Sand Harbor Asian Clam Survey – 2023 Annual Report

FINAL REPORT

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UCDAVIS
Tahoe Environmental
Research Center
Brandon Berry, Katie Senft, Helen Fillmore, Geoff Schladow

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Introduction

The Tahoe Environmental Research Center (TERC) conducted a three-year project to delineate the Asian clam (*Corbicula fluminea*) population at Sand Harbor State Park in collaboration with the Nevada Division of State Lands. The three-year project was initiated in 2021 with the third and final year of monitoring completed in 2023. To complete this assessment, this project included:

- Underwater SCUBA transects and density plot surveys for Asian clams to determine the extent and densities of the invasive Asian clam populations.
- Unmanned aerial vehicle (UAV) flights to obtain aerial photographic imagery of metaphyton coverage.
- Remote sensing of the clam survey area using the collected UAV imagery to assess growth of metaphyton associated with clam populations.

The following report is a summary of methods and results for the three-year project and includes discussions and recommendations for future management actions.

Methods

A survey area was outlined by Nevada Division of State Lands (NDSL) that encompassed the lakeward areas from the shoreline to a depth of approximately 15m (lake surface elevation = 6229.1 feet) surrounding Sand Harbor State Park. The delineated area was approximately 539,000 m^2 (53.9 hectares). Fieldwork and surveys for year three were completed September 5 – 15, 2023.

Scuba Transects

Methods for scuba transects in year three were consistent with years one and two. The survey area was divided into four sections representing changes in the shoreline structure or geographic orientation. These included (1) the large south facing swim beach here to referred to as Big Beach, (2) the rocky point, (3) Divers' Cove, and (4) the boat ramp and adjoining beaches. Forty linear transects, spaced at 25m intervals, were established parallel to shore from the full lake water line (6229.1 ft elevation) to a depth of 15m (Figure 1). Three shoreline transects, located at the high-water line, were included in the forty transects. The water surface elevation of Lake Tahoe during the survey period was 6227.87 ft (9/5/2023; USGS gage height Tahoe City, CA). During the 2022 and 2021 surveys, the water surface elevation was 6223.58 ft and 6223.62 ft respectively. Lake Tahoe's water surface elevation was over four feet higher during 2023 surveys as a result of the above average winter precipitation during the 2023 water year.

Approximately every 5m, each dive team member sieved an area of about 0.04m^2 of sediment to a depth of ~15cm using a fine mesh (6mm) minnow trap. Clams were counted on site and noted on underwater data sheets so that changes in clam abundance would be known along each transect. Divers completing underwater transect counts are shown in Figure 2.

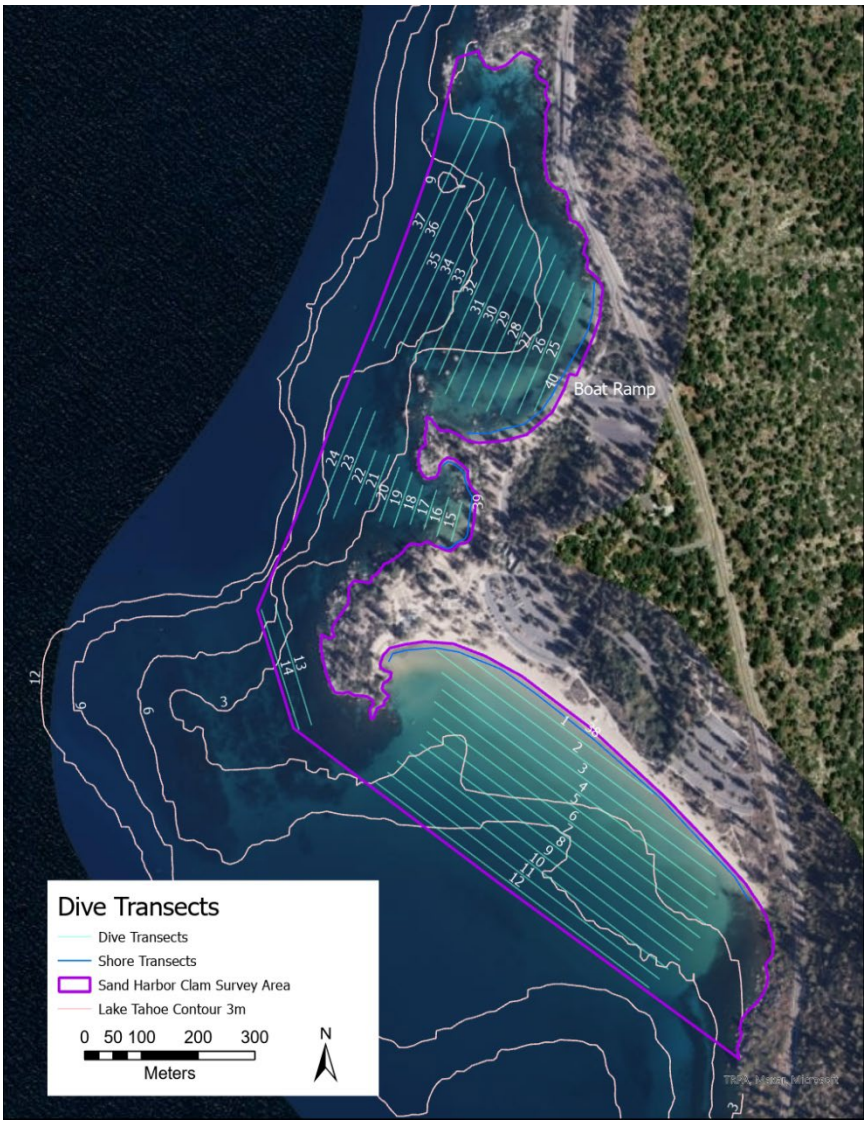


Figure 1: Sand Harbor clam monitoring area with dive and shore transects.

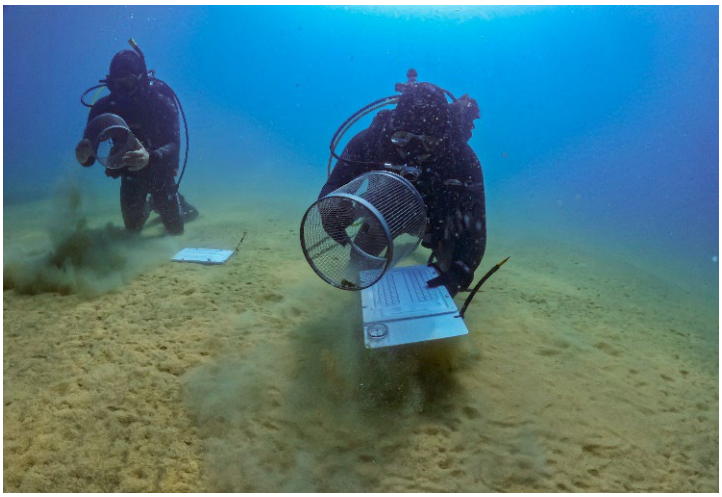


Figure 2: TERC divers complete clam counts along transect lines at Sand Harbor State Park, NV.

Density Plots

To better quantify the density of the clam population throughout the study area, 60 randomly generated excavation plots were created. In each of the three years of monitoring, 60 density plots were randomly regenerated. These plots were moved each year to ensure that clam density data was not affected by previously excavated sites (Figure 3).

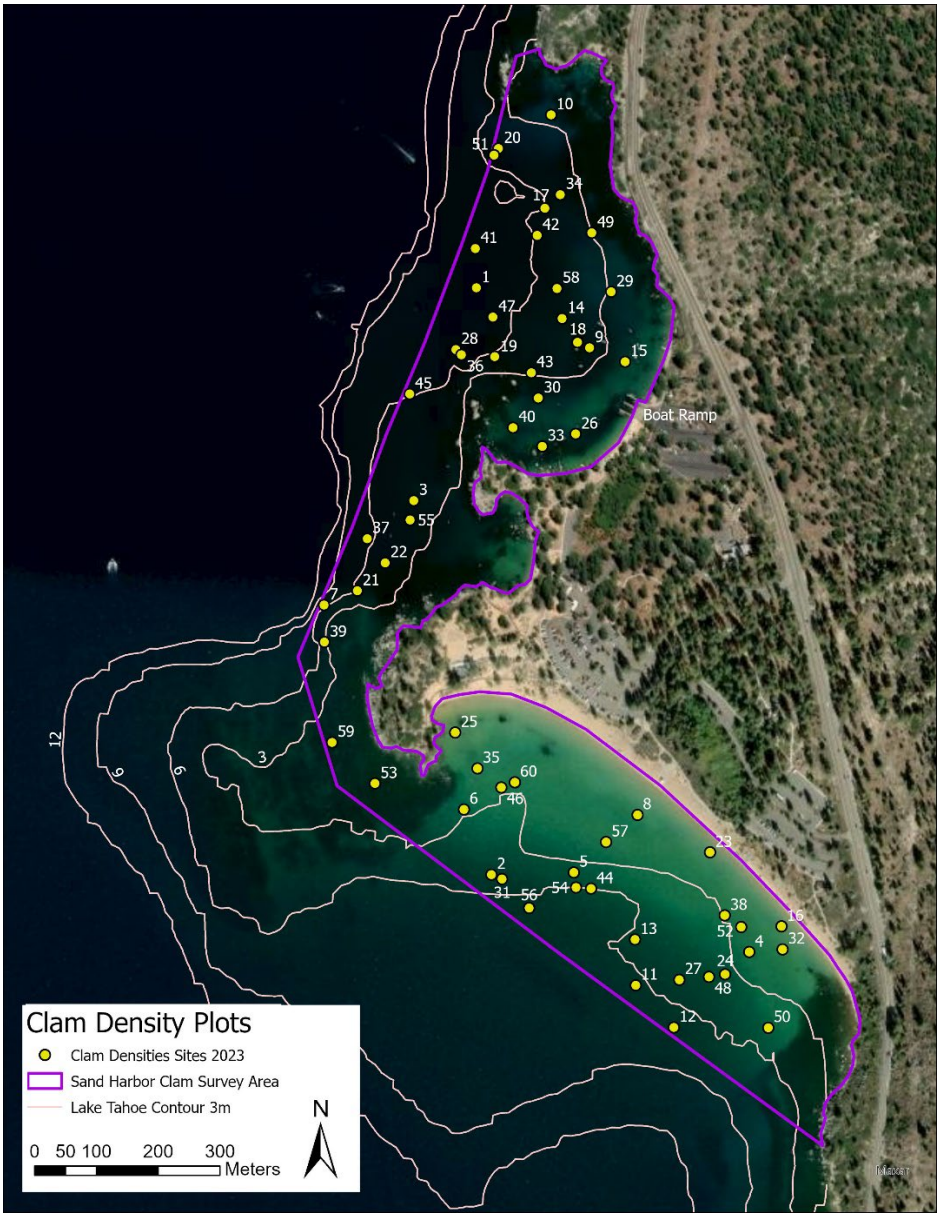


Figure 3: Plot number and location of clam density excavation plots for 2023 monitoring.

A weighted 1 m^2 PVC frame was placed on the substrate. Clams were removed from within the plot using a fine mesh minnow trap. Clams collected from each plot were taken to the laboratory and preserved in 80% ethanol until counting and size determination could be completed. Clam shells that were open and contained no attached tissue were counted as dead clams. Shells that were closed or slightly open and contained clam tissue were considered to be live individuals at the time of collection. The length and width of each clam was measured to the nearest 0.01mm using digital calipers.

Clam size is used to estimate the age structure of the population and whether new recruitment of young is occurring. For the purposes of this survey, clams < 11 mm were classified as juveniles and those >11 mm classified as the adult reproductive segment of the population. These sizes are based on findings of maturity and fecundity in Lake Tahoe (Denton et al. 2012). Determination of the population percentage that is of reproductive size indicates the potential for population expansion the following year.

Orthomosaic Drone Imagery

Unmanned aerial vehicle (UAV) monitoring at Sand Harbor State Park was completed to obtain aerial imagery data associated with metaphyton growth inside the survey area. UAV flights were conducted in conjunction with SCUBA surveys to provide concurrent assessment of metaphyton coverage during monitoring.

The UAV was a DJI Phantom 4 Pro©. The Phantom 4 Pro is a quadcopter format consumer/professional grade UAV. The integrated 20-megapixel camera provides detailed imagery with a sufficient ground sample distance (GSD) for data acquisition. Flight planning and image capture were collected through ESRI Sitescan software. The standard 'lawnmower' flight path was executed to maximize coverage for mapping the clam survey area. Three separate flight paths were completed to cover the Sand Harbor clam survey area; flights were completed over the boat ramp, Divers' Cove, and Big Beach. Adequate overlap between flight paths ensured sufficient coverage of the designated survey area. These techniques have previously been used to assess metaphyton coverage along the southeast shore of Lake Tahoe (Hackley 2020).

Post processing and analysis of aerial imagery is completed using ESRI Sitescan® software. Images collected by the UAV are individually calibrated and geo-referenced in the initial pre-processing of the software. Images are then 'stitched' together using generated keypoints by the Sitescan software. Keypoints are matched between consecutive images, allowing for a seamless stitching of images into one large image. Generally, orthomosaic processing is difficult to complete overwater because of the homogeneity of the water body. However, due to the clarity of Lake Tahoe's water, images of the nearshore (<10m) can be successfully processed. Natural environmental factors such as submerged rocks and woody debris can positively affect the ability to successfully recreate an orthomosaic by generating additional reference points while surface glare, turbidity, and dissolved organic matter (DOM) hinder the process. Therefore, the natural characteristics of the site, weather, and time of day can impact orthomosaic generation.

Determination of percent cover of metaphyton at Sand Harbor was evaluated using ArcGIS Pro®. Completed orthomosaics were analyzed in ArcGIS Pro and used to determine metaphyton coverage in the established survey area. Analysis methods are detailed in previous years reports.

Results

Clam transects

Scuba surveys conducted from September 5 – 15, 2023 detected established clam populations in the waters surrounding Sand Harbor State Park. Similar to the preceding two years, clams were found off the large south facing swim beach (Big Beach), around the rocky point, in Divers' Cove, and throughout the boat ramp area. The data from the sieving along each of the 40 transects was represented as a heat map showing the relative abundance of clams throughout the survey area (Figure 4).

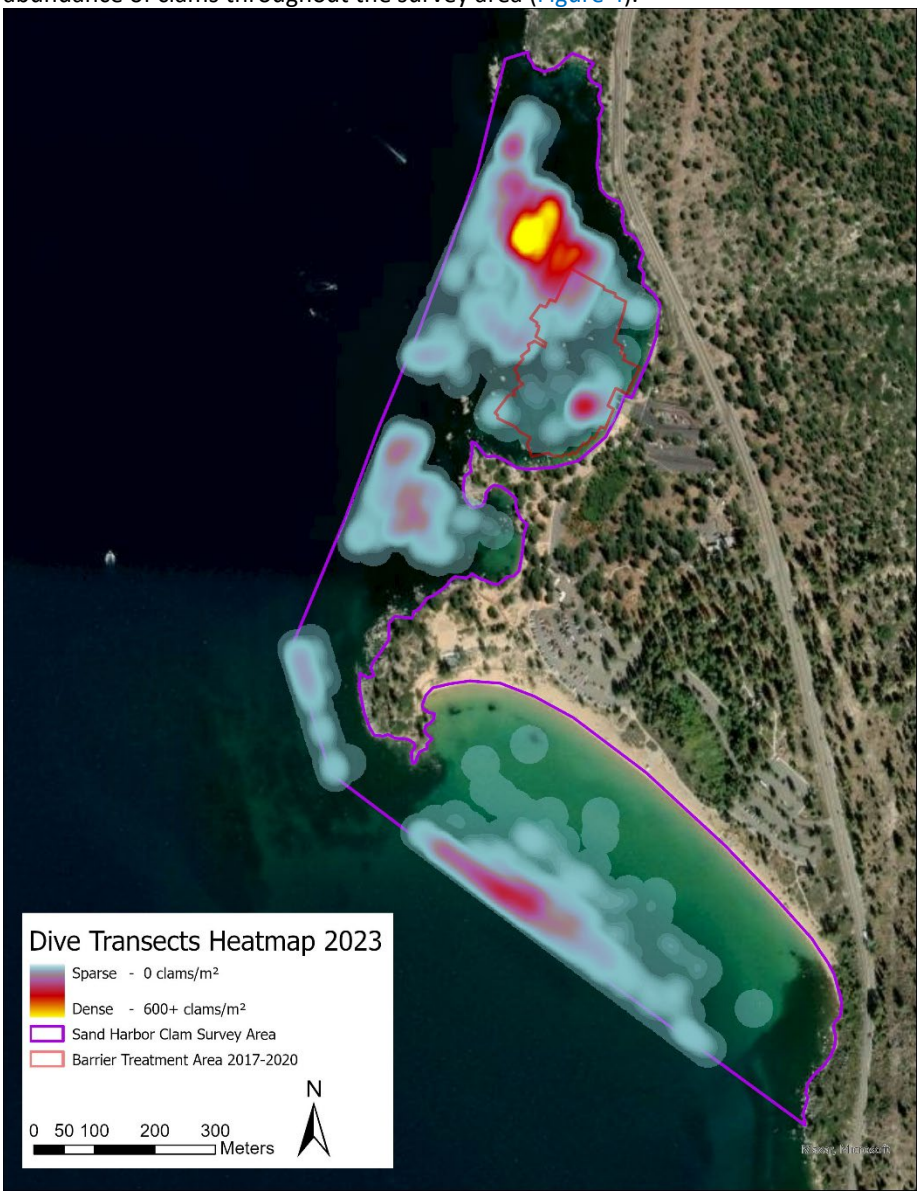


Figure 4: Dive transects clam abundance heat map for 2023 monitoring.

Density Plots

Densities were generally low (0 – 30 clams/m^2) with the exception of localized populations with increased densities (>50 clams/m^2) at the north side of the cove encompassing the boat ramp, the outside of Divers' Cove, and the outer most transects off Big Beach (Figure 5). Clam counts from each diver were averaged and are reported in Appendix 1. These findings were supported by both the relative abundance found along survey transects and by quantified densities from the density plots.

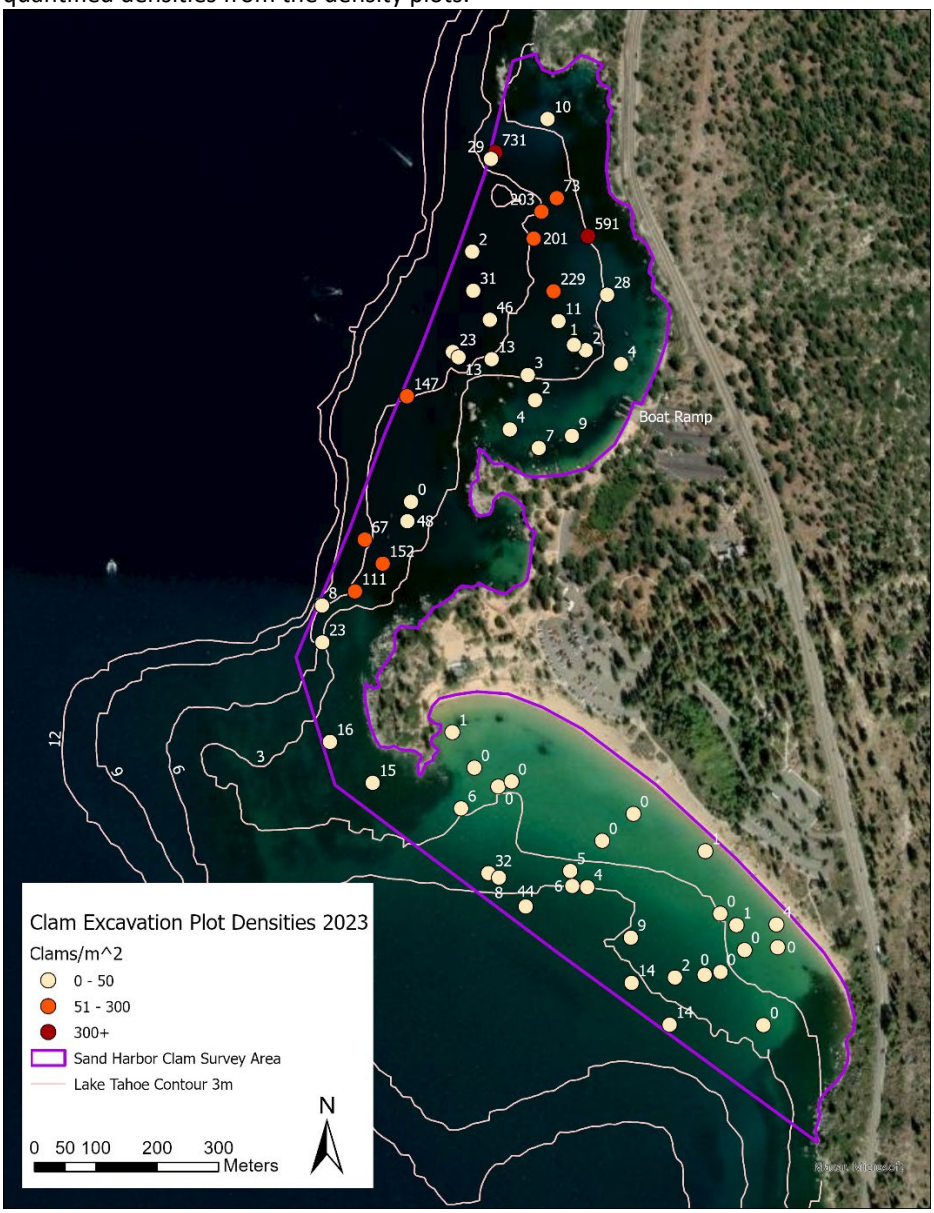


Figure 5: Clam excavation plot densities 2023 monitoring.

The population throughout the Sand Harbor survey area was made up of both juvenile (<11 mm) and adult (>11 mm) clams. Estimates can be made about population dynamics and reproduction based on the percentage of juveniles in each density plot. Reproductive data from 2023 indicates a larger percentage of adult clams throughout the entire survey area. The density plots with the highest numbers of clams collected (Plot #20, #49) contained 66% and 79% adults respectively. Densities composed of primarily adults indicate areas that have the potential to increase significantly through reproduction into 2024.

Observations in areas of established clam growth in Lake Tahoe suggest that clam densities greater than 100 clams/m^2 are capable of supporting heavy metaphyton algae growth. This was corroborated by observations at Sand Harbor State Park during the 2021 and 2022 scuba surveys. Insignificant metaphyton algae was present during 2023 surveys. Decreased metaphyton growth was observed throughout the entire nearshore of Lake Tahoe in 2023 (Smitts et al., 2024).

Orthomosaic Drone Imagery

Orthomosaic imagery of the clam survey area at Sand Harbor was completed to provide a concurrent dataset of the Sand Harbor study area (Figure 6). These surveys were completed in conjunction with the SCUBA surveys in September, 2023. Metaphyton algae was not present in the survey area during 2023.

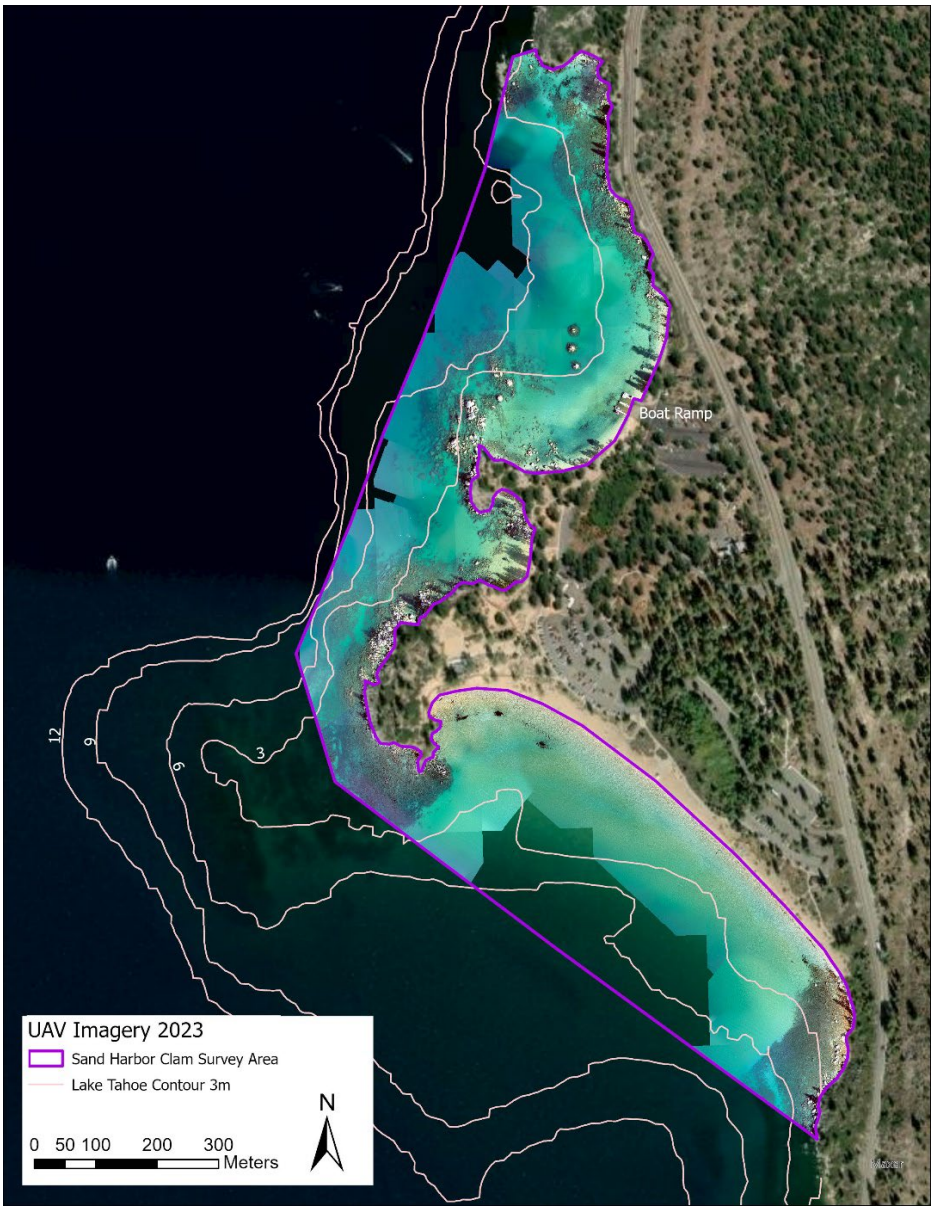


Figure 6: UAV orthomosaic imagery of Sand Harbor survey area for 2023.

Discussion

Overall, the clam population and its spatial extent at Sand Harbor State Park continued to grow during 2023. Peak densities in the boat ramp area remained static with the population shifting geospatially on a localized level. Transect data indicate the boat ramp population shifted to the northwest, with density dynamics of the population comparable to 2022. Clam densities outside of Divers' Cove have increased within the last year. Densities increased in the area and the population continued to expand eastward towards the beach at Divers' Cove. Clam densities in the Rocky Point area increased in 2023. The population continues to expand further into the Big Beach area with densities increasing as well. Figure 7 outlines the spatial expansion of the clam population between 2022 and 2023 surveys.

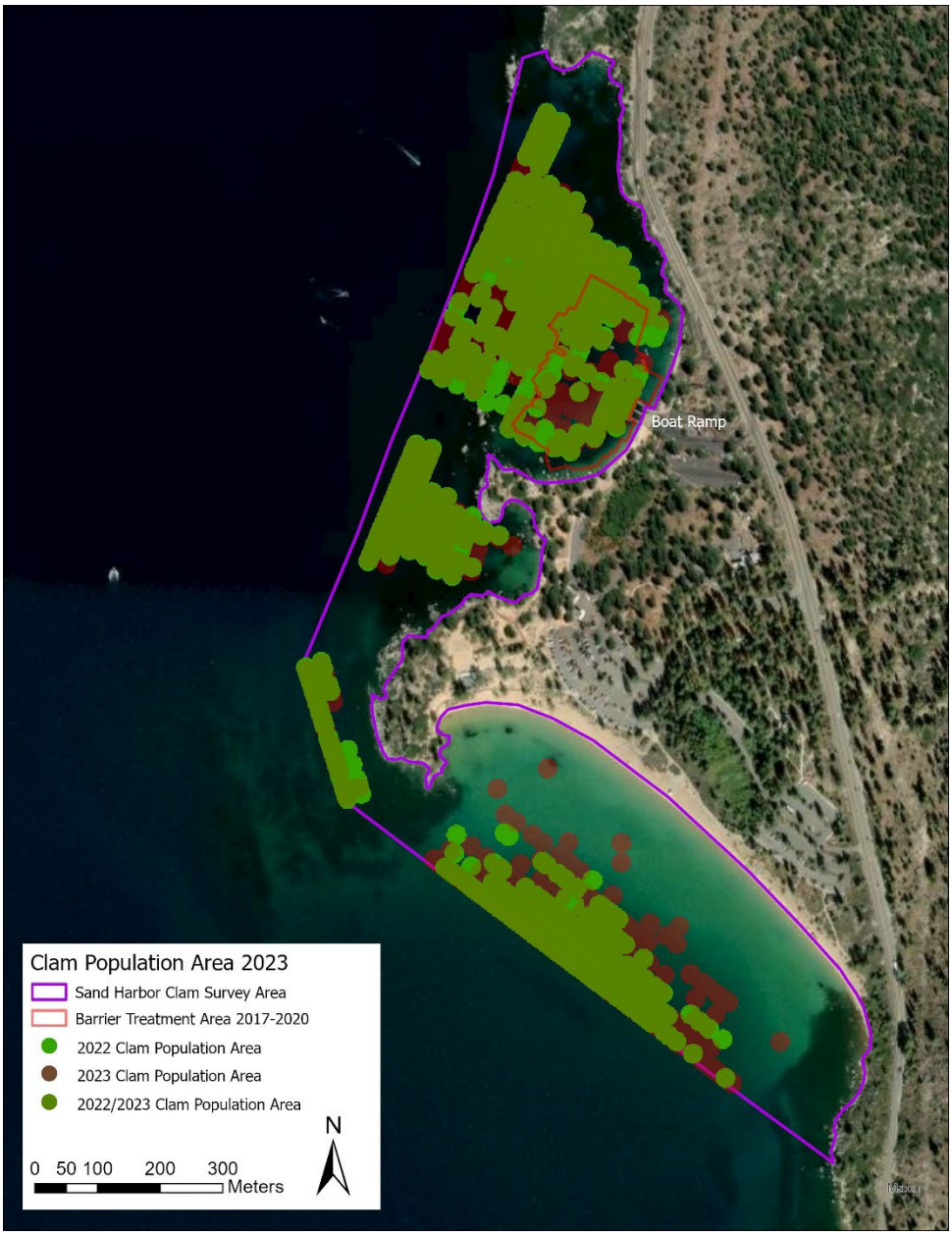


Figure 7: Clam population area expansion from 2022 to 2023.

With all three years of monitoring completed at Sand Harbor State Park, the data provide a compelling narrative that the clam population continues to grow and expand spatially throughout the park year over year. Clam densities and spatial coverage have increased significantly since the first surveys in 2021. Density plot excavation data (Appendix 2) indicates peak density of 1102 clams/m² at plot #65. Transect data (Appendix 1) indicate a constant increase in clam densities throughout the survey area. The one exception to this is the area of highest densities in the northern boat ramp area which remained relatively static between 2022 and 2023, potentially due to increased water surface elevation during the 2023 water year (Figure 8). Geospatial population dynamics may vary slightly between years with localized movements in the densest population areas (boat ramp area). A spatial representation of the increase in clam population between 2021 and 2023 is displayed in Figure 9, red representing areas where population has increased.

Figure 8: Lake Tahoe water surface elevation above gage (6220 ft) data (USGS).

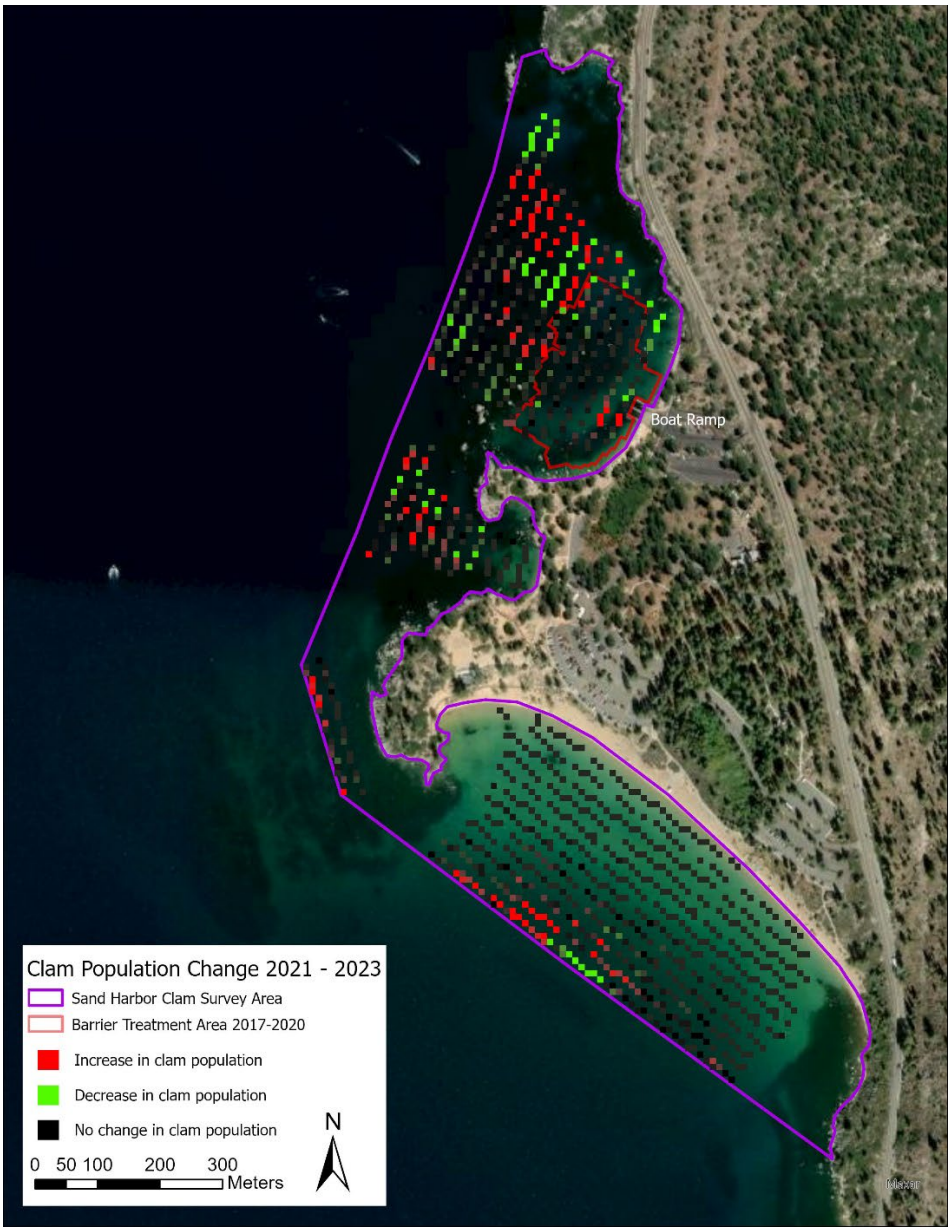


Figure 9: Clam population change between 2021 and 2023 surveys.

Clam densities continue to remain low throughout the bottom barrier treatment area near the boat ramp. The success of the bottom barrier treatments (2017 – 2020) was well documented in 2021. In 2023, the zone treated with bottom barriers contains small areas with increases in population, but overall clam densities are much lower than surrounding areas. The northern section of the treatment area has experienced an increase in population. This section is adjacent to the highest densities in the survey area and is likely due to localized movement and recolonization influenced by physical properties (currents, water surface elevation, temperature). A small section near the boat ramp also experienced an increase in clam numbers in 2023. This is the same location where clams were first discovered at Sand Harbor and may be attributed to transport through watercraft. A map displaying individual clam counts from 2023 surveys of the treatment area provides visual context to the recolonization occurring (Figure 10). Overall, low numbers within the treatment zone, three years post-treatment, are evidence of the effectiveness of bottom barrier treatment in managing clam populations. Despite the intensive economic investment, bottom barriers remain a top solution in combating Asian clams at Lake Tahoe.

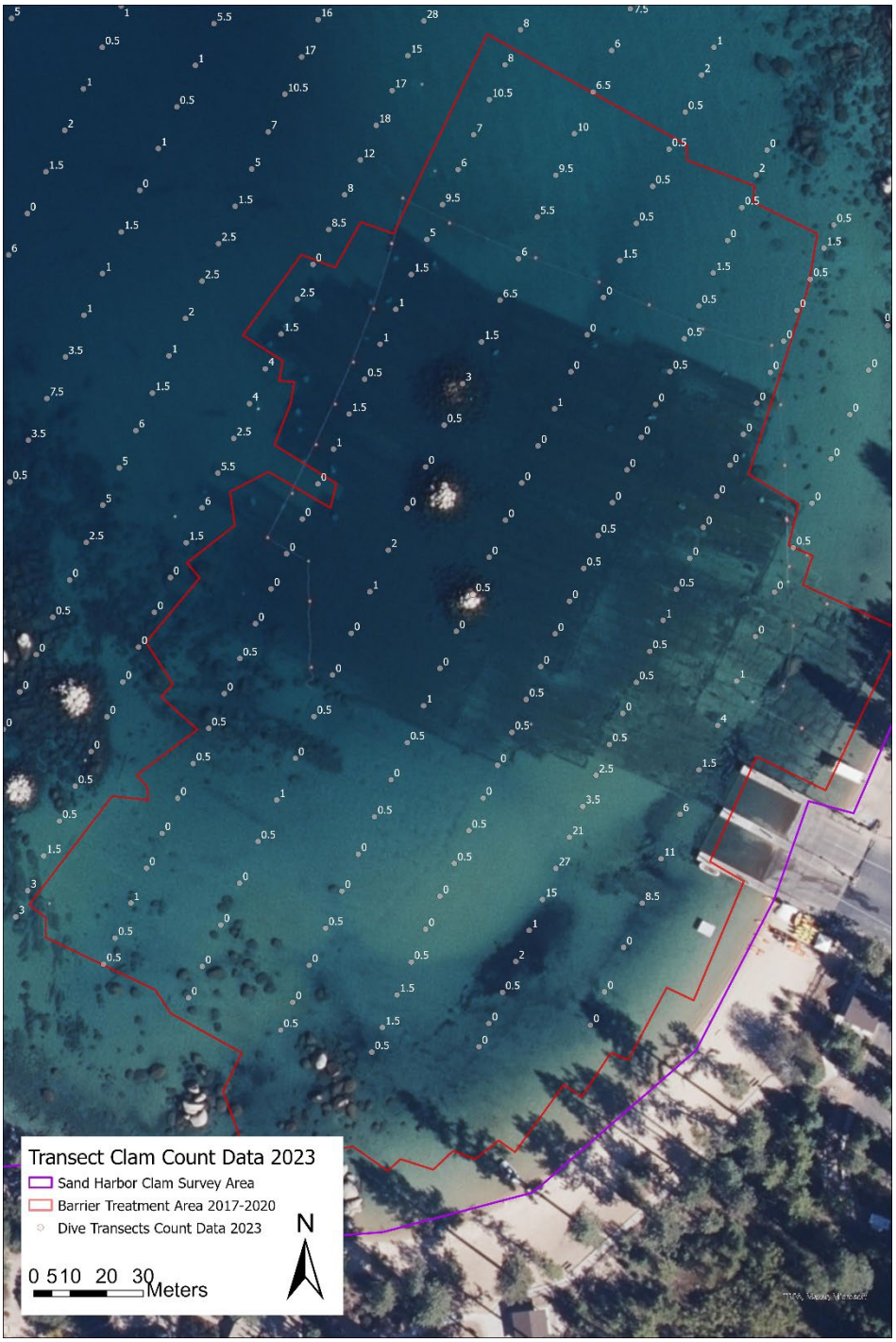


Figure 10: Individual clam counts along transect lines in the treatment area for 2023.

While metaphyton algae growth was insignificant during the 2023 survey period, that should not be considered the standard. The abnormally large winter precipitation during the 2023 water year likely influenced metaphyton growth, resulting in less algae at Sand Harbor as it did the rest of Lake Tahoe. As the clam population continues to increase at Sand Harbor, the likelihood of metaphyton algae blooms will increase in tandem. Asian clams filter water from the water column and excrete nutrients producing a concentration of nutrients in the benthic zone. As water temperatures increase, clams become more metabolically active, producing more nutrients (Denton et al 2012). Warmer water temperatures associated with the summer season at Lake Tahoe promote the process. The

increase in nutrients leads to propagation of algae and increased metaphyton blooms. Anecdotally, metaphyton growth originates around areas of high clam densities (>100 clams/m^2). As Lake Tahoe continues to change due to a warming climate, water temperatures will continue to rise enabling a longer timeframe for Asian clams to remain active. These changes can instigate a feedback loop with warmer temperatures leading to increased clam populations, leading to increases in metaphyton algae production.

Size class data analyzed from the 2023 survey indicates a large portion of the Sand Harbor clam population is comprised of adult/reproductive calms (Figure 11). Clam reproduction occurs at water temperatures >14˚C with veliger release occurring at temperatures >16˚C (Denton et al 2012). Rising water temperatures in Lake Tahoe have led to longer reproductive seasons for clams, especially in warm water environments such as Sand Harbor. Temperature data from the TERC nearshore station at Sand Harbor, located at a depth of ~2m near the boat ramp, signifies the reproduction temperature threshold was met from June through the end of October, 2023, providing adult clams 5 months of reproduction at shallow depths (Figure 12).

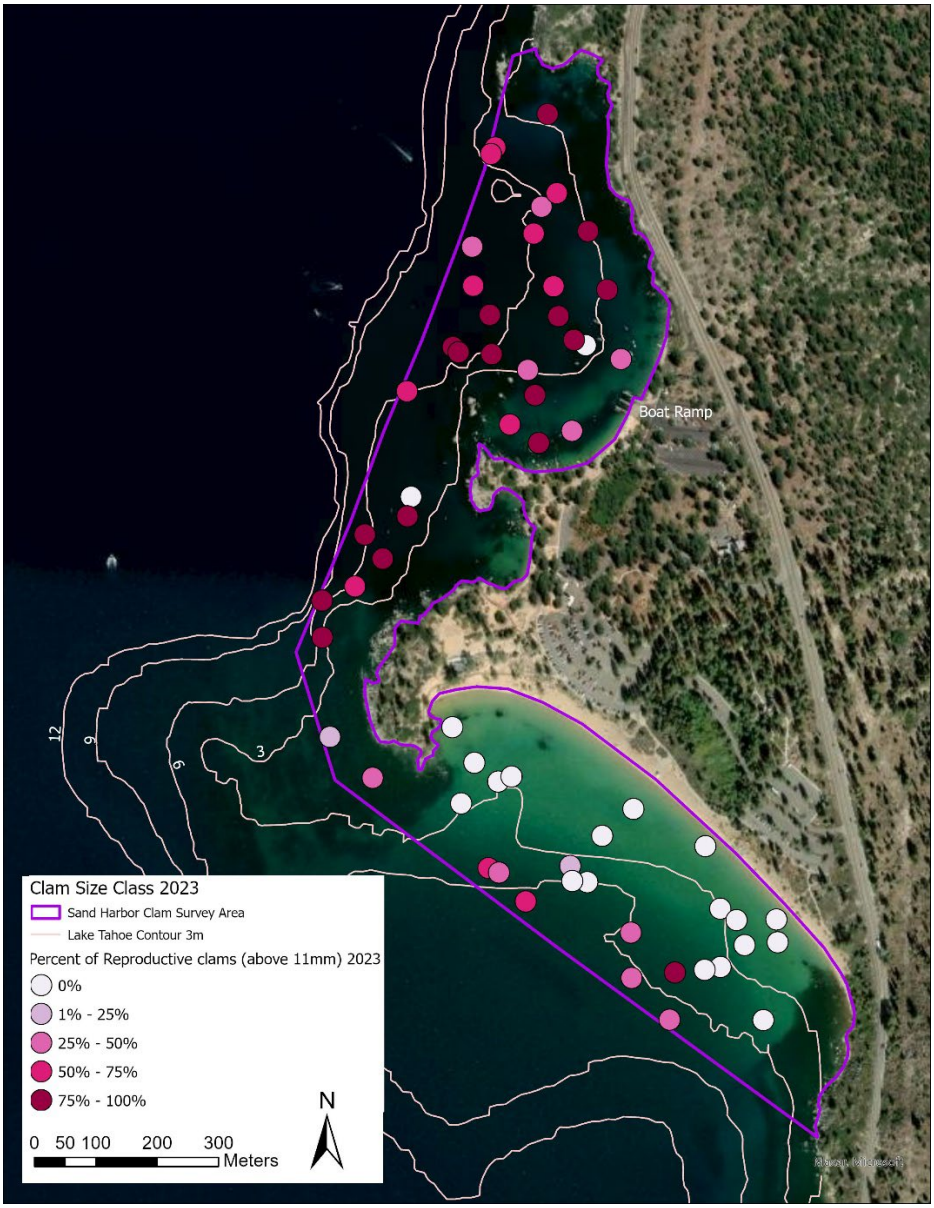


Figure 11: Clam size class densities as percent of reproductive clams (>11mm) at each site.

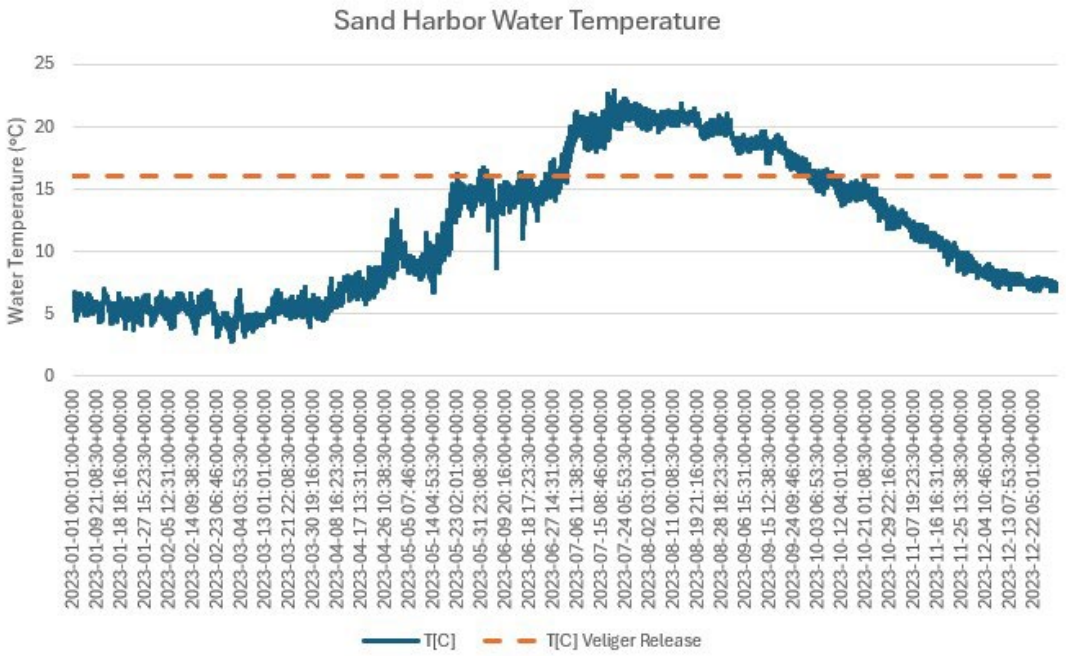


Figure 12: Sand Harbor water temperature data from TERC nearshore station.

Recommendations

Expectedly, the clam population inside Sand Harbor State Park has grown during the duration of the three-year monitoring project (2021 – 2023). Clam densities have increased concurrently with the population expanding spatially throughout the park following the successful bottom barrier treatment. The vast majority of the substrate at Sand Harbor is… sand, providing favorable habitat for Asian clams to inhabit and reproduce. Left unchecked, it can be forecast that the clam population will continue to spread through the entirety of the delineated survey area at Sand Harbor. As the clam population continues to grow, in turn, metaphyton algae growth will follow (Wittmann, 2012). The correlation between increased clam population and increased metaphyton growth is a key metric for the health and aesthetics of Sand Harbor moving forward. A continued understanding of clams and metaphyton will aid in management practices to maintain the pristine environment at Sand Harbor State Park. The following resource management recommendations are displayed in bold. These recommendations should be considered preliminary, and should be followed up with additional data and discussion before implementation.

Relationship between Asian clams and metaphyton growth

The association between Asian clam populations and metaphyton algae growth at Lake Tahoe has been established (Wittmann, 2012). What remains unknown is the Asian clam population density threshold at which clam populations trigger metaphyton production at Lake Tahoe. Research focused on this quantitative relationship would provide resource managers with the necessary information to treat clam populations with the goal of limiting metaphyton algae growth.

Key Management Items:

- Develop research project to determine quantitative relationship between Asian clam densities and metaphyton algae production
- Implement management strategies based on research findings

With an increase in both Asian clams and metaphyton algae over the course of the project, it is recommended that mitigation strategies also be considered. Eradication of clams at Sand Harbor is highly unlikely, but ongoing mitigation efforts may prove sufficient moving forward. Priority should be given to targeted management

strategies aimed at preserving the Tahoe aesthetic represented by the nearshore of Sand Harbor State Park. A strategic implementation plan, specific to Sand Harbor, should be developed to mitigate the negative effects of clams and/or associated metaphyton algae. Controlling the clam population addresses the root of the problem, while management strategies related to metaphyton would be a secondary response.

Treatment of high-density Asian clam population areas

Targeting specific high-density Asian clam population areas may prove an effective method of suppressing clam growth. Strategic maintenance of low clam densities could be enough to limit metaphyton growth in desired locations. Prioritizing high-density areas would limit the size of treatment areas (< 3 acres) and reduce costs while maintaining desired outcomes. This mitigation strategy includes the continued monitoring of Asian clams at Sand Harbor to provide current geospatial/population data and implementing treatment methods to control identified high-density areas.

Key Management Items:

- Continued monitoring of Sand Harbor Asian clam population using established dive transects
- Delineation of high-density Asian clam areas
- Implementation of treatment methods (bottom barriers) at designated areas

Development of new and innovative treatment methods for Asian clams

New techniques for clam removal should continue to be explored. The development of new technologies may provide increasingly efficient solutions that do not exist today. Possible techniques include: suction removal, autonomous vehicles, volunteer divers.

Key Management Items:

- Continued research and development of new treatment methods for controlling Asian clams

Alternatively, if the greatest threat is considered to be the increasing metaphyton blooms, then methods to remove algal mats pre and post transport onshore should be explored. Metaphyton algae can wash onto beaches causing negative impacts to recreation and ecosystem health. The south shore of Lake Tahoe is a good example of the potential negative impacts of metaphyton algae (Figure 13). Potential management actions to address metaphyton include but are not limited to hydrodynamic studies centered at Sand Harbor and algae removal techniques.

Figure 13: Metaphyton algae onshore at a beach in South Lake Tahoe.

Hydrodynamics at Sand Harbor State Park

A deeper understanding of specific hydrodynamic properties, i.e. lake currents, around Sand Harbor would aid in determining the fate of algae within the park (beach vs offshore). Metaphyton algae is free floating, and transport of algae is heavily influenced by the lake's physical properties. If hydrodynamic properties promote the transport of metaphyton offshore, then beaches at Sand Harbor may have reduced impacts from metaphyton. Research focused on the physical properties at Sand Harbor State Park using acoustic doppler current profilers (ADCPs) would provide resource managers with important information on the transport of algae within the state park.

Key Management Items:

- Develop research project to determine the fate of metaphyton algae transport within Sand Harbor State Park
- Implement management strategies based on research findings

Development and implementation of treatment methods for metaphyton

Metaphyton algae removal can be implemented either before or after transport onshore. Metaphyton is a relatively new challenge at Lake Tahoe and exploring innovative removal techniques is an important strategy. For example, using autonomous underwater vehicles (AUV) as a potential removal method. The Tahoe Environmental Research Center is currently collaborating on pilot projects developing AUVs to remove metaphyton algae from the lake.

Key Management Items:

- Determine if metaphyton algae is concern for Sand Harbor State Park
- Explore pre vs post transport onshore removal techniques
- Implement management plan based on removal methods

Sand Harbor State Park and its managing partners have the opportunity to be a leader in the development and implementation of a program to combat the negative impacts of Asian clams and the secondary effects they pose to Lake Tahoe. Sand Harbor is not the only area of the lake facing these challenges but is emerging as a frontrunner in aquatic invasive species management due to the work being done to protect its emblematic environment. TERC would like to thank the Nevada Division of State Lands for their continued partnership in the preservation of Lake Tahoe and its unique ecosystems through scientific knowledge.

Acknowledgements

We are grateful for the efforts of many individuals with the U.C. Davis Tahoe Environmental Research Center who assisted with this work. We would like to acknowledge the assistance provided in the field and the laboratory by Erik Young, Sergio Valbuena, Michael Cane, Michael Welsh, Keeler Nelsen, and Isaiah Bluestein. Special thank you to our volunteer divers: Scott Sherrod, Gena Whitman, Madison Tracewell, and Derek Ali Bahrami.

References

Denton, M. E., S. Chandra, M. Wittmann, J. Reuter, and J. Baguley. Reproduction and population structure of *Corbicula fluminea* in an oligotrophic subalpine lake. *Journal of Shellfish Research* 31.1 (2012): 145-152.

Wittmann, M.E., A.E. Gamble, B.C. Allen, K. Webb, J.E. Reuter, S. Chandra, and S.G. Schladow. 2012. Final Report: The Control of Asian clam (Corbicula fluminea) in Lake Tahoe with Benthic Barriers: The Influence of Water Temperature on Mortality. Submitted to the Tahoe Resource Conservation District.

Hackley S. H., B. Allen, K. Senft, B. Berry, G.Schladow, A. Wong, Y. Chen, Q. Yu, Y. Jin and M. Bruno. A Sustainable Method for The Rapid Assessment of the Extent and Causes of Metaphyton in Lake Tahoe, 2020. Final Report submitted to Nevada Division of State Lands. P.158

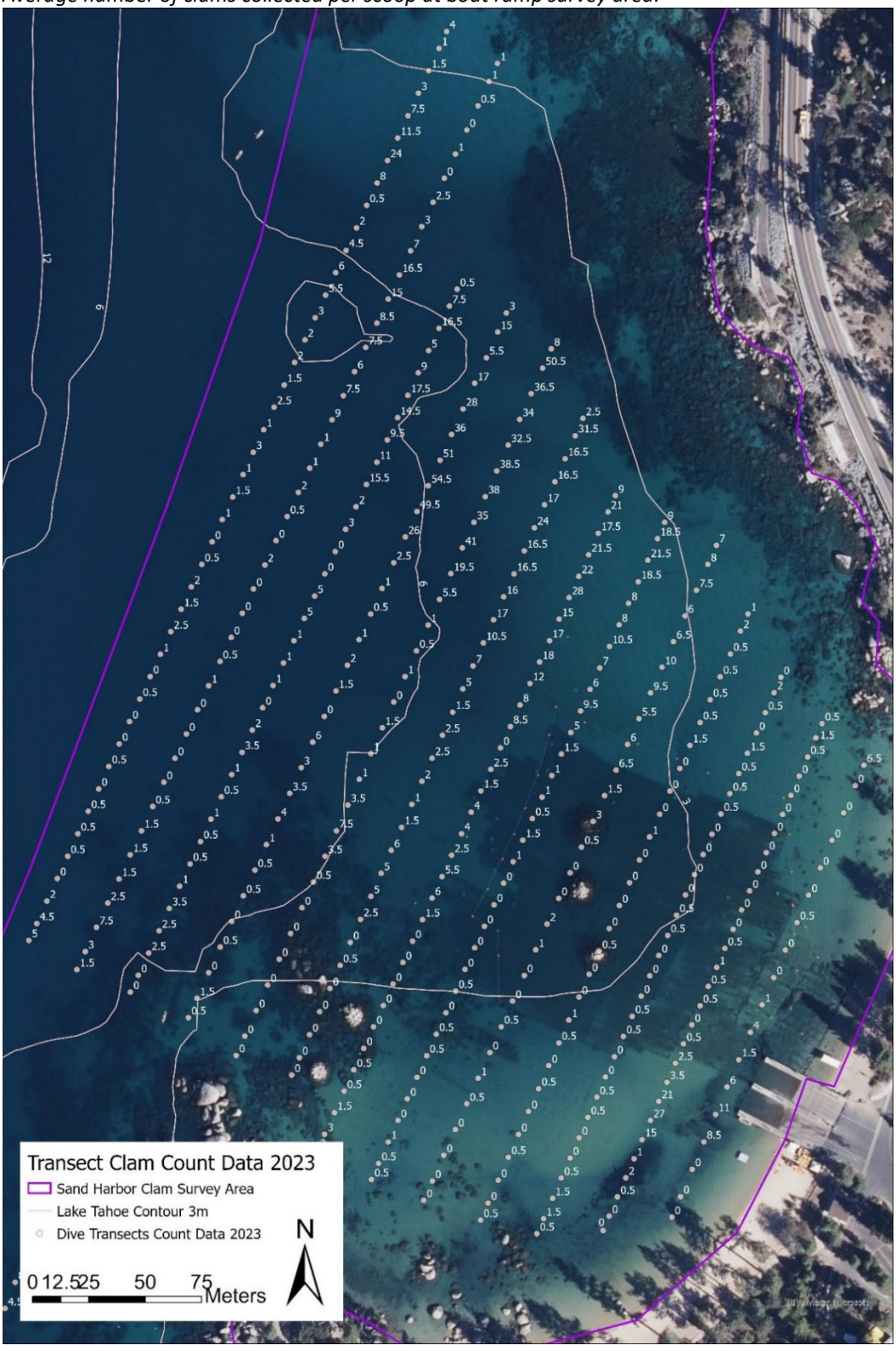
Hoyer, A. B., Schladow, S. G. and Rueda, F. J. 2015. Local dispersion of a non-motile invasive bivalve species by wind-driven lake currents. Limnology and Oceanography, 60: 446-462.

Smitts, A., Senft, K., Berry, B., Tanaka, L. Interim Report: Integrated Nearshore Algal Monitoring (in-situ and aerial surveys), 2024. Interim Report submitted to Tahoe Regional Planning Agency.

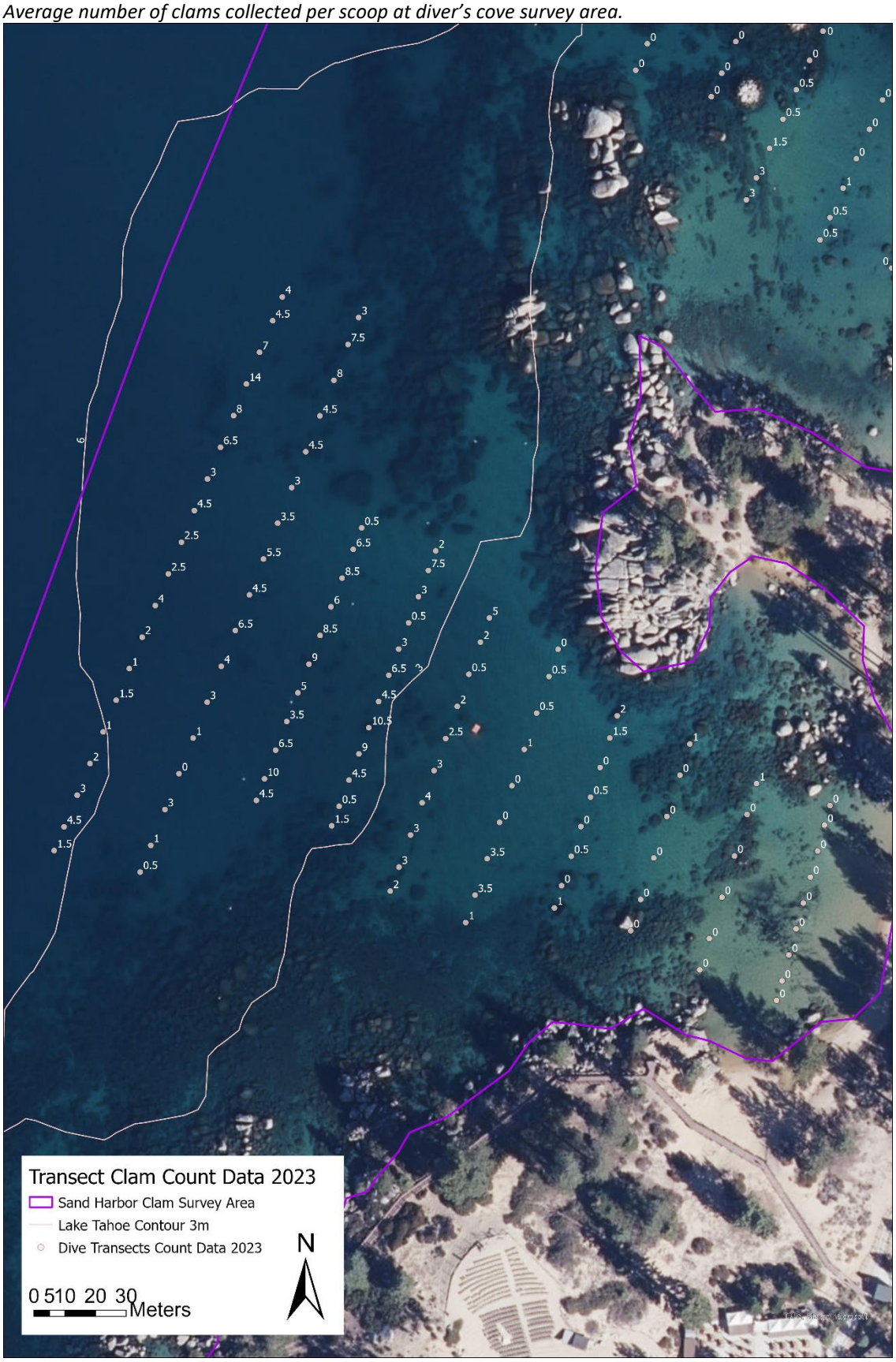
USGS. Lake Tahoe at Tahoe City – 10337000 station. https://waterdata.usgs.gov/monitoring-location/10337000.

Appendix 1

Average number of clams collected per scoop at boat ramp survey area.

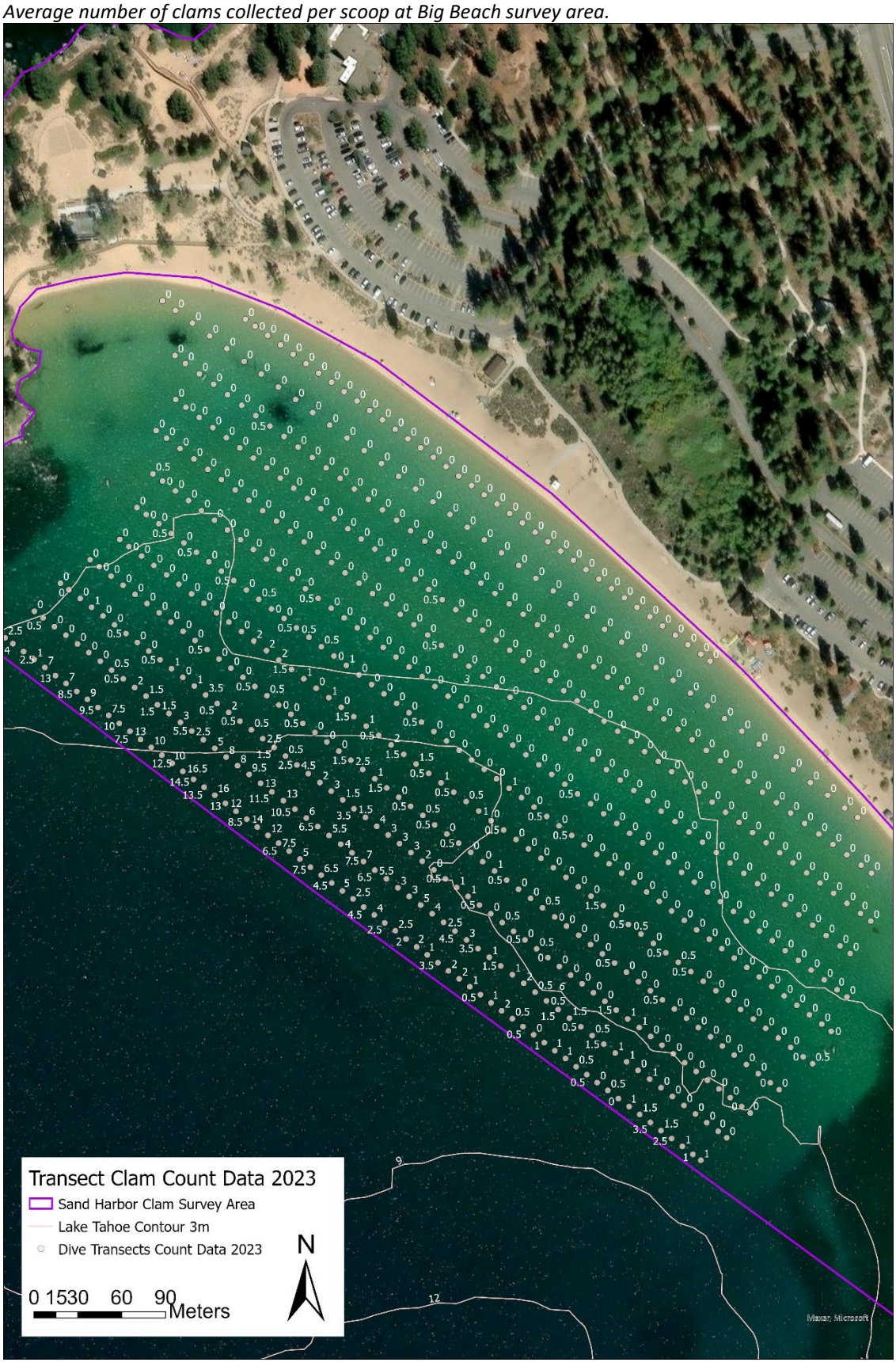


Average number of clams collected per scoop at diver's cove survey area.



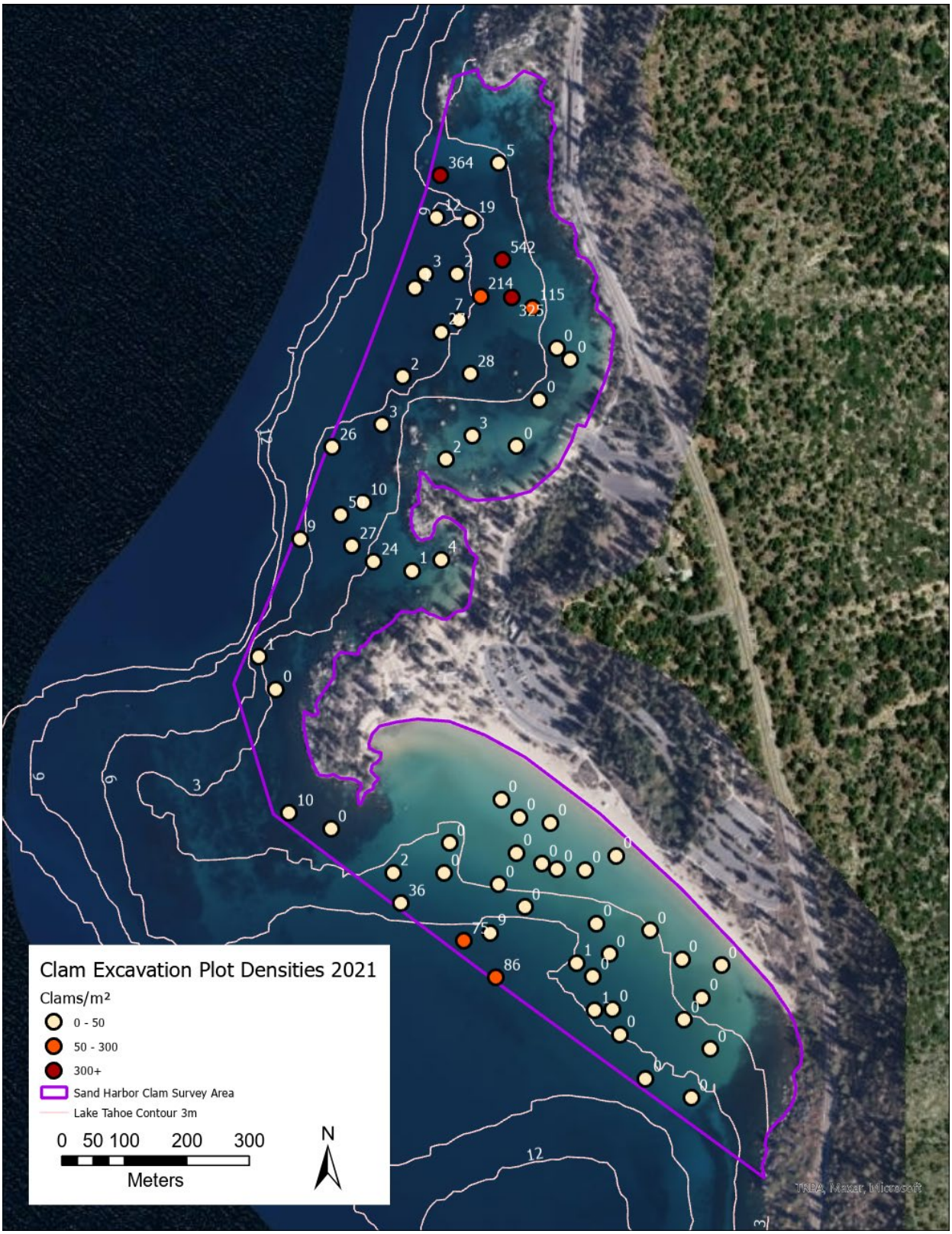
Average number of clams collected per scoop at rocky point survey area.

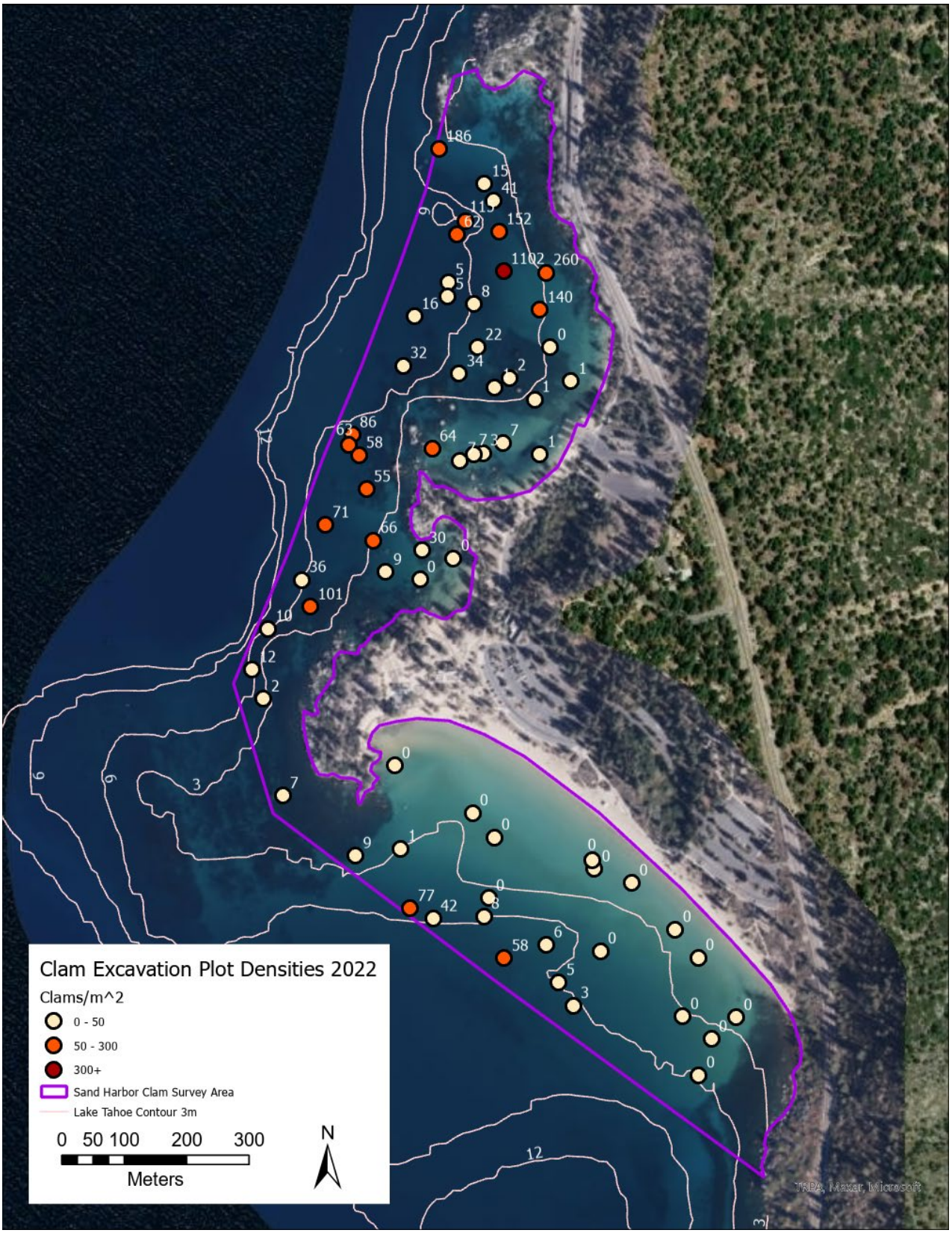
Average number of clams collected per scoop at Big Beach survey area.

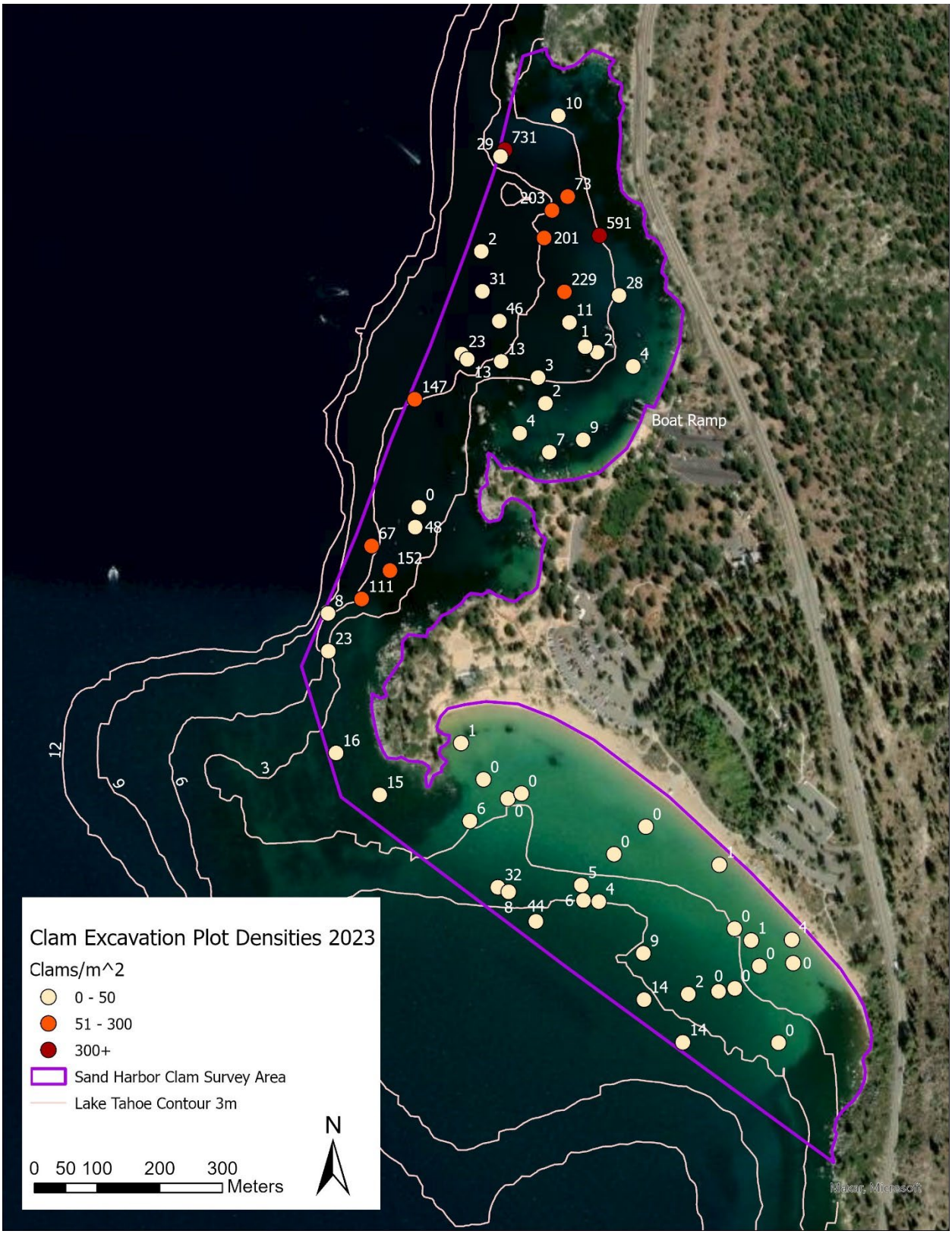


Appendix 2

2021, 2022, 2023 Sand Harbor survey maps.


Clam Excavation Plot Densities 2021
Clams/m²
0 - 50
50 - 300
300+
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N
TRPA, Maxar, Microsoft


Clam Excavation Plot Densities 2022
Clams/m^2
0 - 50
50 - 300
300+
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N
TRPA, Maxar, Microsoft


Clam Excavation Plot Densities 2023
Clams/m^2
0 - 50
51 - 300
300+
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N
Boat Ramp
10
29
731
73
203
591
201
2
31
229
28
46
11
1
2
23
13
4
13
3
147
2
4
7
9
0
48
67
152
111
8
23
16
1
3
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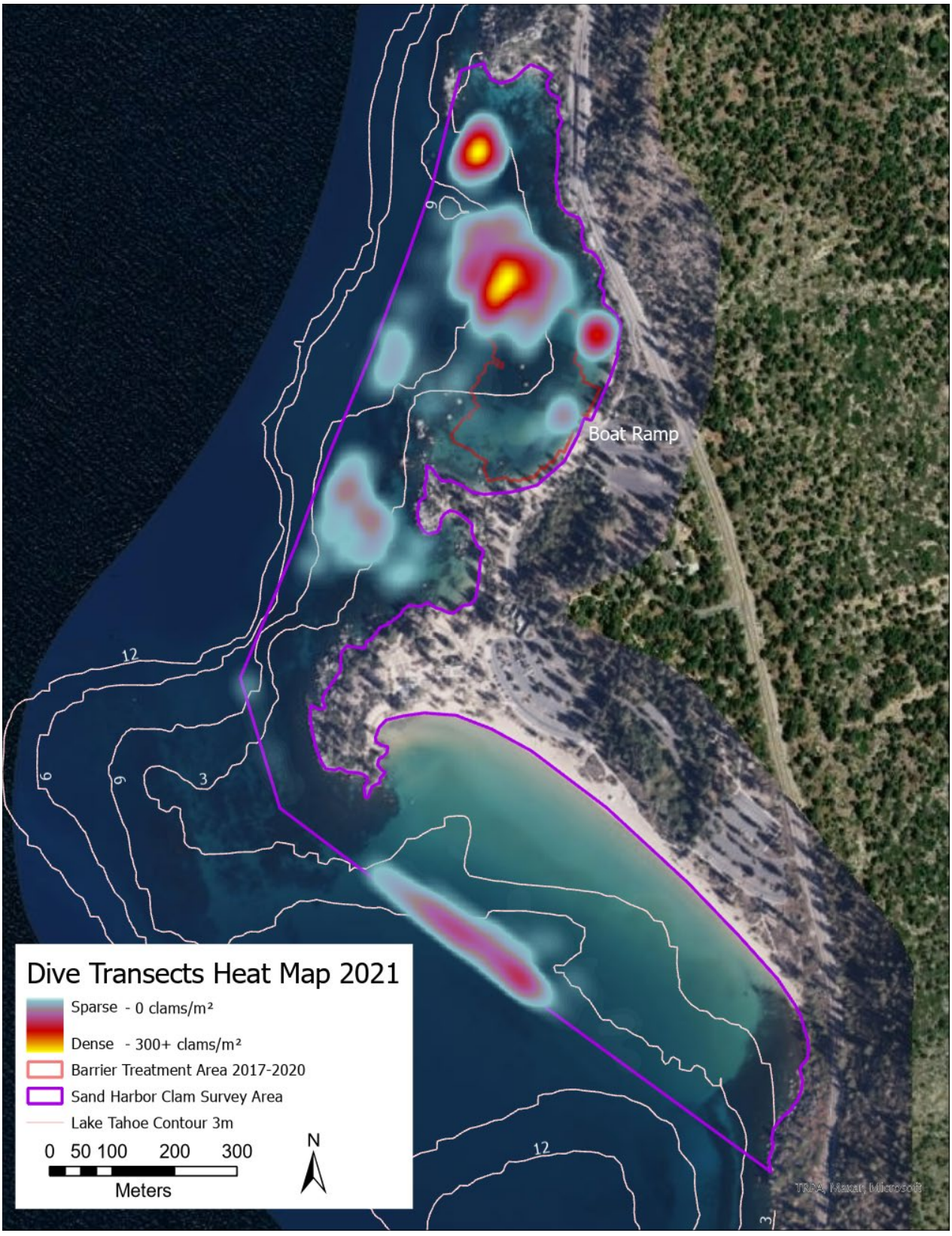
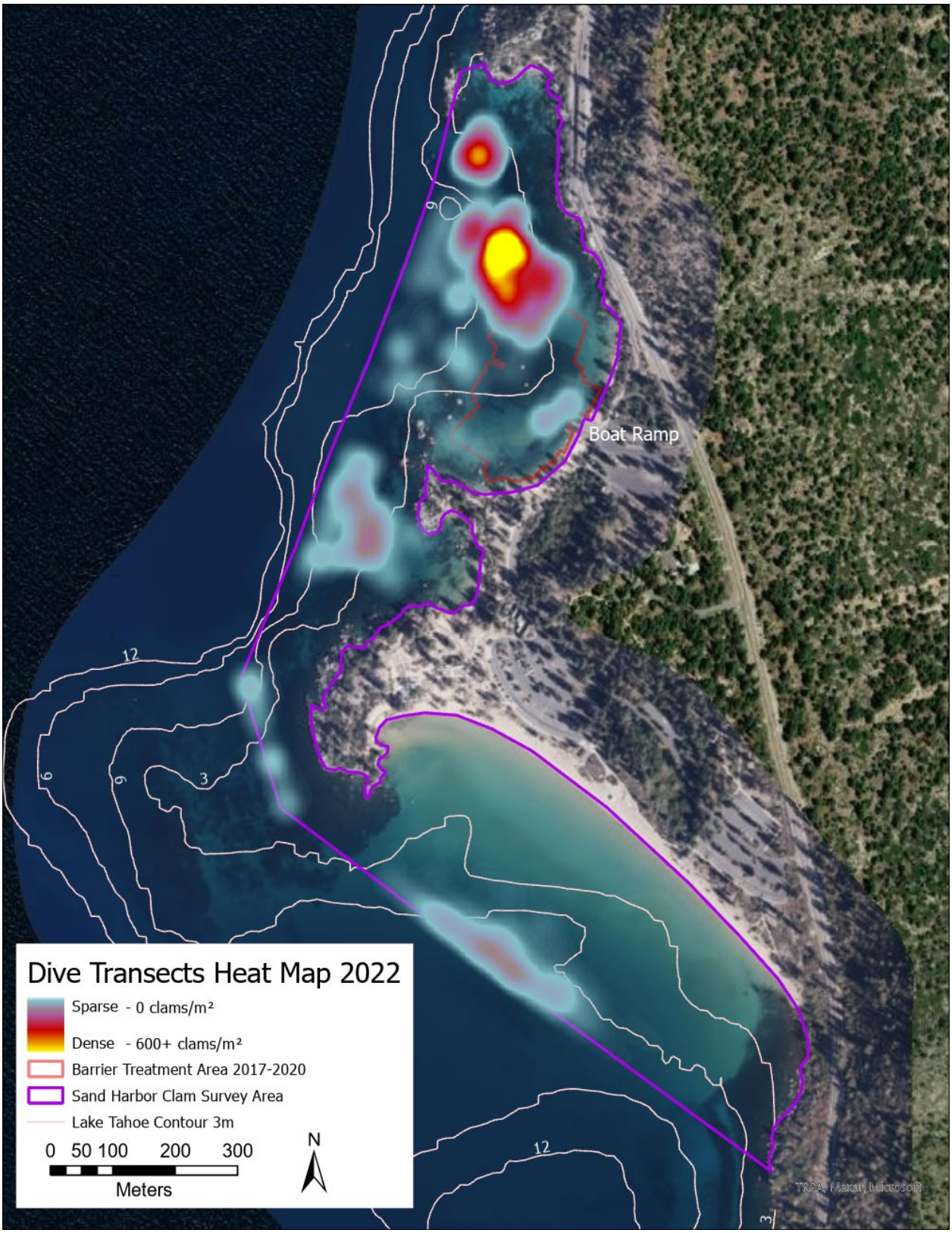
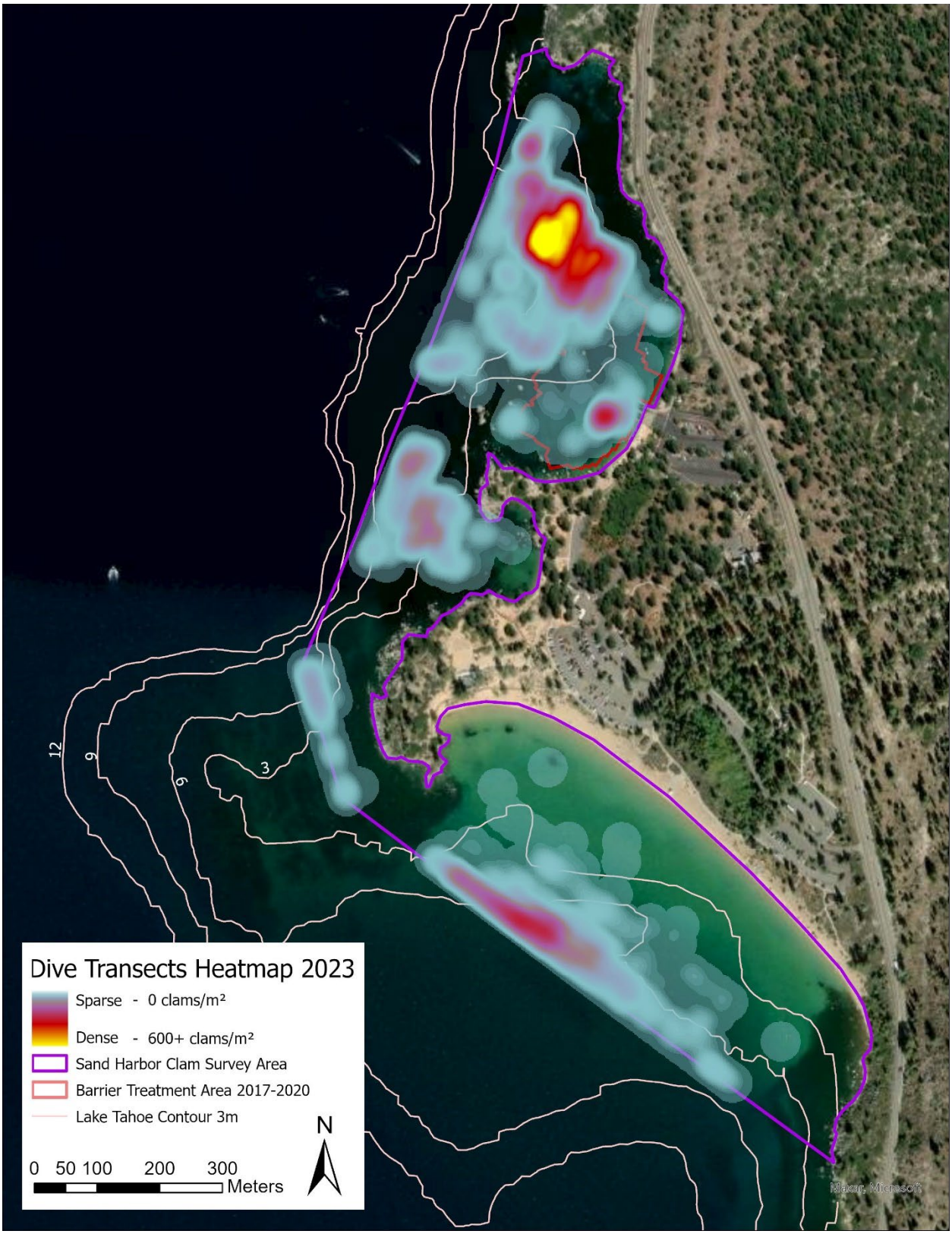
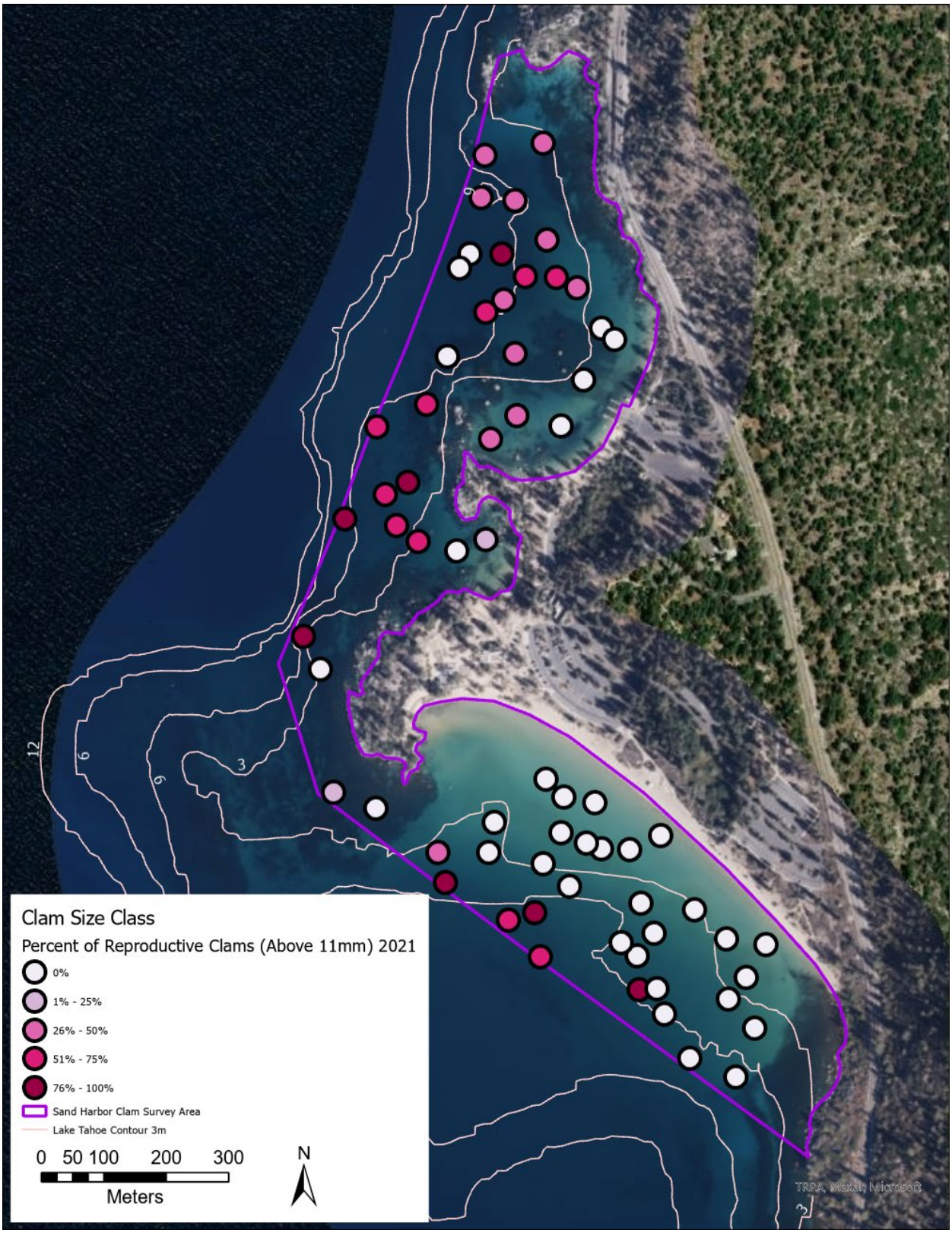
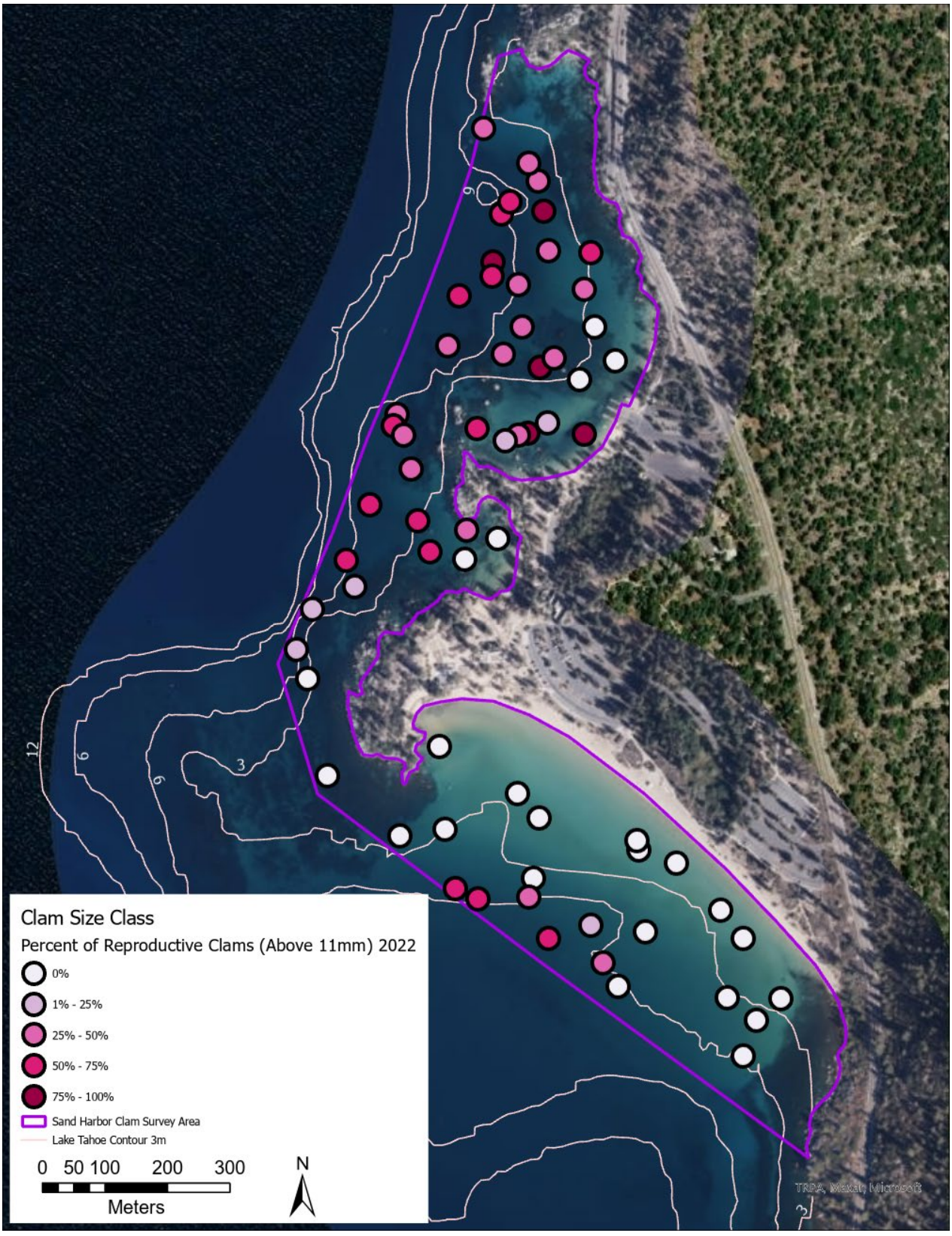
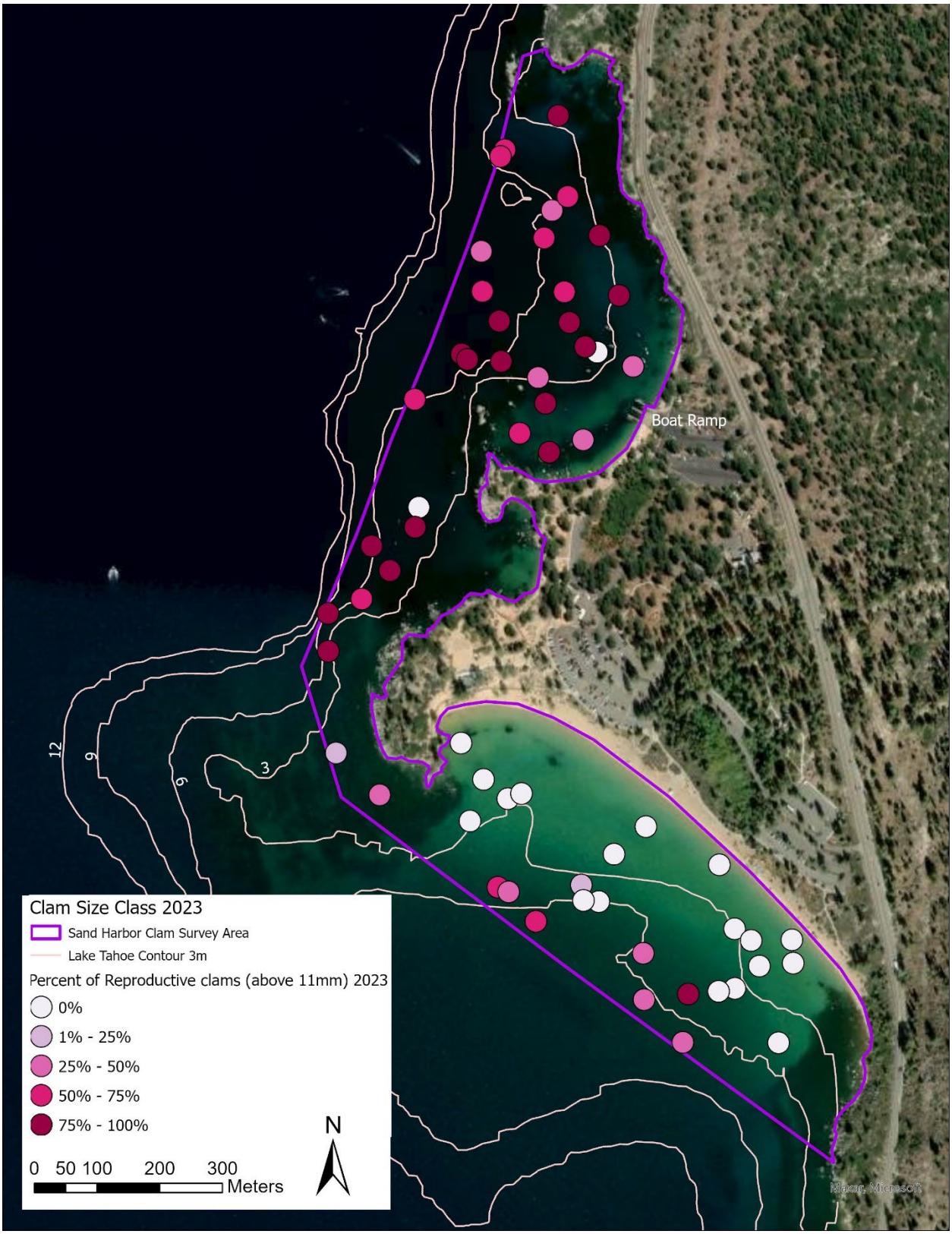

Boat Ramp
12
9
6
3
Dive Transects Heat Map 2021
Sparse - 0 clams/m²
Dense - 300+ clams/m²
Barrier Treatment Area 2017-2020
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N


Boat Ramp
12
9
6
3
Dive Transects Heat Map 2022
Sparse - 0 clams/m²
Dense - 600+ clams/m²
Barrier Treatment Area 2017-2020
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N


Dive Transects Heatmap 2023
Sparse - 0 clams/m²
Dense - 600+ clams/m²
Sand Harbor Clam Survey Area
Barrier Treatment Area 2017-2020
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N
12
9
6
3
6
Maxar, Microsoft


Clam Size Class
Percent of Reproductive Clams (Above 11mm) 2021
0%
1% - 25%
26% - 50%
51% - 75%
76% - 100%
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N
12
9
6
3
TRPA, Maxar, Microsoft


Clam Size Class
Percent of Reproductive Clams (Above 11mm) 2022
0%
1% - 25%
25% - 50%
50% - 75%
75% - 100%
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
0 50 100 200 300
Meters
N
12
6
6
3
9
3
TRPA, Maxar, Microsoft


Boat Ramp
12
9
6
3
Clam Size Class 2023
Sand Harbor Clam Survey Area
Lake Tahoe Contour 3m
Percent of Reproductive clams (above 11mm) 2023
0%
1% - 25%
25% - 50%
50% - 75%
75% - 100%
N
0 50 100 200 300
Meters
Maxar, Microsoft

Appendix 3

Link to Sand Harbor State Park Asian clam monitoring web map.
https://experience.arcgis.com/experience/ec998e1961ee4827a3bccd2c22449309/