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Natural Resource Stewardship and Science

Spatio-Temporal Abundance of Sea Otters in Glacier Bay National Park from 1993 to 2018

Natural Resource Data Series NPS/SEAN/NRDS—2020/1283

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Sea otter resting at Boulder Island in Glacier Bay National Park
NPS/Jamie N. Womble

ON THE COVER
Sea otters resting in kelp at Ripple Cove in Glacier Bay National Park
NPS/Jamie N. Womble

Spatio-Temporal Abundance of Sea Otters in Glacier Bay National Park from 1993 to 2018

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Abstract

In 2015, sea otters (*Enhydra lutris kenyoni*) were identified as a "vital sign" in Glacier Bay National Park and Preserve and an effort was initiated that was built upon existing data collected by the U.S. Geological Survey (USGS) from 1992 to 2012 to understand better the ecological processes governing changes in sea otter distribution and abundance. The new effort, a collaboration between the NPS Southeast Alaska Inventory & Monitoring Network (SEAN), USGS, Glacier Bay National Park and Preserve (GLBA), and Colorado State University (CSU) combined data from observer-based aerial surveys and aerial photographic surveys to develop contemporary modeling methods and an adaptive monitoring framework to minimize model uncertainty and maximize survey efficiency (Williams et al. 2017a, 2017b, 2018; Womble et al. 2018). The development of a robust quantitative framework for monitoring sea otters is important for evaluating population status, spatial distribution, and abundance within Glacier Bay and contributing to Alaska-wide sea otter abundance estimates, which are required under the Marine Mammal Protection Act of 1972. This report presents methods and results from monitoring efforts conducted by NPS from 2017-2018 and includes data collected by USGS from 1992-2012 (Esslinger et al. 2015, Esslinger 2019).

Acknowledgments

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List of Acronyms and Abbreviations

CSU:	Colorado State University
Cm:	centimeter
CSV:	comma-separated values
GLBA:	Glacier Bay National Park and Preserve
km/hr:	kilometers per hour
m:	meter
mm:	millimeter
NPS:	National Park Service
SEAN:	Southeast Alaska Inventory & Monitoring Network
USGS:	U.S. Geological Survey

Introduction

Sea otters (*Enhydra lutris kenyoni*) are an apex consumer in the North Pacific Ocean and are known to influence and structure the nearshore ecosystem and food web (Estes and Palmisano 1974). Sea otters represent an incredible story of conservation, resilience, and change. Prior to 1911, sea otters were overexploited during the commercial fur trade and were extirpated throughout much of their range (Lensink 1962, Kenyon 1969). In the 1960s, sea otters were translocated from remnant colonies in the Aleutian Islands to southeastern Alaska (Jameson et al. 1982). Sea otters began to arrive in Glacier Bay in the late 1980s and since that time, sea otters have increased dramatically and are currently the most abundant marine mammal in the park. The study of sea otter colonization in Glacier Bay provides important insight into the ability of a species to recover from near extirpation and to understand their role in structuring the nearshore food web (Williams et al. 2019).

From 1992-2012, sea otters were monitored in Glacier Bay using observer-based aerial surveys that were conducted by the U.S. Geological Survey-Alaska Science Center (USGS; Esslinger et al. 2015, Esslinger 2019). In 2015, sea otters were designated by the National Park Service (NPS) as a "vital sign" for long-term monitoring of the Glacier Bay marine ecosystem due to their role as a keystone species in the nearshore food web. Subsequently, the NPS Southeast Alaska Inventory & Monitoring Network (SEAN), USGS, Glacier Bay National Park and Preserve (GLBA), and Colorado State University (CSU) embarked upon a new effort to build upon existing data to better understand the ecological processes governing changes in sea otter distribution and abundance.

The primary objectives of the sea otter monitoring program in Glacier Bay are to use contemporary field methods, dynamical spatio-temporal models, and an adaptive monitoring framework to estimate the abundance and spatial distribution of sea otters in Glacier Bay (Williams et al. 2017a, 2017b, 2018; Womble et al. 2018). This report presents methods and results from monitoring efforts conducted by NPS from 2017-2018 and includes data collected by USGS from 1992-2012 (Esslinger et al. 2015, Esslinger 2019). Specific methods and standard operating procedures can be found in Womble et al. 2018 at https://irma.nps.gov/Datastore/Reference/Profile/2248282.

Methods

Aerial photographic surveys were conducted during July of 2017 (4 surveys, n = 18,202 images; Figure 1) and 2018 (4 surveys, n = 13,779 images; Figure 2). The survey design consisted of three types of sampling: (1) random transects, (2) optimal transects that were developed by minimizing model-based prediction variance, and (3) abundance transects that were optimized based upon the predicted abundance of sea otters from the previous survey year (Williams et al. 2018). Data from the three transect types were combined cohesively in a hierarchical model to produce one estimate of abundance (Williams et al. 2017a).

Aerial surveys were conducted from a de Havilland Canada DHC-2 Beaver single-engine high-winged, float-equipped aircraft. The aircraft was flown at ~210-230 m altitude at 157-166 km/hr. Digital photographic images of sea otters (Figure 3) were taken directly below the plane using a digital camera (Nikon D810, 36.3 megapixel) with an 85 mm focal length lens (Zeiss F 1.4 AF.2).

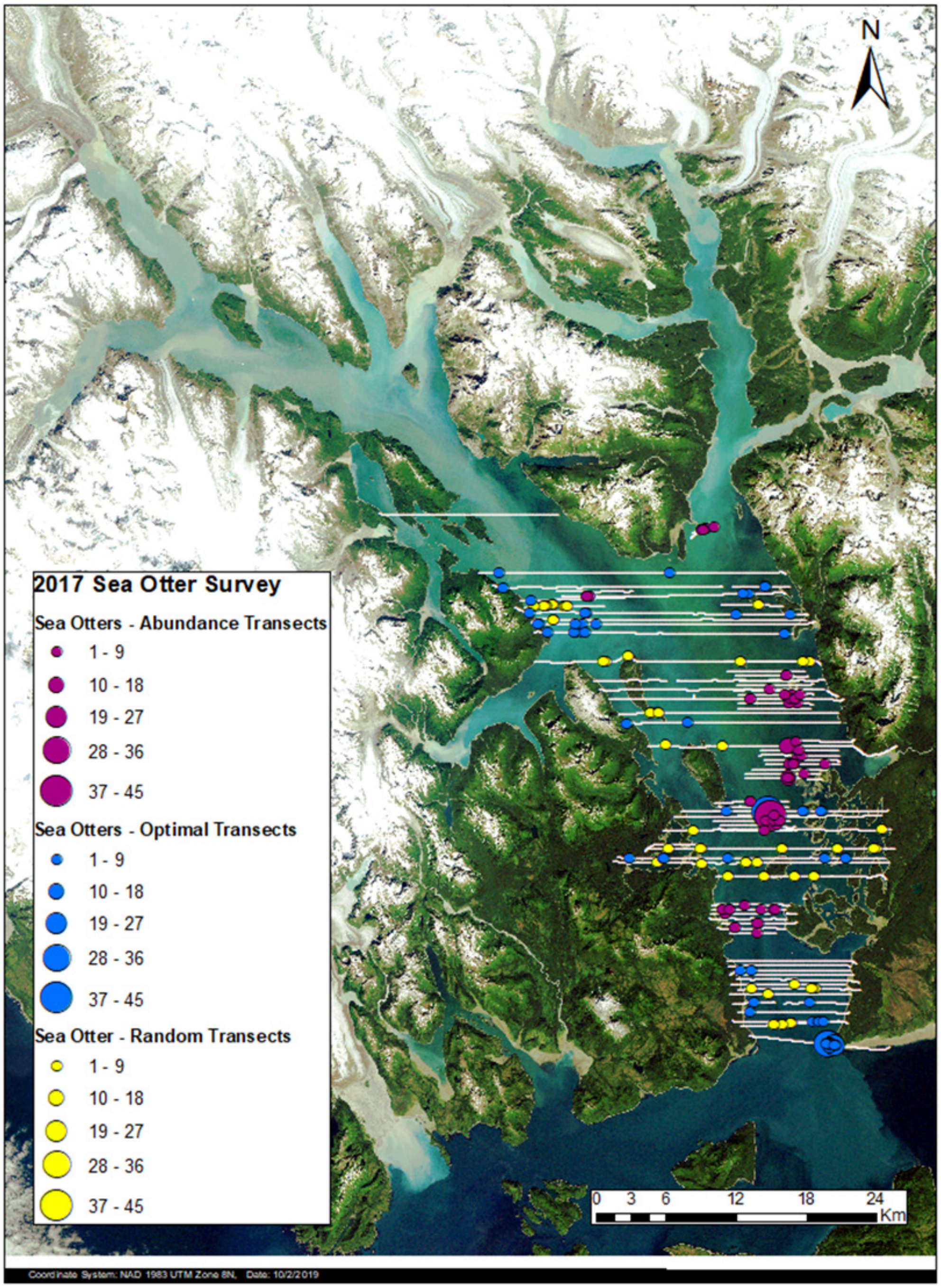

Figure 1. Number and location of sea otters counted in digital photographs that were collected along three transect types: abundance, optimal, and random transects in Glacier Bay National Park during July 2017.

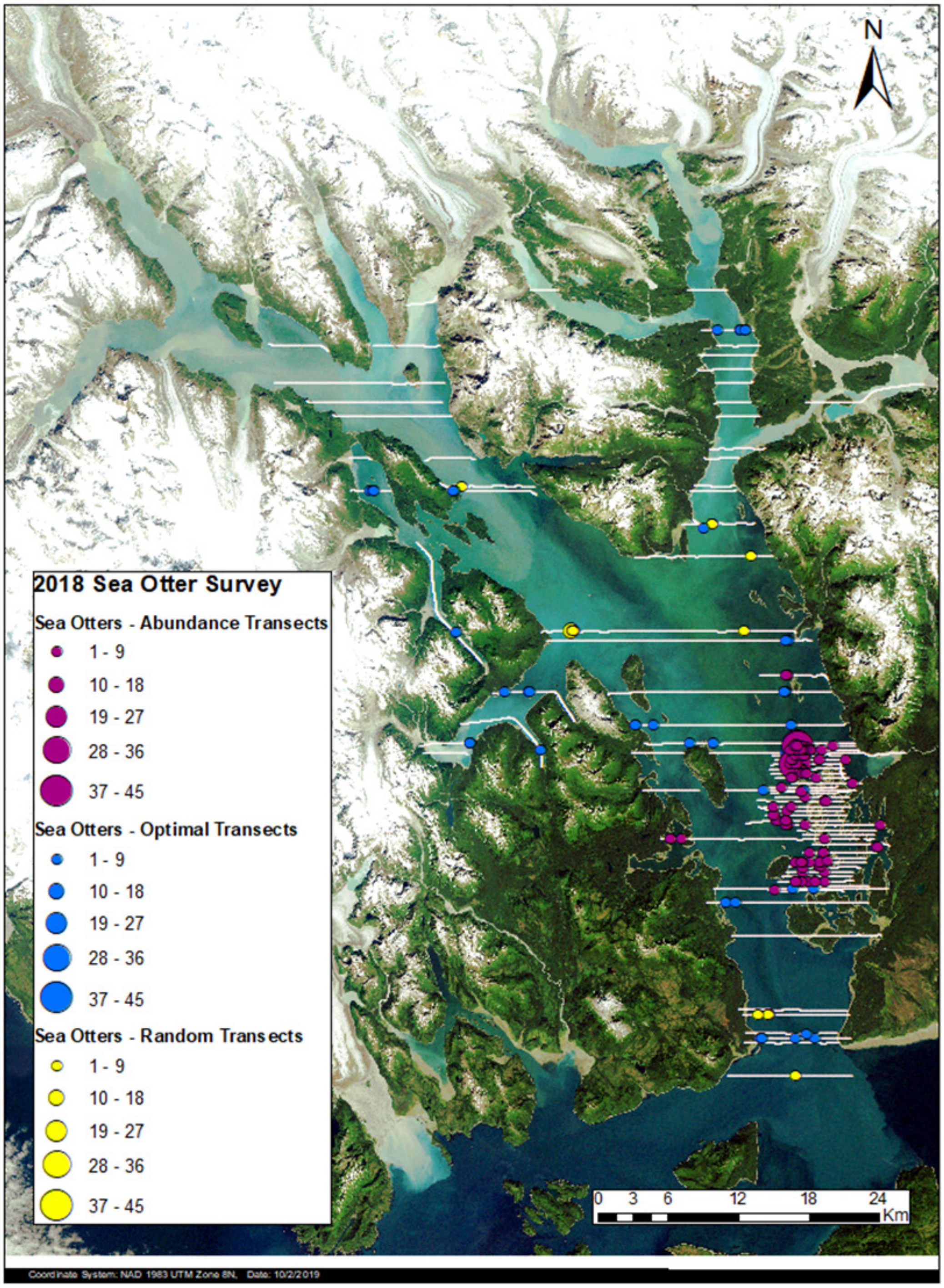

Figure 2. Number and location of sea otters counted in digital photographs that were collected along three transect types: abundance, optimal, and random transects in Glacier Bay National Park during July 2018.

Figure 3. Example of digital image of sea otters taken during aerial photographic surveys in Ripple Cove in Glacier Bay National Park (NPS/Jamie N. Womble).

The camera was attached to a tripod head and vertically aimed and mounted on a platform that was secured in the belly of the aircraft. A digital timer triggered the shutter release at 1-second intervals. Each digital image (7,360 x 4,912 pixel JPG) covered approximately 90 m x 60 m at the surface of the water with an approximate 1.23 cm pixel resolution.

Following the survey, the digital images and GPS tracklogs (Womble and Taylor 2019) were downloaded, renamed, geocoded, and saved to the National Park Service Indian Point server for archiving and storage. All images were reviewed, organized, and renamed. The latitude, longitude, and altitude from the tracklog were written to the EXIF headers of each digital image to embed the location data into each image permanently. Images were imported into CountThings (Dynamic Ventures, Inc., Cupertino, California), a custom software program, where an experienced observer reviewed each image and marked each sea otter in the image. The total number of otters in each image along with attribute data including image name, date, time, latitude, longitude, and altitude were exported from CountThings into a CSV file for analysis (Womble and Taylor 2020a, Womble and Taylor 2020b). Detailed methods for post-processing imagery are described in Womble et al. 2018.

To estimate spatio-temporal sea otter abundance in Glacier Bay from 1993-2018 and to understand the effect of environmental factors on population dynamics, a hierarchical model was developed using three different sources of sea otter aerial survey data: observer-based distribution surveys (1993, 1996-1998, 2004-2006, 2009-2010), observer-based abundance surveys (1999-2004, 2006, and 2012; Esslinger et al. 2015, Esslinger 2019), and counts from aerial photographic surveys (2017-2018; Williams et al. 2017a and 2017b). The initial model incorporated Malthusian (i.e., exponential) growth (Williams et al. 2017a), which assumed that the per capita growth rate remains the same regardless of population size (Turchin 2003). The model was subsequently modified to include logistic growth, which assumes that the per capita growth rate declines linearly as the population size approaches a maximum, which is more realistic to characterize population growth during the colonization phase (Lu et al. 2019). Details of the models and associated code can be found in Williams et al. 2017a, Womble et al. 2018, Lu et al. 2019. Complete details regarding specific methods and procedures for data collection and analysis can be found at the SEAN sea otter monitoring protocol package 2017.1 at https://irma.nps.gov/Datastore/Reference/Profile/2248282. Code used for the analysis can be found in Standard Operating Procedure 9 Version 2.0 at https://irma.nps.gov/Datastore/DownloadFile/640058.

Results and Future Directions

During 2017 and 2018, large aggregations of sea otters occurred at Point Gustavus, Ripple Cove, Boulder Island, Flapjack Island, Scidmore Bay, Caroline Shoal, Geikie Inlet, Lone Island, Geikie Rock, and Russell Island (Figures 1 and 2). Since approximately 2015, smaller groups of sea otters have been documented in the upper reaches of Glacier Bay in Adams Inlet, McBride Inlet, Muir Inlet, Tarr Inlet, and John Hopkins Inlet. Sea otters have also been documented resting on land (at Boulder Island, Spider Reef, Leland Reef, Scidmore Bay) and on icebergs (in Tarr Inlet and McBride Inlet) in Glacier Bay.

The model-based estimates of sea otter abundance in Glacier Bay generally increased through 2016 (Figure 4; Table 1). The incorporation of logistic growth into the model improved forecasts of sea otter abundance in Glacier Bay from 1993 to 2018 (Figure 5; Lu et al. 2019).

Sea otter aerial photographic surveys will continue to occur on an annual basis in Glacier Bay to estimate the distribution and abundance of sea otters and to provide baseline data for understanding the influence of sea otters on the nearshore food web. Beginning in 2020, collaborative efforts to develop a quantitative ecological model of the nearshore food web in Glacier Bay were initiated in collaboration with NPS, USGS, and CSU. The project will assimilate and use long-term monitoring data in a contemporary analytical framework and provide a foundation for understanding both top-down and bottom-up drivers of the nearshore benthic food web in Glacier Bay. Such models can be used to guide future research and monitoring priorities, sampling designs, and optimize efficiency of future efforts related to sea otters and the nearshore benthic food web in Glacier Bay.

Future research that would complement the existing monitoring effort includes the development of methods and algorithms for automated detection of sea otters in aerial photographs (e.g., Seymour et al. 2017), which could provide for more efficient post-processing of data which can be time-consuming and costly. In addition, it would be useful to investigate the utility of using data from time-depth recorders or other telemetry devices to estimate the proportion of time that sea otters are available to be photographed at the surface to refine estimates of availability (Williams et al. 2017b, Womble et al. 2020). Finally, the development and evaluation of unmanned aerial systems (UAS) as a platform for sea otter surveys is planned for 2021 and will be important for reducing risks and costs associated with human-occupied aerial surveys.

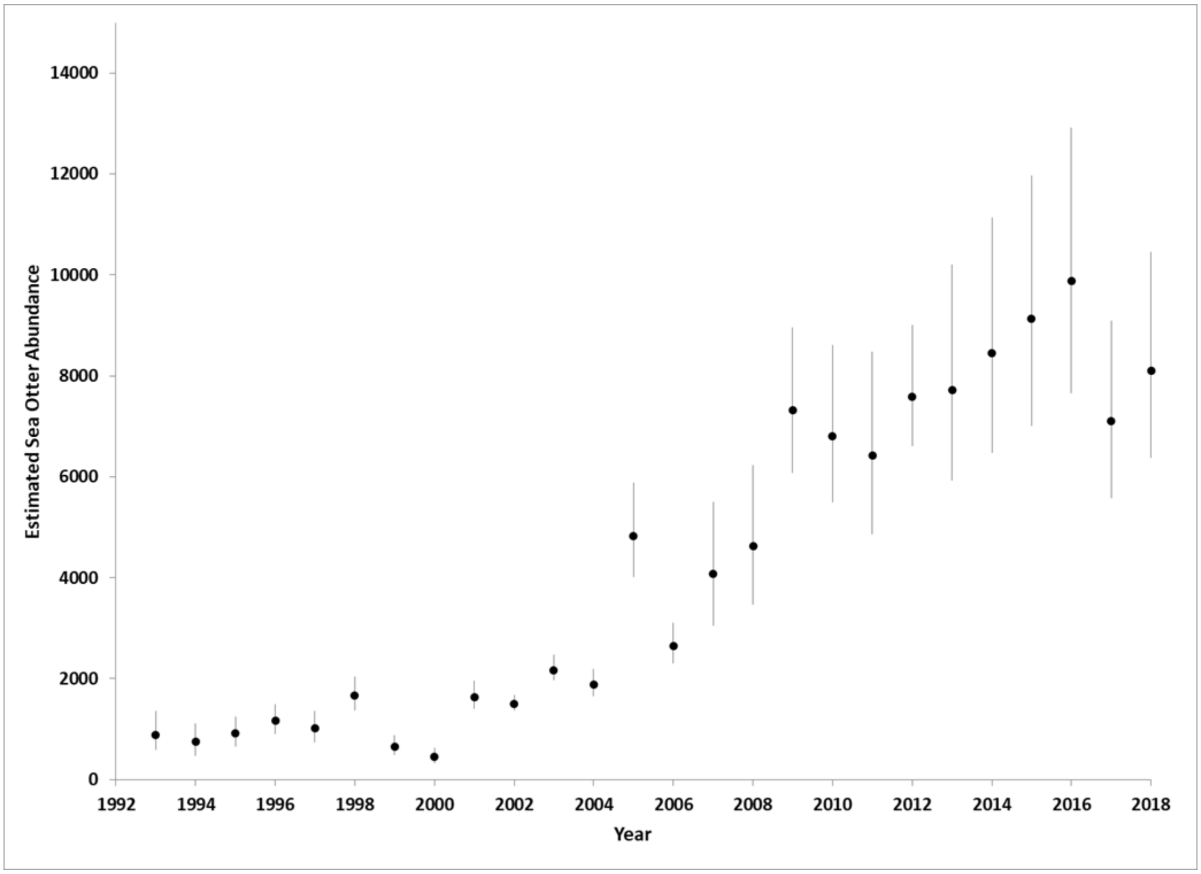

Figure 4. Model-based estimates of sea otter abundance in Glacier Bay National Park from 1993 to 2018 (Lu et al. 2019). Model-based estimates are the posterior mean and 95% credible intervals from the spatio-temporal integrated population model. Data from 1993-2012 were collected during observer-based aerial surveys that were conducted by US Geological Survey (Esslinger et al. 2015, Esslinger 2019). Data from 2017 and 2018 were collected by NPS using aerial photographic methods described in Womble et al. 2018.

Table 1. Model-based abundance estimates (posterior predictive mean) of sea otters and 95% credible intervals in Glacier Bay National Park from Lu et al. 2019. Data from 1993-2012 were collected by US Geological Survey using observer-based aerial surveys (Esslinger et al. 2015, Esslinger et al. 2019). Data from 2017 and 2018 were collected by NPS using aerial photographic methods (Womble et al. 2018).

Year	Mean Abundance	95% Credible Interval
1993	893	(599, 1363)
1994	749	(485, 1112)
1995	915	(667, 1251)
1996	1165	(907, 1495)
1997	1020	(746, 1367)
1998	1667	(1371, 2046)
1999	647	(488, 878)
2000	450	(323, 624)
2001	1635	(1408, 1956)
2002	1505	(1381, 1683)
2003	2174	(1969, 2477)
2004	1886	(1659, 2196)
2005	4823	(4028, 5882)
2006	2646	(2312, 3114)
2007	4076	(3060, 5505)
2008	4623	(3479, 6232)
2009	7321	(6077, 8966)
2010	6810	(5495, 8607)
2011	6417	(4875, 8479)
2012	7592	(6621, 9009)
2013	7724	(5937, 10213)
2014	8454	(6480, 11131)
2015	9138	(7015, 11962)
2016	9889	(7661, 12916)
2017	7100	(5586, 9086)
2018	8108	(6374, 10456)

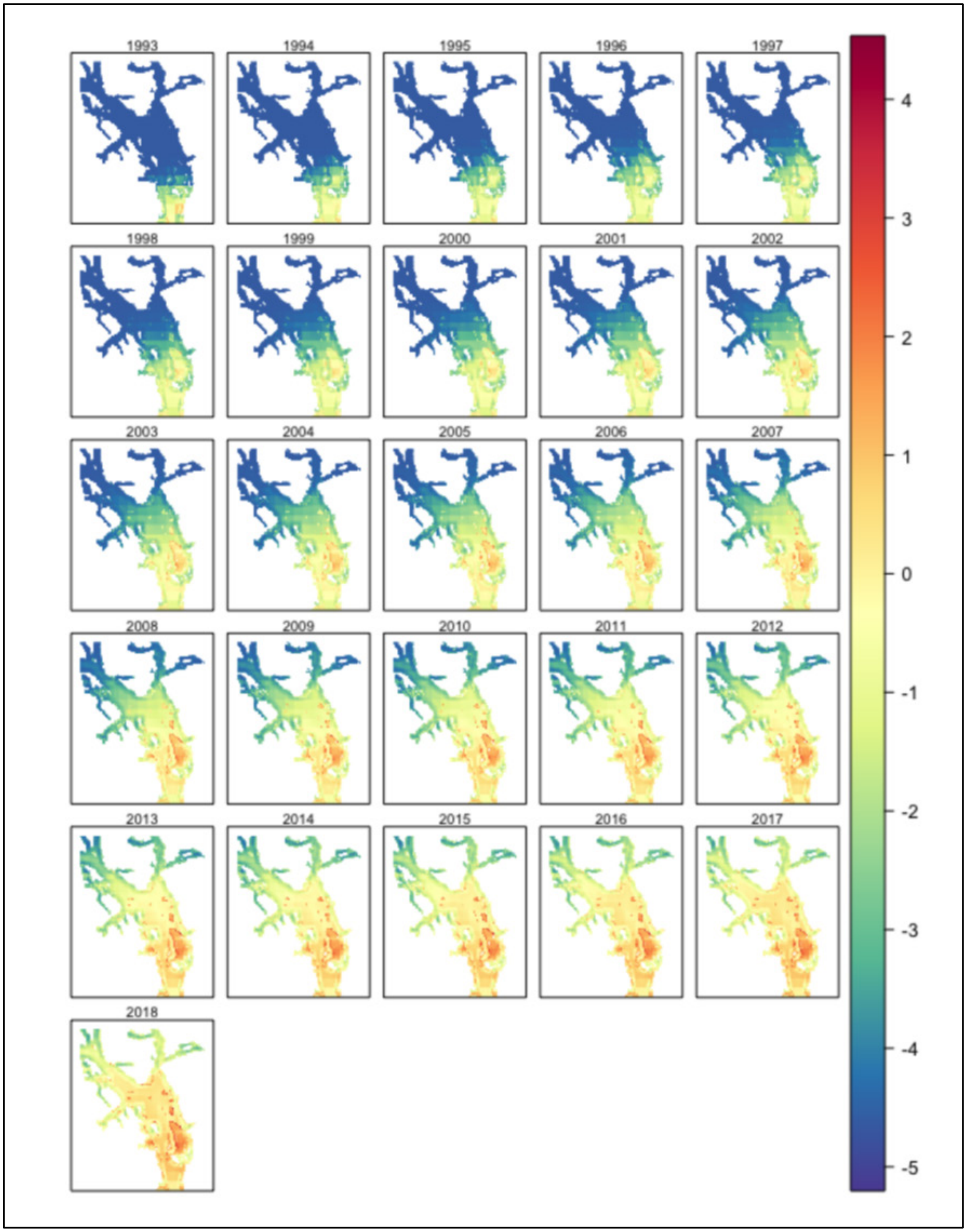

Figure 5. Log of estimated posterior mean sea otter abundance in Glacier Bay from 1993-2018 from Lu et al. 2019.

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