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Relationships between Elevation and Slope at Barred Owl Sites in Southwestern British Columbia

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EXECUTIVE SUMMARY

We used Barred Owl detection data, collected from 2003 to 2005 during Northern Spotted Owl inventories in British Columbia, to examine the distribution of the Barred Owl relative to the range of the Northern Spotted Owl in the province, and to determine habitat use as described by elevation and slope. Barred Owls were detected throughout the areas inventoried for the Northern Spotted Owl. Although the non-random methods used to inventory the Northern Spotted Owl limited our ability to interpret Barred Owl habitat use, our results supported the notion that the Barred Owl is found within the elevational range of the Northern Spotted Owl (i.e., generally at <1200 m). We also found that this range varied slightly by ecological subregion (Maritime, Submaritime, Continental), which is also true for the Northen Spotted Owl. The Barred Owl was detected across the range of sampled slopes ≤50 degrees, while occurrence on slopes >50 degrees was inconclusive due to sparse sampling. Negative unimodal relationships between proportions of Barred Owls detected and elevation were observed within two slope classes. For initial modelling of Barred Owl habitat using these variables, we recommend a simple yes/no habitat classification, with acceptable habitat defined as slopes ≤50 degrees and elevations ≤1200 m excluding elevation outliers. These variables can then be tested for uncertainty.

KEYWORDS

Northern Spotted Owl, Barred Owl, Strix occidentalis caurina, Strix varia, habitat, population, elevation, slope, British Columbia

ACKNOWLEDGEMENTS

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INTRODUCTION

The Northern Spotted Owl (*Strix occidentalis caurina*) is native to coastal and inland areas of the Pacific Northwest, but in Canada it is found only in southwestern British Columbia. It is on Canada`s federal list of Endangered species (COSEWIC 2000) and on British Columbia's Red List (BC Conservation Data Centre 2007). The main threats to the population are loss and fragmentation of habitat (Chutter et al. 2004).

Another identified threat for the Northern Spotted Owl is the Barred Owl (*Strix varia*) (Chutter et al. 2004). The Barred Owl is native to eastern North America and its natural range is east of the Rocky Mountains. Since the 1940s, the Barred Owl has expanded its range westward across North America and has become sympatric with the Northern Spotted Owl (Mazur and James 2000; Gutiérrez et al. 2007). Barred Owl density is thought to be increasing within the zone of sympatry (Dunbar et al. 1991; Pearson and Livezey 2003; Gutiérrez et al. 2004; Olson et al. 2005), and the decline of Northern Spotted Owl populations is coincident with the invasion and subsequent expansion of Barred Owl populations (Gutiérrez et al. 2007). This has lead to concerns that competitive effects from the Barred Owl may interact with and exacerbate the effects of other threats to Northern Spotted Owl populations in both British Columbia (Chutter et al. 2004) and the United States (Gutiérrez et al. 2007), and thus confound efforts to recover these populations.

Our understanding of the Barred Owl's use of habitat in British Columbia is limited because few studies have focused on Barred Owl ecology and demography within the range of the Northern Spotted Owl (Dunbar et al. 1991; Gutiérrez et al. 2007). Unlike the Northern Spotted Owl (see Sutherland et al. 2007), the Barred Owl appears to be more often associated with habitats having a deciduous tree component and it can occupy younger forests (Dunbar et al. 1991; Herter and Hicks 2000; Buchanan et al. 2004; Hamer et al. 2007; Livezey 2007) and environments modified by humans, including urban parks and suburban areas (Campbell et al. 1990). The Barred Owl is not as limited as the Northern Spotted Owl in nesting requirements because the Barred Owl is a generalist forager and uses a variety of nest structures including those available in younger forests (e.g., ≥40 years) and disturbed habitats (Campbell et al. 1990; Mazur and James 2000; Gutiérrez et al. 2004; Livezey 2007).

Although the Barred Owl's distribution fully overlaps that of the Northern Spotted Owl (Gutiérrez et al. 2007), spatial separation of the two species is suggested in some landscapes, with the Barred Owl occupying lower elevation forests closer to rivers and the Northern Spotted Owl occupying higher elevations (Dunbar et al. 1991; Herter and Hicks 2000; Blackburn et al. 2002; Pearson and Livezey 2003, Gremel 2005). Pearson and Livezey (2003) reported Barred Owl use of slopes with a mean gradient of 39±18% in southern Washington and found a decrease in Barred Owl density with increasing elevation. In British Columbia, reported maximum elevations for Barred Owl nests were 900 to 1100 m (Campbell et al. 1990) and maximum elevations for detection were about 1280 m (Dunbar et al. 1991). Mean elevation of detections in southern Washington was 812±276 m (Pearson and Livezey 2003). The majority of Barred Owl habitat studies summarized in Livezey (2007) indicate a tendency for this species to be found on lower slopes and at lower elevations than the Northern Spotted Owl, although results vary with study location.

Given the lack of information on the Barred Owl's use of habitat in British Columbia, the objective of this study was to use Barred Owl detection data collected during Northern Spotted Owl surveys from 2003 to 2005 to improve our understanding of Barred Owl distribution with respect to elevation and slope. Aspect was not considered in this analysis because this variable was not considered a primary determinant of Barred Owl distribution (see Livezey 2007). This analysis was intended to inform a modelling effort designed to evaluate potential Barred Owl influences on the Northern Spotted Owl in British Columbia (Sutherland et al. in preparation).

METHODS

Sample Data

For this study, we focused on the documented geographic range of the Northern Spotted Owl in British Columbia, which comprises ~3.2 million ha in the southwestern part of the province (Figure 1; Chutter et al. 2004). The British Columbia Ministry of Environment[1] conducted Northern Spotted Owl surveys between 2003 and 2005, during which Barred Owl detection information was also collected. Auditory detections were recorded at regular intervals—generally 500 m—along transects that generally followed elevation contour lines. At each sampling point along the transect, surveyors played a Northern Spotted Owl call, and responding owl callbacks were recorded by species and location (Hobbs et al. 2005).

Placement of transects within the landscape was non-random (i.e., transects were generally associated with forest access roads). The use of transects means that individual owl detections cannot be treated as independent samples because individual owls could have been detected more than once on a transect. Furthermore, non-detection at a particular point does not infer the absence of a Barred Owl, in part because detection biases associated with the Barred Owl are poorly known (Livezey and Fleming 2007). This is not just because estimating the probability of non-detection of a species in occupancy surveys is generally difficult (usually requiring significant sampling effort to obtain; Mackenzie et al. 2006), but also because estimating Barred Owl occupancy was not the focus of the detection surveys. Therefore, we consider all analyses and results presented in this report as exploratory.

We stratified the study area into ecologically similar subregions (Maritime, Submaritime, and Continental) based on climate and

[1] Tom Blackbird, Ecosystems Officer, Lower Mainland Regional Office, Environmental Stewardship Division, B.C. Ministry of Environment; personal communication, August 17, 2006.

vegetation by following definitions previously used for modelling Northern Spotted Owl habitat (Sutherland et al. 2007). This approach enabled us to directly relate patterns of habitat occurrence for the Barred Owl and the Northern Spotted Owl as recently modelled in British Columbia by Sutherland et al. (2007). We further limited the Northern Spotted Owl habitat to particular vegetation associations because of forest structure and climate (e.g., snow depth). Because the Barred Owl is apparently more of a habitat generalist than the Northern Spotted Owl, we did not consider the Barred Owl to have similar habitat limitations, except for an avoidance of the treeless alpine tundra.

Landscape Data

Barred Owl and Northern Spotted Owl habitats were spatially modelled using attributes selected from the following data sources: vegetation resource inventory attributes, digital elevation models, roads, streams and lakes, and administrative boundaries (see Appendix 1 in Sutherland et al. 2007). All data were rasterized to a 1-ha resolution (i.e., 100×100 m raster cells) which was the smallest 'grain' size (Fortin and Dale 2005) at which model analyses were undertaken. Each raster cell was assigned a data value for each attribute that was tracked by the model.

Data Analysis

We employed two methods to assess the strength of association between Barred Owl presence and elevation or slope.

The first method used information about the sampling effort expended for each elevation and slope class combination by calculating the percent occurrence of Barred Owls relative to the total number of sample points (Table 1). In the second

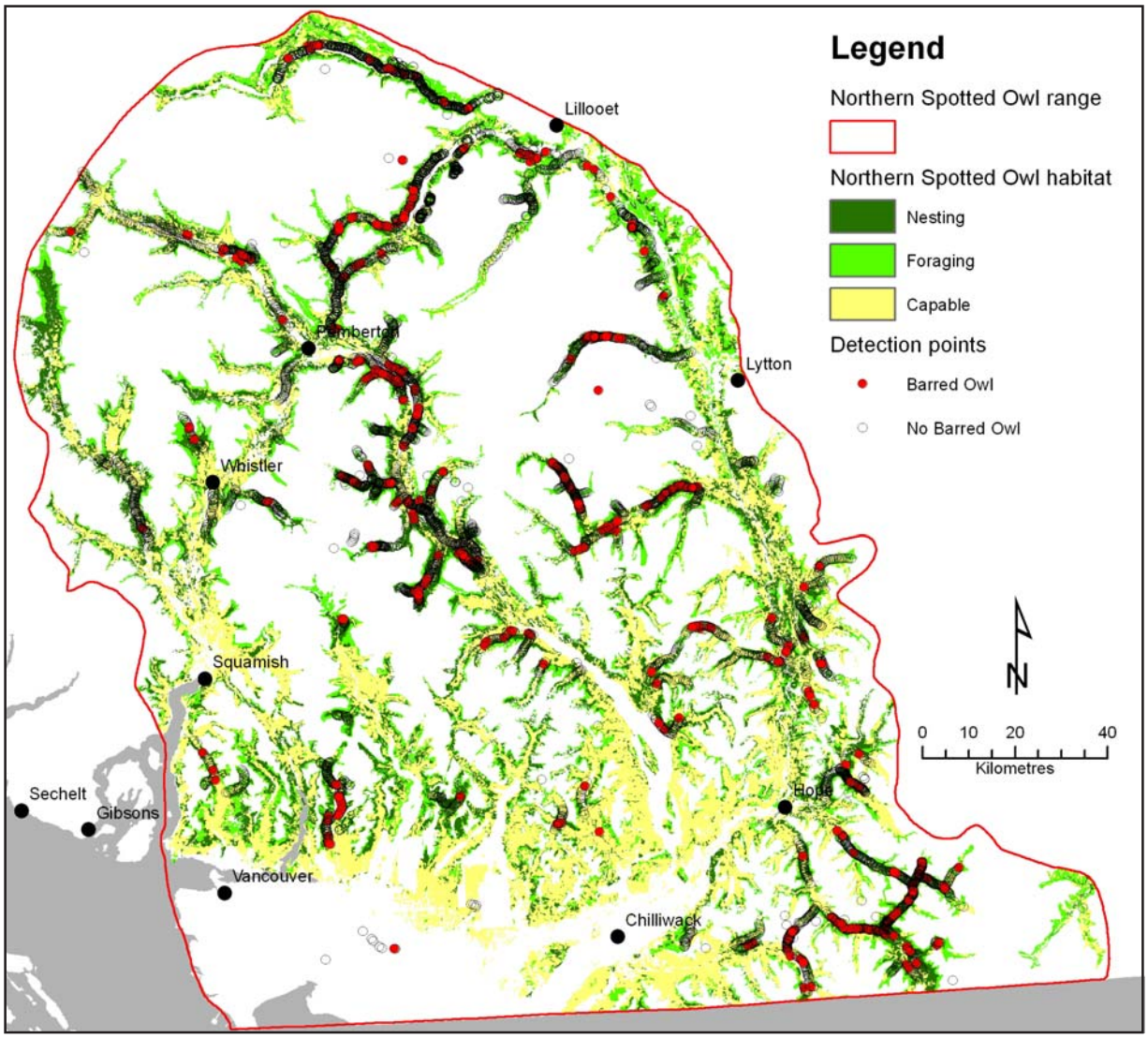

Figure 1. Distribution of Barred Owl detections in relationship to the habitat and range of the Northern Spotted Owl in southwestern British Columbia.

Table 1. Number of Barred Owls and Northern Spotted Owls detected along transects, and total number of sample points, by year and ecological subregion.[a]

Year	Maritime			Submaritime			Continental		
	Barred Owl (no.)	Northern Spotted Owl (no.)	Sample points (no.)	Barred Owl (no.)	Northern Spotted Owl (no.)	Sample points (no.)	Barred Owl (no.)	Northern Spotted Owl (no.)	Sample points (no.)
2003	3	0	17	9	4	163	4	1	66
2004	1	0	53	74	20	957	51	12	986
2005	35	1	323	185	27	2215	90	33	1620

[a] Most of the points surveyed in 2003 and 2004 were re-surveyed in 2005.

method, relative detection rates (in the absence of information regarding total sampling effort) were calculated by relating the number of Barred Owls detected to the total number of Barred Owl and Northern Spotted Owl detections (i.e., number of Barred Owl detections/[number of Barred Owls detections + number of Northern Spotted Owl detections]). The latter method provides information on the overlap in the habitat requirements of the two species.

The complete set of detection points from 2003 to 2005 provided a much larger sample than any single year alone, but the possibility of a single point being sampled in multiple years could introduce bias (e.g., nest fidelity could artificially enhance observed relationships). Because we were unable to discern points that may have been repeatedly sampled among years, we analyzed the entire 2003-to-2005 dataset as well as a subset containing 2005 detection points only, and compared the results to determine if combining data from multiple years introduced bias.

For both analysis methods we aggregated elevation into 100-m classes with the midpoint of the range used to label the class (e.g., 400 to 500 m is plotted at 450 m in all figures). We divided slope into three broad classes: gentle (0 to 30 degrees), moderate (31 to 50 degrees), and steep (>50 degrees). The gentle slope category captured lower slope terrain, similar to that described by Pearson and Livezey (2003), and the steep slope category captured the steepest slopes known to be used by the Northern Spotted Owl in British Columbia (J. Hobbs, unpublished data).

RESULTS

Owl detection surveys undertaken by the British Columbia Ministry of Environment during the period 2003 to 2005 included a total of 6400 sample points, with 452 Barred Owl detections and 98 Northern Spotted Owl detections (Table 1). In general, the survey data indicated that the Barred Owl is broadly distributed within the range of the Northern Spotted Owl in British Columbia (Figure 1).

Effects of Slope and Elevation on Barred Owl Occurrence

Only eleven sample points (0.2% of total) were on steep slopes. Barred Owls were not detected on these slopes. This result is difficult to interpret because of the confounding effect of the low sampling effort. Therefore, the remainder of our discussion about the analysis results is restricted to the gentle and moderate slope categories.

Based on the 2005 inventory data for the Maritime ecological subregion, only one Barred Owl was detected above 500 m on gentle slopes (at 1220 m; Figure 2, top). On moderate slopes the Barred Owl was detected up to 600 m, but the very low sampling effort on moderate slopes made further interpretation of Barred Owl distribution difficult. In the Submaritime and Continental ecological subregions the relationship between Barred Owl occurrence and elevation was roughly unimodal, although there was considerable variability (Figures 3 and 4). For the Submaritime subregion, a single Barred Owl was detected above 1400 m. The bulk of the detections were concentrated in the 200–1200 m elevation range for the gentle slope class and below 1050 m for the moderate class (Figure 3).

Slope class had little detectable effect on the relationship between Barred Owl occurrence and elevation, but occurrence rates were slightly higher in the gentle slope class than in the moderate class (Figure 3). Given the low detection effort above 1400 m, it was difficult to determine whether the observed 1400-m elevation limit was real or a sampling artefact. In the Continental subregion, the Barred Owl was generally detected below 900 m (Figure 3). In the moderate slope class, the elevational range of Barred Owl detections was even more restricted (500 to 700 m; Figure 4, middle). While a single occurrence between 1200 and 1300 m was observed in both the gentle and moderate slope classes, the low sampling effort at high elevations again made it difficult to interpret the upper elevational limit. Because of this uncertainty, we defined our limits in Table 2 on the

Table 2. Proposed habitat parameters in Maritime, Submaritime, and Continental ecological subregions for landscape modelling of stands classified as being suitable for the Barred Owl.

Ecological subregion	Biogeoclimatic subzone/variant [a]	Slope (degrees)	Maximum elevation (m)
Maritime	All BEC subzones and variants, except Alpine-Tundra	≤50	≤600
Submaritime			≤1050
Continental			≤900

[a] For more information on the definitions and ecological basis for the British Columbia Biogeoclimatic Ecosystem Classification (BEC) system, see the Biogeoclimatic units table found at http://www.for.gov.bc.ca/hre/becweb/resources/codes-standards/standards-becdb.html.

basis of the bulk of the observations in each ecological subregion and not on the outlier values.

Patterns of Barred Owl occurrence across elevations and slopes for the 2003-to-2005 aggregate dataset (Figures 5 to 7) were similar to the patterns of occurrence in the 2005 dataset (Figures 2 to 4). These similarities suggest that biases were not introduced by combining the 3-year dataset and similarities likely occurred because the 2005 data comprised 67% of the total sample points contained in the aggregate dataset.

Comparison of Barred Owl Detection Indicators

Visually, the ratio of Barred Owl detections to the combined total Barred Owl and Northern Spotted Owl detections closely tracked actual Barred Owl detections when Northern Spotted Owls were present at a particular elevation and slope (Figures 2 to 7). This suggests a broad overlap of the Barred Owl and Northern Spotted Owl distributions. However, the sample size of Northern Spotted Owl detections was insufficient to permit a more quantitative analysis of co-occurrence.

DISCUSSION

Slope and Elevation

We found Barred Owls to be numerous throughout the area in which Northern Spotted Owl surveys were conducted. Our findings indicate that slope had the potential to influence Barred Owl occurrence, which is consistent with observations reported in other studies (Gutiérrez et al. 2007). Two confounding factors were identified in the analyses of slope: (1) whether the historically expanding pattern of Barred Owl occupancy is influencing detection probabilities in this study, and (2) the lack of surveys at higher elevations. Both factors can be addressed with additional survey effort. Interpreting the data for possible correlations between slope and elevation was also difficult due to sample size and design limitations, although in general slope did not appear to constrain owls to particular elevations.

We observed strong variation in the unimodal relationship documented between Barred Owl detections and elevations for both the gentle and moderate slope classes. This variation may be explained in part by the non-random and non-independent sampling design used to collect the occurrence data. For example, if most of the samples for a particular elevation class came from a portion of the landscape where the Barred Owl was absent due to other factors (e.g., population connectivity, prey availability, Northern Spotted Owl occupancy), the overall elevation–occurrence relationship would be biased by those local conditions. Also, the results could have been influenced by the placement of sampling transects along elevation contour lines.

Given the likely biases discussed above, there are at least two ways in which the Barred Owl occurrence information could be used to inform the relationship between Barred Owl habitat and elevation for modelling landscape habitat use.

1) Elevation thresholds could be established using the minimum and maximum elevations at which the Barred Owl was observed. In establishing these thresholds it would be appropriate to eliminate elevation bands at which only a single owl was observed in order to minimize the effect of outliers on the habitat–elevation relationship. Establishing a minimum detectability threshold for the Barred Owl is a research need in studies of Barred Owl–Northern Spotted Owl interactions (Livezey and Fleming 2007).

(2) A unimodal relationship between habitat and elevation could be estimated from the observed relationships. One approach might be to use a normal distribution centered on the median elevation observed within strata, with the 15th and 85th percentile used to define the lower and upper standard deviations. This approach assumes that the true relationship between elevation and Barred Owl occurrence is unimodal, and observed differences in our data are due to sampling error. Another possible approach would be to fit a semi-parametric distribution based on a kernel smoothing algorithm (e.g., Hastie 1992) applied to the detection data.

Barred Owl Detection Indicators

We found that the proportion of Barred Owls detected at a particular elevation/slope/subregion stratum, relative to the total number of Barred Owls and Northern Spotted Owls, was uninformative as an indicator of Barred Owl occurrence, for at least two reasons. First, the Northern Spotted Owl was absent from many of the strata we examined. In these cases, the resulting ratio equalled one, regardless of whether the Barred Owl was present in high or low numbers. Second, even when the Northern Spotted Owl was present, the Barred Owl was present in much greater numbers and thus tended to dominate the ratio calculation. In general, the ratio approach was limited by the rarity of Northern Spotted Owls and the uneven sampling

effort across strata; overlap in habitat requirements of the two species would have to be measured using less direct means (e.g., comparing single-species habitat descriptions for the Barred Owl and the Northern Spotted Owl).

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Although no firm evidence is available from studies designed to detect cause-and-effect relationships, the Barred Owl is nonetheless believed to have an adverse competitive effect on the Northern Spotted Owl by prey competition, adult displacement, and/or interference with juvenile dispersal (Buchanan et al. 2007; Gutiérrez et al. 2007; Hamer et al. 2007). If such an effect is real, it is important to take action. Inaction may negatively affect and possibly negate efforts to mitigate other threats (e.g., habitat loss) and may render other recovery actions less effective (Buchanan et al. 2007; Spotted Owl Population Enhancement Team 2007). The potential effects of the Barred Owl on the Northern Spotted Owl can be explored using a landscape approach in a modelling framework. The challenge in carrying out such an effort is that much of the available information on the Barred Owl is incidentally collected as part of inventory and research work on the Northern Spotted Owl, and may be biased by sampling objectives (Gutiérrez et al. 2004; Livezey and Fleming 2007). Despite this lack of information we have been able to use such incidental data for guidance on how Barred Owl habitat is related to elevation and slope, which are two key parameters used to define Northern Spotted Owl habitat for strategic modelling (Sutherland et al. 2007).

Based on our findings we make the following recommendations for landscape modelling of Barred Owl habitat for evaluation of potential occupancy.

1. The results indicate some differentiation between low and moderate slopes, but given the lack of statistical association between Barred Owl detections and slope, we recommend including all areas with slopes ≤50 degrees as potential habitat for the Barred Owl. The lack of information for steep slopes makes interpretation difficult, but based on the literature, as well as on our experiences in British Columbia (J. Hobbs, personal observation) and on the stronger associations with lower slope habitats in our analysis, we recommend excluding steep slopes as modelled habitat (Table 2).

2. Although a negative relationship between Barred Owl occurrence and elevation was suggested by the unimodal curves, given the dearth of information we suggest that modelled habitat is best defined by applying upper elevation limits on Barred Owl habitat (see example, Table 2). These limits currently have high uncertainty; therefore the influence of elevation on habitat estimates should be evaluated. These evaluations could examine:

   (a) all measured detection values potentially including outliers, as presented in this report; and

   (b) elevation limits defined by modelled estimates of Northern Spotted Owl nesting habitat and foraging habitat (Sutherland et al. 2007).

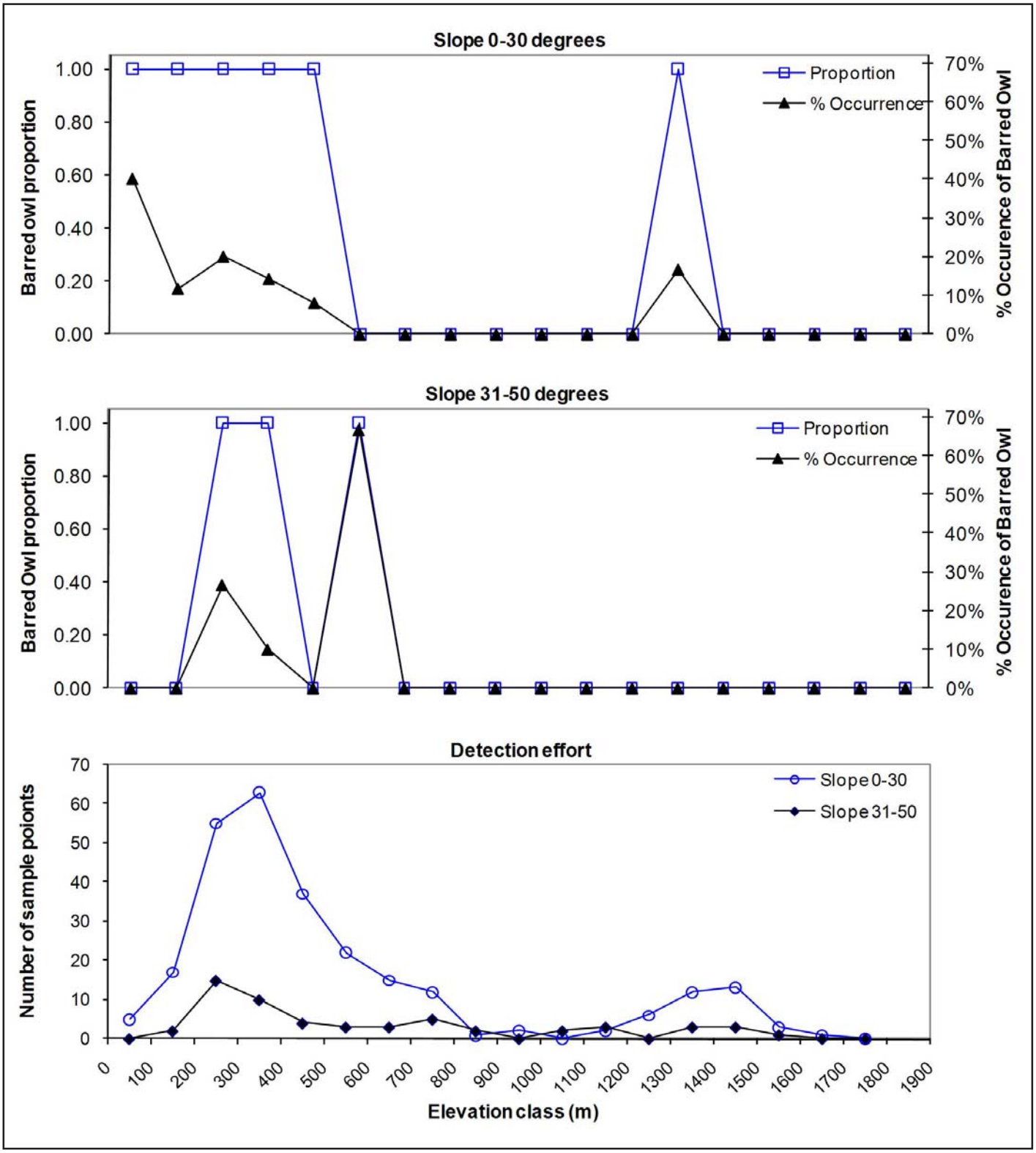

Figure 2. Effects of elevation and slope on two measures of Barred Owl occurrence: **Maritime subregion, 2005 dataset**.
Top: proportion of sample points with owl detections (Barred Owl or Northern Spotted Owl) that were Barred Owl (proportion).
Middle: percentage of sample points with Barred Owl detections (% occurrence).
Bottom: sampling effort at each elevation.

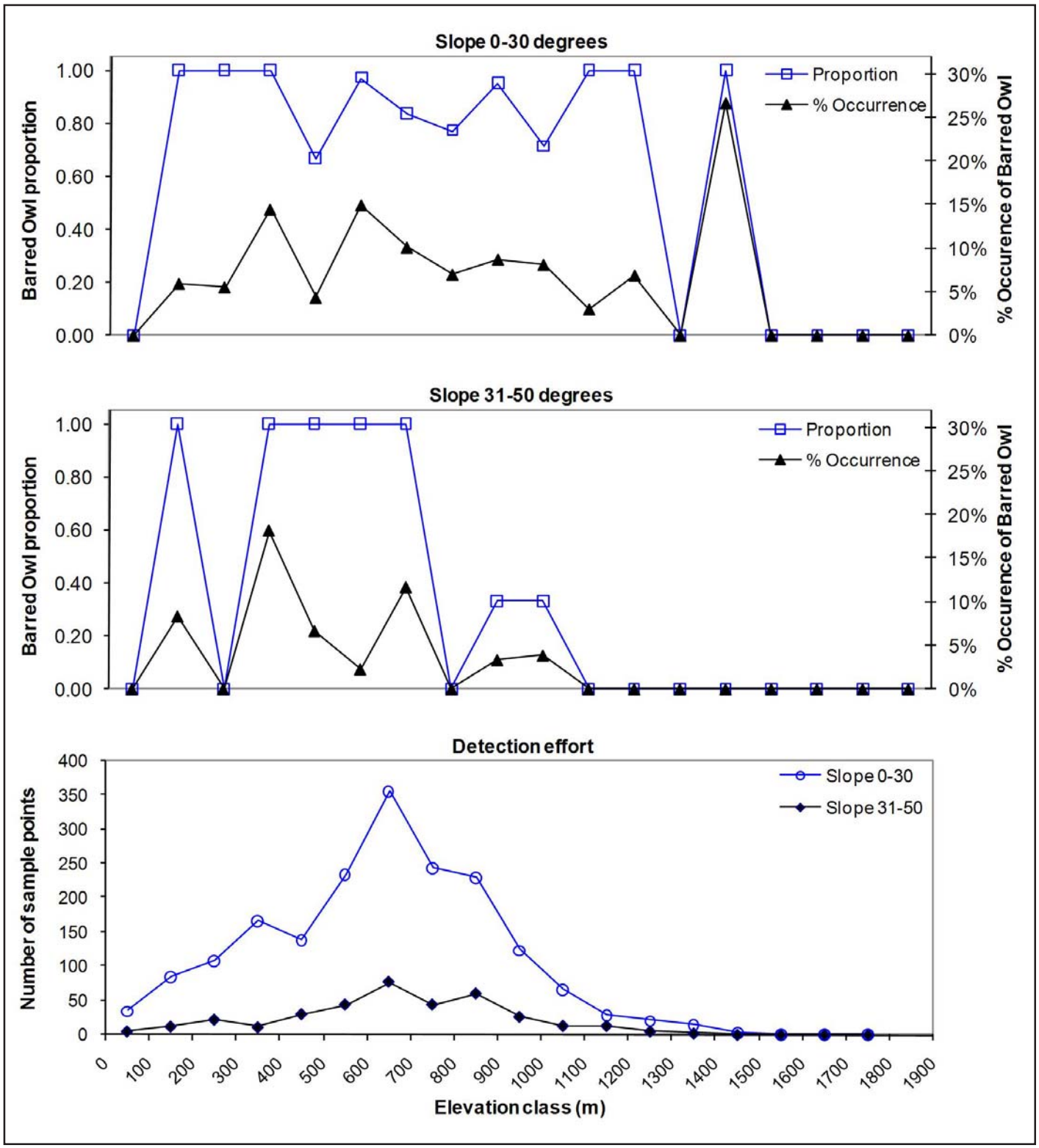

Figure 3. Effects of elevation and slope on two measures of Barred Owl occurrence: **Submaritime subregion, 2005 dataset**.
Top: proportion of sample points with owl detections (Barred Owl or Northern Spotted Owl) that were Barred Owl (proportion).
Middle: percentage sample points with Barred Owl detections (% occurrence).
Bottom: sampling effort at each elevation.

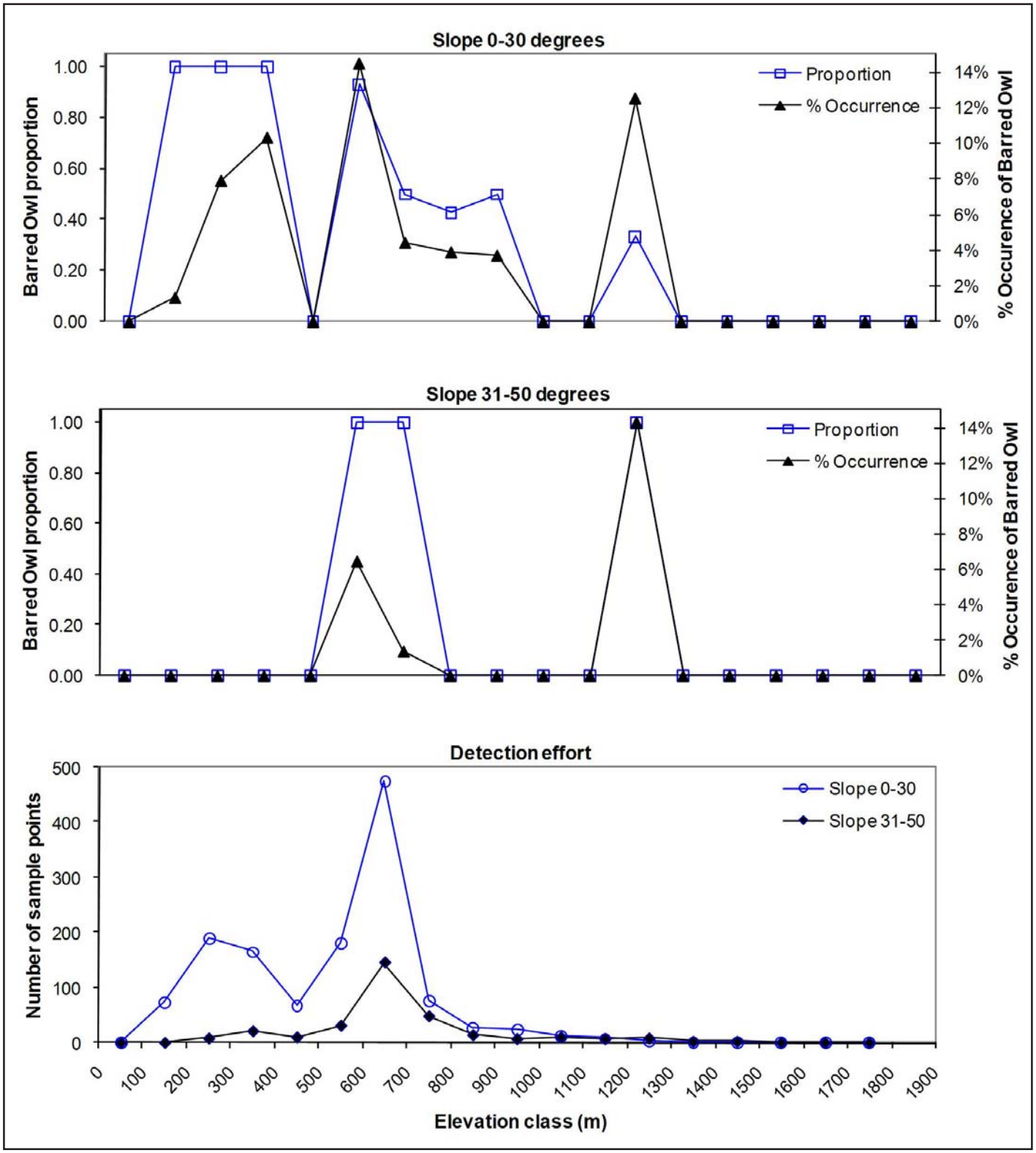

Figure 4. Effects of elevation and slope on two measures of Barred Owl occurrence: **Continental subregion, 2005 dataset**.
Top: proportion of sample points with owl detections (Barred Owl or Northern Spotted Owl) that were Barred Owl (proportion).
Middle: percentage of sample points with Barred Owl detections (% occurrence).
Bottom: sampling effort at each elevation.

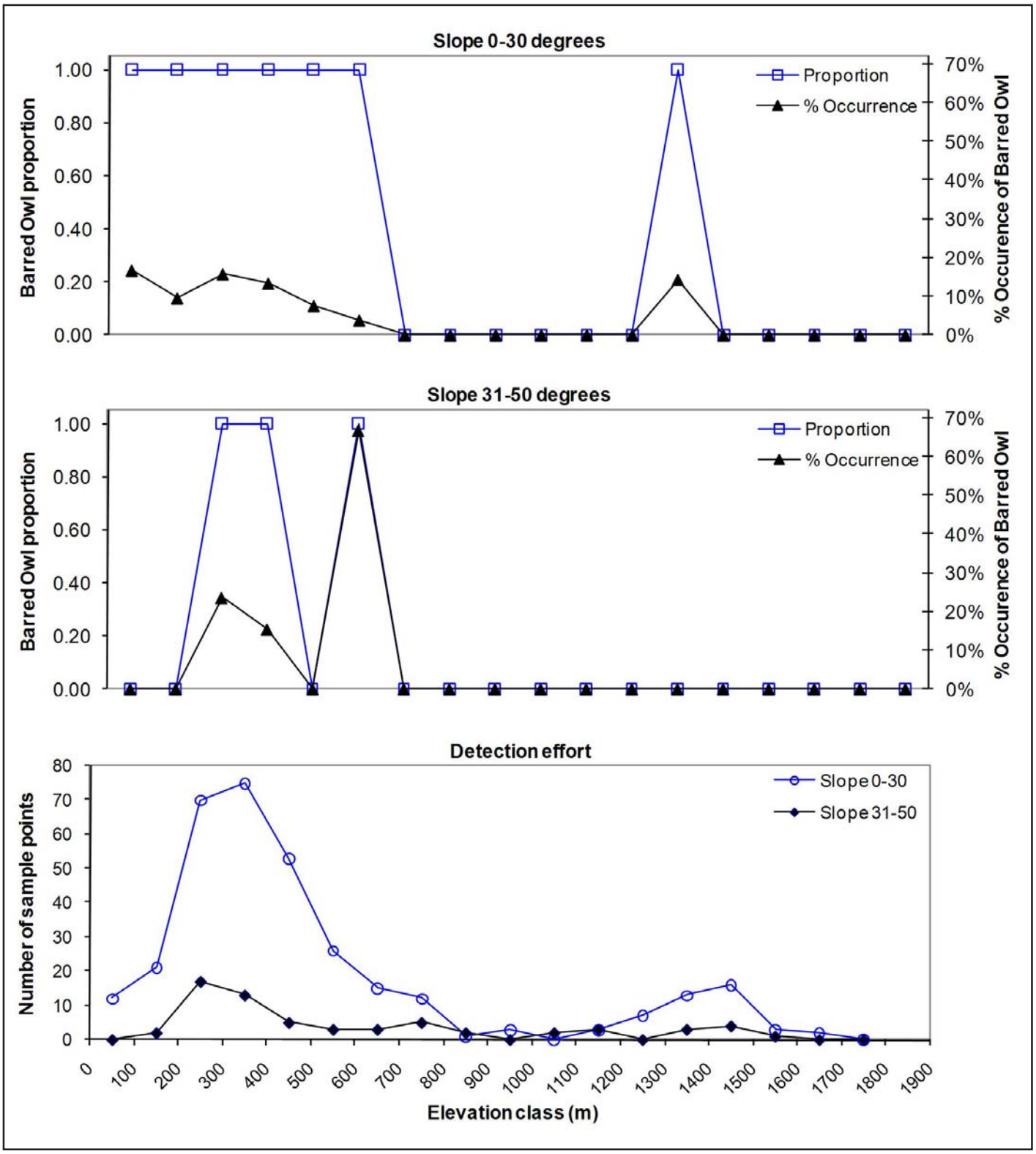

Figure 5. Effects of elevation and slope on two measures of Barred Owl occurrence: **Maritime subregion, 2003-to-2005 dataset**.
Top: proportion of sample points with owl detections (Barred Owl or Northern Spotted Owl) that were Barred Owl (proportion).
Middle: percentage of sample points with Barred Owl detections (% occurrence).
Bottom: sampling effort at each elevation.

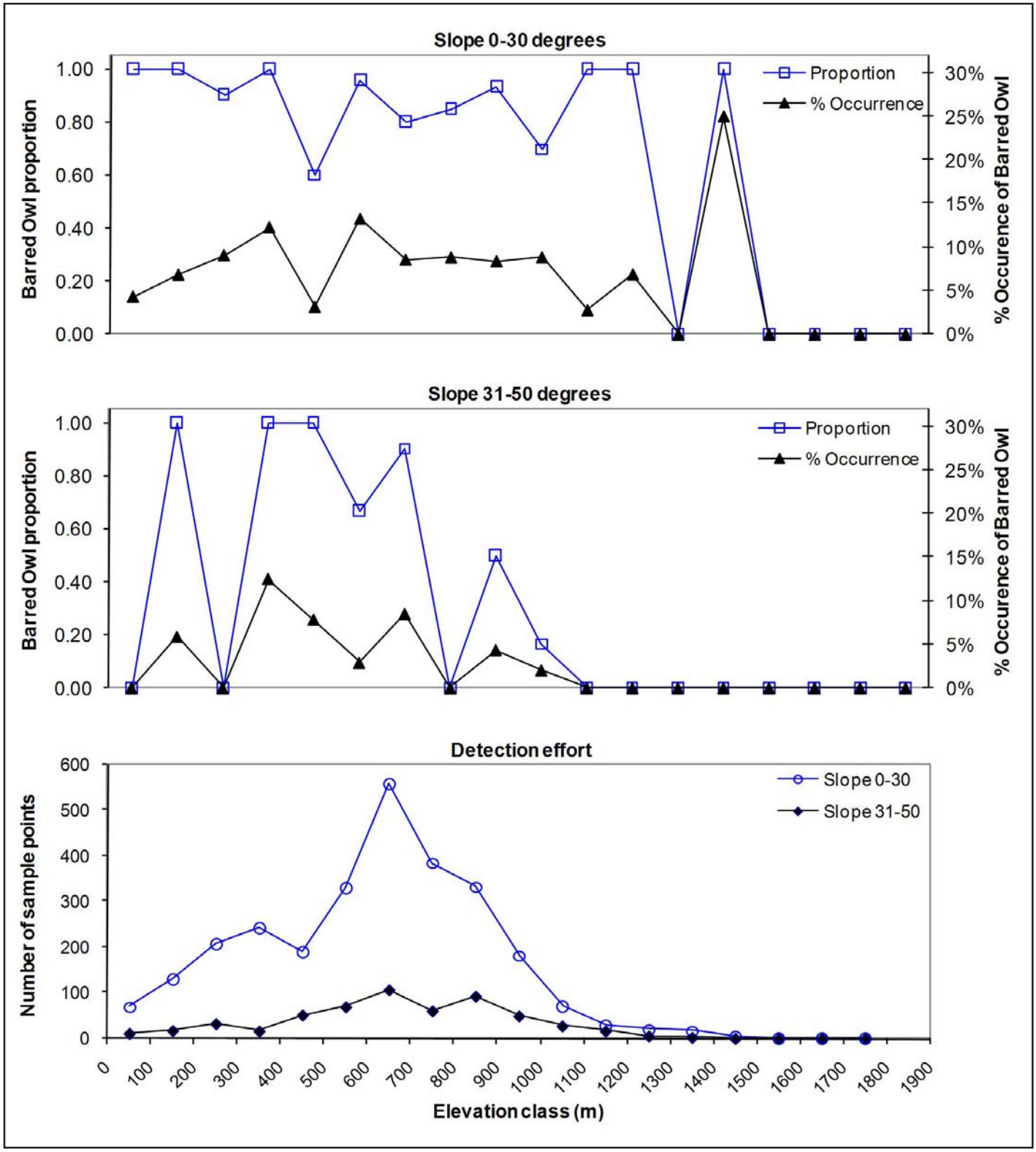

Figure 6. Effects of elevation and slope on two measures of Barred Owl occurrence: **Submaritime subregion, 2003-to-2005 dataset**.
Top: proportion of sample points with owl detections (Barred Owl or Northern Spotted Owl) that were Barred Owl (proportion).
Middle: percentage of sample points with Barred Owl detections (% occurrence).
Bottom: sampling effort at each elevation.

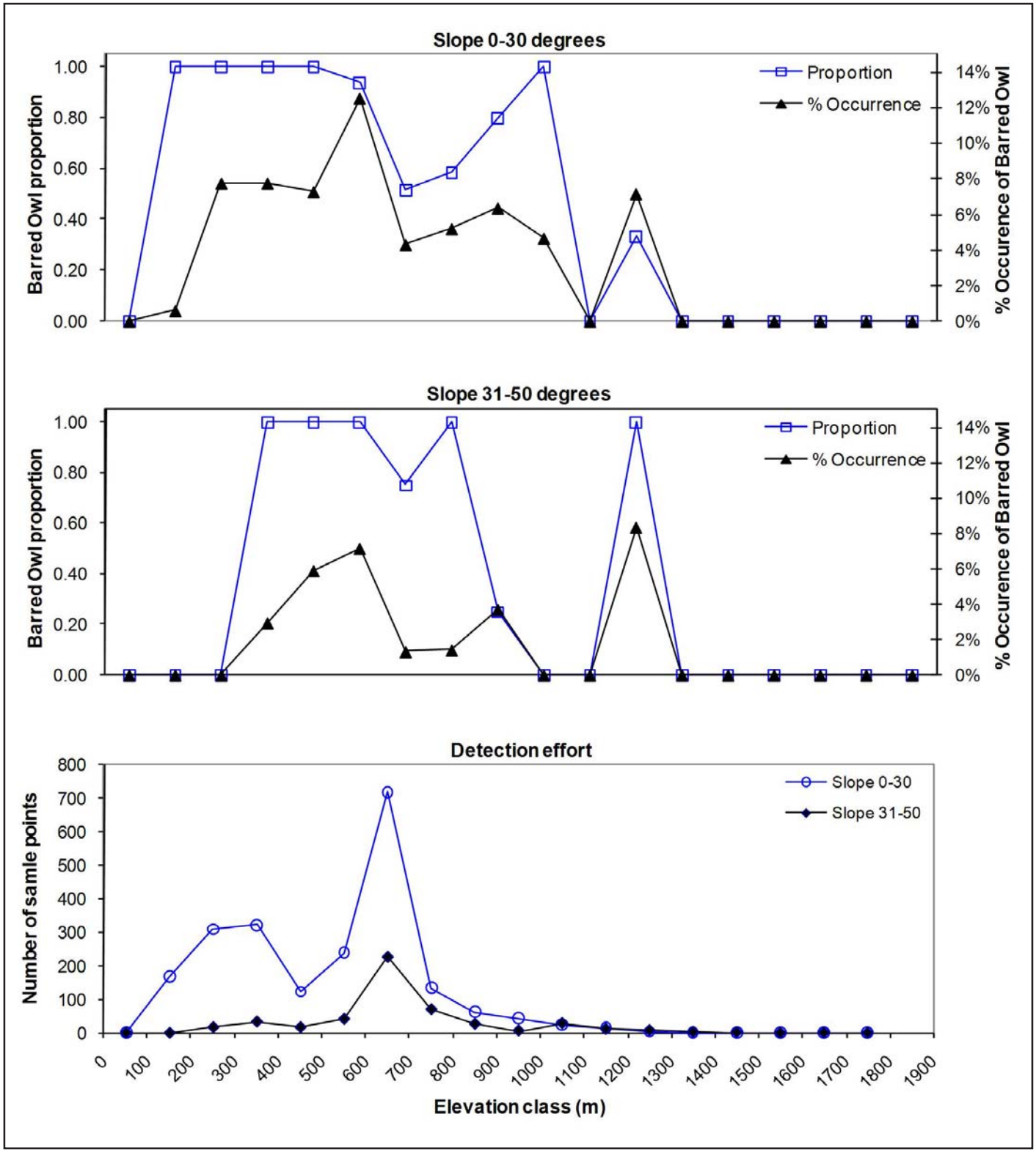

Figure 7. Effects of elevation and slope on two measures of Barred Owl occurrence: **Continental subregions, 2003-to-2005 dataset**.
Top: proportion of sample points with owl detections (Barred Owl or Northern Spotted Owl) that were Barred Owl (proportion).
Middle: percentage sample points with Barred Owl detections (% occurrence).
Bottom: sampling effort at each elevation.

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