4th ANNUAL REPORT

submitted to

The California Department of Fish and Wildlife

by

Green Diamond Resource Company

in fulfillment of requirements specified in the Marten Safe Harbor Agreement with the California Department of Fish and Wildlife, pursuant to the California State Safe Harbor Agreement Program Act (Fish & G. Code, 2089.2 et seq.) for incidental take of Humboldt marten.

1 March 2023

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I. Introduction

On April 27, 2018, Green Diamond Resource Company (Green Diamond) and the California Department of Fish and Wildlife (CDFW) entered into a Safe Harbor Agreement (Agreement) under the California State Safe Harbor Agreement Program Act (Fish & G. Code, 2089.2 et seq.). The purpose of this Agreement is to provide a net conservation benefit to the Humboldt marten (*Martes caurina humboldtensis)* and assure Green Diamond that no additional regulatory burdens, fines, or penalties will result from management activities that are designed to benefit marten within 363,967 acres of the Green Diamond ownership in California (the Enrolled Lands). Based on contemporary survey efforts, the Humboldt marten is rare or absent from the majority of the Enrolled Lands; however, the Enrolled Lands account for approximately 12 percent of the area that is within 15 km (dispersal distance) of the known extant population. Through implementation of habitat management and research commitments, the Marten Safe Harbor Agreement (MSHA) is designed to increase the species' population and range, promote the creation of new habitat, and enhance existing potential habitat within the Enrolled Lands.

The key elements of Green Diamond's MSHA include:

- retention and recruitment of marten denning habitat in the form of green wildlife trees and snags following the Terrestrial Retention of Ecosystem Elements (TREE) guidelines,
- creation of a 2,098-acre no-harvest Marten Reserve Area,
- additional habitat management and monitoring measures applied to the Marten Special Management Area (a 127,217-acre area identified as a high priority connectivity area between known occupied sites),
- incorporate riparian and geologic retention measures as defined in Green Diamond's Aquatic Habitat Conservation Plan,
- technical and financial support for assisted dispersal of martens and associated research,
- retention and protection of known den sites, and
- research and monitoring of the marten population across the property.

The following report documents the fourth year of management under the MSHA and includes details specified to comply with the monitoring and reporting requirements of this agreement. Included are sections about marten occupancy surveys, marten habitat retention in timber harvest plans, water tank monitoring, and other information required for the annual reporting requirements.

The reporting period of this report was from September 1, 2021 to September 1, 2022.

II. Marten Studies

A. Methods

1. Marten Occupancy Surveys

In order to estimate marten occupancy, Green Diamond established a randomly located sampling frame for remote camera stations across the Enrolled Lands and a portion of the Potential Marten Source Area (PMSA). The sampling frame consisted of remote camera stations centered at a 2-km grid spacing within the Marten Special Management Area (MSMA), Moore Tract, and PMSA. Each camera station (sampling unit) consisted of one or two cameras located within 200 meters of the grid point resulting in a total of 163 sampling units. Of the 163 sampling units, 126 were located within the MSMA, 5 were located within the Moore Tract and 32 were located within the PMSA (Figure 1). Green Diamond established an additional 58 sample units centered at a 4-km grid spacing in the balance of the Enrolled Lands resulting in 221 total sample units. These sample units utilized an identical survey protocol and were suitable for detecting marten.

In order to estimate marten occupancy, all sampling units were surveyed each year for the first two years. After the first two years, Green Diamond will continue to monitor marten occupancy by conducting non-invasive surveys on at least one-half of the MSMA every five years such that a complete survey would occur by year ten. The sampling period is October through March for each year the surveys occur. The survey grid was divided into five sampling blocks in order to sample all stations with a logistically feasible approach while accounting for spatial issues and comparisons among the various watersheds. Sampling blocks were randomly selected to determine sampling order. Sampling order in year one will remain the sampling order in subsequent survey years to allow for comparisons and account for seasonal variation in detection rates. All sample units within a sampling block were surveyed simultaneously.

Green Diamond deployed high-end Reconyx brand cameras (Reconyx Inc., Holmen WI, USA) at each sampling station. Models included first generation Hyperfire HC500, HC600, PC800, PC900, and second generation Hyperfire HP2X. Camera stations were baited with two raw chicken drumsticks and commercial trapping lure (Caven's Gusto Lure, Minnesota Trapline Products, Pennock MN) secured to a tree within 5 – 15 feet of the camera.

Cameras were deployed for a minimum of 21 days and were checked and rebaited weekly. During the current reporting period, two cameras were used at 32 stations (20% of 2-km spaced stations) to further evaluate the influence of multiple cameras on estimates of detection probability.

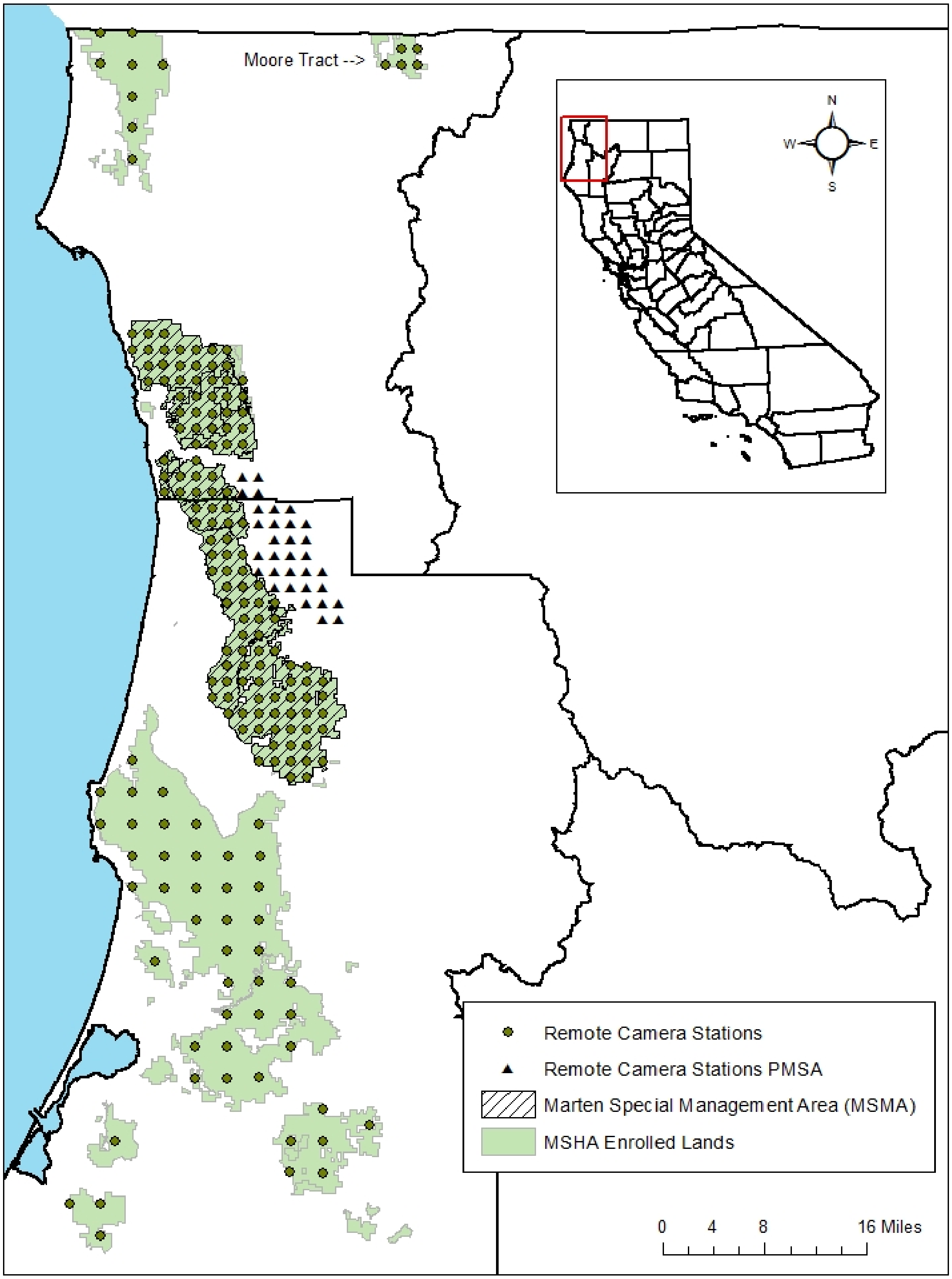

Figure 1. Monitoring stations within the Enrolled Lands and Potential Marten Source Area (PMSA) 2018-2020.

2. Water Tank Surveys

Water tanks within the Enrolled Lands were inspected during the current reporting period and measures were taken to prevent marten from becoming entrapped. Inspections determined if openings greater than two inches existed, and if the openings were secure and effective in excluding wildlife.

Tanks were composed of either plastic (newer/modern tanks) or steel material (older tanks originating from the early 1900s to 1960s). Plastic tanks usually required little to no exclusion efforts while the majority of steel tanks required repairs in this or a previous year using a variety of exclusion techniques and specialized tools. A powder fastener was often utilized to drive nails into the steel surfaces of the tank to fasten mesh around openings. The primary issues with using steel mesh were oxidation which was mitigated by applying a coat of spray paint. However, this technique has been monitored and proven to be a long-lasting repair method.

3. Assisted Dispersal

Green Diamond agreed to provide financial and technical support for a marten assisted dispersal (MAD) feasibility analysis conducted by CDFW. Via the MAD feasibility analysis, CDFW will evaluate and assess habitat suitability of potential release sites for martens within their historical range that are within typical dispersal distance of the core population. Green Diamond will provide financial and technical support for the capture and assisted dispersal of marten based on the recommendations of the MAD feasibility analysis. Green Diamond will work with CDFW and other partners to capture, collar, and release martens from recommended source areas to recommended release areas. The recommended release areas may include portions of the Enrolled Lands. Green Diamond will also provide financial and in-kind technical support to monitor collared martens in the recommended release areas.

4. Marten Research

Green Diamond committed to cooperation with state, federal, tribal, or non-governmental organizations engaged in original research on the Covered Species to advance the understanding of the ecology, conservation, and management of the species. Cooperation shall include a range of activities including but not limited to permitted access to its timberlands, contributions of biological staff time and expertise, or voluntary monetary contributions. Any additional commitments to marten research will be voluntary and established at the time of, and subject to, the terms of an agreed study design with measurable objectives and a demonstrated capacity to complete the research.

5. Prevention of rodenticide use

Anticoagulant rodenticide poisoning has been identified as a potential threat to marten. Anticoagulant rodenticides are used to eradicate or suppress rodent pest populations in illegal marijuana cultivation sites to minimize economic losses. Exposure to anticoagulant rodenticides can cause direct mortality and potentially increase the risk of predation or other diseases. Measures were taken to discourage unauthorized marijuana cultivation and associated rodenticide use within the Enrolled Lands. In addition to maintaining a system of controlled access for the Enrolled Lands, security patrols were conducted to detect cultivation sites, and if detected, eradication efforts were conducted in coordination with the Sheriff's Department.

B. Results

1. Marten Occupancy Surveys

Surveys were not conducted during the reporting period. A comprehensive report on site occupancy from the initial surveys conducted from 2018-2020 is included with this report (Green Diamond 2023).

2. Water Tank Surveys

Eighty-eight water tanks were located within the Plan Area across 70 sites in 2022 (Figure 2, Appendix I). At sites with multiple tanks, each individual tank was assigned its own ID number. In previous years, these tanks were all given the same ID number. This change resulted in an increase in the number of tanks reported in 2022. All 88 tanks were inspected for damage or openings and past installations of barriers were assessed for continued reliability. Forty-six of the 88 tanks had openings repaired in previous years, and 44 were still functional. Three tanks were found to have new openings or damage to previous patches, and all were repaired. Forty-one of the 88 tanks did not require exclusion installations. One tank (4100) is known to be a historic Vaux's swift nesting structure and has an opening on the side of the tank near the top that was not repaired. A board was placed in the opening that would allow any trapped animals to escape. No fisher, marten, or other remains were identified in or around the 88 tanks.

3. Assisted Dispersal

During the current reporting period, Green Diamond continued to collaborate with the U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), Yurok Tribe, and the National Council for Air and Stream Improvement (NCASI) to analyze existing data and collect new data on Humboldt marten within the Enrolled Lands and Potential Source Area as part of the initial feasibility assessment for Assisted Dispersal.

In May 2021, the USFS submitted a final report to the USFWS for these initial Assisted Dispersal feasibility assessment commitments. In total, three reports were submitted to the USFWS detailing demographic summaries, population estimates, and an overall assessment of Assisted Dispersal. Given the small sample size and broad confidence intervals, additional distribution and demographic data are needed to further inform the potential for Assisted Dispersal. The final report outlined these knowledge gaps and prioritized future research needs.

While these projects and reports were not specifically identified within the SHA, they do represent in-kind effort for Green Diamond's Conservation Planning Department. A summary of in-kind contributions is provided Table 1 under Section 4.

4. Marten Research

In 2020, Green Diamond began facilitating a Traditional Section 6 Grant project entitled "Promoting recovery of Humboldt marten with a rapid assessment of population size of the north coastal California extant population." This grant was approved in November 2020, and pilot work was conducted in summer of 2021. Project collaborators include Institute for Natural Resources at Oregon State University, the Yurok Tribe, U.S. Forest Service Six Rivers National Forest, and Cal Poly Humboldt graduate student Erika Anderson. Project implementation began in August 2022 with deployment of 75 hair snare tubes and 35 paired camera stations in areas currently being managed by the Yurok Tribe. Additional sampling will occur throughout the Fall 2022 on Six Rivers National Forest and Green Diamond study areas. Green Diamond will supply remote camera equipment to support this project, and the in-kind contribution will be summarized in the 2023 annual report.

In 2020 and 2021, Green Diamond collaborated with Dr. Katie Moriarty and Oregon State University graduate student Jordan Ellison on a study entitled "Investigating the Conservation Value of Slash Piles for Humboldt Marten and Fisher." Study objectives included:

- documenting martens and fishers visiting slash piles and the surrounding landscape through the use of remote cameras and scat detection dog teams
- identifying pile or stand characteristics associated with detections at piles
- estimating small mammal abundance, diversity, and energetic biomass at slash piles and the surrounding landscape
- Assessing the degree to which pile size, composition, and distribution influence the risk of increasing wildlife severity

The preliminary results of this project were presented at the 2021 Annual Conference of the Western Sections of The Wildlife Society. A total of 69 stands in California were surveyed, and results are pending further analyses including genetic work from the scat collected at 40 of the 69 stands.

In 2022, Green Diamond continued to collaborate with Dr. Katie Moriarty to document marten movement and basic population demographics in areas on and adjacent to the Green Diamond ownership that differed in management intensity. Objectives included:

- Quantifying fine-scale habitat characteristics by comparing marten movements and resting and denning structures in areas differing in management history through the use of GPS collars and LiDAR-derived forest structure
- Tracking and documenting marten fitness (e.g., reproductive history, body condition, causes of morbidity)

- Collecting information on population size and extent, sex and age ratios, home ranges, diet, and density of potential predators

Initial trapping and GPS tracking occurred in January through early-March 2022. Martens were detected at 38 remote camera locations, and 82 traps were deployed. Nine martens were captured and six of the nine were fitted with GPS collars, including one male and one female in the Maple Creek watershed on Green Diamond managed lands near the town of Trinidad representing the southernmost contemporary detections for this species. Additional remote camera monitoring and trap pre-baiting occurred in summer and fall of 2022 in these same areas where GPS collars were previously deployed. Additional GPS monitoring is scheduled to occur in fall 2022 through winter/early spring 2023 on and adjacent to the Enrolled Lands. In summer 2022, Green Diamond conducted remote camera surveys to assist with this project, which represents a total of 356 hours of in-kind effort (Table 1). Additionally, Green Diamond purchased six additional GPS collars for this project, which represents an additional in-kind contribution of $9,450. A detailed progress report for this telemetry work and the slash pile project were provided to CDFW and USFWS in May 2022.

Finally, Green Diamond continued to collaborate with the USFS, NCASI, and the Yurok Tribe to characterize fine-scale vegetation conditions used by martens on the Enrolled Lands and lands currently being managed by the Yurok Tribe. As part of the initial data collected to inform the feasibility of Assisted Dispersal, Green Diamond and collaborators identified resting and denning structures for radio-marked martens monitored between 2013 and 2016. Green Diamond biologists and USFS collaborators conducted vegetation sampling at 94 marten rest/den structures (120 used plots) and 60 random plots between 2015 and 2021. The results of the vegetation sampling were compared with another study area in Lassen to understand fine-scale vegetation conditions used by martens at sites differing in forest composition and past timber harvest intensity. A manuscript presenting these final results is in progress and anticipated for publication in 2023. As these studies are completed, additional references to results will be provided in annual reports.

Table 1. Annual in-kind contributions.

		In-kind Contributions		
Year	Project	Type	Total	Description
2020	Assisted Dispersal Feasibility	Staff Hours	12	Meetings and review for tasks 1-3 reports
2021	Assisted Dispersal Feasibility	Staff Hours	2	Review for task 3 report and manuscript
2022	Marten Movements	Staff Hours	356	Remote camera deployment and monitoring
2022	Marten Movements	Equipment	$15,000	Use of 30 remote cameras
2022	Marten Movements	Equipment	$9,450	Purchase of 6 GPS collars

5. Prevention of rodenticide use

No trespass cultivation sites were identified within the Plan Area in 2022. In 2022, Green Diamond began collaborating with the Humboldt County Sheriff's Department to clean up historic (pre-FHCP) sites.

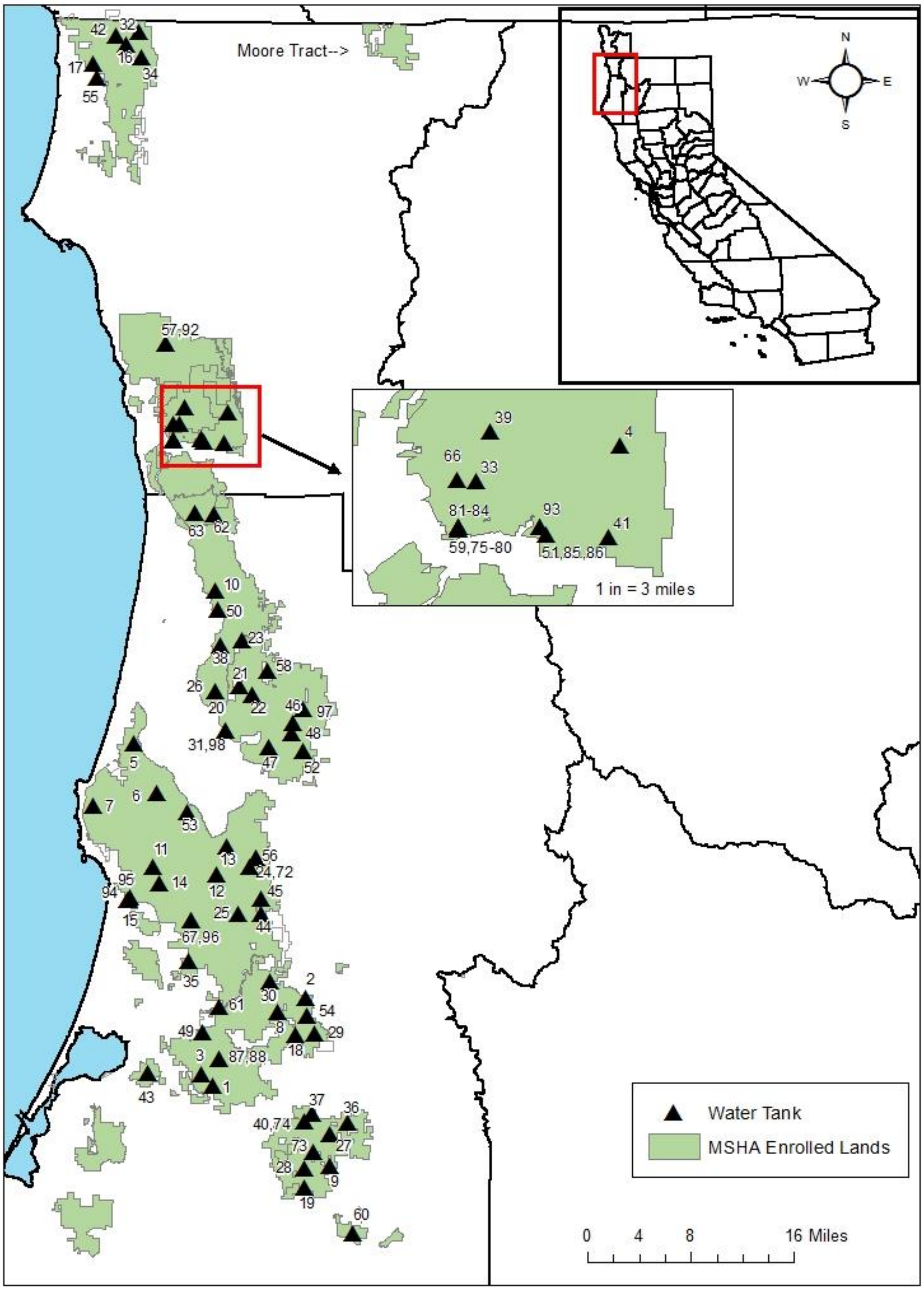

Figure 2. Water tank locations within the Enrolled Lands.

C. Discussion

Green Diamond conducted an occupancy analysis using the results from 2018-2019 and 2019-2020 sampling periods, and the results of this analysis are provided in an attachment to this annual report. All active and historic water tanks were inspected during the current reporting period, and exclusion methods appear to be successful at preventing entrapment and drowning of marten and other species. Water tank inspections will continue in subsequent years to ensure exclusion methods continue to be effective.

III. Habitat Modeling

A. Methods

After two complete surveys to assess marten occupancy within the Enrolled Lands and a portion of the Potential Marten Source Area, provided that an adequate sample size exists for analysis, Green Diamond will attempt to develop a model estimating the probability of marten occupancy in association with various habitat and physiographic variables. This modelling effort shall attempt to include all available and complementary survey efforts conducted within the range of the marten on the Enrolled Land.

B. Results

Surveys for both sampling periods (2018/2019 and 2019/2020) were completed, and results from the initial modeling effort are included in a comprehensive report submitted with this annual report (Green Diamond 2023).

IV. Land Transactions

A. Methods

The major premise of the MSHA was that the extent and quality of habitat suitable for marten on the Enrolled Lands would increase over the 40-year permit term of the agreement. As part of the agreement, the baseline habitat conditions for the Enrolled Lands were quantified and described prior to the start of the permit term. This chapter summarizes the land transactions that occurred during the reporting period and any effect on the Enrolled Lands.

B. Results

There were two land disposals and four land acquisitions in the Enrolled Lands during the reporting period. Approximately 992 acres were added, and 5.82 acres were removed from the Enrolled Lands for a net increase of 986.18 acres (Table 2).

Table 2. Summary of land transactions during the current reporting period within the Enrolled Lands.

Transaction Name	Transaction Type	Transaction Date	Acres
Fort Dick	Disposal	09/10/2021	(3.9)
Fort Dick	Disposal	12/03/2021	(1.92)
Krauss	Acquisition	05/24/2022	130
Grundman	Acquisition	06/23/2022	203
Kahn	Acquisition	06/30/2022	292
Trinidad Morris	Acquisition	07/29/2022	367
Total Change			986.18

C. Discussion

The land disposals were small parcels that did not have an effect on the baseline conditions of the Enrolled Lands. The disposals were located greater than 18 miles from contemporary marten detections, and none were located within the Marten Special Management Area (MSMA). The land acquisitions shared similar characteristics to the surrounding and adjacent Enrolled Lands based on vegetative cover types and forest age from prior harvest history.

V. THP Conservation Measures

A. Methods

As outlined in the MSHA, habitat management measures for marten include timber harvest planning, marten habitat planning, and overall environmental resource planning. Site-specific measures were identified for each timber harvest plan (THP) initiated. The following summarizes habitat management features that were identified before and after timber harvest for THPs within the MSMA and the Moore Tract that were approved after April 27, 2018. Additionally, THPs located within Planning Watersheds located outside of the MSMA or Moore Tract with new marten detections also receive site-specific habitat measures for marten. On October 10, 2019, a marten was detected during a remote camera survey within the Maple Creek Planning Watershed, on October 14, 2021, a marten was detected during a remote camera survey within the Pitcher Creek Planning Watershed, and in February of 2022 a collared marten was detected in the McDonald Creek Planning Watershed.

1. Pre-harvest Habitat Retention Planning

The six major habitat management measures quantified were:

- habitat retention areas (HRAs) planned on the guidelines stated below (number),
- habitat retained as a result of implementation of AHCP Riparian Management Zones (RMZ) and geologically unstable areas,
- retention of green wildlife trees outside of HRAs, RMZs, or geologically unstable areas specifically for marten (planned number of trees to be retained per acre individually or in clumps),
- snag retention (estimated number per acre present before and after harvest),
- large woody debris (LWD) retention specifically to benefit marten (number of structures present before and after harvest), and
- retention of den structures and HRAs around den structures (number of structures retained and acreage of surrounding HRAs).

In June 2007, Green Diamond began operating under an approved Aquatic Habitat Conservation Plan (AHCP)/Candidate Conservation Agreement with Assurances (CCAA). The riparian and slope protection measures under the AHCP also contribute to the development of future marten habitat across the landscape, and the riparian and geologic retention measures defined in the AHCP are incorporated into this MSHA. For young growth THPs, the amount of acreage retained in Class I and II RMZs or other partial harvest areas guided habitat retention. For Enrolled lands outside AHCP coverage (approximately 7,777 acres), riparian and geological retention measures were implemented in accordance with the California Forest Practice Rules, with the exception that RMZ’s in the Moore Tract are limited to one harvest entry within the RMZ during the life of the MSHA concurrent with the even-aged harvest of the adjacent stand. An exception is light thinning harvest conducted with the specific objective of enhancing wildlife structure.

Within the MSMA and Moore Tract, THP prescriptions included retention of downed large woody debris (LWD) to enhance structural complexity, foraging, denning, resting, and escape cover benefitting marten. Harvest units retained pre-existing non-merchantable large woody debris and merchantable large woody debris with existing hollows or evidence of internal rot and hollows. Harvest units also retained all “safe snags” including questionable merchantable snags. Pre-harvest amounts of snags per acre were assessed by ocular estimate.

Green Diamond developed the Terrestrial Retention of Ecosystem Elements (TREE) Guidelines for retaining green trees and snags in young growth stands (see MSHA attachment 5). Green Diamond implemented the TREE guidelines on all Enrolled Lands. Specific TREE measures designed as a conservation benefit to marten were applied through a marten-specific SHA scorecard on timberlands within the MSMA and Moore Tract. Scorecard guidelines and a comparison between the marten-specific SHA scorecard and the scorecard for Enrolled Lands outside of the MSMA and Moore Tract are described below in Section 6. General guidelines for green wildlife tree retention are outlined below. Based on results of the 2018-2020 camera surveys and collaborative studies with NCASI, marten detections outside of the MSMA and Moore Tract resulted in implementation of the marten scorecard in three additional planning watersheds: Pitcher Creek, McDonald Creek, and Maple Creek. These measures will be implemented in planning watersheds where marten are detected in future non-invasive survey efforts and other research.

General Candidate Tree Selection for all Units:

- Prefer defective or poorly formed trees (i.e. animal damaged, forked top, broken top, etc.)
- Prefer a mix of conifers and hardwoods (approximately 50/50 mix where possible)
- Species preference: Douglas fir, hemlock, white fir, cedar, spruce, redwood, tanoak, madrone, California laurel, chinquapin
- Consider protection from wind throw and site preparation burning when designating HRA and tree clump locations
- Retain trees with the average diameter equal to or greater than average diameter of trees in the THP area
- Green wildlife tree retention is in addition to snag, geological and RMZ retention

Tree Retention Guidelines within the MSMA and Moore Tract

Conifer Dominated Harvest Areas with RMZ or Geological Retention:

- Retain all conifer scorecard trees ≥ 7 in non-clearcut areas and in clearcut areas retain conifer scorecard trees at a rate of two trees per clearcut acre
- Retain all hardwood scorecard trees ≥ 7 in non-clearcut areas and in clearcut areas retain hardwood scorecard trees at a rate of three trees per clearcut acre
- Retain other evergreen hardwoods in clearcut areas at a rate of two trees per clearcut acre where they exist

Conifer Dominated Harvest Areas without RMZ or Geological retention:

- Retain all conifer scorecard trees ≥ 7 in non-clearcut areas and in clearcut areas retain conifer scorecard trees at a rate of two trees per clearcut acre
- Retain other conifer at a rate of two trees per clearcut acre
- Retain all hardwood scorecard trees ≥ 7 in non-clearcut areas and within clearcut areas retain hardwood scorecard trees at a rate of three trees per clearcut acre
- Retain other evergreen hardwoods within clearcut areas at a rate of two trees per clearcut acre where they exist (if a unit lacks hardwoods, retain conifer up to two trees per clearcut acre within clearcut areas)

Hardwood Dominated Harvest Areas with RMZ or Geological Retention:

- Retain two trees per clearcut acre
- Retain all conifer scorecard trees ≥ 7 within non-clearcut areas and in clearcut areas retain conifer scorecard trees at a rate of two trees per clearcut acre
- Retain all hardwood scorecard trees ≥ 7 in non-clearcut areas and in clearcut areas retain hardwood scorecard trees at a rate of three trees per clearcut acre
- Retain other evergreen hardwoods in clearcut areas at a rate of two trees per clearcut acre where they exist

Hardwood Dominated Harvest Areas without RMZ or Geological Retention:

- Retain all conifer scorecard trees ≥ 7 in non-clearcut areas and in clearcut areas retain conifer scorecard trees at a rate of two trees per clearcut acre
- Retain all hardwood scorecard trees ≥ 7 in non-clearcut areas and in clearcut areas retain hardwood scorecard trees at a rate of three trees per clearcut acre
- Retain a minimum 0.5 acre HRA or clumps totaling 0.5 acres and additional scattered or clumped evergreen hardwood trees at a rate of two trees per clearcut acre.

2. Post-harvest Habitat Retention

Post-harvest completion data were collected for units that received company harvest plan completions (all harvest and logging activities such as falling, yarding, loading, and hauling were completed) during the reporting period. For plan completions, the number of green wildlife trees retained was estimated as the number of remaining trees > 12” dbh per acre. Post-harvest LWD and snag retention for all units within the MSMA and Moore Tract were measured by ocular estimate following the completion of the harvest unit. Slash piles to benefit marten occupancy within the MSMA and Moore Tract were created post-harvest and retained at a rate of one structure per 5-10 clearcut acres within each ground-based unit. Slash pile numbers for clearcut harvest units were measured by ocular estimate following the completion of the harvest unit. If a THP was to be burned for site preparation, the completion data was not collected until after the plan was burned. It was noted for each completion whether site preparation, burning, windthrow or some other form of forest management damaged the retained habitat features.

3. Commercial Thinning

Commercial thinning involves removing selected trees that may contain commercial value in order to create additional growing space for crop trees. Commercial thinning on Green Diamond's forest lands is typically an intermediate treatment applied to younger stands that allows for the release of the selected crop trees by providing more light and in cases, more nutrients and soil moisture when they are limiting factors. The log size of these younger thinned stands is inherently smaller than those of an older stand ready for the final harvest stages of even-aged management (i.e., clearcut harvest). In addition to the release of crop trees, commercial thinning allows for the release of understory vegetation through increased light exposure. The release of understory vegetation may provide additional cover and an increase in mast production that may benefit martens. The protection measures and mitigations included in a final clearcut harvest also apply to these intermediate thinning harvests with exception of the creation of slash piles. Given the goal of thinning harvests and amount of post-harvest habitat retention associated with this type of silviculture, marten habitat is at a minimum maintained, but this type of harvest should advance the development of marten habitat. Therefore, these units meet or exceed post-harvest habitat retention standards of the MSHA and are excluded from the pre- and post-harvest retention summaries in the annual report.

4. Herbicide Applications

Herbicide applications involve treating selected areas to eliminate vegetation in order to create growing space for crop trees (site preparation). Herbicide applications on Green Diamond's forest lands are applied via backpack spraying and hack and squirt applications. These herbicide applications allow for the release of selected crop trees by increasing light and in cases, more nutrients and soil moisture when they are limiting factors. Green Diamond utilizes backpack spraying to reduce competing vegetation and allow for the release of crop tree seedlings. These applications are typically applied during the end of the second growing season after the completion of a final clearcut harvest unit. The backpack application of herbicides does not affect the retention of green wildlife trees, tree clumps or HRAs within the original final harvest unit. Therefore, all prescribed retention including green wildlife trees retained as the result of the marten-specific TREE scorecard, are unaffected by these treatments. Hack and squirt herbicide applications on Green Diamond's forest lands are prescribed in units with sprouting hardwoods or young stands with a high volume of standing hardwoods. The log size of these younger stands is inherently smaller than those of an older stand ready for the final harvest stages of even-aged management (i.e., clearcut harvest). Given the smaller log size of treated stands and the amount of post-treatment habitat retention described above, marten habitat is maintained, but hack and squirt applications could also advance the development of marten habitat. Therefore, the units treated with these herbicide applications meet or exceed the habitat retention standards of the MSHA and are excluded from the pre- and post-harvest retention summaries in the annual report. However, the number of units and total acreage treated with herbicides are provided in the results.

Hack and squirt treatments may also be utilized in older stands as a stand-replacing harvest (commercial treatment) with post-harvest results similar to clearcut silviculture. The protection measures and mitigations included in final clearcut harvest units also apply to commercial hack and squirt units. The number of units and total acreage treated with hack and squirt applications that involve the elimination of commercial age trees are provided in the results.

5. Den Sites

Natal or maternal den structures were retained on the landscape, and tree retention around the den structure was incorporated when appropriate. The standard for tree retention around a natal den structure included a no-less-than 0.5-acre no-harvest HRA. Any harvest conducted within the natal den HRA was only done in consultation with CDFW. Harvest conducted within the natal den HRA was designed to protect the biological integrity of the site and increase/accelerate development of large trees within the HRA.

Habitat retention around maternal den structures may have included the individual den structure element (live tree, snag, log, etc.), the individual structure with tree clump retention, or the individual structure and a 0.5-acre HRA with 70 percent over story tree canopy composed of a variety of tree sizes and tree species present in the existing pre-harvest stand. The tree retention around known den structures helped to retain existing biologically important habitat elements such as large trees, snags and large down wood.

6. TREE Scorecard Habitat Retention Comparison

Green Diamond will use a stratified random sample to analyze 10 percent of the THP units (pre-harvest) to quantify tree retention using the marten-specific TREE scorecard applied to the MSMA and Moore Tract versus the scorecard applied to the balance of the enrolled lands (Table 3). Green Diamond will conduct and report the results of this analysis at 5-year intervals. Green Diamond and CDFW will evaluate the results at the 5-year reporting intervals and during the adaptive management review in year 25 to determine if this monitoring process should be modified.

Table 3. Comparison of live tree retention features and scores associated with the TREE retention scorecards.

Marten-specific SHA Tracts (MSMA and Moore Tract)[1]		**Balance of Enrolled Lands**	
Tree Elements	Score	Tree Elements	Score
Conifer > 30", hardwood > 18"	3	Conifer > 30", hardwood > 18"	3
Large cavity, hollow, basal hollow	4	Large cavity, hollow, basal hollow	4
Small cavity, broken top, reiteration	3	Small cavity, internal rot or mistletoe broom*	2
Crevice cover (fissure, loose bark, furrowed bark)	1	Crevice cover (loose or deeply furrowed bark)	1
Complex crown (dead or forked top, lateral large limbs, epicormic branching, ledge/platform)	1	Complex crown (lateral large limbs, epicormic branching)	1
Internal decay, mistletoe broom	2		

***** In marten-specific tracts, small cavities, broken tops, and reiterations are assigned higher values as these features pose a conservation benefit to marten.

[1] Specific TREE measures designed as a conservation benefit to marten are applied through a marten-specific safe harbor agreement scorecard on Green Diamond timberlands within the Marten Special Management Area, the Moore Tract, (tracts 51, 53, 56, 61, 66, 67, 70, 71, 72, 73, 85, 87, 88, 98, and within California Interagency Watershed Map (i.e., Calwater 2.2.1) watersheds when the Covered Species are detected.

B. Results

Forty THPs comprised of 89 clearcut harvest units and two emergency salvage units totaling 2093.74 acres received a company approved completion during the reporting period. Sixty-seven of these units were in the MSMA, two units were in the Moore Tract, and twenty-two units were in the Maple Creek, Pitcher Creek, or McDonald Creek Planning Watersheds. Three commercially thinned harvest units totaling 241.97 acres and two emergency salvage units totaling 50.75 acres received approved completions during the reporting period and are excluded from the clearcut summary tables. For more details on the clearcut harvest unit retention see Appendix II and Tables 4, 5, 6, 7, 8, and 9.

1. Pre-harvest Habitat Retention Planning

Of the 89 clearcut harvest units, 79 were conifer dominated with RMZ or geological retention and prescribed an average of 2.37 green wildlife trees (GWT) per clearcut acre (Table 4). Seven units were conifer dominated without RMZ or geological retention and prescribed an average of 2.40 GWT per clearcut acre. The remaining three units were hardwood dominated with RMZ or geological retention and retained an average of 2.0 GWT per clearcut acre. The average number of scorecard trees marked for retention was 0.65 per clearcut acre. Twenty-two HRAs were prescribed across 17 units and the average number of snags pre-harvest was estimated to be 0.70 snags per acre (Table 5).

Table 4. Summary of pre-harvest green wildlife tree retention measures for completed THP units (n=89 units).

	GWT/acre* with RMZ/GEO Conifer	GWT/acre without RMZ/GEO Conifer	GWT/acre with RMZ/GEO Hardwood
Minimum	0.33	2.00	2.00
Maximum	8.00	4.00	2.00
Average	2.37	2.40	2.00

*All acres are clearcut acres
GWT = Green Wildlife Tree
GEO = Geologically Unstable Area
THP = Timber Harvest Plan

Table 5. Summary of pre-harvest THP conservation measures for completed THP units (n=89 units).

	Snags/ acre*	HRAs (#)	Scorecard Trees (#)	Scorecard Trees /acre
Minimum	0.00	0.00	0.00	0.00
Maximum	2.00	2.00	193.00	7.11
Average	0.70	0.25	14.92	0.65

*All acres are clearcut acres
HRA = Habitat Retention Area
THP = Timber Harvest Plan

2. Post-harvest Habitat Retention

The 79 conifer dominated units with RMZ or geological retention retained an average of 2.91 GWT per clearcut acre. The seven conifer dominated units without RMZ or geological retention retained at least two GWT per clearcut acre with an average of 2.47 per clearcut acre. The three hardwood dominated units with RMZ or geological retention retained an average of 2.0 GWT per clearcut acre (Table 6). The average number of scorecard trees retained was 0.71 per clearcut acre, and all 22 HRAs were retained post-harvest. The average number of snags and large woody debris pieces retained post-harvest was 0.70 and 1.64 per acre, respectively (Table 7). A total of 719.67 acres were retained within riparian and geological retention areas, which were a mix of selection and no harvest. Harvest within these riparian areas represent the single entry allowed under the Aquatic Habitat Conservation Plan and MSHA permit terms.

Sixty-two of the 69 completed units in the MSMA and Moore tract used ground-based harvesting methods on 1177.9 acres; and therefore, required creation and retention of at least one slash pile structure for every ten acres. All units requiring slash pile structures retained at least the minimum required number of slash pile structures with an average of 9.52 structures per 10 acres (Appendix II). Additional slash pile retention acres are included in the appendix when the data was available, but slash pile retention is not typically reported for units lacking ground-based clearcut acres. Therefore, the slash pile acres reported in the appendix underestimate the structures retained.

Table 6. Summary of post-harvest green wildlife tree retention measures for completed THP units (n=89 units).

	GWT/acre* with RMZ/GEO Conifer	GWT/acre without RMZ/GEO Conifer	GWT/acre With RMZ/GEO Hardwood	GWT/acre without RMZ/GEO Hardwood
Minimum	0.33	2.00	2.00	N.A.
Maximum	15.0	4.00	2.00	N.A.
Average	2.91	2.47	2.00	N.A.

*All acres are clearcut acres
GWT = Green Wildlife Tree
RMZ = Riparian Management Zone
GEO = Geologically Unstable Area
THP = Timber Harvest Plan

Table 7. Summary of post-harvest THP conservation measures for completed THP units (n=89 units).

	Snags/ acre*	HRAs (#)	Scorecard trees (#)	Scorecard trees/acre	LWD (#/acre)
Minimum	0.00	0.00	0.00	0.00	0.00
Maximum	2.00	2.00	188.00	7.24	11.00
Average	0.70	0.25	16.36	0.71	1.64

*All acres are clearcut acres
HRA = Habitat Retention Area
LWD = Large Woody Debris
THP = Timber Harvest Plan

Post-harvest slash pile burning occurred in eight ground-based units associated with six THPs (1-20-018-HUM, 1-17-143-HUM, 1-16-042-HUM, 1-18-091-HUM, 1-18-091-HUM, 1-18-007-DEL, and 1-18-177-DEL) that were either completed in 2022 or a previous reporting period. All units maintained more than the minimum number of slash piles required post-burning.

3. Comparison of Pre- and Post-harvest Wildlife Retention Measures

The prescribed pre-harvest and post-harvest data were compared for the 89 THP units with company approved completions during the reporting period (Table 8 and Table 9). At times, trees were left for unanticipated reasons, and as long as they satisfied the criteria for a green tree, they were counted as additional trees in the post-harvest evaluation. However, they were not counted towards the green tree tallies unless previously marked during plan layout. In some cases, additional tree clumps were retained to comply with the Forest Stewardship Council (FSC) standards, but this additional retention was not counted towards the green tree or HRA tallies unless it satisfied green tree or HRA criteria.

Average post-harvest retention of green trees was greater than pre-harvest prescriptions, and all units retained equal to or greater than the required minimum (Table 8). Average post-harvest retention of wildlife scorecard trees was greater than pre-harvest prescriptions. In 2022, four units reported a loss of wildlife scorecard trees due to a combination of operational and safety constraints and windthrow. Post-harvest estimate of retained snags was equal to pre-harvest prescriptions. Pre-harvest estimates for large woody debris were not available during the reporting period; and therefore, no comparisons were included in this section. Likewise, slash pile creation and retention only occur post-harvest, and all ground-based clearcut units retained at least the minimum number of required structures.

Table 8. Comparison of pre- and post-harvest green tree retention for completed THP units (n=89 units).

	Pre GWT/ acre* with RMZ/GEO Conifer	Post GWT/ acre with RMZ/GEO Conifer	Pre GWT/ acre without RMZ/GEO Conifer	Post GWT/ acre without RMZ/GEO Conifer	Pre GWT/ acre with RMZ/GEO Hardwood	Post GWT/ acre with RMZ/GEO Hardwood
Average	2.37	2.91	2.40	2.47	2.00	2.00
Average change/ unit	0.54		0.07		0.00	

*All acres are clearcut acres
THP = Timber Harvest Plan
GWT = Green Wildlife Tree
GEO = Geologically Unstable Area
RMZ = Riparian Management Zone

Table 9. Comparison of pre- and post-harvest THP conservation measures for completed THP units (n = 89 units).

	Pre Snag/ acre*	Post Snag/ acre	Pre HRA (#)	Post HRA (#)	Pre Scorecard Trees/acre	Post Scorecard Trees/acre	Pre Scorecard Trees (#)	Post Scorecard Trees (#)
Avg.	0.70	0.70	0.25	0.25	0.65	0.71	14.92	16.36
Avg. change/ unit	0.00		0.00		0.06		1.44	

*All acres are clearcut acres
HRA = Habitat Retention Area
THP = Timber Harvest Plan

The Moore Tract had one THP comprised of two emergency salvage units (50.75 acres) that terminated logging activity during the reporting period. The emergency salvage was in response to the Slater fire, which burned approximately 4,000 acres of the tract. The intent of salvage logging is to recover the dead and dying trees, therefore no live trees were harvested. In areas where the wildfire left less than two live trees per acre, additional dead or dying trees were retained to meet a minimum of two trees per acre. Given the nature of the emergency it was not possible to collect pre-harvest data and no comparison can be made.

4. Herbicide Applications

Two-hundred-six units (4372.1 total acres) were treated with herbicide applications during the reporting period. Zero of the 206 units were treated with hack and squirt herbicide applications that involved the treatment of commercial age trees. Additionally, 1338 acres within the Moore Tract emergency salvage areas were treated during the current reporting period.

5. Den Site Retention Measures

No marten den structures were discovered within the Enrolled Lands during the reporting period.

6. TREE Scorecard Habitat Retention Comparison

Green Diamond will conduct and report the results of this analysis at 5-year intervals. Therefore, the results of the initial analysis will not be available until the 5th annual report (due March 2024).

C. Discussion

Retention measures were implemented in compliance with the MSHA, and all required habitat retention features were successfully retained. Areas of habitat retained compared to the planned level of retention were equal in acreage for all but wildlife scorecard trees and green trees in conifer dominated stands. Overall green tree retention was greater than the planned retention. At times, trees were left for unanticipated reasons, and if they satisfied the criteria for green trees, they were counted as additional retention. Additional marking of trees prior to operations may also occur. These trees are counted post-harvest because they were marked, however, they were not reported on during pre-harvest because they had not been marked or recorded on the pre-harvest form. RPFs noted the additional incidental retention of scattered and clumped sub-merchantable trees as a result of Green Diamond's Forest Stewardship Council (FSC) certification, but these habitat features were not quantified in this report. In many instances, this incidental structure is likely to add another element of structural diversity to future forest stands. Four units experienced a loss in wildlife scorecard trees due to a combination of operational and safety constraints and windthrow, but the overall number of scorecard trees retained post-harvest was greater than reported pre-harvest. Snag retention did not change, however discrepancies between estimates of pre- and post-harvest snags are common. Since snags are not marked and tallied individually, inaccurate ocular estimates are often made on the number per acre, particularly during the pre-harvest phase when they are less obvious in the unharvested stand.

The greatest amount of habitat retention occurred in riparian and geologic retention areas. Class I and II watercourses are usually given canopy retention that exceeds the standard Forest Practice Rules, therefore representing a significant amount of retention for future marten habitat. Additionally, Green Diamond did not locate any marten den sites within 0.25 miles of a timber harvesting unit. Therefore, no den site protection or habitat retention measures were implemented during the current reporting period.

Appendix I. Inspection dates for all water tanks located within the Enrolled Lands in 2022.

Tank ID	Tank Name	Inspection Date
1	7010	10/20/2022
2	2000 Drafting	10/14/2022
3	5000/Dry Creek	10/20/2022
4	U10 Terwar Creek Drafting	10/18/2022
5	BL1100	10/19/2022
6	BL2000	10/19/2022
7	BL3900	10/19/2022
8	C900	10/14/2022
9	Chaparrel	10/13/2022
10	CL South	11/2/2022
11	CR1300 Drafting	10/19/2022
12	CR2700 Drafting	10/27/2022
13	CR2900	10/14/2022
14	CR3000	10/19/2022
15	Crannell Well	10/19/2022
16	D1000/W1000	10/5/2022
17	D111/Ritmer Creek	10/5/2022
18	Fernwood	10/14/2022
19	Graham Creek Lower	10/14/2022
20	HC120	10/20/2022
21	HC130	10/20/2022
22	HC132	10/20/2022
23	J1100	10/26/2022
24	K&K 900 A	10/12/2022
25	K&K LR	10/12/2022
26	K&K North	10/26/2022
27	Little Boulder Creek	10/14/2022
28	Miller’s Road	10/13/2022
29	Noisy Creek	10/14/2022
30	Old-299	10/14/2022
31	R120 A	10/26/2022
32	R2000	10/5/2022
33	R4	10/21/2022
34	Ravine Creek	10/28/2022
35	Ribar	10/7/2022
36	Roddiscraft	10/14/2022

Tank ID	Tank Name	Inspection Date
37	Snow Camp Powerline	10/14/2022
38	T100 Bridge	10/26/2022
39	Teepo Ridge	10/21/2022
40	Twin Tanks A	10/14/2022
41	U10 Dandy Creek	10/19/2022
42	W2300	10/5/2022
43	Washington Gulch Drafting	10/28/2022
44	Wiregrass South	12/13/2022
45	Wiregrass North	10/28/2022
46	WM10	10/26/2022
47	WM200	10/26/2022
48	WM710	10/26/2022
49	4100	10/7/2022
50	A400 Bridge Drafting	11/2/2022
51	Arrow Mills Historic Mill A	10/21/2022
52	BH1900	10/26/2022
53	BL2011	10/14/2022
54	CP2000	10/14/2022
55	D1000 Culvert Yard	10/5/2022
56	DV2400	10/12/2022
57	H400 A	12/1/2022
58	HC1000	10/20/2022
59	Klamath Mill A	10/21/2022
60	Morgan Creek	8/3/2022
61	NF1000	12/2/2022
62	SA800	11/2/2022
63	S-Line	11/2/2022
64	Sproul East A*	11/4/2022
65	Sproul West*	11/4/2022
66	T150	10/21/2022
**67	CR3100 A	11/18/2022
72	K&K 900 B	10/12/2022
73	Boulder Creek	10/13/2022
74	Twin Tanks B	10/14/2022
75	Klamath Mill B	10/21/2022
76	Klamath Mill C	10/21/2022
77	Klamath Mill D	10/21/2022
78	Klamath Mill E	10/21/2022
79	Klamath Mill F	10/21/2022

Tank ID	Tank Name	Inspection Date
80	Klamath Mill G	10/21/2022
81	Hoppaw Creek A	10/21/2022
82	Hoppaw Creek B	10/21/2022
83	Hoppaw Creek C	10/21/2022
84	Hoppaw Creek D	10/21/2022
85	Arrow Mills Historic Mill B	10/21/2022
86	Arrow Mills Historic Mill C	10/21/2022
87	Sweet Flat A	10/28/2022
88	Sweet Flat B	10/28/2022
89	Sproul East B*	11/4/2022
90	Sproul East C*	11/4/2022
91	Sproul East D*	11/4/2022
92	H400 B	12/1/2022
93	Arrow Mills Truck	12/1/2022
94	White House	12/2/2022
95	CR2000	12/1/2022
96	CR3100 B	11/18/2022
97	Turkey Foot	7/19/2022
98	R120 B	10/26/2022

*Denotes tanks inspected but not located within the Enrolled Lands, and therefore not included in the report summaries.

**Gap in sequential numbering are the result of tanks that are no longer located on the Green Diamond ownership or that have been decommissioned and removed from the Enrolled Lands.

Appendix II. Raw data for habitat retention measures for individual clearcut harvest units summarized in Tables 4, 5, 6, 7, 8, and 9 (2022).

THP #[1,2]	Unit	Acres	Pre HRA #	Post HRA #	Pre green trees/ acre	Post green trees/ acre	Pre snags/ acre	Post snags/ acre	Pre scorecard trees/acre	Post scorecard trees/acre	LWD/ acre	Dominance	RMZ and Geo acres	Slash piles retained #[3,4]
471902[1]	A	30.09	2	2	0.33	0.33	0.50	0.50	6	6	0.5	Conifer	9.15	2
471902[1]	D	28.26	0	0	1.20	1.20	1.00	1.00	6	6	0.5	Conifer	13.14	3
471903[1]	B	22.84	0	0	1.00	1.00	0.00	0.10	5	5	0.2	Conifer	13.23	0
471903[1]	D	20.48	0	0	1.70	1.70	0.10	0.10	5	5	0.2	Conifer	4.12	0
471904[1]	B	28.69	0	0	1.00	1.00	0.00	0.00	6	6	1	Conifer	9.80	3
471906[1]	C	20.21	0	0	1.00	1.00	0.10	0.50	2	2	0.1	Conifer	16.69	38
472001[1]	B	26.08	0	0	2.00	2.00	0.00	0.00	5	5	0.1	Conifer	9.94	0
472002[1]	H	25.10	0	0	3.50	3.50	0.30	0.30	28	28	1	Conifer	14.19	30
472002[1]	I	22.46	0	0	8.00	8.00	0.30	0.30	3	3	1.5	Conifer	14.62	12
472003[1]	A	11.64	0	0	1.50	1.50	0.10	0.10	5	5	1	Conifer	16.30	7
472004[1]	C	28.94	0	0	1.30	1.30	0.10	0.00	15	13	0.5	Conifer	9.96	55
472004[1]	D	24.69	0	0	1.50	2.20	0.10	0.45	0	9	0.16	Conifer	8.86	57
472004[1]	E	23.68	0	0	1.30	1.91	0.10	0.38	3	15	0.51	Conifer	4.09	56
472101[1]	A	24.36	0	0	2.00	2.00	0.30	0.21	11	11	1	Conifer	8.49	3
472101[1]	B	28.68	0	0	2.00	2.00	0.00	0.00	4	4	1	Conifer	4.86	7
472101[1]	E	24.52	0	0	2.00	2.00	0.00	0.00	11	17	1	Conifer	9.60	3
472102[1]	A	21.44	0	0	2.00	2.00	0.00	0.00	1	1	1	Conifer	7.33	5
472102[1]	B	28.98	1	1	4.00	4.00	0.00	0.00	1	1	1	Conifer	0.00	7
472102[1]	C	30.70	1	1	4.00	4.00	0.00	0.00	5	5	1	Conifer	0.57	6
472103[1]	B	13.50	0	0	4.30	4.30	0.25	0.25	1	1	1	Conifer	6.83	1
472103[1]	C	8.59	0	0	3.60	3.60	0.25	0.25	1	1	0	Conifer	2.39	1
472104[1]	C	21.55	0	0	1.00	1.00	0.00	0.00	4	4	0.1	Conifer	5.79	2
511706	G	27.27	0	0	1.00	1.00	0.50	0.50	21	20	0.2	Conifer	3.93	4

THP #[1,2]	Unit	Acres	Pre HRA #	Post HRA #	Pre green trees/ acre	Post green trees/ acre	Pre snags/ acre	Post snags/ acre	Pre scorecard trees/acre	Post scorecard trees/acre	LWD/ acre	Dominance	RMZ and Geo acres	Slash piles retained #[3,4]
511707	A	31.68	0	0	2.00	7.50	1.00	0.33	51	67	7	Conifer	12.76	20
511707	B	25.98	0	0	7.00	15.00	1.00	1.46	164	188	9	Conifer	15.46	28
511707	C	18.71	0	0	4.80	10.50	1.00	1.21	90	100	11	Conifer	16.41	30
511707	D	20.31	0	0	4.70	6.90	1.00	0.68	84	86	10	Conifer	1.97	37
511707	E	22.30	0	0	2.00	13.50	1.00	1.70	44	87	9	Conifer	1.27	18
511707	G	27.13	0	0	7.50	10.00	1.00	0.38	193	183	11	Conifer	0.27	24
511801	B	27.86	0	0	2.00	2.00	1.00	1.00	43	43	1	Hardwood	44.17	10
511801	C	32.16	0	0	2.00	2.00	1.00	1.00	15	15	1	Hardwood	10.22	15
511801	F	32.09	0	0	2.00	2.00	1.00	1.00	60	73	1	Hardwood	6.40	20
561802	D	30.24	0	0	2.00	2.50	0.50	0.50	49	49	1	Conifer	4.56	30
561804	C	13.09	0	0	5.20	5.20	0.00	0.00	18	18	0	Conifer	13.94	4
561806	F	19.53	0	0	3.00	3.00	0.10	0.10	8	8	0	Conifer	26.45	7[4]
561902	E	26.15	1	1	2.00	2.00	0.50	0.00	14	10	1	Conifer	0.84	3
561902	G	24.99	0	0	2.00	2.00	0.50	0.00	17	17	1	Conifer	4.53	6
562001	B	21.91	0	0	2.30	2.80	0.00	0.20	22	22	0.4	Conifer	0.72	17
562001	C	27.83	0	0	1.25	2.30	0.00	0.50	10	10	0.4	Conifer	7.63	14
562002	A	20.02	1	1	1.40	1.40	0.50	0.50	0	0	0.5	Conifer	0.44	40
562002	B	26.54	2	2	2.00	2.00	0.50	0.50	2	2	0.5	Conifer	1.41	40
562002	C	21.40	0	0	2.80	2.80	0.50	0.50	0	0	0.5	Conifer	9.83	30
562002	D	22.34	2	2	2.00	2.00	0.00	0.00	0	0	0.5	Conifer	0.00	40
562002	E	19.58	0	0	1.00	1.00	0.00	0.00	0	0	0.5	Conifer	5.81	40
562002	F	19.54	0	0	2.10	2.10	0.00	0.00	1	1	0.5	Conifer	7.59	40
562002	G	22.86	1	1	2.80	2.80	0.50	0.00	10	10	1	Conifer	0.79	35
562002	H	24.13	0	0	2.50	2.50	0.00	0.30	3	3	1	Conifer	7.52	35
562002	I	18.92	0	0	2.10	2.10	0.00	0.30	0	0	1	Conifer	5.22	45

THP #[1,2]	Unit	Acres	Pre HRA #	Post HRA #	Pre green trees/ acre	Post green trees/ acre	Pre snags/ acre	Post snags/ acre	Pre scorecard trees/acre	Post scorecard trees/acre	LWD/ acre	Dominance	RMZ and Geo acres	Slash piles retained #[3,4]
562002	J	16.24	0	0	2.60	2.60	0.00	0.00	15	15	1	Conifer	2.36	30
562101	B	26.88	0	0	2.50	2.50	0.50	0.20	0	0	0.5	Conifer	4.96	40
562101	E	29.54	0	0	2.70	2.70	0.50	0.20	1	1	0.5	Conifer	18.23	40
562101	F	28.78	1	1	2.80	2.80	0.20	0.20	6	6	0.5	Conifer	0.00	48
562101	G	23.79	0	0	2.40	2.40	0.50	0.20	4	4	1	Conifer	5.87	38
611901	A	14.62	0	0	2.00	2.00	2.00	2.00	0	0	2	Conifer	7.13	2
611901	B	18.60	0	0	2.00	2.00	2.00	2.00	5	5	2	Conifer	16.27	2
611901	C	27.71	0	0	2.00	2.00	2.00	2.00	4	4	2	Conifer	12.56	2
611901	D	28.66	1	1	2.00	2.00	2.00	2.00	45	45	2	Conifer	1.15	2
611901	E	18.10	0	0	2.00	2.00	2.00	2.00	1	1	2	Conifer	11.45	2
611901	F	16.92	0	0	2.00	2.00	2.00	2.00	1	1	2	Conifer	13.00	2
661802	H	32.00	0	0	2.00	2.00	0.25	1.00	5	5	1.4	Conifer	13.26	40
662002	A	22.15	0	0	2.00	2.00	0.50	0.50	1	1	3	Conifer	10.06	3[4]
662002	C	24.26	0	0	2.00	2.00	0.50	0.50	0	0	5	Conifer	9.61	4
662002	D	26.93	1	1	2.00	2.00	0.50	0.50	4	4	3	Conifer	0.00	4
711802	B	26.87	0	0	2.00	2.00	0.10	0.10	21	21	4	Conifer	2.85	4
711802	C	26.74	1	1	2.00	2.50	0.10	0.20	27	27	0.2	Conifer	0.00	3
711901	A	22.87	0	0	3.60	3.60	0.00	0.20	1	1	0.1	Conifer	11.45	8
711901	B	17.41	0	0	2.30	2.30	0.00	0.00	0	0	0.1	Conifer	6.86	30
711903	D	24.30	0	0	2.00	2.00	0.50	0.50	8	8	2	Conifer	11.02	3[4]
711904	A	17.55	0	0	2.00	2.00	1.00	1.00	1	8	1	Conifer	5.40	6
711904	B	30.62	0	0	2.00	2.00	1.00	1.00	10	10	1	Conifer	25.51	10
731802	D	29.86	2	2	3.00	3.00	0.20	0.20	0	0	0.5	Conifer	1.66	30
731901	A	19.57	2	2	2.00	2.00	0.50	0.50	0	0	2	Conifer	0.00	2
732001	C	19.32	0	0	2.30	5.00	0.00	0.20	9	9	0.1	Conifer	3.87	45

THP #[1,2]	Unit	Acres	Pre HRA #	Post HRA #	Pre green trees/ acre	Post green trees/ acre	Pre snags/ acre	Post snags/ acre	Pre scorecard trees/acre	Post scorecard trees/acre	LWD/ acre	Dominance	RMZ and Geo acres	Slash piles retained #[3,4]
732001	E	26.84	0	0	2.00	3.00	0.00	0.00	3	3	0	Conifer	12.99	7[4]
732002	D	13.88	0	0	2.00	2.00	0.00	0.10	3	3	0	Conifer	4.93	2[4]
851602	F	12.79	0	0	2.00	2.00	2.00	2.00	31	31	2	Conifer	5.13	2
851602	G	16.81	0	0	2.00	2.00	2.00	1.00	9	9	2	Conifer	16.25	2
851802	B	17.90	1	1	2.00	2.00	0.50	0.50	9	9	3	Conifer	0.00	3
851803	D	30.78	0	0	2.00	2.00	2.00	2.00	3	3	2	Conifer	1.47	3
851803	F	11.40	0	0	2.00	2.00	2.00	2.00	4	4	1	Conifer	4.01	4
851901	B	8.63	0	0	2.00	2.00	2.00	2.00	0	2	2	Conifer	15.71	1
852001	A	26.06	0	0	2.00	2.00	2.00	2.00	8	8	1	Conifer	1.57	13
852001	B	20.19	0	0	2.00	2.00	2.00	2.00	2	2	1	Conifer	18.02	14
852001	C	13.98	0	0	2.00	2.00	2.00	2.00	1	2	1	Conifer	16.75	10
852001	D	23.05	0	0	2.00	2.00	2.00	2.00	7	7	1	Conifer	9.67	12
852001	E	26.01	0	0	2.00	2.00	2.00	2.00	4	4	1	Conifer	6.83	9
852002	A	23.60	1	1	2.00	2.00	2.00	2.00	4	4	2	Conifer	2.88	3
852002	C	23.83	0	0	2.00	2.00	2.00	2.00	0	0	2	Conifer	8.19	2
852002	D	16.91	1	1	2.00	2.00	2.00	2.00	24	24	2	Conifer	0.65	2
872103[2]	B	27.29	0	0	NA	2.00	NA	2.00	NA	0	2	Conifer	7.04	0[4]
872103[2]	C	23.46	0	0	NA	2.00	NA	2.00	NA	0	2	Conifer	5.69	0[4]

[1] Units located within the Maple Creek, Pitcher Creek, or McDonald Creek Planning Watersheds.
[2] Emergency salvage units.
[3] Units with zero slash pile retention did not require slash pile retention due to being located with the Maple Creek Planning Watershed or due to the unit not containing ground-based clearcut acres.
[4] Units not requiring slash pile retention due to a lack of ground-based clearcut acres but where slash piles were retained and reported post-harvest. Acres not included in chapter summaries.
[5] Not Applicable.

Site Occupancy of Humboldt Marten on Managed Forests in Northern California

Ryan Nielsen[1], David Lamphear[2], Keith Hamm[2], Desiree Dorvall[2]

Introduction

The Humboldt subspecies of marten (*Martes caurina humboldtensis*) as described by Grinnell and Dixon (1926), historically occupied the north coastal California region from Sonoma County into Oregon and within 50 miles of the seacoast. A later account (Grinnell 1933) similarly described the species as occurring along the humid north coast strip chiefly within the limits of redwoods from the Oregon line south to Sonoma County, California. The altitudinal range was from the seacoast to about 3,000 feet, but animals taken by fur trappers at the time were found inland from the seacoast on higher ridges where redwoods gave way to Douglas-fir and hardwoods. Twining and Hensley (1947) noted that trappers seeking Humboldt pine marten in northwestern California had not taken marten in Lake or Sonoma Counties in many years and that recent records of trapped marten were also scarce in Mendocino County. The authors also described that few (mean = two marten/trapper) marten were taken in Humboldt and Del Norte Counties, and the “occasional trapper willing to fight heavy brush and down timber in remote country could occasionally catch one.” This apparent depletion of marten in northwestern California prompted Fish and Game to close the season in northwestern California (Humboldt, Del Norte, Trinity and Siskiyou Counties) in 1946 (Twining and Hensley 1947). The subspecies was thought to be extirpated due to trapping and loss of habitat from harvesting of late seral

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forests until a small population was rediscovered in 1996 within a portion of the historical range (Zielinski and Golightly 1996).

From the 1950s to the mid-1990s, there were few verifiable detections of Humboldt marten (Zielinski and Golightly 1996). Beginning in 1989, an increase in rigorous survey efforts for fisher (*Pekania pennanti*) and marten also failed to detect marten in the area (Beyer and Golightly 1995, Zielinski et al. 1995, Klug 1997). However, since 1996, surveys for martens have been conducted in much of the northwestern California region and the results suggested that martens no longer occupied much of their historical range in this portion of California (Zielinski et al. 2001, Slauson 2003). Further investigations by Slauson et al. (2007) indicated that a sole extant population of coastal martens within the historical range of the Humboldt marten subspecies occurred as an isolated population found almost exclusively on USFS lands east of the Klamath River.

Historical records suggest that martens in northwestern California were closely tied to late-successional coast redwood forests (Grinnell and Dixon 1926, Grinnell 1933). The one remnant population in this region occurs in an area dominated by Douglas-fir and tanoak forest associations with coast redwood associations limited to the western edge of the currently occupied range (Slauson 2003, Slauson et al. 2007). This population uses two structurally distinct forest types, with one occurring on serpentine soils which contained large expanses of dense shrub cover, open tree canopies, and boulder piles and the other on more productive non-serpentine soils having the oldest seral stages with closed, multi-layered tree canopies and dense shrub cover (Slauson 2003, Slauson et al. 2007). Evidence suggested that shrub layers may provide the necessary overhead cover, as some serpentine sites lacked trees (Slauson 2003). On serpentine sites, boulders and rocky outcrops provide habitat for prey species and may be used for escape cover where trees are sparse (Slauson 2003, Slauson et al. 2007). Dense shrub cover was the most consistent habitat feature at sites selected by martens in both serpentine and non-serpentine stands in north coastal California (Slauson et al. 2007), while martens showed the strongest selection for conifer stands with greater than 80% shrub cover and selected against stands with less than 60% shrub cover (Slauson and Zielinski 2007a). Shrub layers were predominately comprised of shade tolerant, long-lived, mast and berry producing ericaceous species (Slauson and Zielinski 2009).

More recent studies have documented coastal martens occurring in a broader range of habitat types such as coastal dune habitat and a broad range of forest stand ages (Eriksson et al. 2019, Moriarty et al. 2019). Recent range-wide habitat modeling based on contemporary location data also found the species utilizing habitat types with increased shrub cover, mast producing trees, presence of pine species, low and high canopy cover and slope and increased precipitation (Moriarty et al. 2021). The study found little association with old growth structural attributes reported in other studies (Slauson et al. 2019). These differences highlight that repeatable research is needed to better understand the contemporary distribution and persistence of this rare carnivore through large scale efforts across the range as well as finer scale studies of habitat selection and demography that may providing insight to habitat quality, habitat connectivity, and population persistence.

Green Diamond initiated research on mesocarnivores in 1994 with more focused research on Humboldt marten in 2010 and was a part of the Humboldt Marten Conservation Group that produced the Humboldt Marten Conservation Assessment and Strategy (Slauson et al. 2019). In 2016, Green Diamond began working with the California Department of Fish and Wildlife on a Safe Harbor Agreement for Humboldt Marten, and in April 2018, the Department issued an approved Agreement. The Humboldt marten was listed as Endangered by the California Fish and Game Commission in August 2018, and the U.S. Fish and Wildlife Service listed the Coastal Distinct Population Segment of Pacific marten as Threatened in October 2020. The Safe Harbor Agreement between the California Department of Fish and Wildlife includes numerous Monitoring and Reporting Requirements (MRRs), and MRR 2 requires that within three years of Agreement approval, Green Diamond shall use noninvasive survey results to estimate marten occupancy within the Marten Special Management Area and Enrolled Lands and lands located within the Potential Marten Source Area. An analysis of occupancy rates shall be submitted in the fourth annual report. This report satisfies MRR 2, and Green Diamond is accepting input from the Department on this document and its findings.

Study Area

The study was located on approximately 367,457 acres of commercial timberlands with adjacent state, federal, and other private lands in Humboldt and Del Norte Counties, California (Figure 1). The bulk of Green Diamond's ownership is within 20 miles of the coast, with the eastern-most tract located approximately 50 miles inland. The holdings range in size from isolated 20-acre parcels to contiguous blocks of over 100,000 acres. The ownership has been managed for timber harvest over the past century with over 99 percent of the forest area comprised of second and third growth ranging from recently harvested to about 120 years of age. Older forest areas and older trees (both >180 years) occur as small patches, clumps, and scattered individuals.

Green Diamond's California timberlands are generally colder and wetter in the north with more moderate temperatures and less precipitation towards the south. The east-west trend is for cold winters and hot summers in the high elevation interior region and moderate year-round temperatures in the coastal areas. Precipitation shows an east-west trend with increasing precipitation in the high elevation interior region and more moderate precipitation toward the coast. The effect of the summer coastal fog extends 20 to 30 miles inland along major river valleys.

Green Diamond's California timberlands occurs primarily within three major Ecological Regions (Ecoregions) as described by the U.S. Forest Service (Miles and Goudey 1997). The Northern California Coast Ecoregion is characterized by mountains, hills and valleys of the northern Coast Ranges and portions of the Klamath Mountains that are close enough to the Pacific Ocean for the climate to be greatly modified by the marine influence. Redwoods dominate the forested area, with Douglas-fir becoming a more common inland. On western aspects near the coastal plain, Sitka spruce is a major stand component. Dominant hardwoods are red alder, California bay, big-leaf maple and tanoak. Red alder dominates along the riparian zones and north aspects. Western hemlock, western red cedar and grand fir also occur as minor stand components on lower slopes near the coast. Tanoak and madrone are common on drier sites toward the interior. Elevations range from sea level to 3,000 feet, and precipitation varies from 20 to 120 inches annually. The Northern California Coast Ranges Ecoregion includes the interior portion of the California Coast Range Mountains that also has a marine influence but to a much smaller degree. Elevations range from just above sea level to 8,000 feet. The growing season is 80 to 250 days, and summer fog is generally limited to low elevations and major watercourses. Coastal redwood forests occur along the coastal face and transition to more mesic interior landscapes dominated by Douglas-fir/tanoak forests, with grasslands appearing on some drier ridge tops and south to west aspects. Minor amounts of grand fir, western red cedar and western hemlock occur on lower slopes near the coast and in riparian zones. Red alder is the most common hardwood in riparian areas and northern aspects with tanoak and madrone more common inland or on drier sites. In some areas, Douglas-fir exists as pure or nearly pure stands due to underlying soil characteristics. Higher elevations at the eastern boundary of this area (4,000 - 4,500 feet) support montane conifer forests dominated by Douglas-fir and white fir with golden chinquapin as a stand component. Oregon white oak is common at the margins of grasslands, with California black oak also found on drier soils. The Klamath Mountains Ecoregion is located between the Southern Cascades and Coast Range Mountains. It is characterized by greater temperature extremes and elevations from 200 to over 9,000 feet. The predominant forest types are Douglas-fir, Douglas-fir/tanoak, Douglas-fir/pine, mixed conifer, white fir, Jeffrey Pine, red fir, canyon live oak and Oregon white oak. Redwood and Douglas-fir Forest rapidly give way to non-forest landscape dominated by manzanita, with knobcone pine, ponderosa pine, and Port-Orford cedar at the transition and persisting along the bottom of many watercourses. This ecotone results from a band of serpentinaceous soils on the Red Mountain/Rattlesnake Mountain ridge that divides Terwer Creek and Goose Creek.

Green Diamond utilizes a combination of even-aged, uneven-aged and intermediate timber harvest methods to produce a sustainable yield of forest products while providing for the retention and development of key ecological habitat elements and structure. At a landscape level, the timberlands are composed of a mosaic of multiple age classes created by even aged regeneration harvest areas set within a network of selectively harvested older stands that typically follow the stream networks. Additional key ecological habitat elements are retained in the even-aged openings and across the landscape. The selection harvest method occurs in Riparian Management Zones (RMZs) and unstable areas that provide a dendritic network of older forests with high basal area and dense canopy cover. Approximately 25% of the landscape will be in RMZs and other partial harvest retention areas that will continue to increase in age and develop large trees with cavities, broken tops, debris accumulations and various types of structures for wildlife species. The even-aged harvest areas will create a mosaic of small to large openings that will result in multiple age classes distributed as small patches across the landscape. Approximately 75% of the landscape will be occupied by these small even-aged stands. The average even-aged opening is expected to be approximately 15 acres and to range in size from less than one acre up to 40 acres. These even-aged openings are typically a component of a larger harvest unit that includes a matrix of openings and retention areas. Harvest units (as compared to even-aged openings) are expected to average approximately 30 acres and may range from a few acres to over 50 acres.

Methods

Green Diamond Resource Company (GDRC) conducted camera trapping for Humboldt Marten; hereafter 'marten') from October through March in 2018-2019 (session 1) and 2019-2020 (session 2) on GDRC property and Yurok lands in northern CA. Our goal was to use detections of marten in photos at each camera station (aka site) to estimate occupancy during each trapping session, considering that the probability of detecting a marten at a trapping station, given the site was occupied, was <1, and accounting for varying numbers of camera operating days across stations.

Camera traps

We used a randomly located sampling frame of baited camera stations with 2- and 4-km grid spacing across five spatiotemporal blocks (Figure 1). This variable spacing was developed by intensifying sampling efforts (2-km grid) in areas where we believed marten to exist or may soon be on GDRC property. Areas not expected to have near-term marten presence were sampled using the 4-km grid. Grid spacing was based on estimated home ranges for marten and fisher in our study area. We analyzed counts of marten photos, recorded to the second, during a 21-day sampling period at 221 camera stations (Table 1). Single cameras were located at 94 of the 126 stations in the Marten Special Management Area (MSMA), with the remaining 32 having two cameras intended to operate simultaneously in both years (Figure 2). All stations with dual cameras were in the MSMA.

Modeling occupancy

Identifying the presence or absence of species can determine occupancy at individual sites. However, when the likelihood of detecting a species at an occupied site is <1, adjustments are required, and the result is an estimate of the probability of site occupancy (MacKenzie et al. 2017). There are various approaches to estimating site occupancy while adjusting for the probability of detection. Many methods include covariates representing biophysical and climatic habitat characteristics to improve estimation by reducing bias and increasing precision. The addition of these spatial covariates helps us understand how the probability of detection and occupancy change over space and time, thereby improving estimates and allowing for predictions at other locations within the spatial range of the study area.

The first analysis focused on the Yurok Study Area (YSA). The YSA had the largest proportion of sites with marten detections (Table 1). Because of the higher detection rates in the YSA, we were able to model marten site occupancy in the sub-area using management-related covariates (e.g., mean surface fuels within a 2 km diameter circle.) and static covariates (e.g., distance from coast) as predictors of occupancy and detection (Table 2). These models were used to estimate marten occupancy within the YSA during each trapping session.

Martens were detected at only a handful of sites in the other sub-areas (not YSA; Table 1). Due to this scarcity of detections, we did not feel it was appropriate to attempt to model occupancy in those sub-areas using landscape covariates. Too few detections in areas potentially suitable for marten but not yet occupied in the beginning stages of spatial expansion of the species could result in misleading (biased), relationships between occupancy and habitat covariates. For this reason, we conducted a separate analysis to estimate marten occupancy for all sub-areas (Figure 1, Table 1). We did not consider any habitat or management-related covariates in this second analysis. Instead, we modeled marten site occupancy based solely on the indicator variables for sub-area and trapping session.

We applied a multi-season site occupancy model using detections and non-detections at each station during each trapping session. We assumed that marten detections just a few days apart were not independent, so we divided the 21-day primary sampling period at each site into seven 3-day secondary sampling periods and determined if a marten was detected at least once during each 3-day period. We defined a day as midnight-to-midnight local time. Due to malfunctions, not all traps were operational each day of an entire 21-day trapping session. We reduced camera data to binary results of detection (1) or non-detection (0) for each 3-day period.

The site occupancy model assumes geographic closure around a single station within a trapping session, meaning occupancy doesn’t change (MacKenzie et al. 2017). To assume closure during the primary sampling period would require that if a site was occupied during any of the secondary periods, then there was a non-zero probability of detection across all secondary periods. This closure assumption has often been found to be violated for highly mobile species with large home ranges (Stewart et al. 2018, Emmet et al. 2021). The site occupancy model also assumes that the detections across secondary sampling periods are independent, or correctly modeled with covariates and arise from a Binomial process. In addition, the model assumes that occupancy status is independent between sites or correctly modeled with covariates, and there were no false detections.

We considered a suite of covariates when modeling occupancy and the probability of detection in the YSA (Table 2). However, due to limited sample sizes, and the preliminary nature of this analysis, we limited models to contain only one covariate in addition to the trapping session effect. Although, some of the covariates could have been in linear and quadratic forms. We did not consider continuous covariates, only indicator variables for sub-areas when modeling marten occupancy across the entire sampling frame.

As mentioned above, the MSMA had 32 stations with dual cameras. Before modeling occupancy within the sub-areas, we evaluated the similarities in marten detections among the two cameras at the thirty-two stations operating dual cameras. Only three of the thirty-two dual camera stations detected martens, and detections occurred using both cameras. Based on these results, we determined that although using marten sightings by both cameras at a station could improve model estimation, it would have complicated our analysis. In addition, given the assumed high detection probability, we believed the potential reward of using data from two cameras would be negligible. Therefore, we randomly selected one of the two cameras within each session for our analysis.

Covariate data and model selection

We identified covariates related to each station and potentially associated with marten occupancy and probability of detection in the YSA (Table 2). We generated static covariates and covariates that could vary by trapping session, some of which could be affected by forest management (e.g., road edge density). We measured several covariates at two scales (focal means based on 1 and 2 km diameter circles; Table 2); however, we did not allow both the 1 and 2 km versions of a covariate to be in the same model. We chose the largest circular buffer based on approximated marten home range size within our region (Slauson et al. 2007). We calculated Pearson's correlation between all pairs of continuous covariates. We either dropped one of two within a pair if their correlation was >0.6, or we didn't allow both covariates to be in the same model. We considered quadratics for a subset of covariates (Table 2), but quadratic terms had to be accompanied by their linear versions in the models.

We performed model selection for covariates related to occupancy and probability of detection using the Watanabe-Akaike information criterion (WAIC; Vehtari et al. 2017). The use of WAIC is like other information criteria such as Akaike's (AIC; Burnham and Anderson 2002), the Bayesian information criterion (BIC; Burnham and Anderson 2002), and the Deviance information criterion (DIC; Gilks et al. 1995) in that the model with the lowest value is determined to have the best predictive performance. However, compared to the others, WAIC is fully Bayesian (unlike AIC or BIC), based on the actual predictive procedure (not DIC), and is valid for hierarchical models (unlike AIC, BIC, or DIC; Hobbs and Hooten 2015). Although WAIC contains a penalty for increased model complexity, that penalty is not simply based on the count of model coefficients (e.g., p + 2 in equation 3) and the overall sample size of the modeled data, as in AIC and BIC. The WAIC penalty for model complexity is based on an estimate of the number of effective parameters, which can be much larger than the number of covariates and change based on the parameterization of the model (Hobbs and Hooten 2015, Vehtari et al. 2017).

We began modeling site occupancy by identifying covariates potentially related to the probability of detection (λ), and we created a list of all possible detection models containing one covariate in addition to the indicator for trapping session (Eqn. 3). Next, we fit all models for probability of detection while holding the model for occupancy (ψ) constant, with only the covariate for the trapping session. We then ranked the models and selected the best model for λ as the one with the lowest WAIC. Traditionally, differences in AIC <2 have been used to identify competing models (Burnham and Anderson 2002). There is no recommended cut-off for WAIC differences, and the rule of thumb of 2 information-theoretic criterion values does not apply. Thus, we selected the model for the probability of detection with the lowest WAIC. This process

Next, we identified all possible models for ψ containing a covariate for the trapping session and one additional covariate. We considered both quadratic and linear forms of some covariates, and together we viewed them as contributing one covariate to a model because both come from a single measurement. Finally, we fit those models using the best model for the probability of detection, and we ranked the models according to WAIC.

We fit all models in a Bayesian hierarchical framework using MCMC methods and the R package jagsUI (Kellner 2021). We standardized all covariates before modeling to improve convergence. We calculated 95% Bayesian credible intervals (CI) for all coefficients. If the 95% CI included 0, we concluded that the estimate was not statistically significant (equivalent to an alpha level of 0.05). We used Uniform (0,1) priors for mean occupancy and detection parameters. We used Uniform (-10, 10) priors for model covariates for occupancy, the probability of detection, and the random effects of each trapping station. We ran three chains of 20,000 iterations following a burn-in of 5,000 iterations. We did not thin or reduce the number of iterations in the MCMC process. Although thinning is often seen in the literature, it is only advantageous in storage costs and data handling (Gilks et al. 1998:140). Hobbs and Hooten

(2015:173) state that posterior distributions are better approximated without thinning – a sentiment shared by Richardson and Spiegelhalter (1998:140).

Assessing convergence and model fit

We used the Gelman-Rubin diagnostic (Rhat: Gelman and Rubin 1992), trace plots, and plots of posterior distributions function to evaluate model convergence (Sinharay 2003). We assumed that we obtained sufficient convergence when all Rhat values were <1.05 and there appeared to be adequate mixing among chains.

We evaluated the fit of all models using posterior predictive checks and the area under the receiver operating characteristic curve (AUC; Hosmer, Lemeshow, and Sturdivant 2013). First, we used a posterior predictive check and determined model fit if the Bayesian p-value (P_B; Hobbs and Hooten 2015, Conn et al. 2018) was >0.05 and <0.95. Specifically, we calculated p-values for differences in simulated data from the model and the actual observations. We focused on differences in the residuals using the Freeman-Tukey fit statistic (Conn et al. 2018) and the SD of the detections. Both Bayesian p-values provide evidence of whether the underlying distributions of the detections at a site matched a Binomial distribution (a series of independent Bernoulli trials) or if the data were overdispersed. For example, if the average proportion of non-detections in the simulated data from the model was the same as that of the observed data, the p-value would be close to 0.5. The Binomial distribution assumes that detections and non-detections across 3-day periods were independent. If the p-value for our tests of differences in the residuals or the SDs of detections were far from 0.5, we would conclude that the independence assumption may have been violated.

Second, we estimated the AUC for each model. The AUC measures a model's ability to discriminate between occupied sites compared to those that were not. Values near 1 indicate near-perfect discrimination of sites, and values near 0.5 indicate that the model provides little insight into occupancy compared to random assignment. The AUC evaluation requires that occupancy is known for all primary sampling units. Although we don't know the latent state of all sites within a trapping session, if the probability of detecting a marten during the trapping session was very high (>0.9), we considered that a site with ≥1 detection to be occupied and a site with 0 detections to be unoccupied for AUC calculation. If the probability of detection was low, this may result in over-confidence in a model's ability to distinguish between occupied and unoccupied sites. Still, the bias is expected to be small, given our high detection rates.

We created prediction plots for each continuous covariate in each model by computing the occupancy estimates at each sampled site based on that specific model and plotting those predictions against the observed values for the covariate. Prediction plots show the estimated effect of each covariate on occupancy for each site from a model. Smoothed lines based on LOESS methods for each session illustrate the general pattern within the data. Marginal plots illustrating the average relationship of one covariate on site occupancy while holding others constant at their median values were not generated from each model. Because we only fit models with a maximum of one continuous covariate for both occupancy and probability of detection, marginal plots would not differ significantly from prediction plots.

Model averaging

We calculated WAIC weights for each model using the method Burnham and Anderson (2002) described for other information-theoretic approaches. We evaluated WAIC weights, model convergence, precision in model estimates, and AUC values to identify a subset of competing models. However, no clear pattern emerged showing that a subset of the 40 models were clearly more competitive than the rest (e.g., larger weights, higher AUC values, smaller

CIs), therefore, we used a weighted average across all models considered. In addition, we predicted marten occupancy for all 221 sites based on the model estimated for all sub-areas. Lastly, and notwithstanding potential extrapolation issues, we predicted marten occupancy for all 221 sites based on the 40 models estimated for the YSA. Based on the distributions of some covariates in the 40 models, that required making predictions outside the range of covariate values used for modeling (e.g., latitude). However, individual models that did not require making predictions outside the range of the modeling data (e.g., canopy cover) may help predict future occupancy rates. Finally, we mapped the model-averaged occupancy at each of the 32 sampled sites for the analysis of marten occupancy specific to the YSA (Figure 2). This process involved making predictions from the 40 models and taking a weighted average of the predictions at each site based on the WAIC weight of each model.

Results

Yurok Study Area

Across 32 sites within the YSA, we detected marten at 9 trapping stations during session 1 (Figure 3, Table 1), and 6 of those stations detected marten in more than one 3-day period. We detected marten at 15 trappings stations during session 2 (Figure 3, Table 1), and 10 of those stations had >1 3-day period with marten detections. The number of detections of marten per trap operating day was scattered across the seven 3-day periods, indicating no evidence that marten were trap-happy or trap-averse during the 21-day trapping session (Figure 4). The average number of operating days within a 3-day period was 2.8661 (SD = 0.3162) during trapping session 1 and 2.9420 (SD = 0.2291) during session 2. The average number of marten detections per day within 3-day periods was 0.0445 in session 1 (SD = 0.0123) and 0.0714 in session 2 (SD = 0.0152).

The best-fitting model for the probability of detection was intercept-only (Table 3), representing a constant probability of detection. Using the best model for the probability of detection and our rules for covariates to bring forward for modeling occupancy (Figure A1, Table 2), we fit 40 models. One of the models contained only the trapping session effect, and the other 39 included an additional single covariate, or that covariate and its quadratic (Table 4). Watanabe-Akaike information criterion revealed little discernment between all 40 models (Figure 5, Table 4). The maximum ΔWAIC was 2.833, and 31 of the models were within 1 WAIC value of the top model. The top model for site occupancy was the trapping session-only model. The next best model (ΔWAIC = 0.0703) contained a positive coefficient for Mean_Canopy_Cover_2km_Circle (estimate = 1.1608, 95% CI 0.2625 to 2.3031), indicating that occupancy rates increased with increasing Mean_Canopy_Cover_2km_Circle (Appendix C.3 and C.4). However, the Rhat for this coefficient was 1.21, indicating a lack of convergence. The mean AUC value across the 40 models was 0.6360 (SD = 0.0361, min = 0.5848, max = 0.7508; Table 4, Figure 5). Interestingly, the top model had the lowest AUC value, and the 2nd best model (Rhat = 1.21) had the 2nd highest AUC. The four models with mean canopy cover within a 1 or 2-km buffer and their quadratics had the highest AUC values (Table 4).

Estimates of the effect of trapping session (2 vs. 1) in all 40 models were positive, indicating an increase in occupancy across the YSA between trapping sessions. Estimates of the occupancy rate of the sample of sites during each trapping session, as opposed to average occupancy across the study area, were statistically different (Appendix C.1 and C.3). The average estimate of marten occupancy rate for the sample of 32 sites was 0.2998 in trapping session 1 (range = 0.2962 to 0.3057) and 0.42626 during session 2 (range = 0.4596 to 0.4682; Table 5). However, estimates of the trapping session effect were not statistically significant (all 95% CIs included 0;

Figure 6, Appendices C.3 and C.4), and there wasn't evidence of a statistically significant difference of a trapping session effect on the overall average probability of occupancy within the YSA (population parameter). Although the average estimate of the overall probability of occupancy within the YSA was 0.3125 in trapping session 1 (range = 0.3074 to 0.3208) and 0.4627 in trapping session 2 (range = 0.4592 to 0.4692; Table 5), 95% CIs for individual estimates of overall occupancy during trapping sessions 1 and 2 overlapped (Appendix C.1). Model weighted predictions of marten occupancy with the YSA using WAIC weights are presented in Figure 7.

The average estimated probability of detecting a marten across all 40 models if a camera was operational all three days of a 3-day period was 0.3667 (range = 0.3618 to 0.3682). The probability of detecting a marten at a site, given occupancy, across a 21-day trapping session was 0.9592 (range = 0.9569 to 0.9598). Given the realized operation of the cameras, the average probability of detection across all 40 models was 0.9482 (range = 0.9458 to 0.9492).

Rhat values for all parameters in all models, except for the 2nd best model, were < 1.02. Trace and posterior density plots showed no evidence of a lack of convergence for the final model (Appendix C.2). The posterior predictive checks did not indicate a lack of fit or violation of distributional assumptions. Bayesian p-values for the differences in residuals and SDs (posterior predictive checks) for all models were ~0.5 (mean = 0.4937, range from 0.4809 to 0.5063), indicating the modeling assumptions were met.

Full Study Area

Across 221 sites within the entire study area and based on all single-camera trapping stations and our random sample of one of two cameras at double-camera trapping stations, we detected marten at 13 trapping stations during session 1 (Figure 3, Table 1), and 10 of those stations detected marten in more than one 3-day period. We detected marten at 21 trappings stations during session 2, and 17 of those stations had >1 3-day period with marten detections. The number of detections of marten per trap operating day was scattered across the seven 3-day periods, indicating no evidence that marten exhibited trap-happiness or trap-aversion during the 21-day trapping session (Figure 8). The average number of operating days within a 3-day period was 2.8526 (SD = 0.3709) during trapping session 1 and 2.9147 (SD = 0.3704) during session 2. The average number of marten detections per day within 3-day periods was 0.0086 in session 1 (SD = 0.00357) and 0.0131 in session 2 (SD = 0.00265).

Using the best model for the probability of detection, we fit the site occupancy model with a covariate for the trapping session and indicator variables for the sub-area (Figure 9, Table 5). The results indicate that marten site occupancy was lower in the MSMA and the Remainder compared to the YSA (95% CIs were <0; Figure 9), and the occupancy of the Moore Tract was not different than the YSA (95% CI included 0; Figure 9). Still, based on this model, the estimates of the proportion of stations occupied by marten were different in the YSA compared to the Moore Tract in the 2018–2019 trapping session (Figure 10). The AUC for the marten site occupancy model for the entire study area was 0.8812.

The Rhat values for all parameters in the all-areas model were 1.0. Trace and posterior density plots showed no evidence of a lack of convergence for the final model (Appendix C.5). The posterior predictive checks did not indicate a lack of fit or violation of distributional assumptions. Bayesian p-values for the differences in residuals and SDs (posterior predictive checks) were 0.5049 and 0.5240.

Discussion

The results of our initial two-year effort of camera surveys for Humboldt marten supported the initial premise of the Safe Harbor Agreement that marten were rare or absent from the majority of the enrolled lands. The findings from year one of the effort indicated that marten were not detected in the Remainder sub-area (64% of Enrolled Lands) and the southern portion of the MSMA. The areas that were known to be occupied as baseline prior to the implementation of the Agreement remained occupied and new detections west of the Marten Reserve Area in the northern portion of the MSMA suggested that marten may have expanded beyond the known occupied area. The Yurok Study area (and former Green Diamond ownership) where marten were first detected in 2004 during property-wide mesocarnivore surveys (Hamm et al. 2016) showed consistent occupancy in a north-south direction and an overall probability of occupancy in the sub-area of approximately 0.3. This result is an encouraging finding as marten occupancy in this managed forest sub-area has persisted for the past 16 years, and other collaborative research has shown that reproduction is occurring and estimated survival rates are fairly high but with substantial variation (Delheimer et al. 2021, Martin et al. 2022). Nonetheless, these findings that were a surprise a decade ago continue to provide encouragement for the persistence of marten in this sub-area and opportunities for conservation originally identified in the Humboldt Marten Conservation Assessment and Strategy and adopted in the Agreement. The early work in this sub-area provided insight into marten ecology for the north coast of California that informed management actions adopted as a net conservation benefit for marten in the Agreement (e.g., slash pile retention, and TREE score card for marten). It is also worth noting that marten were again detected in the remote Moore Tract near the Oregon-California border, another area with documented baseline occupancy by marten prior to the Agreement.

The second year of surveys on the Enrolled Lands and the YSA provided additional interesting findings including increased estimates of occupancy in all sub-areas and detections of marten in new areas of the Enrolled Lands. In the YSA, we observed more detections in an east-west pattern, but the north-south distribution of stations with detections did not change. There was a statistically significant effect for session (year) at the site level, but not for average estimate of occupancy for the entire sub-area. There was no change in site occupancy for the Moore Tract between sessions and estimates did not differ from the YSA. However, the total number of camera stations in the Moore Tract was much lower (n=5) than the YSA and 40% detected marten in both sessions. The Moore Tract was devastated by the Slater Fire in 2020 with over 80% of the area having moderate to severe levels of burned followed by a salvage timber harvest operation in 2021. Despite the apparent negative impacts on habitat from the fire, we deployed cameras at several stations in Moore Tract in 2022 and detected marten. The next full survey in 2024-25 will provide a better indication of marten occupancy within this burned portion of the Enrolled Lands, but it is encouraging that marten are still present in this area and may persist and expand as the habitat recovers in the burn area.

The number of detections in the MSMA increased by two stations in the second session with one additional detection in the northern portion in an already occupied area and one new detection in the southern portion of the MSMA between Redwood National and State Parks and the Klamath River. This area was identified as an important landscape connectivity area in the Humboldt Marten Conservation Assessment and Strategy to connect the extant population area to the east on Yurok and USFS lands and the suitable habitat on Park lands to the west (Slauson et al. 2019). We do not know whether the detected marten is resident or transient, but this is another positive indication of marten passing through the Enrolled Lands and potential evidence of habitat connectivity. A collaborative study with the National Council for Air and Stream Improvement (NCASI) initiated in 2020 prompted additional camera surveys in this same area for potential deployment of GPS radio collars, and this more focused and intensive camera work resulted in two additional detections of marten in the summer of 2022, two years after the detection in 2020. These additional detections provide encouraging empirical findings of marten using the managed lands to connect the extant population and potential habitat on the Parks to the west. An effort to deploy GPS or VHF collars on marten in this area is anticipated in early 2023. A second interesting finding occurred in the Remainder sub-area northeast of the town of Trinidad. A marten was detected at a camera station in the Big Lagoon area in 2020. This detection was at least 15 miles south of the nearest known location and prompted additional effort under the collaborative study with NCASI. A male and female marten were captured and fitted with GPS collars in January 2022. These results were reported to the Department in an April 2022 update provided by Green Diamond. The telemetry study is ongoing with a total of three males collared in this area and the same female collared in 2022 was captured and outfitted with a new GPS collar almost one year later on January 23, 2023. These findings provide substantial evidence that marten are able to traverse and persist in the managed landscape of the Enrolled Lands, make use of the Riparian Management Zones, regenerating forest stands, retained woody structure, and the diversity of forest ages. These findings indicate that at least four marten have made use of the Enrolled Lands in the Maple Creek drainage and that management actions implemented under the Agreement are working for marten. Marten have dispersed into the Enrolled Lands and are occupying an area that is fully representative of the contemporary forest management practices occurring under the Agreement. These findings are direct evidence of a net conservation benefit to Humboldt marten under the Agreement.

The two-year camera survey effort also provided evidence that if a camera survey site was occupied by a marten, there was a high probability that it would be detected within our 21-day survey period. The average estimated probability of detecting a marten across all 40 models in 3-day period was approximately 0.37, and the probability of detecting a marten at a site, given occupancy, across a 21-day trapping session was greater than 0.95. Our estimates of detection probability are consistent with other studies of Humboldt (coastal) marten (Moriarty et al. 2016) and give us confidence in our survey coverage and estimates of site occupancy for the Enrolled Lands. While it was not a requirement to model site occupancy with habitat covariates at this stage of the Agreement (MRR 4 states that modeling with habitat covariates would be attempted after two complete surveys, or 10 years), we attempted to model site occupancy within the YSA with a suite of covariates. (It should be noted that our initial survey effort conducted over a two-year period was voluntary and not required under the Agreement and differs from the two complete surveys described under MRR 4). The top model for site occupancy was the trapping session-only model with the next best model containing a positive coefficient for mean canopy cover within a 2-km radius buffer, indicating that occupancy rates increased with increasing canopy cover. The Rhat coefficient was 1.2 indicating a lack of convergence in the MCMC process and an indication that the data do not fit the model well because there are too many poorly fitting observations. Consequently, the best model contained only a trapping session effect for this effort applied to the data for the YSA. Additional attempts to model site occupancy with covariates will occur after additional data is collected from future camera survey efforts.

Early indications from the survey effort in 2018-2019 and 2019-2020 are that the Agreement is working. Green Diamond has complied with implementation of management actions and reporting requirements for the agreement. Green Diamond has initiated and completed monitoring and reporting requirements as shown in this report. Green Diamond has collaborated with numerous research organizations and universities (NCASI, Oregon State University, Cal Poly Humboldt) on original marten research for the benefit of the species under the Marten Research Commitment. And most importantly, the Agreement is working for the marten. The estimates of modeled site occupancy in this report indicate that marten occupancy increased from session one to session two, and marten have expanded into areas identified as a conservation emphasis area for marten by the Humboldt Marten Conservation Group. These results point to a net conservation benefit for marten in just a few years of implementing the Agreement.

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Tables

Table 1. Summaries of the number of camera stations, the number of operating days (out of 21), and the number and proportion of stations with marten detections during each trapping session. The proportion of stations with marten detections (not accounting for the probability of detection) are naïve estimates of occupancy rates.

Sub-area	Trapping session	Camera stations	Mean operating days	Stations with marten detections	Proportion with marten detections
YSA	1	32	20.06	9	0.2813
41,602 acres	2	32	20.59	15	0.4688
Moore_Tract	1	5	18.60	2	0.4000
4,995 acres	2	5	16.20	2	0.4000
MSMA	1	126	20.10	2	0.0159
127,217 acres	2	126	20.56	3	0.0238
Remainder	1	58	19.76	0	0.0000
235,245 acres	2	58	20.31	1	0.0172
Total	1	221	19.97	13	0.0588
409,060 acres	2	221	20.40	21	0.0950

Table 2. Variable name and description for all covariates considered during the initial phase of model development for the Yurok Study Area multi-season site occupancy model. The use category indicates if a covariate was included in the official model selection or discarded due to a pairwise Pearson correlation or other reasons. The quadratic category indicates if the quadratic form of the covariate was included in model selection. Lastly, the Pearson r. Group shows the pairwise correlation (collinearity) groupings that required separation during model development.

Variable Name (Psi: Occupancy)	Source	Variable Description	Use	Quadratic
Hydro_Buff_1km_PerArea	GDRCo	Percent of a 1-km circular area with Riparian Management Zone (RMZ).	1	0
Hydro_Buff_2km_PerArea	GDRCo	Percent of a 2-km circular area with Riparian Management Zone (RMZ).	1	0
RoadEdge_Density_1km_Circle	GDRCo	Road density in km/km2 within a 1-km circular area.	1	0
RoadEdge_Density_2km_Circle	GDRCo	Road density in km/km2 within a 2-km circular area.	1	0
Mean_Slope_p_5m_1km	GDRCo	Mean percent slope within a 1-km circular area.	1	1
Mean_Slope_p_5m_2km	GDRCo	Mean percent slope within a 2-km circular area.	1	1
Annual_Mean_August_Air_Normal	PRISM	30-yr normal (1981-2010) August average mean temperature (Celsius)	1	0
Annual_Max_August_Air_Normal	PRISM	30-yr normal (1981-2010) August average maximum temperature (Celsius)	1	0
Annual_Max_Air_Normal	PRISM	30-yr normal (1981-2010) annual average maximum temperature (Celsius)	1	0
Annual_Mean_Air_Normal	PRISM	30-yr normal (1981-2010) annual average mean temperature (Celsius)	1	0
Annual_Min_Air_Normal	PRISM	30-yr normal (1981-2010) annual average minimum temperature (Celsius)	1	0
Annual_Precip_Normal	PRISM	30-yr normal (1981-2010) annual precipitation (mm)	1	0
Mean_Canopy_Height_1km_Circle	CA Forest Observatory	Mean canopy height (Meters) within a 1-km circular area.	1	0
Mean_Canopy_Height_2km_Circle	CA Forest Observatory	Mean canopy height (Meters) within a 2-km circular area.	1	0
Mean_Canopy_Cover_1km_Circle	CA Forest Observatory	Mean canopy cover (%) within a 1-km circular area.	1	1
Mean_Canopy_Cover_2km_Circle	CA Forest Observatory	Mean canopy cover (%) within a 2-km circular area.	1	1
Mean_Surface_Fuels_1km_Circle	CA Forest Observatory	Mean proportion of surface fuels in the understory within a 1-km circular area.	1	1
Mean_Surface_Fuels_2km_Circle	CA Forest Observatory	Mean proportion of surface fuels in the understory within a 2-km circular area.	1	1
Mean_Surface_Fuels_100m_Circle	CA Forest Observatory	Mean proportion of surface fuels in the understory within a 100-m circular area.	1	0
Mean_OGSI_1km	LEMMA	Mean regionalized old-growth structure index within a 1-km circular area. Calculated from abundance of large live trees, snags and down wood, and diversity of tree sizes.	1	0
Mean_OGSI_2km	LEMMA	Mean regionalized old-growth structure index within a 2-km circular area. Calculated from abundance of large live trees, snags and down wood, and diversity of tree sizes.	1	0
Mean_Age_Dom_1km	LEMMA	Mean basal area weighted stand age within a 1-km circular area.	1	0
Mean_Age_Dom_2km	LEMMA	Mean basal area weighted stand age within a 2-km circular area.	1	0
Mean_DDI_1km	LEMMA	Mean diameter diversity index within a 1-km circular area.	1	0
Mean_DDI_2km	LEMMA	Mean diameter diversity index within a 2-km circular area.	1	0
Mean_Qmd_Dom_1km	LEMMA	Mean quadratic mean diameter of all dominant and codominant trees within a 1-km circular area.	1	0
Mean_Qmd_Dom_2km	LEMMA	Mean quadratic mean diameter of all dominant and codominant trees within a 2-km circular area.	1	0
Mean_STPH_GE_25_1km	LEMMA	Mean density of snags >=25 cm dbh and >=2 m tall within a 1-km circular area.	1	0
Mean_STPH_GE_25_2km	LEMMA	Mean density of snags >=25 cm dbh and >=2 m tall within a 2-km circular area.	1	0
Coast_Dist_5m	GDRCo	Distance inland from the Pacific Ocean in meters	1	1
Latitude_5m	GDRCo	Latitude measured in decimal degrees	1	1
Trapping_Session	GDRCo	Two sampling periods comprised of October through March 2018/2019 and 2019/2020.	1	0
Variable Name (Lambda: Detection Probability)		**Variable Description**	**Use**	**Quadratic**
Trapping_Session	GDRCo	Two sampling periods comprised of October through March 2018/2019 and 2019/2020.	1	0
Mean_Surface_Fuels_100m_Circle	CA Forest Observatory	Mean proportion of surface fuels in the understory within a 100-m circular area.	1	0

* Total basal area is the sum of all tree species basal area measured (diameter at breast height) during field inventory collection.

Table 3. Model ranks based on Watanabe-Akaike information criterion (WAIC) for each probability of detection model considered for the Yurok Study Area. Delta-WAIC is the difference in WAIC compared to the top model. The indicator variable for trapping session 2 is denoted by I(trapping session = 2).

Model rank	Probability of detection model	ΔWAIC
1	Intercept only	0.0000
2	Trapping_session	0.0111
3	Mean_Surface_Fuels_100m_Circle	4.0908
4	Trapping_session + Mean_Surface_Fuels_100m_Circle	7.9542

Table 4. Model ranks based on Watanabe-Akaike information criterion (WAIC) for the all 40 site occupancy models considered for the Yurok Study Area, along with delta-WAIC and the area under the curve (AUC). Delta-WAIC is the difference in WAIC compared to the top model. A positive coefficient is represented by a '+' before the covariate, and a negative coefficient is represented by '–'. All coefficients for Trapping session were positive. Covariates with significant coefficients ($\alpha = 0.05$) based on 95% Bayesian credible intervals excluding 0 are noted by '*'.

Model rank	Probability of occupancy model	ΔWAIC	AUC
1	Trapping_session	0.0000	0.5848
2	Trapping_session + Mean_Canopy_Cover_2km_Circle*	0.0703	0.7413
3	Trapping_session + Mean_STPH_GE_25_2km	0.1096	0.6225
4	Trapping_session + Mean_Canopy_Cover_1km_Circle*	0.1380	0.7041
5	Trapping_session + Mean_Canopy_Height_2km_Circle	0.1390	0.6384
6	Trapping_session + Mean_STPH_GE_25_1km	0.1974	0.6341
7	Trapping_session + Mean_Canopy_Height_1km_Circle	0.2315	0.6140
8	Trapping_session + Annual_Max_Air_Normal	0.3063	0.6050
9	Trapping_session – RoadEdge_Density_2km_Circle	0.3103	0.6135
10	Trapping_session + Annual_Mean_August_Air_Normal	0.3164	0.6262
11	Trapping_session + Hydro_Buff_1km_PerArea	0.3456	0.5992
12	Trapping_session – Mean_Slope_p_5m_1km	0.3468	0.6055
13	Trapping_session + Annual_Max_August_Air_Normal	0.3642	0.6453
14	Trapping_session + RoadEdge_Density_1km_Circle	0.4004	0.5907
15	Trapping_session – Mean_Slope_p_5m_2km	0.4005	0.6023
16	Trapping_session – Hydro_Buff_2km_PerArea	0.4218	0.6108
17	Trapping_session + Annual_Mean_Air_Normal	0.4317	0.6007
18	Trapping_session + Coast_Dist_5m	0.4778	0.6394
19	Trapping_session + Mean_OGSI_2km	0.5462	0.6405
20	Trapping_session – Mean_Qmd_Dom_1km	0.5780	0.6140
21	Trapping_session + Mean_OGSI_1km	0.5958	0.6161
22	Trapping_session – Mean_Age_Dom_2km	0.6852	0.6384
23	Trapping_session – Latitude_5m	0.6857	0.6098
24	Trapping_session – Annual_Min_Air_Normal	0.7248	0.6373
25	Trapping_session + Mean_Canopy_Cover_2km_Circle* + Mean_Canopy_Cover_2km_Circle^2	0.7667	0.7508
26	Trapping_session – Latitude_5m – Latitude_5m^2	0.8280	0.6225
27	Trapping_session + Mean_Surface_Fuels_1km_Circle	0.8607	0.6235
28	Trapping_session – Mean_Slope_p_5m_1km + Mean_Slope_p_5m_1km^2	0.8919	0.6161
29	Trapping_session – Mean_Age_Dom_1km	0.8947	0.6331
30	Trapping_session + Annual_Precip_Normal	0.9137	0.6479
31	Trapping_session + Mean_Surface_Fuels_2km_Circle	0.9560	0.6437
32	Trapping_session – Mean_Slope_p_5m_2km + Mean_Slope_p_5m_2km^2	1.0084	0.6246
33	Trapping_session + Mean_Surface_Fuels_100m_Circle*	1.0864	0.6548
34	Trapping_session – Mean_DDI_1km	1.1272	0.6384
35	Trapping_session – Mean_Qmd_Dom_2km	1.1437	0.6532
36	Trapping_session + Mean_Surface_Fuels_2km_Circle* – Mean_Surface_Fuels_2km_Circle^2	1.3462	0.6501
37	Trapping_session – Mean_DDI_2km	1.6763	0.6723
38	Trapping_session + Mean_Canopy_Cover_1km_Circle + Mean_Canopy_Cover_1km_Circle^2	1.8180	0.7052
39	Trapping_session + Mean_Surface_Fuels_1km_Circle – Mean_Surface_Fuels_1km_Circle^2	2.1728	0.6288
40	Trapping_session + Coast_Dist_5m + Coast_Dist_5m^2	2.8329	0.6416

*Ninety-five percent Bayesian credible interval does not contain 0.

Table 5. Estimates of marten occupancy rates at sampled sites and the overall average probability of occupancy across the sub-areas during each trapping session, along with 95% Bayesian credible intervals (CI).

		Occupany rate of sampled sites			Overall probability of occupancy within sub-area		
Sub-area	Trapping session	Estimate	95% CI lower limit	95% CI upper limit	Estimate	95% CI lower limit	95% CI upper limit
YSA	1	0.2927	0.2813	0.3438	0.3118	0.1794	0.4629
41,602 acres	2	0.4843	0.4688	0.5313	0.4753	0.3193	0.6360
Moore_Tract	1	0.4260	0.4000	0.6000	0.3685	0.1033	0.7261
4,995 acres	2	0.4633	0.4000	0.8000	0.5228	0.1925	0.8507
MSMA	1	0.0165	0.0159	0.0238	0.0139	0.0037	0.0322
127,217 acres	2	0.0249	0.0238	0.0317	0.0275	0.0086	0.0577
Remainder	1	0.0000	0.0000	0.0000	0.0061	0.0002	0.0238
235,245 acres	2	0.0178	0.0172	0.0345	0.0120	0.0003	0.0447
Total	1	0.0615	0.0588	0.0724	0.0630	0.0375	0.0926
409,060 acres	2	0.0995	0.0950	0.1131	0.0995	0.0684	0.1339

Figures

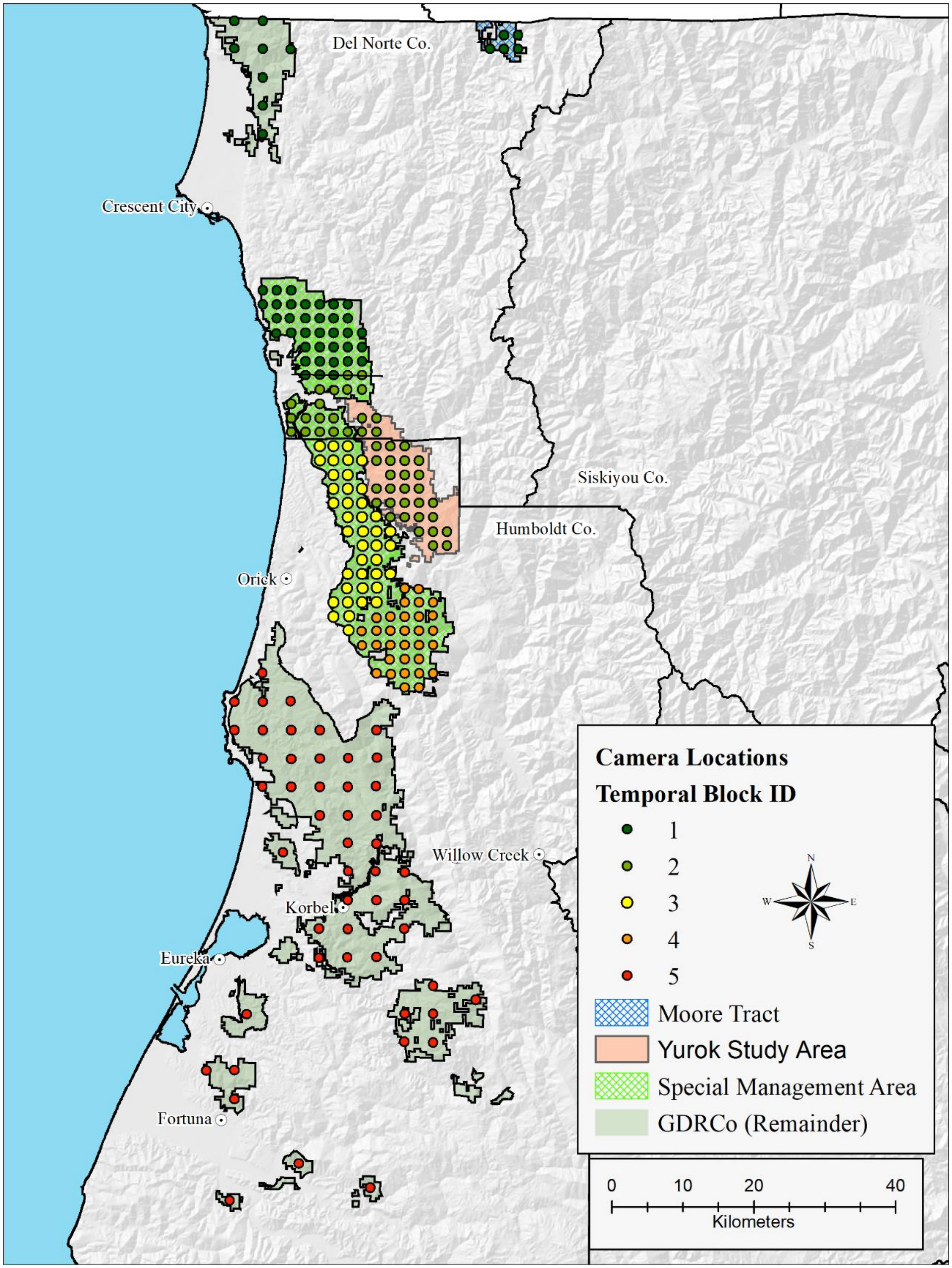

Figure 1. Trapping stations on 2-km and 4-km grids across the study areas.

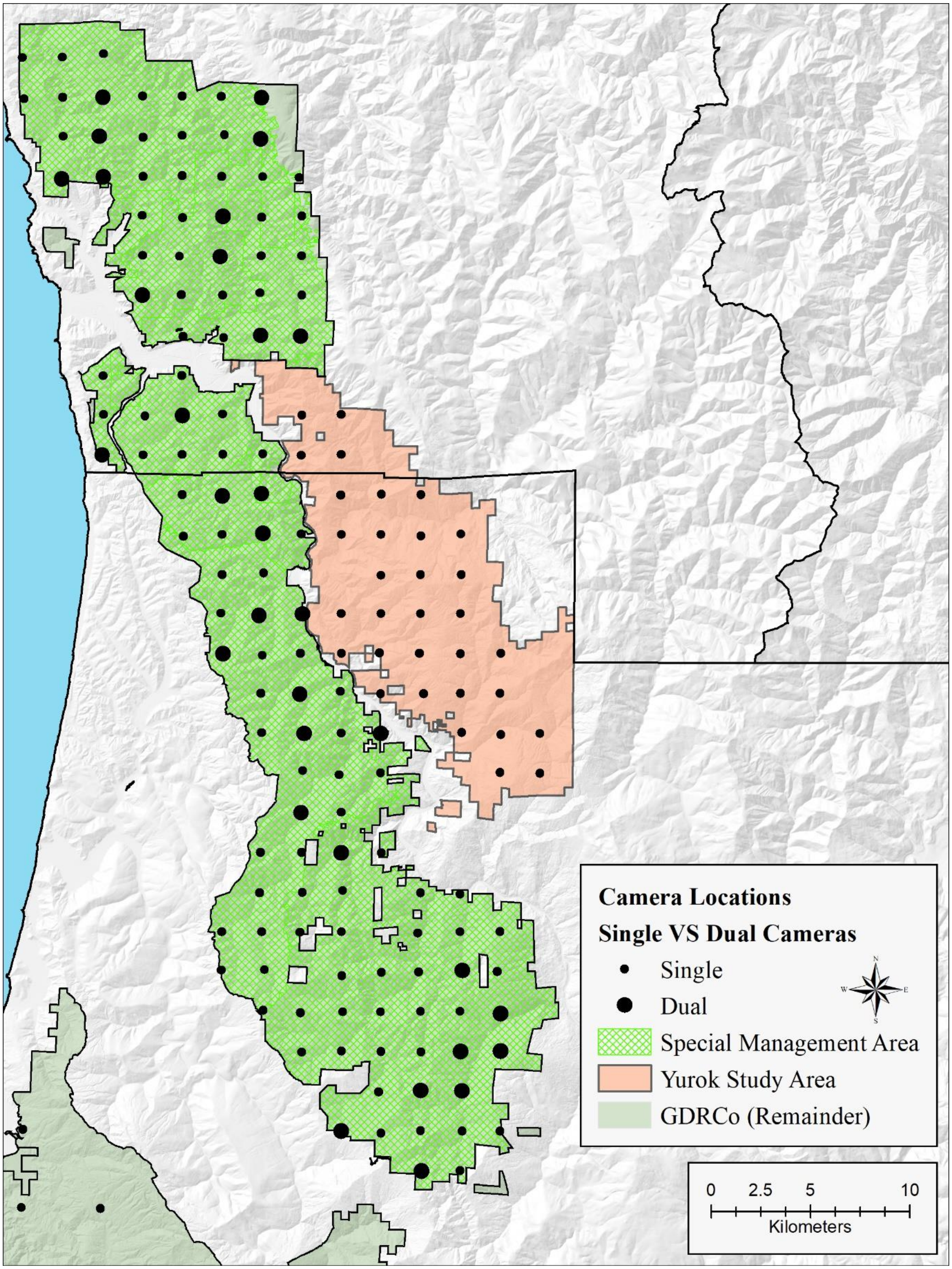

Figure 2. Locations of single and dual camera trapping stations. A large 'dot' indicates stations with dual cameras.

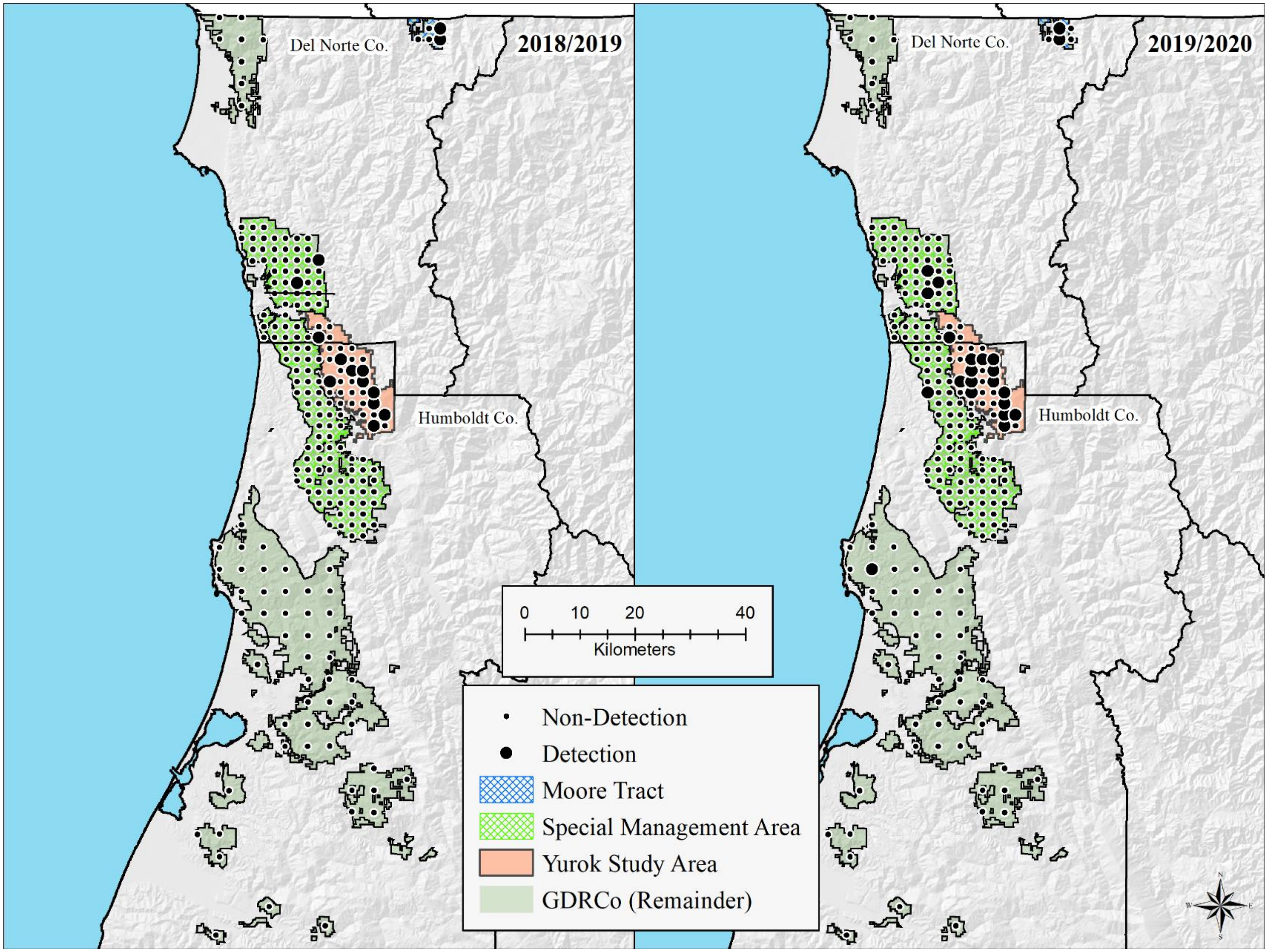

Figure 3. Camara traps with marten detections during each trapping session. A large 'dot' indicates a marten was present and detected at least once. Sessions 1 and 2 were conducted from October through March in 2018-2019 and 2019-2020. Marten detected outside the designated 21-day trapping session are not represented in this figure.

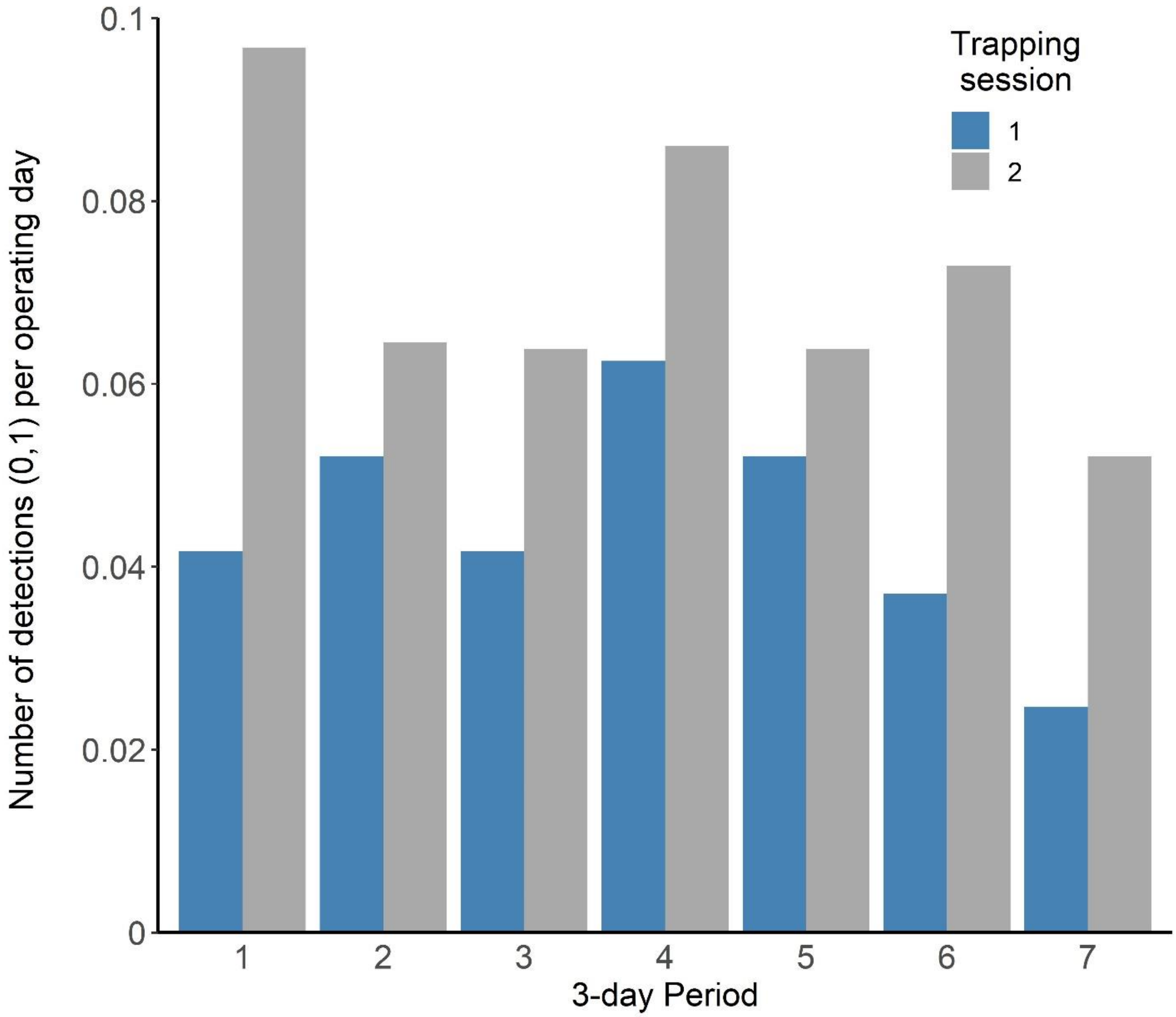

Figure 4. The number of detections per operating day for each 3-day sampling period during a trapping session for the Yurok Study Area. Not all traps were in operation during each 3-day period. Sessions 1 and 2 were conducted from October through March in 2018-2019 and 2019-2020. A trend in the number of detections per operating day could suggest trap happiness or aversion.

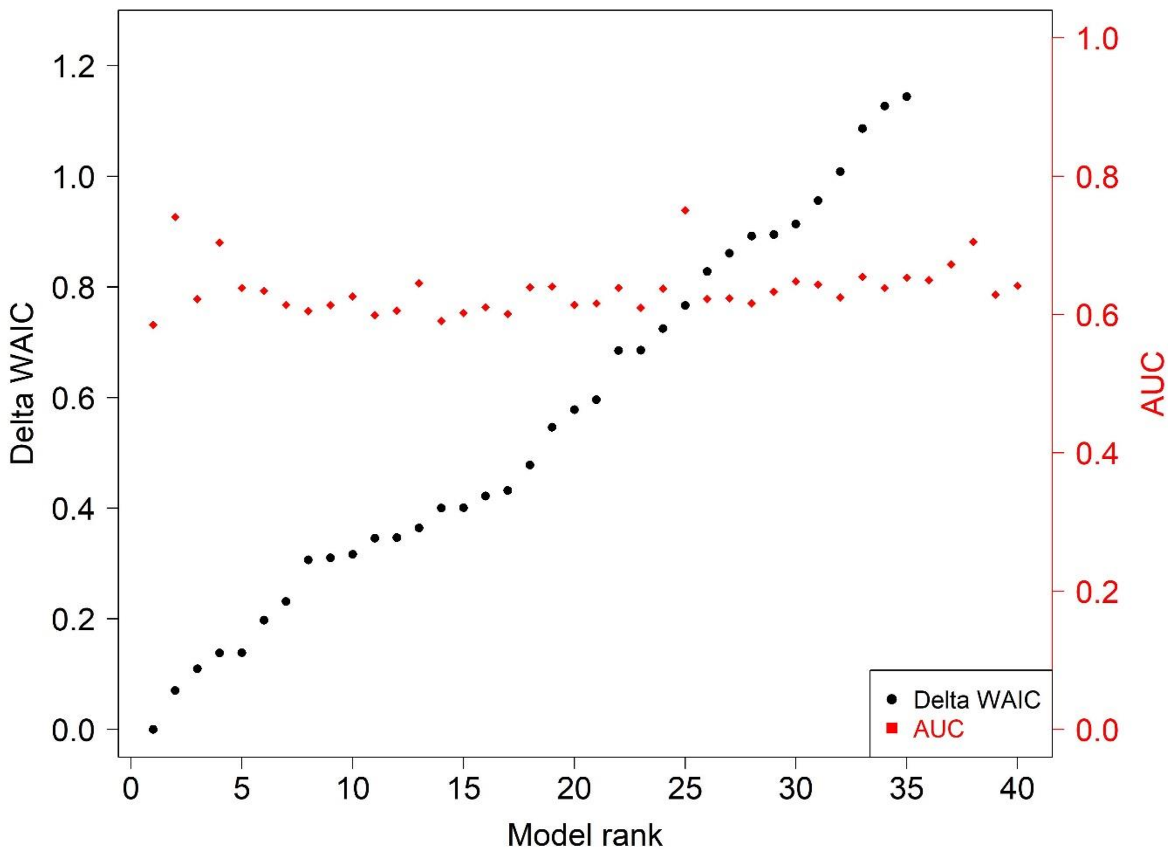

Figure 5. The difference in Watanabe-Akaike information criterion (Delta WAIC) from the best model, the area under the curve (AUC), and model rank for all 40 site occupancy models fit to the marten data in the Yurok Study Area.

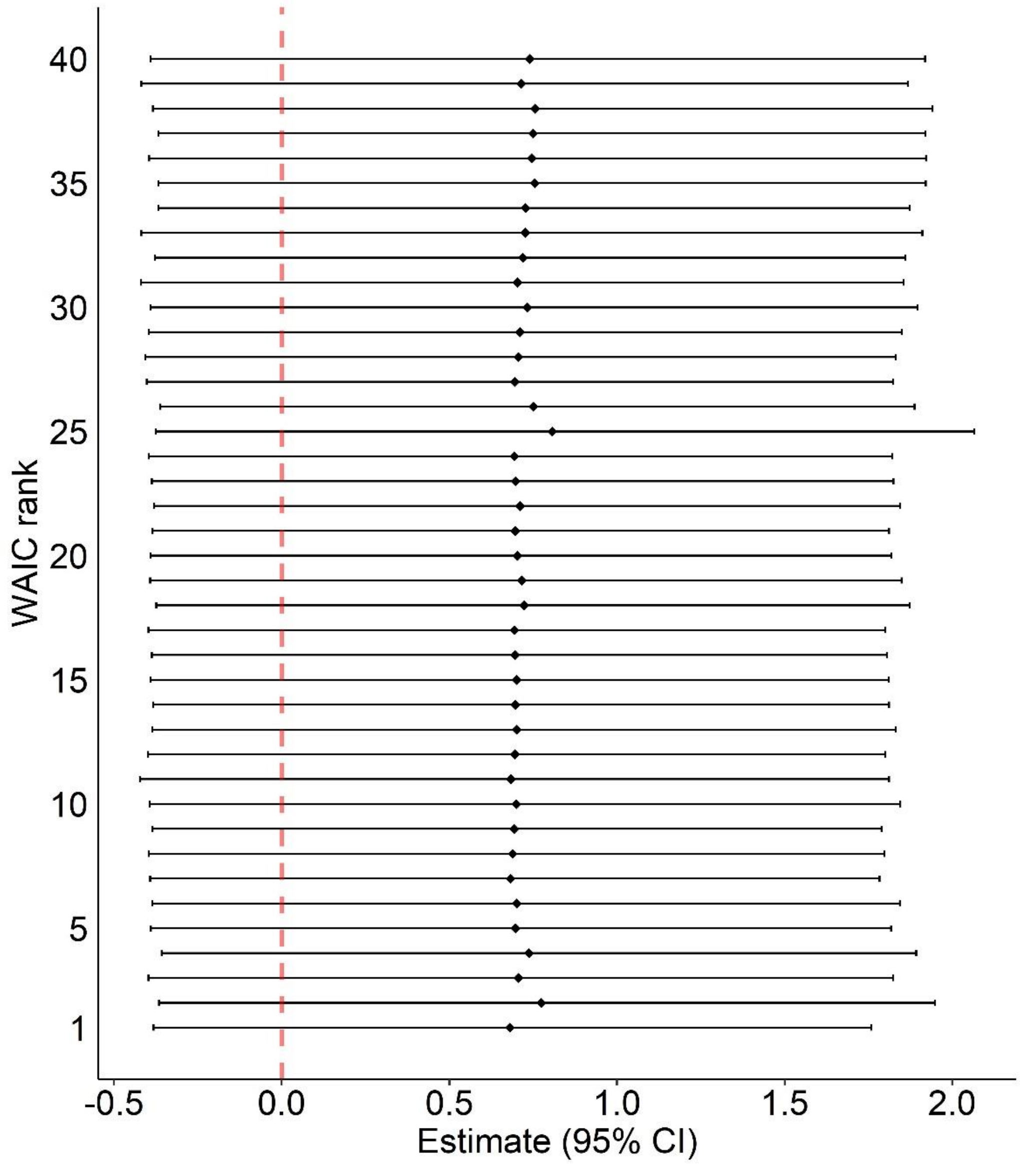

Figure 6. Estimates of trapping session effect in the psi occupancy models for the Yurok Study Area, with 95% Bayesian credible interval (CI), for each of the 40 models based on WAIC rankings.

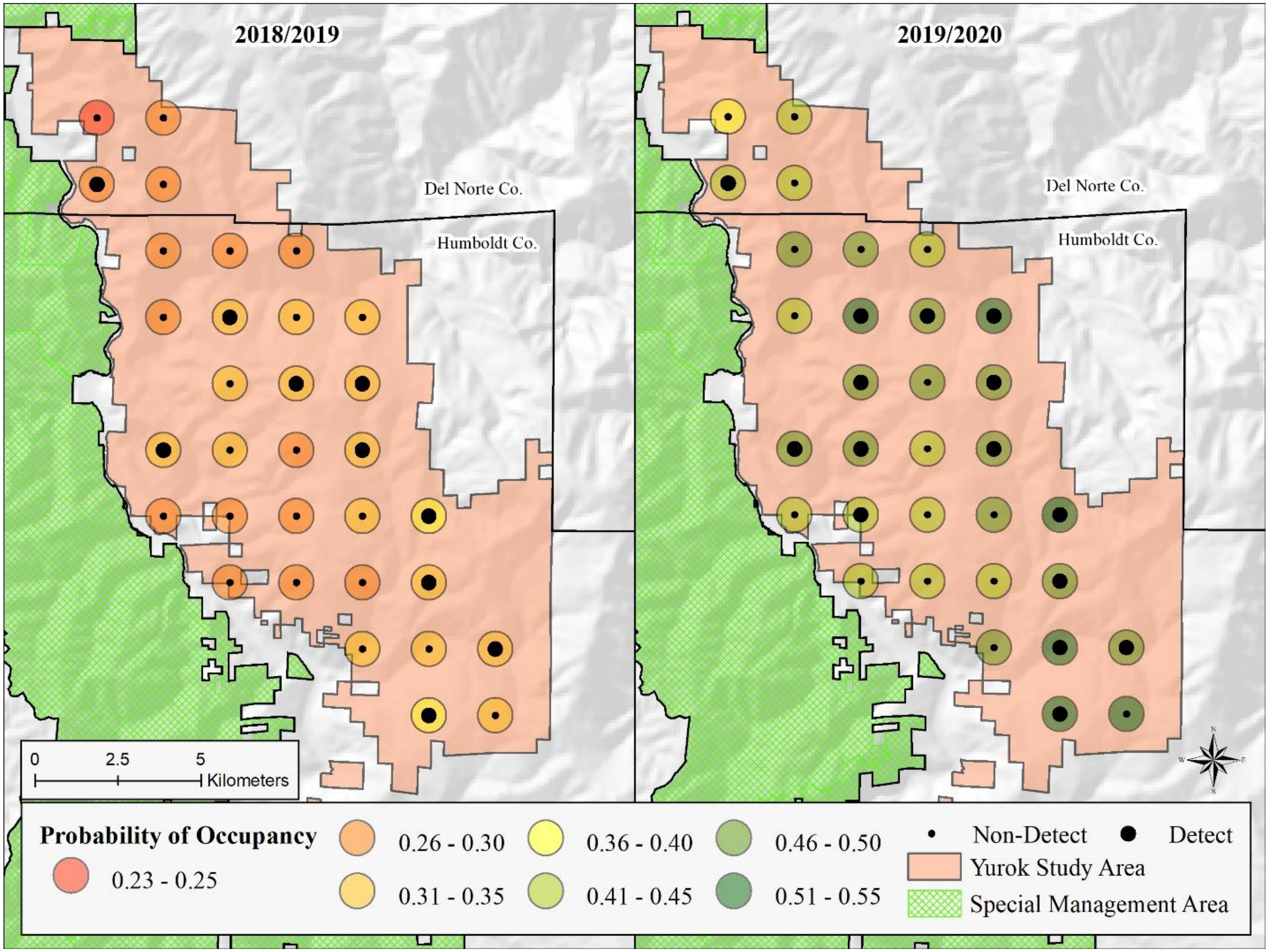

Figure 7. Trapping stations on a 4-km grid across the Yurok Study Area. A large ‘dot’ indicates a marten was present and detected at least once. The probability of occupancy values were calculated using the model-averaged predictions across forty multi-season site occupancy models.

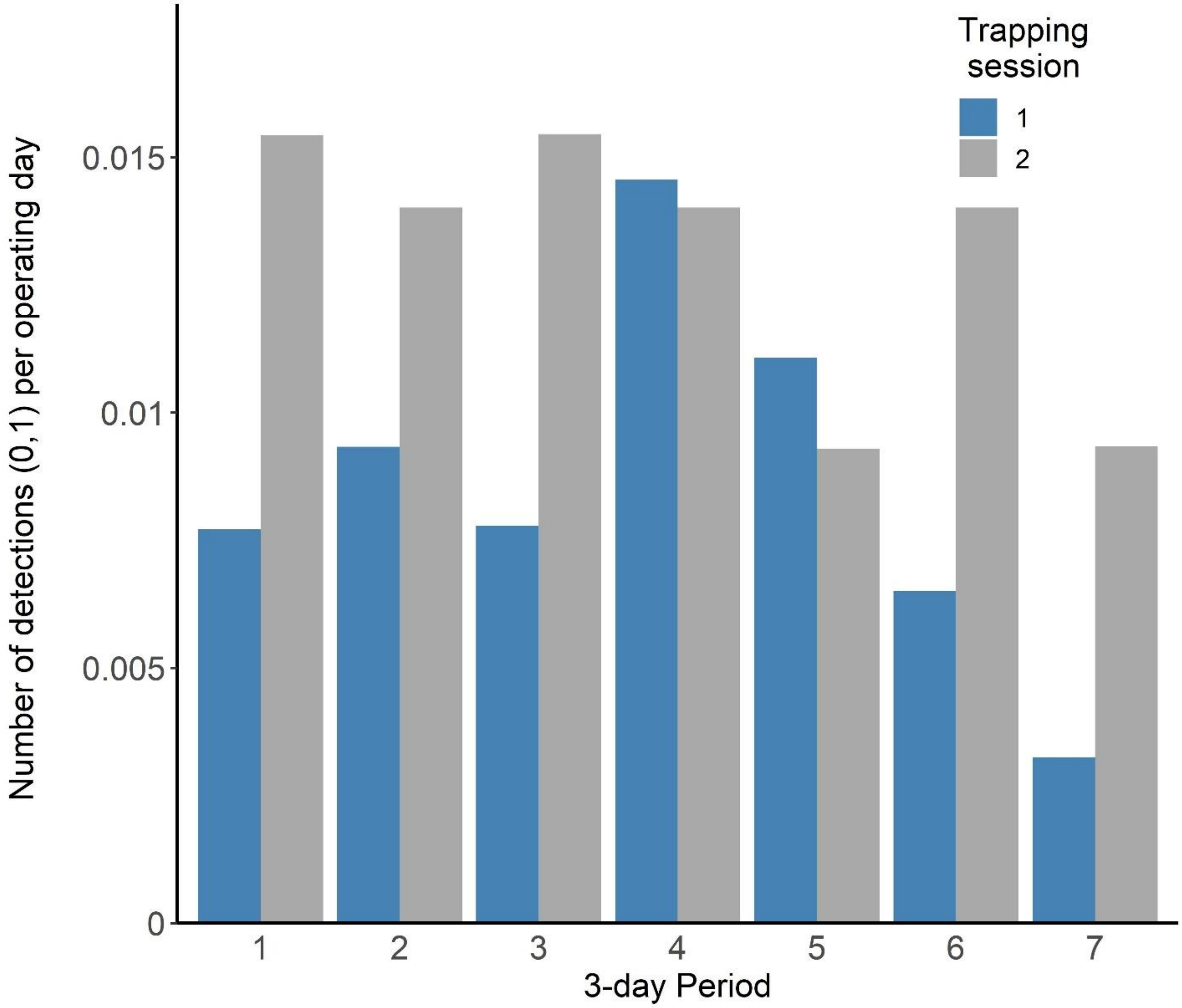

Figure 8. The number of detections per operating day for each 3-day sampling period during a trapping session for the Entire Study Area. Not all traps were in operation during each 3-day period. Sessions 1 and 2 were conducted from October through March in 2018-2019 and 2019-2020. A trend in the number of detections per operating day could suggest trap happiness or aversion.

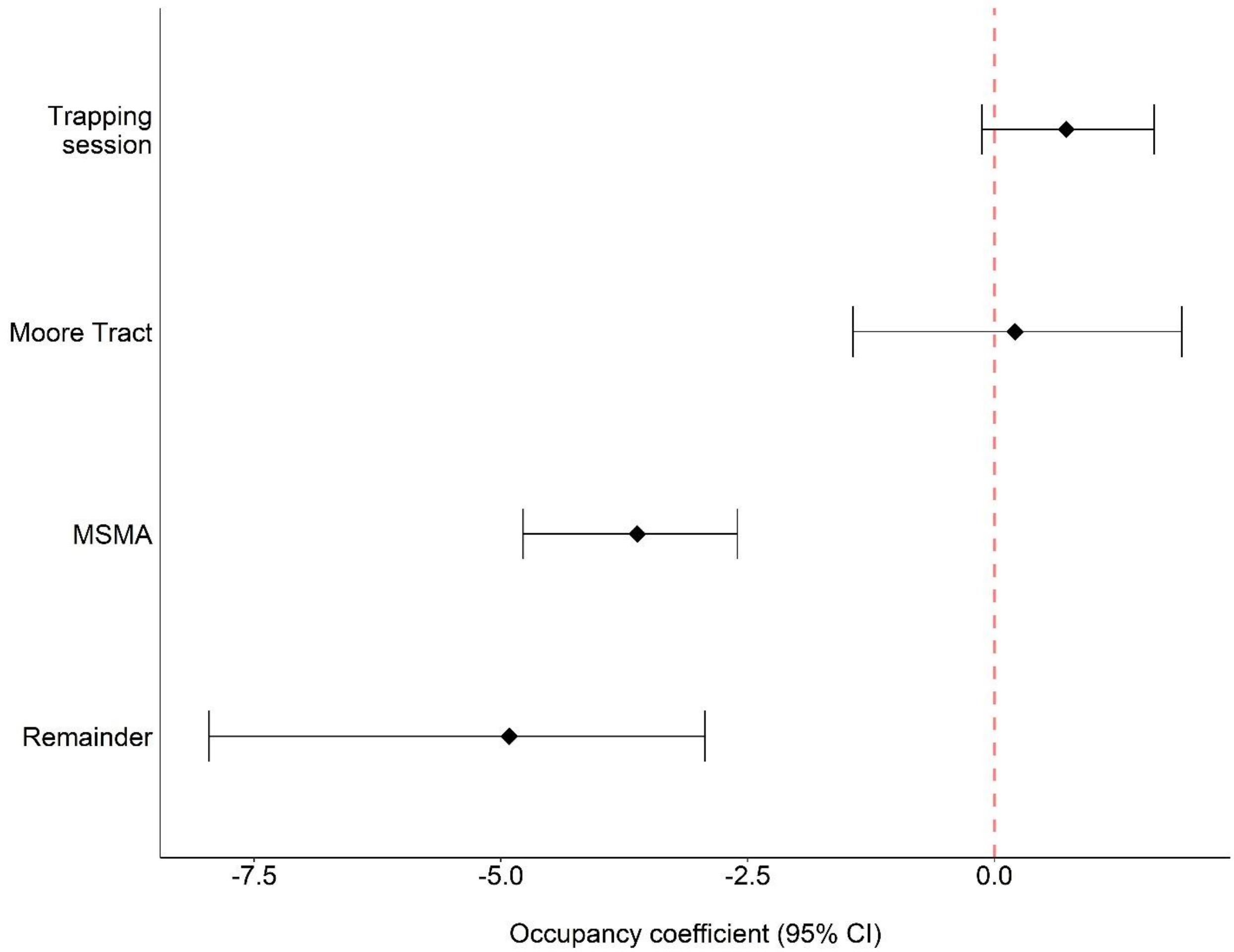

Figure 9. Estimates of coefficients for occupancy (psi) in the marten site occupancy model for the Entire Study Area. Horizontal bars represent 95% Bayesian credible intervals (CI). An estimated effect was determined to be statistically different from 0 if the 95% CI did not overlap 0, represented by the red dashed line.

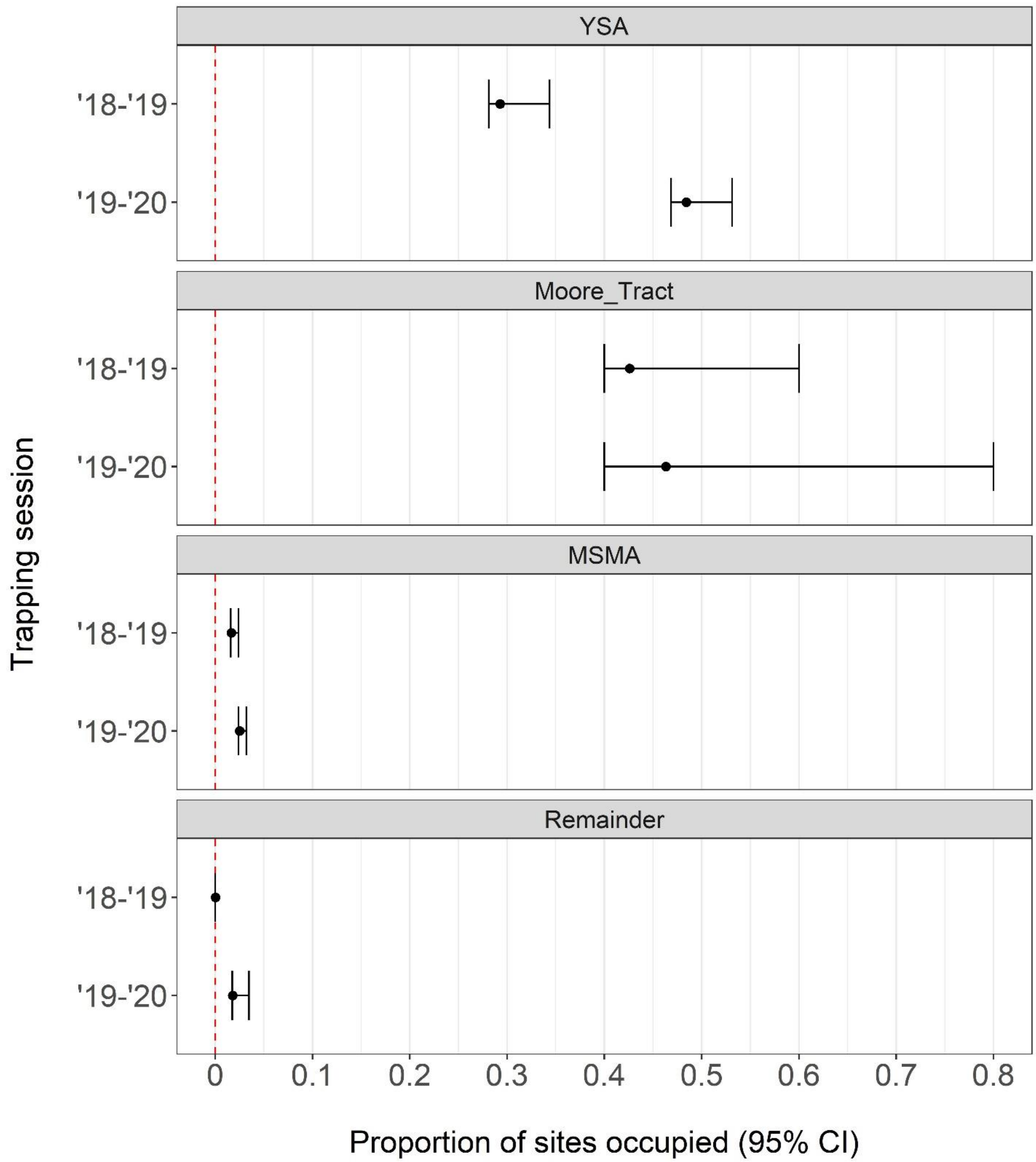

Figure 10. The estimated proportion of camera stations (sites) occupied in each sub-area during each trapping session, along with 95% Bayesian credible intervals (CI).

Appendix A: Correlations

Figure A1. Pearson’s pairwise correlation between covariates considered for the multi-season marten site occupancy models.

Hydro_Buff_1km_PerArea																													
Hydro_Buff_2km_PerArea	0.73																												
RoadEdge_Density_1km_Circle	0.14	0.28																											
RoadEdge_Density_2km_Circle	0.26	0.40	0.84																										
Latitude_5m	0.08	0.08	-0.03	0.02																									
Coast_Dist_5m	-0.24	-0.39	-0.40	-0.55	-0.16																								
Mean_Slope_p_5m_1km_Circle	0.11	0.04	-0.14	-0.11	0.37	0.01																							
Mean_Slope_p_5m_2km_Circle	0.02	-0.02	-0.14	-0.14	0.41	0.05	0.93																						
Annual_Mean_August_Air_Normal	-0.38	-0.50	-0.42	-0.59	-0.06	0.74	0.14	0.23																					
Annual_Max_August_Air_Normal	-0.30	-0.41	-0.43	-0.59	-0.04	0.75	0.18	0.27	0.96																				
Annual_Max_Air_Normal	-0.11	-0.13	-0.30	-0.42	-0.14	0.48	0.24	0.30	0.73	0.84																			
Annual_Mean_Air_Normal	-0.11	-0.11	-0.23	-0.31	-0.34	0.29	0.05	0.08	0.66	0.69	0.85																		
Annual_Min_Air_Normal	-0.03	0.02	0.09	0.13	-0.41	-0.27	-0.32	-0.36	0.01	-0.14	-0.10	0.44																	
Annual_Precip_Normal	-0.26	-0.41	-0.27	-0.37	0.32	0.37	0.19	0.26	0.64	0.51	0.17	0.16	0.01																
Mean_Canopy_Height_1km_Circle	0.04	-0.01	-0.06	0.01	0.03	-0.09	0.18	0.12	-0.15	-0.09	0.05	-0.08	-0.24	-0.24															
Mean_Canopy_Height_2km_Circle	-0.03	-0.07	0.03	0.07	0.05	-0.12	0.18	0.21	-0.14	-0.08	0.06	-0.08	-0.25	-0.24	0.83														
Mean_Canopy_Cover_1km_Circle	-0.14	-0.23	-0.18	-0.18	-0.03	0.14	0.33	0.29	0.15	0.17	0.16	0.03	-0.22	0.01	0.69	0.53													
Mean_Canopy_Cover_2km_Circle	-0.22	-0.33	-0.08	-0.12	0.05	0.13	0.37	0.43	0.22	0.22	0.21	0.06	-0.25	0.09	0.50	0.65	0.80												
Mean_Surface_Fuels_1km_Circle	-0.10	-0.08	0.03	0.10	-0.24	-0.14	-0.25	-0.29	-0.14	-0.15	-0.04	0.09	0.24	-0.17	0.25	0.22	0.04	-0.02											
Mean_Surface_Fuels_2km_Circle	-0.02	-0.11	0.06	0.10	-0.27	-0.10	-0.22	-0.24	-0.09	-0.09	0.02	0.14	0.23	-0.11	0.13	0.24	-0.03	0.06	0.84										
Mean_OGSI_1km_Circle	0.08	0.06	0.24	0.30	-0.11	-0.25	-0.02	-0.07	-0.51	-0.47	-0.39	-0.40	-0.09	-0.43	0.25	0.25	0.16	0.12	0.11	0.07									
Mean_OGSI_2km_Circle	0.12	0.09	0.28	0.32	-0.12	-0.23	-0.02	-0.04	-0.51	-0.46	-0.36	-0.40	-0.13	-0.46	0.15	0.23	0.08	0.13	0.04	0.06	0.94								
Mean_Age_Dom_1km_Circle	-0.26	-0.33	-0.27	-0.28	0.09	0.34	0.06	0.06	0.15	0.15	-0.01	-0.13	-0.22	0.14	0.11	0.11	0.03	0.04	0.02	0.01	0.38	0.33							
Mean_Age_Dom_2km_Circle	-0.22	-0.30	-0.24	-0.29	0.12	0.33	0.07	0.11	0.16	0.18	0.03	-0.11	-0.27	0.16	0.09	0.17	0.03	0.07	-0.07	-0.03	0.35	0.38	0.90						
Mean_DDI_1km_Circle	-0.13	-0.15	-0.09	-0.03	-0.23	0.01	0.03	-0.03	-0.18	-0.19	-0.15	-0.12	0.03	-0.28	0.40	0.36	0.37	0.28	0.28	0.21	0.60	0.48	0.52	0.40					
Mean_DDI_2km_Circle	-0.11	-0.17	-0.04	-0.09	-0.28	0.09	0.04	0.05	-0.12	-0.11	-0.06	-0.08	-0.04	-0.28	0.26	0.37	0.29	0.37	0.16	0.24	0.56	0.58	0.49	0.51	0.86				
Mean_Qmd_Dom_1km_Circle	-0.08	-0.06	-0.05	0.07	-0.05	-0.14	-0.04	-0.09	-0.29	-0.27	-0.20	-0.19	-0.02	-0.23	0.37	0.35	0.05	0.01	0.28	0.21	0.55	0.45	0.71	0.63	0.73	0.60			
Mean_Qmd_Dom_2km_Circle	0.00	-0.02	0.13	0.15	0.03	-0.15	-0.03	-0.03	-0.26	-0.22	-0.12	-0.15	-0.09	-0.17	0.16	0.31	-0.01	0.07	0.11	0.19	0.45	0.51	0.49	0.63	0.42	0.53	0.67		
Mean_STPH_GE_25_1km_Circle	0.23	0.23	0.22	0.33	-0.03	-0.39	-0.05	-0.10	-0.57	-0.51	-0.34	-0.33	-0.05	-0.37	0.23	0.22	-0.07	-0.11	0.20	0.20	0.51	0.44	0.13	0.10	0.33	0.23	0.46	0.34	
Mean_STPH_GE_25_2km_Circle	0.22	0.27	0.36	0.45	-0.05	-0.42	-0.13	-0.16	-0.64	-0.59	-0.40	-0.39	-0.04	-0.40	0.04	0.15	-0.19	-0.13	0.18	0.26	0.49	0.56	0.10	0.13	0.22	0.28	0.38	0.52	0.76

Appendix B: Discussion

Future data may have sufficient marten detections in the sub-areas to warrant modeling with management covariates. In addition, future modeling may consider other methods for recognizing that cameras were not always operational. For our modeling approach, we assumed that a camera operating only 1 day out of a 3-day period would have $1/3^{rd}$ the probability of detection as a full three days of operation. Another approach would be to assume that detections within a 3-day period were independent and followed a binomial distribution with the number of trials equal to the number of operating days (1, 2, or 3). However, the independence assumption is tenuous. Alternatively, we could model the effect of the number of operating days on the probability of detection using covariates in the lambda model. This option is appealing because it is more flexible in estimating the differences in the probability of detection between 1, 2, and 3 days of camera operation. We investigated using this approach, but model convergence was problematic, and estimates of the effects of the number of days of camera operation were not intuitive, possibly because of small sample sizes (e.g., fewer working days had more detections). We recommend reconsidering these options for future multi-season site occupancy models with variable effort.

Appendix C: Model Output

C.1: *Marten_model_selection.xlsx* : The list of all models fit, their WAIC and AUC values, and estimates of model parameters (with 95% and 90% Bayesian credible intervals) for all models (YSA and all-areas model).

C.2: *Marten_trace_plots.pdf* : Trace plots and posterior density plots for the YSA analysis.

C.3: *Marten_forest_psi_coefs_plots.pdf* : Plots of estimated model coefficients, along with 95% Bayesian credible intervals, for the 40 site occupancy models fit to the YSA.

C.4: *Marten_prediction_plots.pdf* : Predictions of occupancy at sites vs. the covariate values at the site, based on the YSA model only. The plots contain smoothed lines based on Loess smoothing for visualization of the relationships.

C.5: *Marten_trace_plots_all_areas.pdf* : Trace plots and posterior density plots for the analysis of all areas within the sampling frame.