PRELIMINARY ASSESSMENT OF BREEDING-SITE OCCUPANCY, MICROHABITAT, AND SAMPLING FOR WESTERN TOAD MONITORING IN LOWER GLACIER BAY

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Abstract

Large-scale monitoring efforts directed at western toads (Bufo boreas), an amphibian reported to have undergone declines in Southeast Alaska, are most effective where baseline estimates of occupancy are not excessively low (e.g. <15%). To help inform and calibrate future monitoring efforts, we conducted a preliminary assessment of western toads in the lower Glacier Bay area to evaluate breeding-site occupancy and related microhabitat characteristics, as well as to investigate sampling designs appropriate for monitoring in low-occupancy landscapes. Although we did not correct for detection error and non-random selection of ponds, we observed low breeding-site occupancy (0.05; n=94). Microhabitat comparisons between occupied and unoccupied sites did not yield any strong patterns, but this is not surprising given our low sample size. Nonetheless, solar exposure, which was quite high at some breeding sites, pH, and successional state are 3 variables that we feel warrant further investigation for the Glacier Bay area. Initial GIS-based simulations suggest that sampling designs composed of grid cells that are 0.0625 km^2 (250 m x 250 m) to 0.25 km^2 (500 m x 500 m), and cover at least 60% of an area of interest, may be effective approaches for estimating occupancy at scales larger than individual ponds. When planning for monitoring in low occupancy landscapes we recommend conducting a preliminary assessment to 1) gather and integrate habitat information to define monitoring-area boundaries, and 2) derive coarse-scale sampling units appropriate for monitoring trends in occupancy.

Introduction

The western toad (Bufo boreas Fig. 1) merits attention for conservation in Southeast Alaska because its current distribution and population trends remain virtually unknown. As in other parts of the Pacific Northwest and Rocky Mountains, anecdotal records in Southeast Alaska suggest that this biologically vulnerable species may have already declined at some locales during the last 10-20yrs (Carstensen et al. 2003). The most promising method for meeting inventory and monitoring needs over large and complex landscapes like Glacier Bay (GLBA) is estimation of site occupancy rates using the Proportion of Area Occupied (PAO), a measure of the fraction of a landscape that is occupied by a species (Mackenzie et al. 2002). PAO-based protocols are statistically robust methods to assess changes in amphibian distribution and reliably identify areas where conservation action is imperative. But when occupancy rates are generally low (< 0.15) and little is known about toad distribution and habitat, the ability to detect trends becomes limited. Two possible means to overcome this challenge are to focus monitoring in the highest-quality breeding habitat and employ larger-scale sampling designs (e.g. grid cells) that yield occupancy rates (e.g., > 0.15) that are suitable for monitoring. To help calibrate future monitoring efforts, we conducted a preliminary survey of western toads in lower GLBA, with a specific focus on the following:

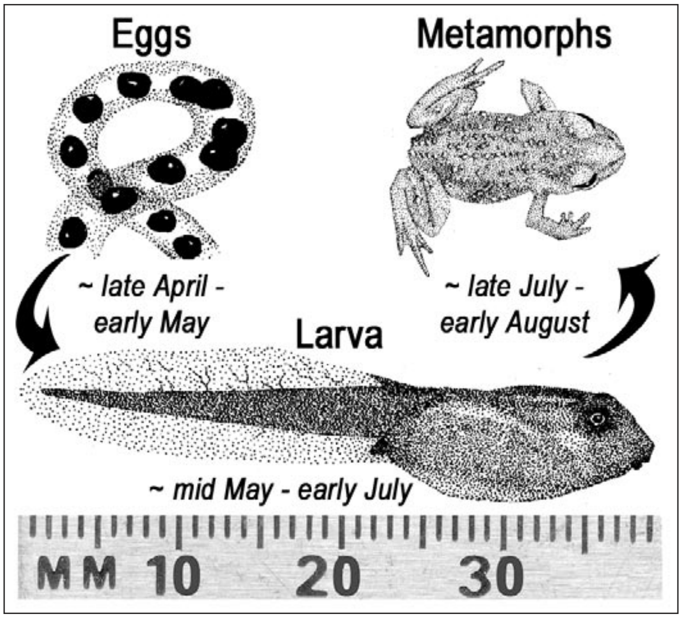


Figure 1. Three life stages for western toad. Because eggs hatch quickly and metamorphs disperse rapidly detection error may be lowest if surveys are conducted during the longer-lasting larval stage. Dates shown are averages documented in Juneau, AK.

1. What are breeding-site occupancy rates for toads in lower GLBA?
2. What microhabitat characteristics are associated with breeding sites?
3. What is an efficient and effective way to locate western toad monitoring sites in patchy, low occupancy landscapes?
4. What sampling designs and scales of analysis are appropriate for future toad monitoring in GLBA?

Methods

Our field surveys in Glacier Bay were conducted in the last week of June, 2004, a time when larvae are typically large and easily detectable in shallow ponds. We used 30 m pixel satellite, 2 m pixel B/W digital orthophoto imagery, and 2 ft pixel, color infra-red "Coastwalker" imagery to identify 4 focal areas with abundant potential breeding habitat that were located to include a broad geographic range in lower GLBA: Taylor Bay, Ripple Cove, Berg Bay, and Bartlett Cove. We later verified that these were appropriate areas of interest by digitizing ponds within 2.5 km of the beach, and conducting a "hot spot" analysis using Arc-

GIS 8.3 Spatial Analyst (Christensen et al. 2004). We employed pre-field review and Intuitive Controlled Survey methods (Molina et al. 2003) to maximize our coverage of potential breeding habitats and to increase the likelihood of documenting at least some breeding activity at each site. We also opportunistically visited a small number of ponds in 2 nearby areas that were outside the park: Gustavus and Chichagof Island. We conducted rapid surveys at ponds by scanning shorelines and shallower margins for toad larvae. We measured 16 microhabitat variables at all sites with larvae and a select number of sites with no signs of breeding. The site selection process is illustrated in Fig. 2, a portion of the research team's GLBA Science Symposium poster (Christensen, et al. 2004).

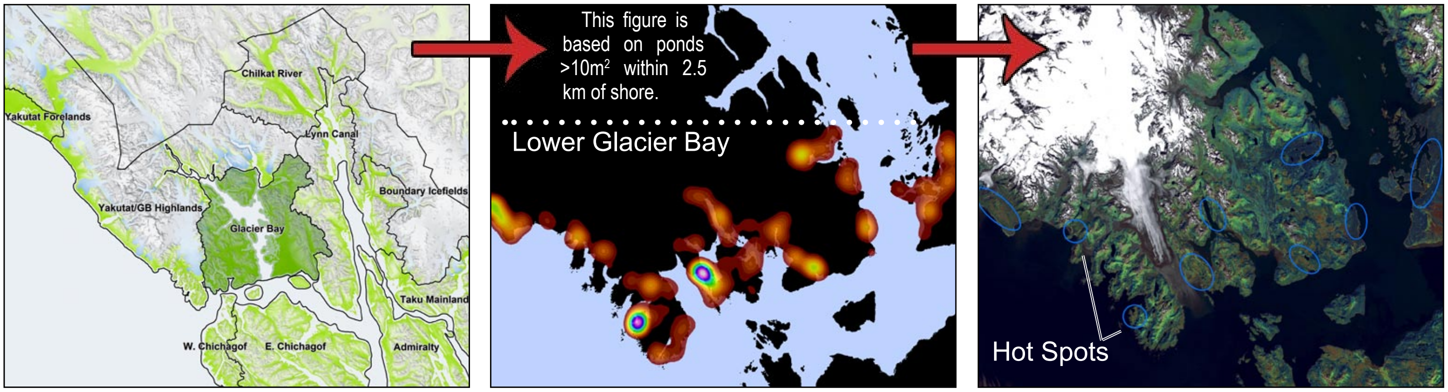
We also conducted spatially-explicit simulations to investigate the utility of alternate sampling units (grid cells) under a low-occupancy scenario in GLBA. We used ArcGIS 8.3 and Arcview 3.2 with the Animal Movement Extension to conduct these simulations by: 1) modeling a random distribution of ponds using a pond-occupancy rate of 0.1; 2) overlaying a grid cell-based sampling design that varied with respect to grid cell size and proportion of grid cells surveyed, and 3) derived grid-cell based occupancy estimates for each design. We ran 5 iterations for 4 grid cell sizes ranging from 0.1 km to 1 km on a side; and 10 iterations of each sample-size ranging from 10 to 90% of grid cells surveyed, in 10% increments. We assumed detection error was negligible for these initial simulations.

Results

Breeding-site occupancy was < 5% (4 of 94 ponds surveyed); an uncorrected estimate that assumes detection error is negligible and is based on a Intuitive Controlled Sampling regime that aimed to document at least some breeding activity in each area. We found general evidence of toad activity at 9% (8) of these ponds.

We measured and compared 16 habitat variables at 23 ponds, 9 of which are displayed in Table 1. Breeding ponds ranged in size from uplifted tidal ponds < 1 m^2 to vast wetland complexes > 9 km^2 (Carstensen 2004). Microhabitat patterns were generally not strong, but solar exposure (i.e., mean distance to forest cover in 3 directions) was nearly significant ($p<0.07$) at sites with breeding activity. In addition, 3 of 4 breeding sites and 7 of 8 sites with general evidence of toad activity were associated with recent disturbance phenomena such as uplift, glacial recession, and human dredging. Finally, statistical analysis indicated that % floating vegetation was significantly less at sites with larvae present. This contradicts the results of more exhaustive work in the Juneau and Taku river area (Carstensen et al. 2003) and is more likely an ar-

Figure 2. Monitoring site selection process presented at the GLBA Science Symposium: http/www.seawead.org/amphibs.



1) 1 of 23 **biogeographic provinces** was selected for the pilot study. These provinces are based on species composition, climate, landscape features, and geologic barriers.

2) Near-shore **Pond density** was used to identify accessible hot spots in lower Glacier Bay that had a relativley high probability of meeting sample size criteria for PAO (>= 30 ponds).

3) **Broad-scale habitat assessments** were conducted through satellite photo interpretation to increase likelihood of breeding site suitability and to include a broad geographic scope.

6) **Monitoring sites** were located to meet PAO parameters (occupancy >20%); buffers were created to include marginal habitats (to increase sensitivity); and grids were generated where ponds as sample units were inappropriate.

5) **Fine-scale rapid assessment surveys** were conducted to validate visual habitat assessments and to survey ponds for: tadpoles, metamorphs, yearlings & adults, water quality, pond depth, aquatic vegetation, pond origin and solar exposure.

4) **Survey routes**: High resolution imagery was used to visually assess obvious pond habitat types at select hot spots (i.e. forested, fen, uplift, and bog) and to plan survey routes that maximized pond assessments across the range of habitat variation.

Table 1. Summary of 10 habitat variables that were evaluated at 23 potential breeding sites in the lower Glacier Bay area, June 2004. Results from the 1 successional variable we evaluated are provided in text. *Denotes means are significantly different between occupied and unoccupied breeding sites ($p<0.05$, 2-tailed t-test). ** Denotes means are nearly significantly different ($p<0.07$)

Habitat Variable	Occupied(n=4)		Unoccupied (n=19)		Occupied, all stages(n=8)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Area (m2)	5182.50	3901.18	9942.37	18535.8	12216.88	12216.88
Depth (dm)	4.63	3.95	4.03	2.73	4.95	4.95
Organic Muck (dm)	2.00	2.16	2.82	2.75	2.25	2.25
Solar Exposure (m)**	197.50	118.42	37.58	39.10	105.88	105.88
% Emergent Vegetation	55.00	36.97	59.46	38.51	59.71	59.71
% Floating Vegetation*	0.33	0.58	36.89	39.30	35.00	35.00
% Submerged Vegetation	56.67	51.32	38.33	49.16	40.00	40.00
Water Temp (C°)	22.75	2.21	20.79	3.534	23.14	23.14
pH	7.17	1.00	6.52	1.12	7.30	7.30
% DO	9.25	1.5	9.10	2.14	9.71	9.71

tifact of the early successional stage of most GLBA ponds (when ponds tend to lack floating vegetation) than it is a breeding habitat correlation.

GIS-based simulations of ponds in the lower GLBA landscape suggested that when pond occupancy is low (<0.10), grid cells that are at least 250 m on a side (0.0625 km^2) yielded relatively consistent estimates of occupancy > 0.15 (Fig. 3). Increasing cell size resulted in higher estimated occupancy rates, but these estimates decreased rapidly in accuracy, particularly when cells approached 1 km x 1km in size. Using 250 m x 250 m grid cells, simulations also suggested that accurate occupancy estimates tended to stabilize when at least 60% of cells with available habitat (i.e. cells containing ponds) had been surveyed (Fig. 4).

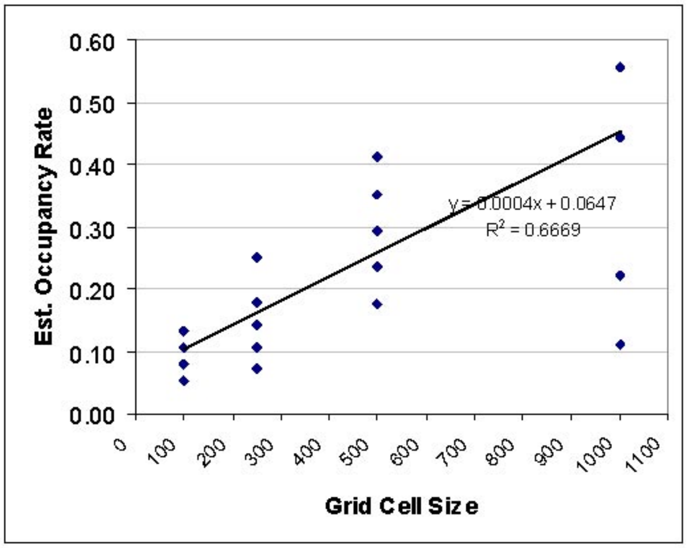
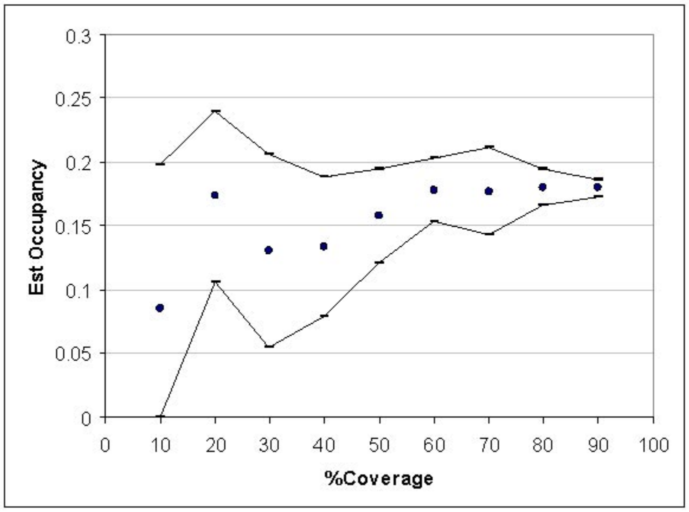


Figure 3. Scatter plot showing the effects of variation in the size of sampling units (.01 – 1 km) on occupancy estimates for western toads in the lower Glacier Bay region. Five iterations were run for each grid cell size. We assumed negligible detection error and maintained "true" occupancy rates at 0.1 for all simulations.

Figure 4. Simulated effects of varying the number of 0.0625km^2 (250 m x 250 m) grid cells surveyed (e.g. sample size) on occupancy estimates for western toads in the lower Glacier Bay region. 10 Iterations were run for each 10% increase in area covered. We assumed negligible detection error and maintained "true" occupancy rates at 0.1 for all simulations. Outer lines represent upper and lower 95% confidence intervals.



Discussion and Conclusions

Although our study was preliminary in nature, we believe it is safe to assume that western toad breeding sites are sparsely distributed at coarse scales of analysis in lower GLBA: even if we adjusted our "observed" occupancy rates with modest detection-error estimates documented elsewhere (Mackenzie et al. 2002; Bailey et al. 2004), "true" occupancy rates at coarse scales probably do not exceed 10%. This pattern may be another example of declines noted in GLBA and much of the southeast region since the early 1980s. For the areas surveyed that were on the Gustavus Flats, or in similar habitats, it is possible that post-glacial uplift and consequential wetland drying may be contributing to these apparent declines (Anderson 2004). For other areas in GLBA low occupancy may simply represent a baseline condition. More research is needed to understand the low occupancy conditions in GLBA.

Because breeding site occupancy is probably low and patchy in GLBA and much of Southeast Alaska we recommend incorporating fine-scale habitat information - particularly GIS layers that have been extensively ground-truthed - to more effectively select monitoring areas. For instance, solar exposure, a potentially important variable in our assessment, is interpretable with most existing imagery and could be used to identify zones with low overstory cover within GLBA. Similarly, given the association between neutral-to-basic pH levels and toad occurrence documented elsewhere, perhaps some types of GIS data (e.g. geological data, vegetation cover) associated with more extreme pH levels could also be used to exclude marginal areas from consideration. For transitional ecosystems like GLBA, it might also be appropriate to emphasize monitoring in successional zones that are changing at rapid to moderate levels, e.g. uplifting, supratidal zones. Because selection of monitoring locations in low occupancy landscapes may bias against marginal or undocumented habitat types, it is important to include an adequate proportion of these habitats as second-tier priorities within longer-term inventory and monitoring efforts.

Although ponds are biologically relevant, a grid-based rather than pond-based analysis may be preferable in GLBA for detecting the type of broad-scale declines that have been documented elsewhere. Clearly, our GIS simulations were simple and will require additional refinement (e.g. corrections for detection error and non-random pond selections), but these simulations demonstrate that at scales of survey and analysis larger than ponds, resulting occupancy estimates are more appropriate for use with existing monitoring protocols like the PAO-based protocol developed by the USGS (USGS 2004). Grid cells can also be used for diverse types of potential breeding sites, e.g. ponds, large wetland complexes, intertidal and river shorelines, and thus allow estimates of occupancy to be calculated for a standard type of landscape unit. We do caution that when using sampling units that are too large (e.g. 1 km x 1 km grid cells); statistical power to detect changes in occupancy may be limited and may result in inconsistent estimates of occupancy.

Management Implications

The western toad can be considered as a "linkage" species connecting terrestrial, freshwater and even marine ecosystems in the Park. Considering also that it has declined throughout its North American range, and very likely within the Park as well, we recommend giving a high priority to this species for any forthcoming inventory and monitoring efforts in GLBA. Currently, however, western toads are probably very patchy in distribution and exhibit low occupancy rates at coarse scales in GLBA, a condition that we suspect also exists in many parts of Southeast Alaska. This does not make large-scale monitoring efforts for GLBA or similar areas inappropriate. Rather, this simply underscores the need to ensure monitoring areas include predominantly higher-probability habitat, and the utility of employing alternative sampling approaches, like grid-cells, to estimate occupancy. We encourage the development and use of preliminary assessments to derive large-scale monitoring protocols appropriate for amphibians in these types of landscapes. Rapid assessments, such as the type we conducted, are very cost-effective ways to 1) gauge the extent of toad distribution; 2) optimize monitoring-area boundaries using ground-truthed habitat associations; 3) develop scales of analysis that are most appropriate for future monitoring of trends; 4) identify access constraints; and, although we did not include this element in this particular effort, 5) gauge detection error. We strongly recommend undertaking these efforts concurrently with inventory and monitoring planning in Southeast Alaska landscapes, because time may be of the essence.

Acknowledgements

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