Arctic LCC Project Summary

1. PROJECT INFORMATION

Title:	Development of Shorebird Distribution Maps for the North Slope of Alaska Using Geospatial Habitat Modeling: the First Step in Assessing Effects of Climate Change
Report submission date	24th September 2012
Author of report	Sarah Saalfeld, Richard Lanctot, Stephen Brown
Key words	Alaska; Arctic; coastal plain; habitat suitability; niche model; North Slope; partitioned Mahalanobis distance; shorebirds.

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2. PROJECT OVERVIEW

a. **Briefly (4-5 sentences) describe both the research purpose and the underlying need for this research.**

The Arctic Coastal Plain (ACP) of Alaska is an important region for millions of migrating and nesting shorebirds. However, climate change and increased human development (e.g., oil and gas production) have the potential to greatly impact shorebird populations and breeding habitat. The first step in evaluating the potential impacts of climate-mediated changes and development on shorebird species within the ACP of Alaska is to document the current distribution of shorebirds within this region. Unfortunately, the contemporary distribution of shorebirds is poorly known and only coarsely defined (e.g., distribution maps presented in the Birds of North America series). An understanding of contemporary distributions based on detailed, large-scale habitat associations will allow the identification of important areas as indicated by greater species richness and/or presence of imperiled or at-risk shorebird species. These distributions provide the starting point for evaluating impacts from future changes predicted for the ACP.

b. **List the objective(s) of the project, exactly as described in your Statement of Work.**

(1) Assemble authoritative, spatially linked (GIS) databases on shorebird presence/absence that are compatible with data layers that describe the physical and ecological parameters that describe habitat characteristics.
(2) Work with Arctic LCC partners to identify priority physical and ecological parameters derived from ground or satellite-based data.
(3) Document the association between the presence of shorebird species and the ground or satellite-based data to document the geographic distribution of a species on the Coastal Plain.
(4) Compare the predictability (and accuracy) of habitat selection models to assess at which scale species habitat maps are more reliable.

3. PROJECT SUMMARY

The Arctic Coastal Plain (ACP) of Alaska encompasses several diverse landholdings including state and Native corporation lands, the Arctic National Wildlife Refuge (Arctic NWR), and the National Petroleum Reserve-Alaska (NPR-A), as well as the largest oil field in North America (Prudhoe Bay Oil Field). This region has already experienced habitat alteration associated with climate warming and increased human development (e.g., oil and gas production), and these trends are expected to continue into the future. Shorebirds dominate the avian fauna of the ACP, both in terms of abundance and diversity, with many species exhibiting breeding ranges restricted entirely to the Arctic. Therefore, it is an ideal species group to investigate potential impacts from development and climate change within this region. Because historic data on shorebird distributions in the ACP are coarse and incomplete, we sought to develop detailed, contemporary distribution maps so that the potential impacts of climate-mediated changes and development could be ascertained.

We developed and mapped habitat suitability indices for 8 species of shorebirds (Black-bellied Plover [*Pluvialis squatarola*], American Golden-Plover [*Pluvialis dominica*], Semipalmated Sandpiper [*Calidris pusilla*], Pectoral Sandpiper [*Calidris melanotos*], Dunlin [*Calidris alpina*], Long-billled Dowitcher [*Limnodromus scolopaceus*], Red-necked Phalarope [*Phalaropus lobatus*], and Red Phalarope [*Phalaropus fulicarius*]) that commonly breed within the ACP of Alaska. These habitat suitability models were based on 767 plots surveyed during 9 years between 1998 and 2008 (surveys were not conducted in 2003 and 2005) as part of the Program for Regional and International Shorebird Monitoring (PRISM; Fig.1). Surveys were conducted using single-visit rapid area searches during territory establishment and incubation (8 June – 1 July). We developed habitat suitability indices for each species and mapped suitability over an 85,000 km^2 region of the ACP of Alaska using presence-only modeling techniques (partitioned Mahalanobis distance) and landscape environmental variables.

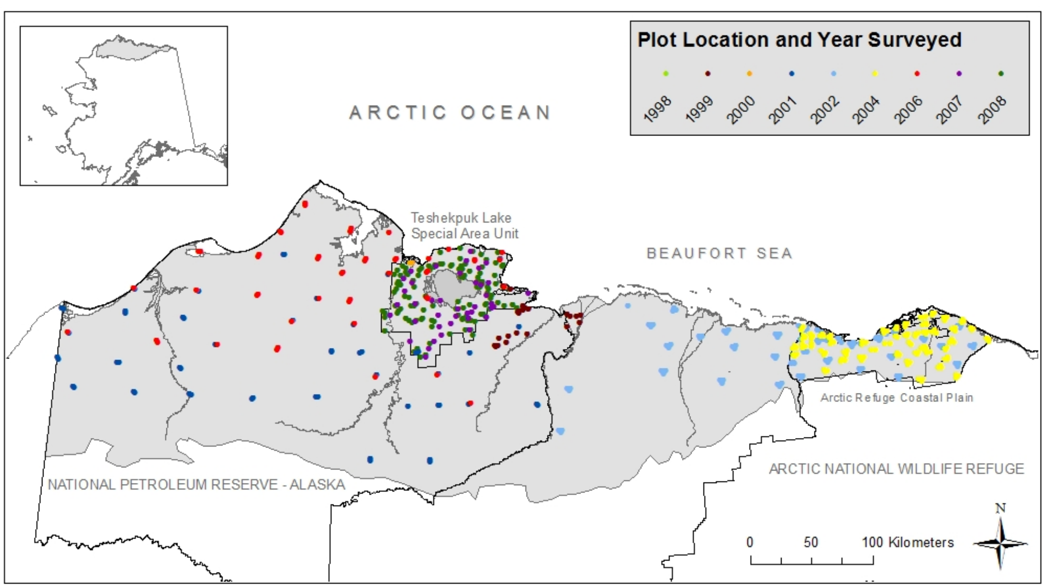

Figure 1. Location of the study area (shaded), major administrative boundaries, major riverine areas, and plots surveyed between 1998 and 2008.

For most species, habitat suitability was greater at lower elevations (i.e., near the coast and river deltas) and lower within upland habitats (e.g., upland tussock tundra, upland shrubby tussock tundra, and upland scrub tundra). Unlike the majority of species, however, elevation was not an important variable for American Golden-Plover and Long-billed Dowitcher, with predicted ranges for these species extending further south into the foothill region. Accuracy of models was high for all species, ranging from 65 – 98%. We predicted that the largest fraction of suitable habitat for the majority of species occurred within the National Petroleum Reserve-Alaska, with highly suitable habitat also occurring within coastal areas of the Arctic NWR west to Prudhoe Bay.

For the first time, this study provides habitat suitability maps that illustrate predicted distributions for 8 species of shorebirds breeding within the ACP of Alaska. The habitat suitability maps developed in this study identify important regions for nesting shorebird species that may be used when establishing conservation priorities. Current distribution maps can now be used to understand and compare the potential impacts of specific development scenarios on nesting shorebirds. Additionally, habitat alterations due to climate change can now be assessed using climate change scenarios and current shorebird habitat associations.

While conducting this study, we became aware of limitations in the spatial data layers needed to more definitively predict locations where various species of shorebirds are likely to breed on the ACP. This knowledge was conveyed in a white paper describing these needs (Appendix A).

4. PRODUCTS

a. Publications, conference papers, and presentations.

Journal publications:

- Saalfeld, S.T., R. B. Lanctot, S. C. Brown, D. T. Saalfeld, J. A. Johnson, B. A. Andres, and J. R. Bart (in review, 2012): Predicting breeding shorebird distributions on the Arctic Coastal Plain of Alaska. Ecosphere.

Reports:

- Saalfeld, S.T., R. B. Lanctot, and S. C. Brown. (2012). GIS-based environmental layers needed for future predictive shorebird habitat models on the Arctic Coastal Plain of Alaska. Arctic Landscape Conservation Cooperative, U.S. Fish and Wildlife Service, Fairbanks.

Conference presentations:

- Saalfeld, S. T., R. Lanctot, S. Brown, J. Johnson, B. Andres, J. Bart. (2011): Predicting shorebird habitat on the Arctic Coastal Plain of Alaska. Western Hemisphere Shorebird Group Meeting, Vancouver, BC.

- Saalfeld, S. T., R. Lanctot, S. Brown, J. Johnson, B. Andres, J. Bart. (2011): Predicting shorebird habitat on the Arctic Coastal Plain of Alaska. Alaska Shorebird Group Meeting, Anchorage, Alaska.

b. Education and outreach.

Our conference presentations reached 50-75 people working in environmental planning; subsequent communications with people initially met at these meetings have brought the products of this project to bear on numerous conservation and planning efforts on the ACP. For example, information from this project were provided and used in the BLM environmental planning process for the NPR-A.

c. Other products resulting from the project.

Data layers associated with this project are archived with the Arctic LCC and available via the internet:

- PRISM survey data layer (polygon layer), survey plot location linked with shorebird counts.
- PRISM survey data layer (point layer), point location for each shorebird sighting.
- Habitat suitability maps for 8 shorebird species, derived from partitioned Mahalanobis distance models; example of one species provided below (Fig.2).

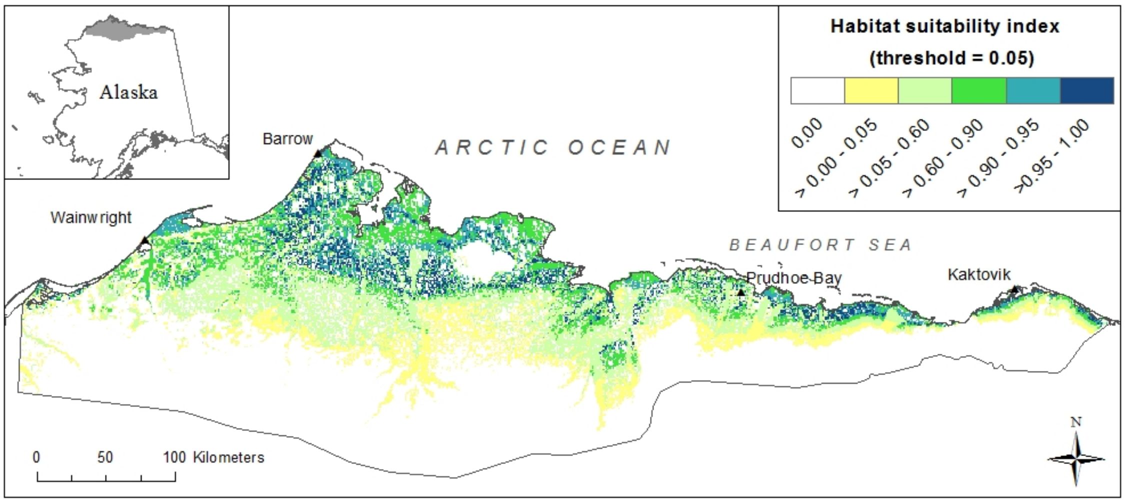

Figure 2. Habitat suitability map for Dunlin (*Calidris alpina*) breeding in the Arctic Coastal Plain of Alaska, 1998 – 2008. Colors below the 0.05 threshold value indicated the predicted absence of this species. Solid line indicates study area.

Appendix A

GIS-based environmental layers needed for future predictive shorebird habitat models on the Arctic Coastal Plain of Alaska

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Using geospatial habitat models to develop distribution maps for species dispersed across a large geographic extent is dependent on the availability and accuracy of underlying GIS-based environmental datasets. Regardless of the specific habitat model used to predict the distribution of a species, the underlying concept is the same (i.e., relate the distribution of a species from occurrence records to the spatial distribution of environmental predictors). These relationships can then be used to predict the probability of occurrence for a given species across the landscape (in particular areas not visited previously) based on the combination of environmental variables at any given location. However, if important variables are excluded from initial model development, the predicted distribution may not accurately reflect the current distribution of a species. Additionally, if underlying environmental layers are inaccurate or too coarsely defined, an inaccurate or biased predicted distribution may result.

While developing shorebird distribution maps for the Arctic Coastal Plain (ACP) of Alaska, we were asked by the Science Coordinator of the Arctic Landscape Conservation Cooperative (LCC) (which funded our work) to identify environmental layers that were missing, and would have been useful to conduct our study. At the beginning of our project, we identified several environmental factors (either from expert opinion or published literature) as potentially influential to shorebird distributions within this region, regardless of yearly variation. These included elevation, distance to coast, surface water, vegetation, soil type, longitude, latitude, and landforms (e.g., non-patterned, polygonization, strangmoor habitat; see Walker et al. 1980 for landform descriptions). Although many of these metrics were available in GIS format for the entire ACP of Alaska (Table 1), several were too coarse or unavailable for the entire region. For example, soil types, as obtained from the Soil Survey Geographic Database (Soil Survey Staff 2011), were too coarsely defined for Alaska to be of much use when developing shorebird distribution maps. Additionally, several datasets were available at resolutions sufficient for broad-scale habitat associations used in this study, but may be insufficient for future or fine-scale studies. For example, all available datasets had resolutions ≥ 30 m (Table 1), too coarse to investigate nest site selection patterns in the ACP of Alaska (a previously identified objective for our Arctic LCC funded study), as shorebirds appear to place nests in microhabitats (e.g., polygon rims or small upland sites [e.g., *Carex* spp. patches] within much larger wetlands) that are not readily distinguishable in such low resolution datasets. Additionally, accuracy of future studies determining habitat associations of shorebirds within the ACP of Alaska can be improved with the use of higher resolution datasets. Therefore, for future work within this region, all data layers should be available at resolutions ≤ 30 m for habitat associations (e.g., distribution patterns) and ≤ 10 m for fine-scale associations (e.g., nest site selection patterns). Although we realize high resolution data layers will likely not be available for the entire ACP of Alaska, specific locations or study sites with this level of detail will allow biologists to evaluate at what scale species appear to be selecting sites for nesting or territory establishment, and thus whether fine scale information is needed for a larger area.

As vegetation is thought to be a primary factor influencing shorebird selection patterns (Myers and Pitelka 1980, Garner and Reynolds 1986), more detailed and accurate land cover classifications are needed for the ACP of Alaska. Although fairly detailed land cover maps are available for portions of the ACP (e.g., National Petroleum Reserve of Alaska; Ducks Unlimited 1998), land cover maps for the entire ACP of Alaska are generally less detailed and coarsely defined. For example, in this study we used land cover classifications available from Jorgenson and Heiner (2003). While we were able to determine some coarse-scale habitat associations in this study, we were unable to differentiate between shorebird use in lowland habitats (i.e., %

water, % wet meadow, and % moist meadow) in the ACP of Alaska. Although this may be due to lack of habitat segregation among lowland habitats by shorebirds, these results could also have been due to the coarse-level of detail in the land cover map, where shorebird habitat preferences are occurring at a finer level than the broad habitat classifications defined in the land cover map. Therefore, future work within this region would likely benefit from a more detailed land cover map with additional vegetation categories defined within these large scale habitat classifications. As we found that shorebirds preferentially selected lowland habitat types (e.g., wet meadow and moist meadow), greater differentiation within these broad classifications would most likely benefit future shorebird habitat models. Accuracy of land cover datasets also needs to be improved and rigorously checked as new datasets are created or existing datasets are updated. For example, as a part of the LANDFIRE dataset, detailed vegetation types are available across the ACP of Alaska (LANDFIRE 2006); however, the accuracy of these classifications is questionable. Although the level of detail provided in these vegetation maps was much improved over existing maps, poor accuracy of these maps make them unsuitable for predicting shorebird distributions and nest sites.

Current work by the North Slope Science Initiative to develop a new vegetation map at 30-m resolution based on classification of LANDSAT imagery would likely provide a more accurate land cover classification for the ACP of Alaska. However, the provisional map classes to be delineated do not include much additional differentiation among lowland habitat types than is currently available. In fact, the provisional map classes only include differentiation among freshwater marsh and wet sedge. These data will likely not add additional information concerning shorebird habitat selection patterns than what we were able to develop previously. It seems the greatest potential contribution of these data would be to increase accuracy of current maps and the coarse-scale habitat associations.

Along with vegetation, shorebird distributions within the ACP of Alaska are highly dependent on surface water hydrology, as surface water influences both nesting habitat and food availability (e.g., via insect emergence patterns in relation to water). For this study we relied on the National Hydrography Dataset (Simley and Carswell 2009) to develop several metrics (e.g., waterbody density) to describe surface water availability. Although this dataset provides some coarse information concerning number, size, and location of permanent waterbodies; information concerning ephemeral wetlands (e.g., polygons), surface hydrology (e.g., standing water), and wetland characteristics (e.g., depth, salinity) is generally lacking. As these factors can influence both shorebird distributions and nest placement (either directly through nest site selection or indirectly through adults selecting areas near high quality food resources), future studies would likely benefit from detailed GIS datasets depicting these various metrics associated with surface hydrology. Specifically, we suggest obtaining the maximum extent of surface water hydrology on the landscape, and if possible, the rate of change of surface water during the breeding season. In addition, understanding how surface water is related to landform types will help define how surface water ultimately affects shorebird distributions. As these data are likely to exhibit both spatial and temporal variation, these data should match the dates when bird data are collected, both annually and seasonally. Obviously surface water is tied closely with snow levels and snow melt (see below), but emergent vegetation is also likely an important component in relating bird presence and surface water hydrology. Salinity has been shown to be an important factor influencing distribution of eiders, however, little is known concerning the importance of this variable to nesting shorebirds. More research is needed to determine shorebird responses to salinity and invertebrate prey. Although several components of surface water could be mapped and obtained on a large scale, including water depth and extent of exposed sediment, we do not believe these factors would be greatly influential on breeding shorebird distributions and habitat selection patterns (although both factors are likely important for post-breeding shorebirds).

Despite these information needs, by far the most lacking data for this region, is the availability of a landform data layer. Based on our work on the ACP of Alaska, key landforms influencing shorebird distributions include non-patterned ground, high and low centered polygons, and strangmoor habitat (see Walker et al. 1980 for landform descriptions). Although development of a toolkit that extracts polygonal ground from high resolution Lidar or satellite data is being developed (C. Gangodagamage, personal communication), no GIS data layer currently exists depicting spatial locations of landforms for the entire ACP of Alaska. As landforms such as high- and low-centered polygons have been identified as important variables for shorebird habitat selection during the breeding season in the ACP of Alaska (Myers and Pitelka 1980), these data could greatly enhance future predictions within the ACP of Alaska. However, generation of such a data layer would likely be dependent on a detailed (< 1 m resolution) elevation dataset that would be needed for most if not all of the entire ACP of Alaska (unless small scale studies are conducted). In fact, elevation was identified as a primary factor influencing shorebird distributions. While this study used elevation currently available from the National Elevation Dataset (Gesch 2007), future work within this region would likely benefit from a more detailed elevation dataset (e.g., derived from aerial or ground-based Lidar) that would reflect information on terrain heterogeneity (e.g., ridges of polygons and strangmoor habitat).

Along with the important environmental variables identified above, several yearly variables were also identified as important for breeding shorebirds on the ACP of Alaska. Within any given year, shorebird distributions may change based on yearly variation in habitat conditions on arrival to the breeding grounds. As such, it is important to have metrics that describe yearly variation including Normalized Difference Vegetation Index (NDVI) and associated metrics (e.g., green up), temperature, precipitation (e.g., snow depth), and snow melt. However, availability of yearly metrics is generally restricted to specific years for the ACP of Alaska. For example, historic precipitation data from Scenarios Network for Alaska Planning (SNAP) is only available from 1901-2006 (Scenarios Network for Alaska Planning 2011). Similarly, NDVI from the eMODIS data (Jenkerson and Schmidt 2009) is only available from 2000 – 2008. However, NDVI metrics for the ACP of Alaska is currently being developed for a longer period of time (D. Ward, personal communication). Once developed, it remains important to update these annual metrics to maintain uninterrupted time series data. Perhaps the most important yearly GIS data layer that is lacking for the ACP of Alaska is the extent of snow and timing of snow melt. The amount of snow present upon shorebird arrival to the ACP of Alaska is likely an important variable determining yearly variation in distributions, as it influences not only habitat availability but also cover for lemmings that influences subsequent breeding productivity of shorebirds. Specifically, annual extent of snow accumulation during shorebird arrival in relation to landform and vegetation classification, as well as rate of change in snow levels (due to melt) as the breeding season progresses would provide the most useful data to model shorebird distributions and habitat selection patterns.

Now that current distribution models for shorebirds breeding on the ACP of Alaska have been developed, these current distributions and their associated habitat relationships can be used to assess potential impacts due to climate change scenarios. However, to effectively do this, predictions concerning changes to environmental variables under different climate change scenarios need to be developed. Because temperature and precipitation increases within the ACP of Alaska (Martin et al. 2009) have the potential to greatly alter current shorebird nesting habitat, it remains important to predict how such changes may impact current shorebird distributions. Two of the main habitat components that will likely result in the greatest impact to shorebird distributions are vegetation structure and surface water availability. Therefore, there is a great need to develop GIS-based predictions of future vegetation and surface water availability under different climate change scenarios. Along with this, predicted changes in yearly variables such as snow accumulation in relation to climate change scenarios would also be beneficial to evaluate changes that may occur in shorebird distributions. However, current models determining the relationship between shorebird distributions and these yearly variables must first be developed; following which, future predictions can then be modeled.

SUMMARY

While developing shorebird distribution maps for the Arctic Coastal Plain (ACP) of Alaska, we identified several environmental layers that were missing, and would have been useful to have to conduct our study. By far the most lacking data for this region was the availability of a landform (e.g., non-patterned, polygonization, strangmoor habitat; see Walker et al. 1980 for landform descriptions) data layer, as well as data depicting yearly patterns of habitat availability (which is affected by snow cover, timing of snow melt, and ultimately surface water distributions as it relates to landscape elevation). Because of the paucity of these data layers for the ACP of Alaska, as well as the potential importance of these variables for predicting shorebird distributions, we believe these two data layers should be given the highest priority for development. Although of lesser priority, development of shorebird distribution maps for the ACP of Alaska would also benefit from finer resolution and greater accuracy land cover (i.e., vegetation) classification maps. Finally, as a primary goal of the Arctic LCC is to predict the effects of climate driven changes, prioritization of future changes in vegetation structure and surface water availability and distribution under climate change scenarios is also warranted.

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Table 1. Available physical and ecological datasets for use in shorebird distribution models on the Arctic Coastal Plain of Alaska.

Variable	Format	Resolution	Website	Citation
Monthly Air Temperature for each year from 1901 - 2009	Raster	2 km	http://www.snap.uaf.edu/downloads/alaska-climate-datasets	Scenarios Network for Alaska Planning, 1901-2009, CRU Historical Dataset - Air Temperature.
Total Monthly Precipitation for each year from 1901 - 2006	Raster	2 km	http://www.snap.uaf.edu/downloads/alaska-climate-datasets	Scenarios Network for Alaska Planning, 1901-2009, CRU Historical Dataset - Precipitation.
Soil Type	Polygon		http://soildatamart.nrcs.usda.gov/	Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for [Alaska]. Available online at http://soildatamart.nrcs.usda.gov.
Elevation	Raster	2 arc second ~ 60 m	http://seamless.usgs.gov/	Gesch, D.B., 2007, The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p. 99-118.
River and Stream Boundaries	Polyline		http://nhd.usgs.gov/data.html	Simley, J.D., Carswell, W.J., Jr. 2009, *The National Map*—Hydrography: U.S. Geological Survey Fact Sheet 2009-3054, 4 p.

Table 1. Continued.

Variable	Format	Resolution	Website	Citation
Waterbody Boundaries	Polygon		http://nhd.usgs.gov/data.html	Simley, J.D., Carswell, W.J., Jr. 2009, *The National Map*—Hydrography: U.S. Geological Survey Fact Sheet 2009-3054, 4 p.
Vegetation	Raster	30 m		Jorgenson, M. T. and M. Heiner. 2003. Ecosystems of Northern Alaska. Unpublished 1:2.5 million-scale map produced by ABR, Inc., Fairbanks, AK and The Nature Conservancy, Anchorage, AK.
Weekly NDVI for each year from 2000 - 2008	Raster	250 m	http://docs.gina.alaska.edu/ndvi/	Jenkerson, C. B. and G. L. Schmidt. 2009. eMODIS Alaska. ASPRS 2009 Annual Conference. Baltimore, MD.