Research activities at HIHWNMS during the 2019-20 whale season

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Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS) leads and collaborates in research efforts to study the segment of the north Pacific humpback whale population that breeds in the Hawaiian archipelago each winter and spring. Research on humpback whales and their habitat includes documenting trends in the whales' distribution and abundance, studying their behavior while in sanctuary waters, and monitoring potential human impacts. The HIHWNMS research team is composed of Research Coordinator Dr. Marc Lammers, Research Specialist Eden Zang, and University of Hawai'i at Manoa Graduate Assistant Anke Kuegler. Below is a summary of the team's activities and accomplishments during the 2019-20 field season (October 2019 – May 2020).

Acoustic monitoring of whale singing activity

HIHWNMS staff members deploying an acoustic mooring off Olowalu, Maui. Photo: Ed Lyman

Background: Between December and April, male humpback whale song becomes the dominant source of underwater ambient noise in many parts of Hawai'i, creating a chorus of whale singing. Because whale song can transmit over several miles, the acoustic energy produced by singing whales can be used to track the relative presence of whales in an area, revealing the timing of their arrival, their peak abundance, and their departure. The abundance of song can also be used to compare the relative occurrence of whales across locations and between years, providing a useful metric for studying geographic variability and annual trends in whale presence. Metrics of whale song abundance are obtained through bottom-moored acoustic recorders that measure the soundscape of an area, which includes whale chorusing, over the course of the breeding season. Automated algorithms are then used to quantify the amount of whale song present in recordings. In addition to monitoring whale song, the recorders are also used to quantify vessel traffic in various parts of sanctuary waters, offering a unique opportunity to examine human use patterns, including in relation to the current global Covid-19 pandemic. Acoustic monitoring efforts are led by HIHWNMS in partnership with Oceanwide Science Institute, Scripps Institution of Oceanography (SIO), and with funding support from the SanctSound Project, an Office of National Marine Sanctuaries endeavor to characterize the soundscapes in seven national marine sanctuaries and one marine national monument.

Accomplishments: Beginning in October of 2019, seven Ecological Acoustic Recorders (EARs) were deployed in waters around Maui Nui (Maui, Molokai, Lanai, and Kahoolawe) at locations ranging in depth between 15 m and 200 m. Several of these sites have been acoustically monitored since 2014, providing a time series of acoustic recordings that can be used to track inter-annual variability in whale chorusing levels. In addition to the EARs, five SoundTrap recorders were deployed in sanctuary waters off Maui (Olowalu), Molokai (Penguin Bank), Oahu (Makapuu Point), Kauai (north shore) and Hawai'i Island (Kohala Coast) as part of the SanctSound Project. Four SoundTrap recorders and one EAR were also deployed at Middle Bank,

Nihoa, Mokumanamana, French Frigate Shoals, and Gardner Pinnacle in Papahānaumokuākea Marine National Monument (PMNM) as part of the SanctSound Project in July 2019. Finally, on March 11 three Directional Autonomous Seafloor Acoustic Recorders (DASARs) were deployed as part of a project led by SIO and Greenridge Sciences, Inc. to localize and count the number of humpback whales singing at any given time in the sanctuary's focal study area off west Maui. The EARs and SoundTraps in HIHWNMS were recovered in May/June/July. The five PMNM recorders will be recovered during a chartered research cruise in September 2020. The three DASARs will be recovered at a date still to be determined pending restrictions related to the Covid-19 pandemic. Figure 1 in Appendix A shows preliminary results from the shallow-water EAR deployed off Olowalu.

Tagging humpback whales to understand their behavior

HIHWNMS research staff deploying an acoustic tag on a whale.
Photo: Anke Kuegler

Background: Although humpback whales have been studied in Hawai'i for decades, much of their behavior remains a mystery. For example, not much is known about what whales do at night and whether their activities differ from those observed during the day. Very little is also still known about how whales respond to acoustic disturbances, such as vessel traffic and other sources of human-generated noise. Animal-borne sensor tags have the ability to dramatically expand our understanding of animal behavior. When placed on humpback whales, these tags can provide insights into the lives of whales that are otherwise impossible to obtain through observations from the surface. These tags that are placed on whales using suction cups measure sound, dive behavior, and the whales' three-dimensional movements using tri-axial accelerometers and magnetometers. The data generated provide unique insights into what whales do when they slip under the surface and out of our view, allowing us to examine questions about their communication, movements, and activity levels. Over the past two years, HIHWNMS has increased its involvement in this type of research through partnerships, the acquisition of tools, and expanded analytical capabilities, and now leads and collaborates in efforts to examine some of the open questions about whale behavior through the use of tags.

Accomplishments: During the 2020 field season, two important new collaborative relationships were established. One of these is with the Marine Mammal Research Program of the University of Hawai'i, in which suction-cup CATS (Customized Animal Tracking Solutions) video tags were deployed on humpback whale calves to study nursing behavior. A video was developed to highlight the nursing behavior of humpback whales. The other new collaboration is with Syracuse University, where the focus is on examining the development of singing behavior in juvenile male humpback whales by using Acousonde and DTAG suction-cup acoustic tags. As part of this effort, Ph.D. student Julia Zeh spent approximately three weeks in Maui while housed at HIHWNMS' Kīhei campus. Ms. Zeh provided sanctuary staff training on the use of software tools that allow the visualization of whale movements in three dimensions (3-D) using tag data. An example of such a 3-D track is seen in Figure 2 of Appendix A. In total, 23 successful tag deployments on humpback whales were made during the 2020 field season between these collaborative efforts. These new partnerships add to existing tagging collaborations with the University of Hawai'i at Hilo and Moss Landing Marine Laboratory and are helping to establish HIHWNMS as a center for humpback whale tagging research.

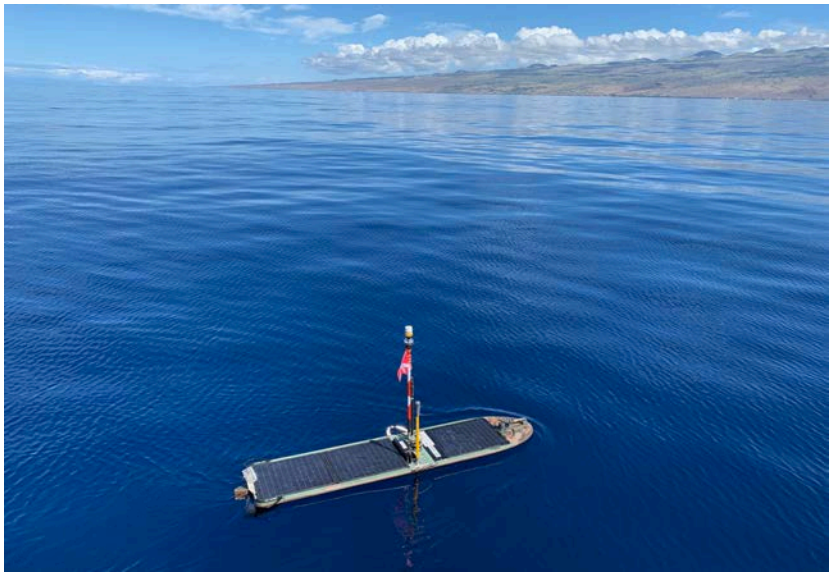
Vessel and shore-based surveys to quantify whale abundance

HIHWNMS staff and collaborators conducting a land-based whale survey using a theodolite. Photo: Marc Lammers

Background: The abundance of whales in the Hawaiian Islands has been fluctuating during the past several years, likely due to ecosystem changes in Alaska waters that have influenced whale migration patterns in the north Pacific. Acoustic monitoring efforts are providing an estimate of whale presence in Hawai'i based on the singing activity of males, but it is not clear how well this captures trends in the population overall, including non-singing males, females, and calves. To more accurately measure whale abundance in Maui Nui and to relate whale numbers to recorded levels of song chorusing (see above), both shore-based and vessel-based surveys are conducted each season in a focal study area off west Maui. Shore-based surveys employ a surveyor's theodolite to geospatially "fix" the position of whales from an observation station off Olowalu during 30-minute scans of the area. In addition, vessel surveys using the R/V *Koholā* record whale sightings along a systematic transect line that overlaps the area monitored from the shore station and also by several bottom-moored acoustic recorders. The use of distance sampling methods during vessel surveys allows the estimation of absolute whale densities. The two data streams are then combined to create time series of whale abundance off west Maui within and between seasons.

Accomplishments: Weekly shore-station counts of whales began on January 16, 2020, and ended on March 19, 2020, resulting in a total of 11 survey days. A total of eight vessel surveys were conducted between December 11, 2019 and March 19, 2020. The partial work shutdown due to the Covid-19 pandemic resulted in the cancellation of all surveys after March 19, 2020. These data are being used to compare annual whale abundance trends and to relate whale song chorusing levels measured in decibels to metrics of whale density measured visually. Preliminary results of whale density trends calculated from vessel surveys conducted over the past two seasons are shown in Figure 3 of Appendix A.

Wave Glider mission to PMNM



The Wave Glider *Europa.* Photo: Marc Lammers

Background: The Hawaiian archipelago is the primary breeding habitat for the north Pacific humpback whale population. Within the archipelago, approximately one third of the whales' preferred habitat (shallow water less than 600 feet deep) is found in the main Hawaiian Islands and two thirds occurs in the Northwestern Hawaiian Islands, which encompass Papahānaumokuākea Marine National Monument (PMNM). Acoustic recordings and visual sightings confirm that humpback whales use PMNM, but it is not known in what abundance and where the highest concentrations of whales occur. Previous surveys for humpback whales in the monument have been extremely limited due to the challenges of conducting vessel based surveys during harsh winter month conditions. Both HIHWNMS and PMNM

have prioritized better understanding the connectivity between whale habitats across the archipelago. To this end, HIHWNMS and PMNM partnered with The Jupiter Research Foundation (JRF) through the SanctSound Project (see above) to conduct a passive acoustic survey in PMNM using a Wave Glider autonomous surface vehicle to document the relative occurrence of whale song across the archipelago. The remotely piloted Wave Glider uses wave energy to propel itself and photovoltaic systems with batteries to power scientific instrumentation, including a hydrophone that was used to record the presence of humpback whale song and other sounds.

Accomplishments: The autonomous surface vehicle SV3 Wave Glider *Europa* conducted a 67-day mission departing Hawai‘i Island January 8, 2020, transiting through the monument as far as Lisianski Island and returning March 14, 2020. It traveled over 2,500 nautical miles in total (Figure 4 in Appendix A), covering the distance equivalent to a roundtrip flight from Washington D.C. to Denver, Colorado. The Wave Glider collected passive acoustic recordings, weather, and oceanographic data throughout the survey. It handled the rough winter seas and successfully surveyed 18 banks, shoals, and seamounts resulting in the first recorded presence of humpback whales at several of these locations. Multiple other marine mammal species were also acoustically detected throughout the survey, including at locations not previously documented during the winter. Research staff at HIHWNMS will apply machine-learning algorithms on the large volume of data obtained to establish the occurrence and distribution of humpback whales within the monument. These tools were originally developed as part of a collaborative effort between NOAA and Google, and are being evolved in partnership with JRF.

Acknowledgments: The efforts described would not be possible without the dedicated help of many individuals who contributed in numerous ways. These include (in alphabetical order): Trisha Alvarez, Shannon Atkinson, Whitlow Au, Lars Bejder, Isabella Canepa, Debra Caswell, Peter Colombo, Alex Conrad, Amy Eldredge, Rachel Finn, Beth Goodwin, Will Goth, Ted Gruppenhoff, Russell Hansen, Matt Harvey, Leila Hatch, Brian Hauk, Lee James, Jessie Kittel, Dani Kleinhenz, Jason Leonard, Keolohilani Lopes, Ed Lyman, Kiki Mann, Jonathan Martinez, Stephen Matadobra, Megan McElligott, Karlina Merkens, Jason Moore, Adam Pack, Susan Parks, Jeannine Rossa, Marcus Richter, Sabena Siddiqui, Heather Spillane, Aaron Thode, Martin Van Aswegen, Sara Wood, Julia Zeh, and Joan Zwar.

APPENDIX A – Preliminary Results

NOTE: The figures below are preliminary and unpublished. Please do not publish or post on social media. Contact Dr. Marc Lammers (marc.lammers@noaa,gov) before disseminating further.

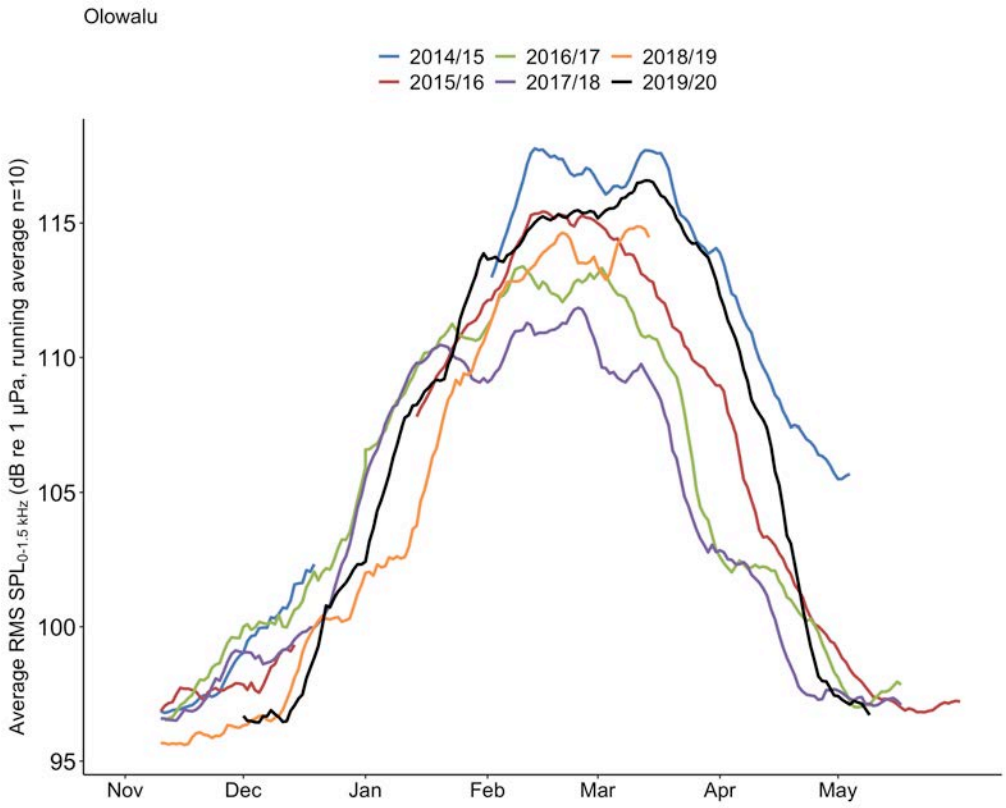


Figure 1 – Humpback whale chorusing levels in decibels measured by an Ecological Acoustic Recorder (EAR) deployed off Olowalu over the past six years. Data gaps represent periods when the EAR did not record.

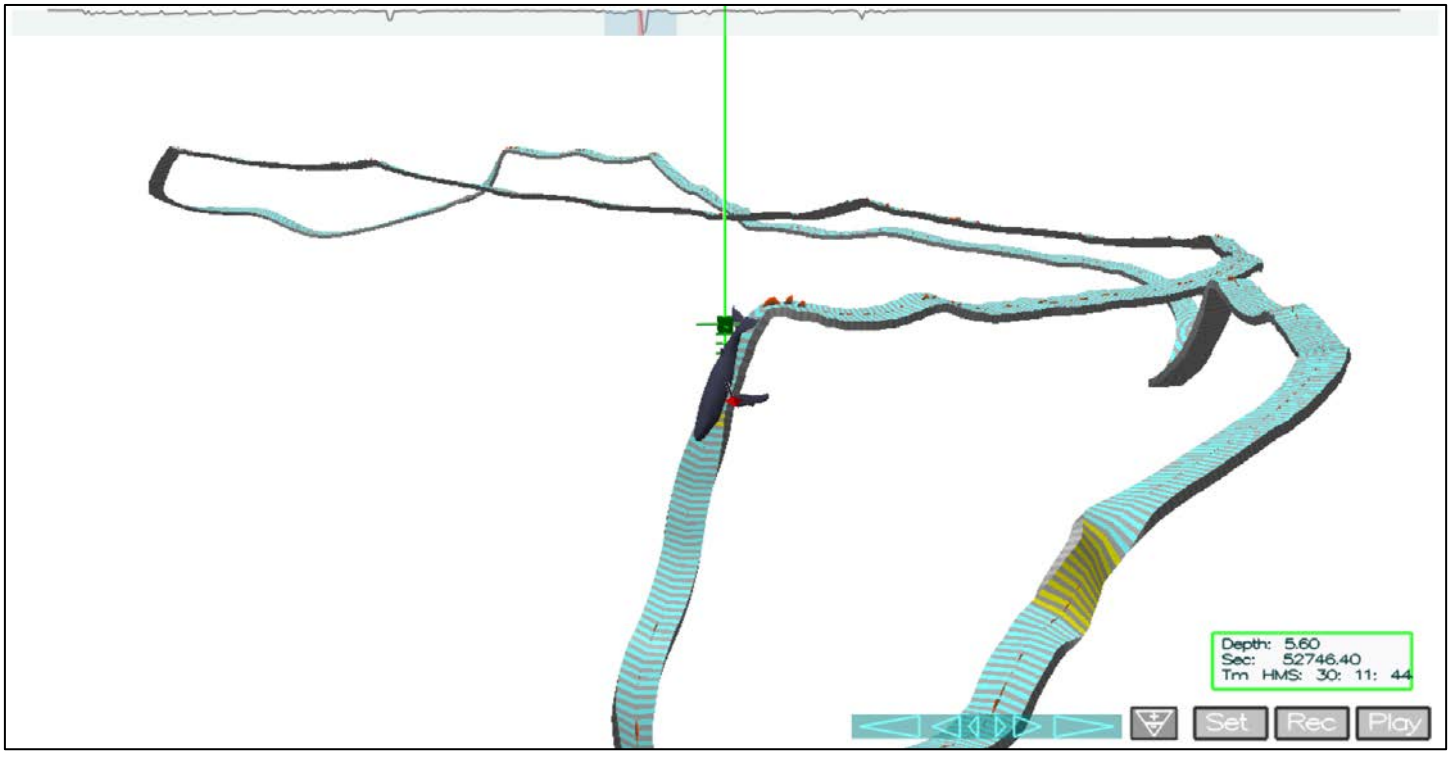


Figure 2 – Three-dimensional track of a tagged whale's movement as measured by the tag's accelerometers and magnetometers, and reconstructed using the program TrackPlot.

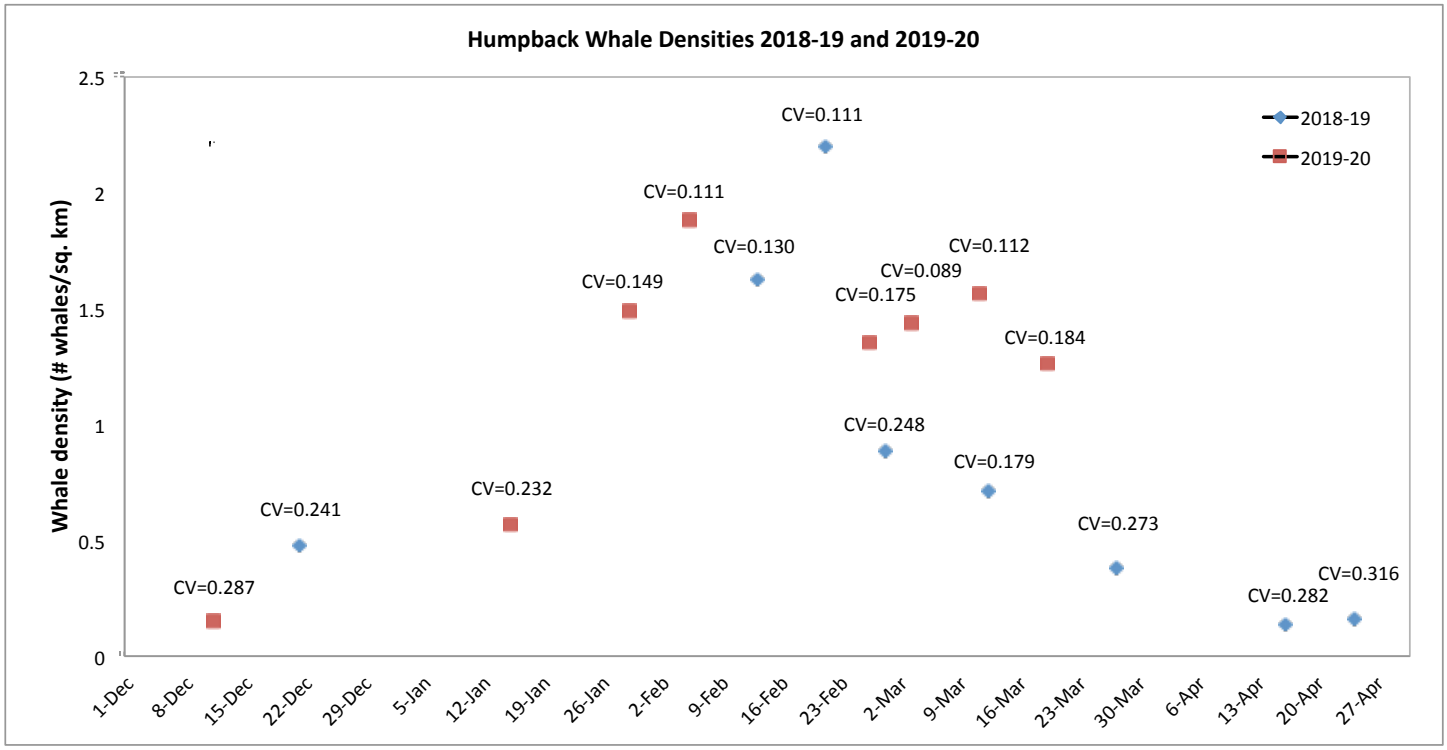


Figure 3 – Estimated density of whales (whales/km^2 and coefficient of variation (CV)) in the west Maui area calculated during 16 vessel-transect surveys during 2018-19 and 2019-20 whale seasons.

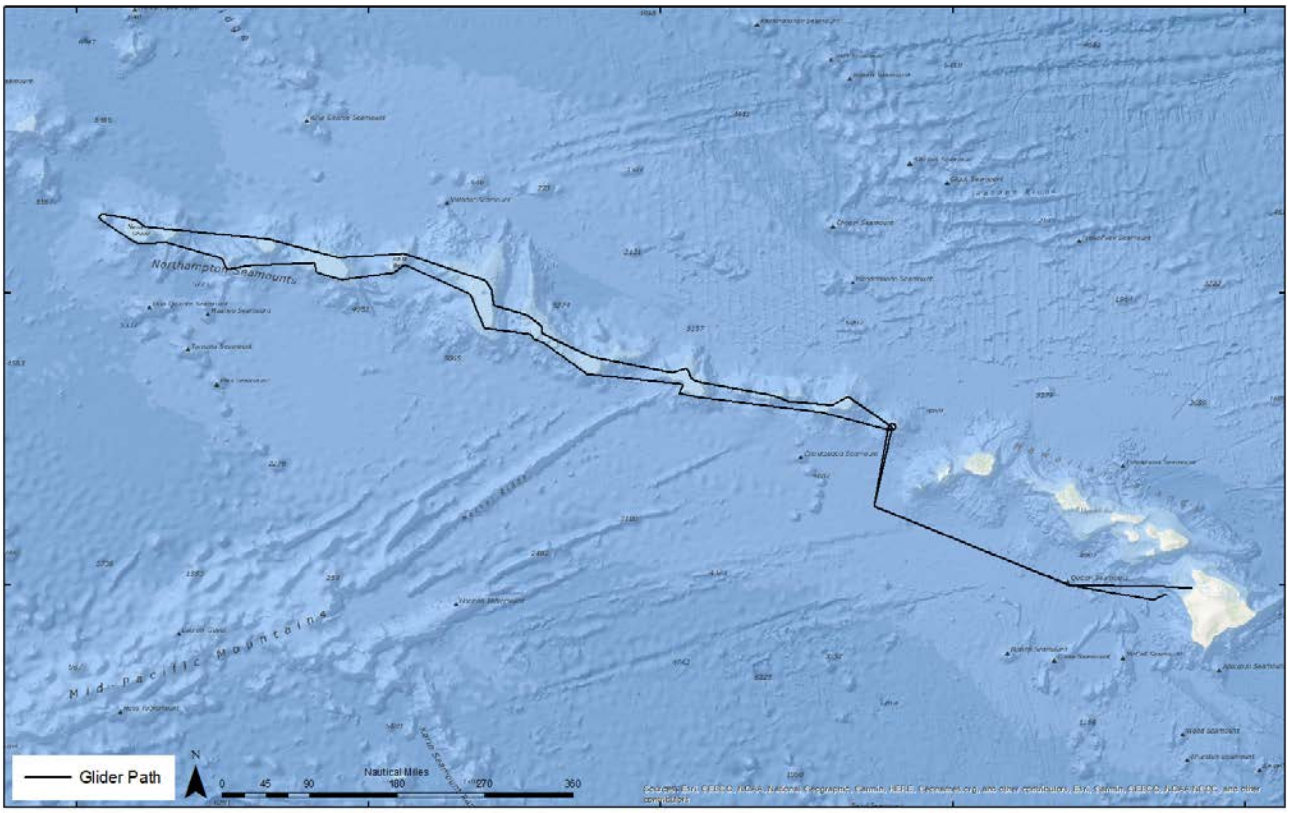


Figure 4 – Track of the Wave Glider *Europa* during its 67-day mission to PMNM.