCCUPANCY



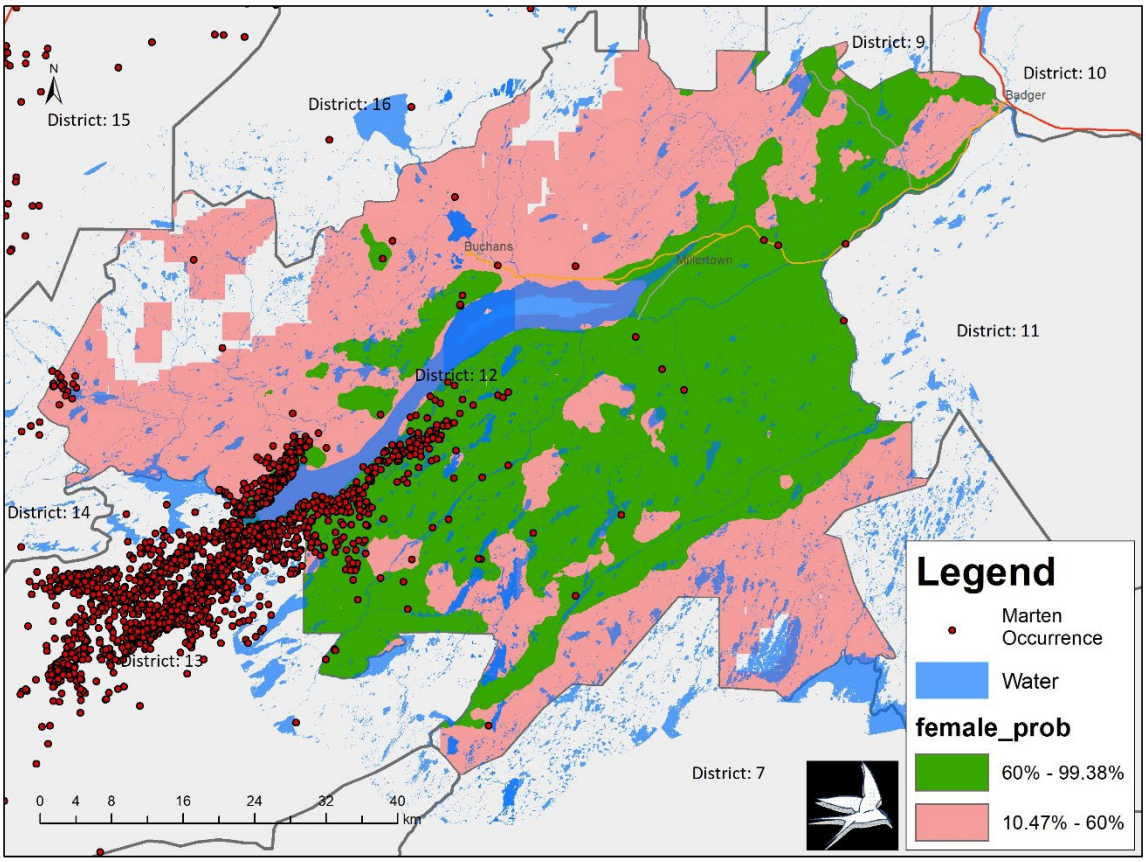
APPENDIX 8. MARTEN HABITAT IN FMD 9 WITH ≥ 60% PROBABILITY OF OCCUPANCY



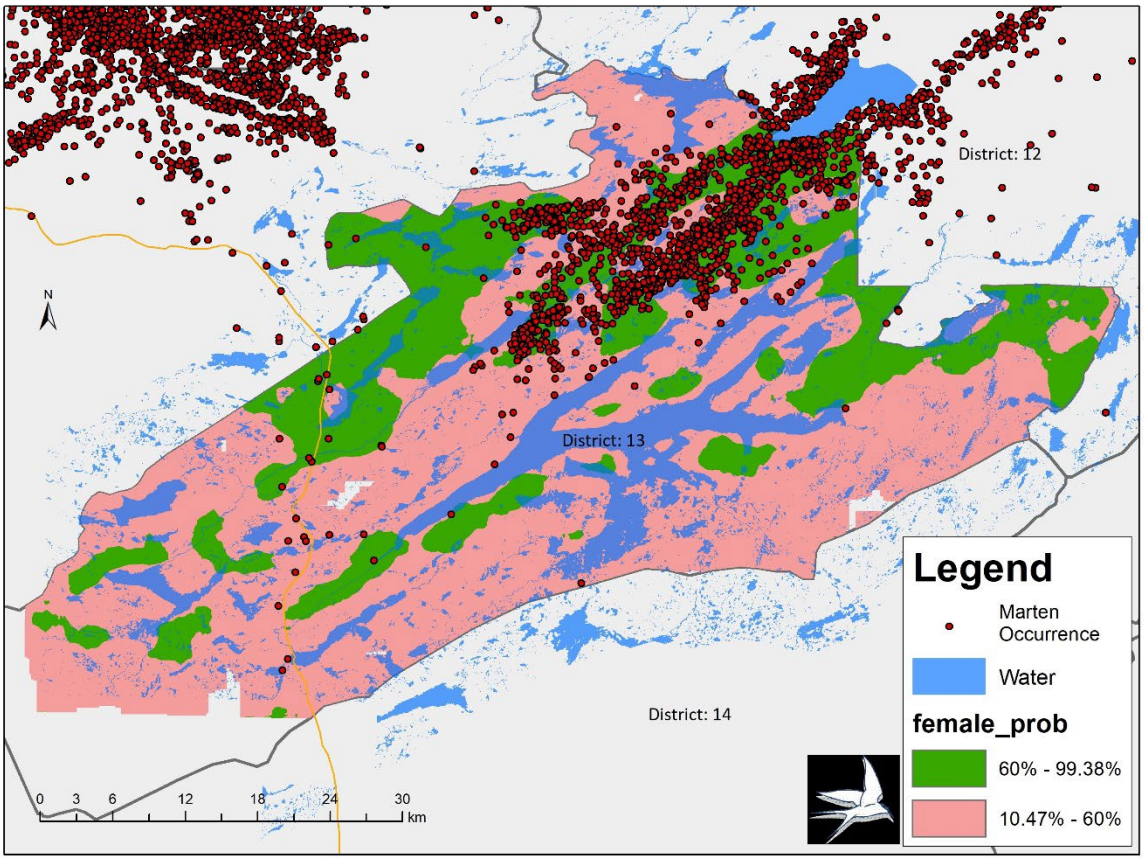
APPENDIX 9. MARTEN HABITAT IN FMD 10 WITH ≥ 60% PROBABILITY OF OCCUPANCY



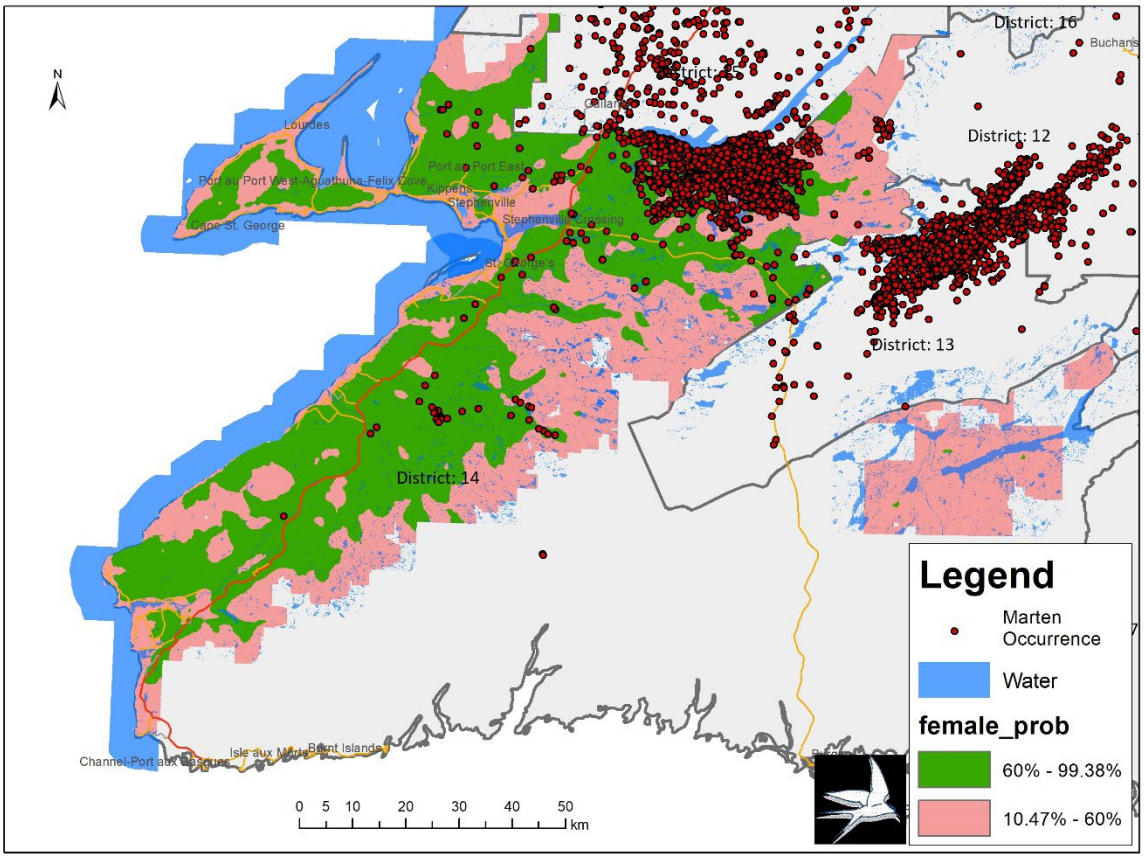
APPENDIX 10. MARTEN HABITAT IN FMD 11 WITH ≥ 60% PROBABILITY OF OCCUPANCY



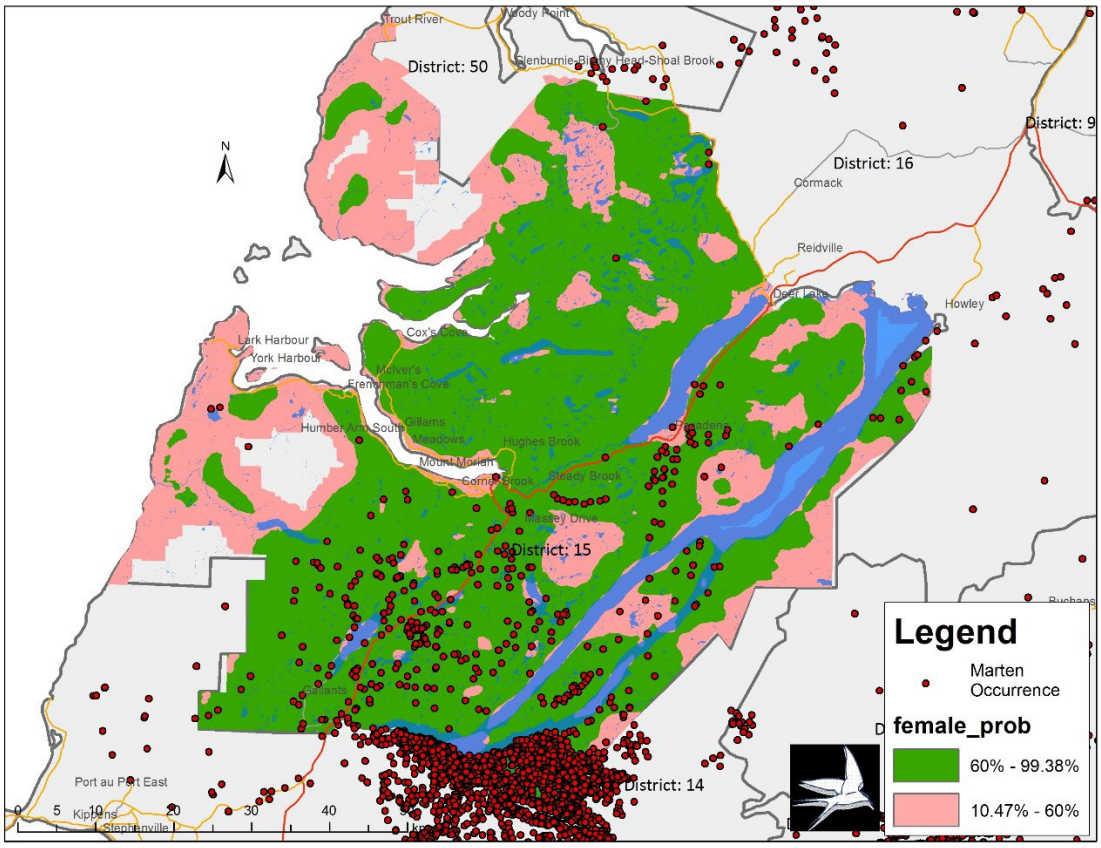
APPENDIX 11. MARTEN HABITAT IN FMD 12 WITH ≥ 60% PROBABILITY OF OCCUPANCY



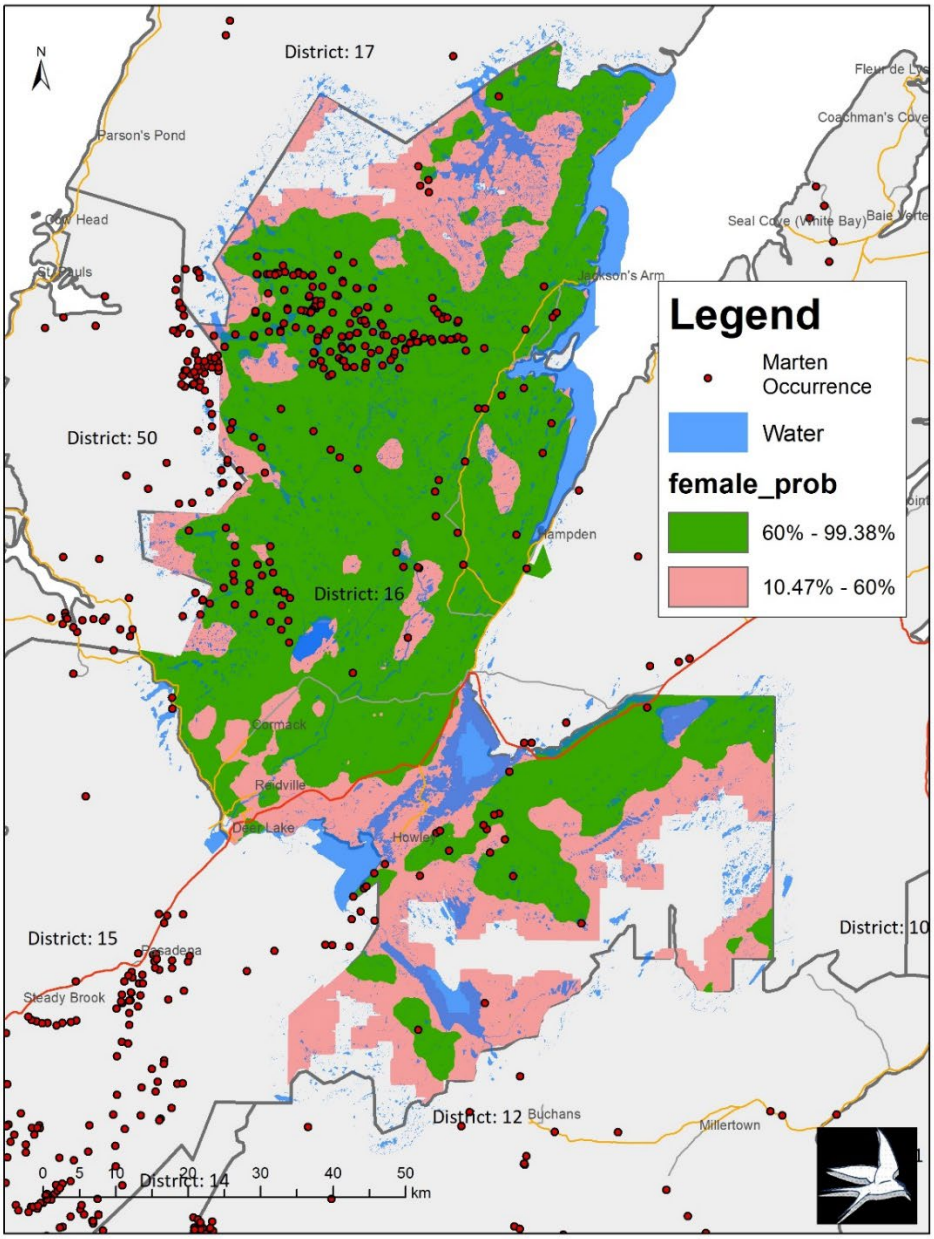
APPENDIX 12. MARTEN HABITAT IN FMD 13 WITH ≥ 60% PROBABILITY OF OCCURRENCE



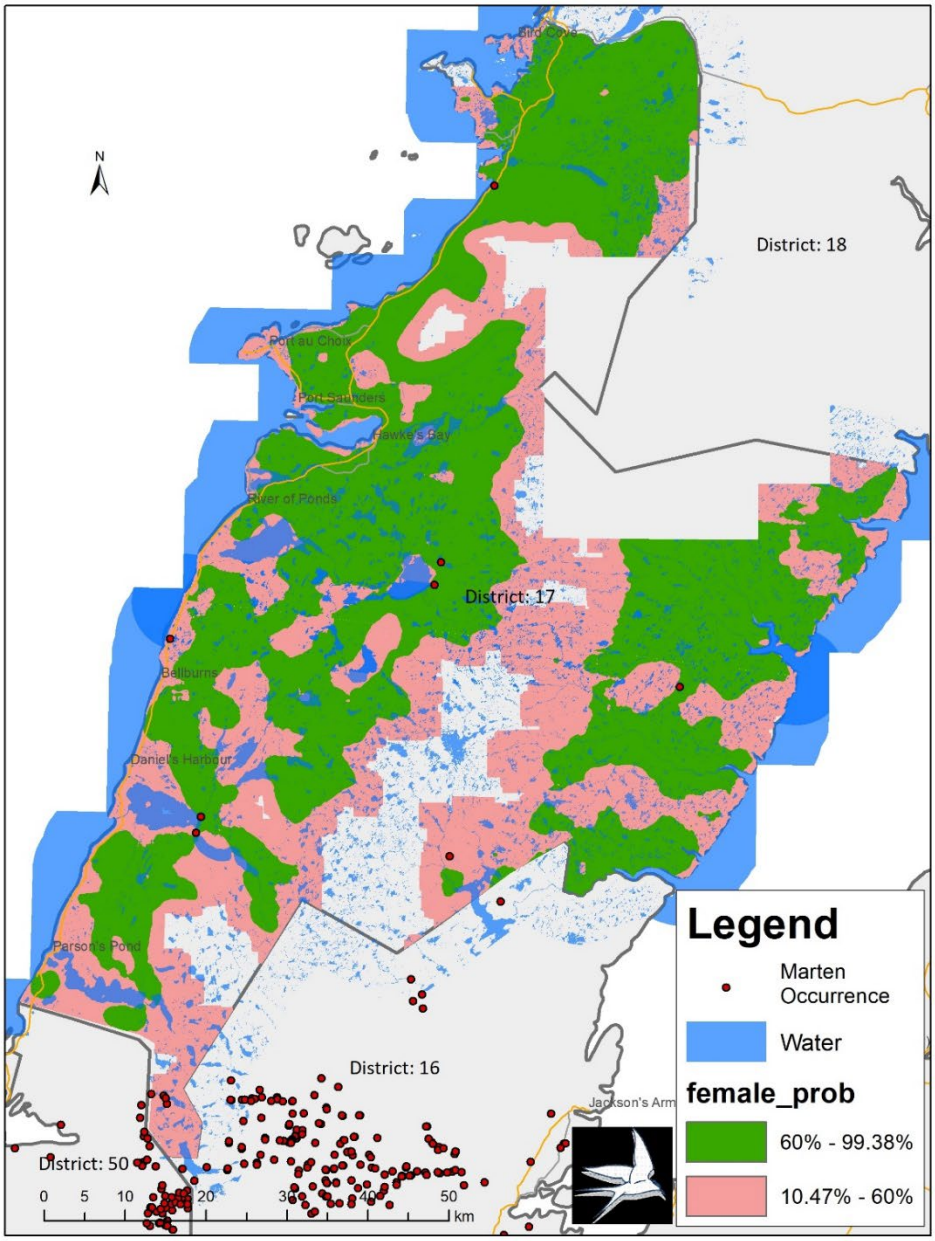
APPENDIX 13. MARTEN HABITAT IN FMD 14 WITH ≥ 60% PROBABILITY OF OCCUPANCY



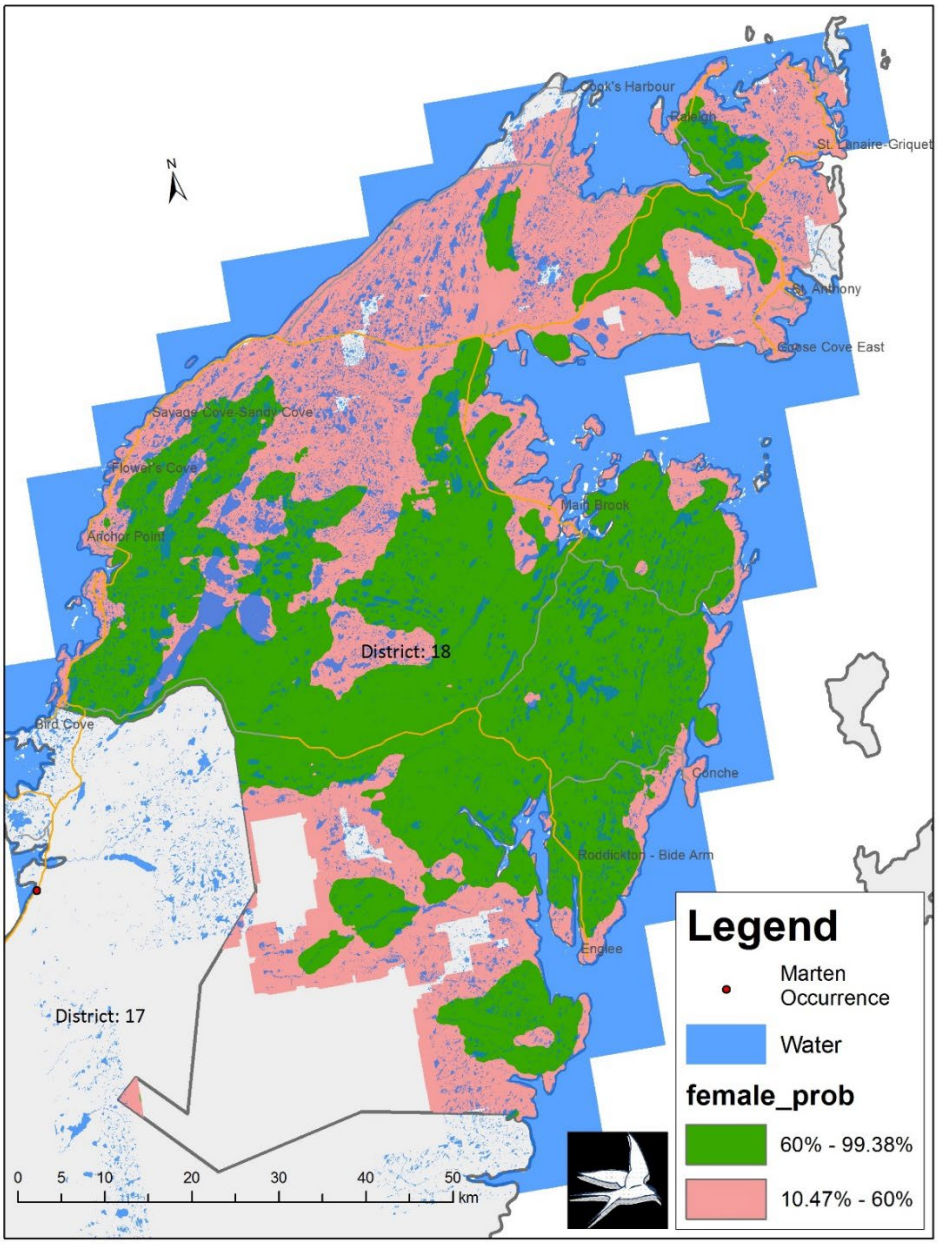
APPENDIX 14. MARTEN HABITAT IN FMD 15 WITH ≥ 60% PROBABILITY OF OCCUPANCY



APPENDIX 15. MARTEN HABITAT IN FMD 16 WITH ≥ 60% PROBABILITY OF OCCUPANCY



APPENDIX 16. MARTEN HABITAT IN FMD 17 WITH ≥ 60% PROBABILITY OF OCCUPANCY



APPENDIX 17. MARTEN HABITAT IN FMD 18 WITH ≥ 60% PROBABILITY OF OCCUPANCY