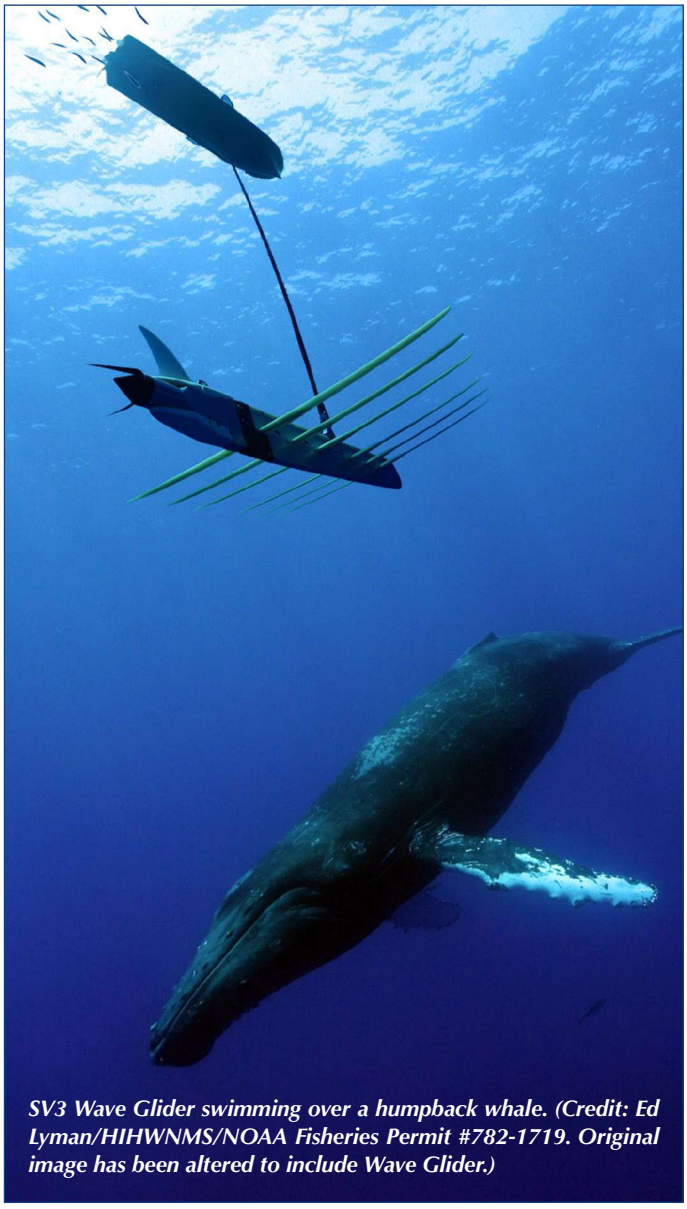
New Era of Humpback Whale Research

Using a Wave Glider SV3 to Search for Whale Song

By Maya Goodoni • Beth Goodwin • Kurt Kiesow

For more than 15 years, Jupiter Research Foundation (JRF), based in Los Altos, California, has immersed itself in science and technology research and development with the primary objective of learning and creating something new. Over the years, JRF has broadcast live whale song to the world, analyzed electrical signals from single-cell organisms, developed an autonomous ocean-going amateur radio and microscope and co-invented a high-tech, ocean-going, unmanned surface vehicle, the Wave Glider (WG) that has revolutionized how researchers monitor the world's oceans. This invention led to the formation of Liquid Robotics, a Sunnyvale, California, business that was acquired by The Boeing Co. of Seattle, Washington, in 2016.

JRF has recently embarked on its most ambitious project yet: the Humpback Pacific Survey (HUMPACS). This mission combines two of JRF's passions: humpback whales and radio technology.



SV3 Wave Glider swimming over a humpback whale. (Credit: Ed Lyman/HIHWNMS/NOAA Fisheries Permit #782-1719. Original image has been altered to include Wave Glider.)

Background

A humpback whale's migration of 6,000 mi. is one of the longest of any mammal. It is well known that North Pacific humpback whales migrate from their northern, summer feeding grounds to nearshore, winter breeding grounds in Mexico, Hawaii, Japan and the Philippines. Some studies suggest there may be humpback whales congregating in deeper waters between these nearshore grounds; however, scientists have not documented this. These studies include a photo-identification record of a humpback whale that traveled between Mexico and Hawaii in one winter season and the study called "Structures of Population, Levels of Abundance, and Status of Humpback Whales" on migratory destinations. Moreover, there are anecdotes of humpback whales near atolls far to the south and west of Hawaii. Previous song studies show there is mixing of humpbacks throughout the north Pacific, but it is not known when or how this occurs. While in their breeding grounds, humpbacks sing a song. Fifty years

ago, this fascinating discovery was made by listening to the sounds of the ocean. This discovery helped create the modern conservation movement "Save The Whale." The subsequent album produced by Dr. Roger Payne, "Song of The Humpback Whale," is the most successful natural history recording ever made.

Today, it is still unclear why only male humpback whales sing. Dr. Jim Darling, a humpback whale song expert from Whale Trust Maui in Hawaii, is in pursuit of this mystery. Darling and his team hypothesize the song may be a way for individual males to recognize how closely associated they are with other males and may determine if specific males cooperate or compete for females. Darling's research focuses on comparing songs from different regions within the North Pacific Basin to identify the similarities and differences between them.

(Top) Europa, the SV3 Wave Glider. (Bottom) A spectrogram of humpback whale WAV file (0 to 10 kHz): a graphical representation of mp3 audio.

JRF is exploring the hypothesis that humpback whales may be congregating around shallow-water seamounts between Hawaii and Mexico, which provide diverse ecosystems for marine life. Even one record of a humpback song in the deep waters would be significant and could lead to further investigations. Furthermore, tracking their song and migration patterns could shed some light on biological responses to environmental changes, including climate change and global warming.

The HUMPACS Mission

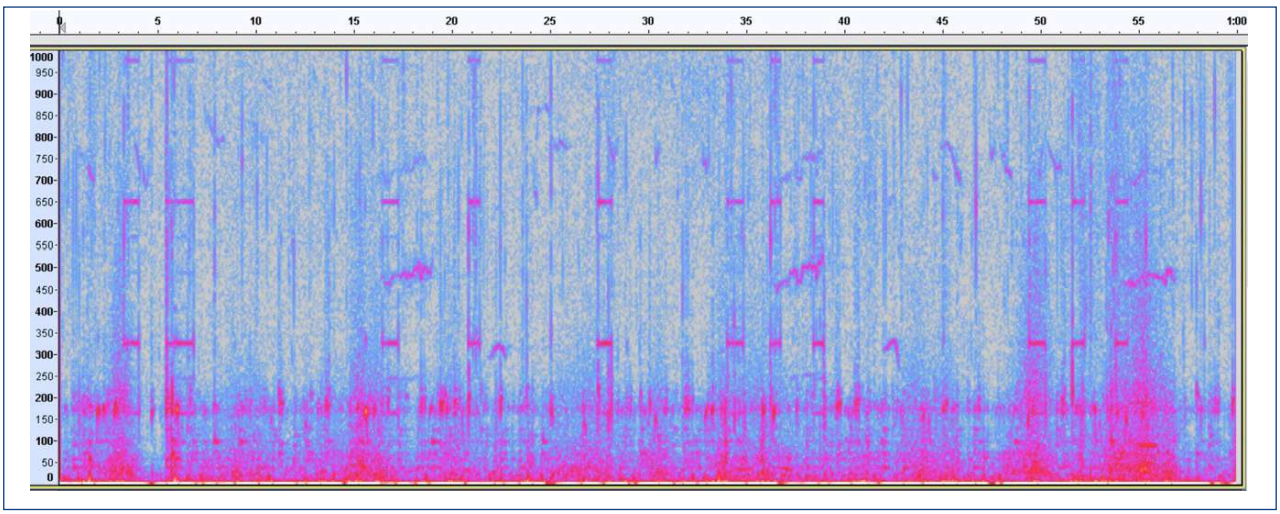
JRF has partnered with Darling to search for humpback whales by listening for their song in the deeper waters between their known breeding grounds. To perform this mission, they used a Wave Glider SV3, called Europa, to transect the Pacific between Hawaii and Mexico. Europa is a wave- and solar-powered unmanned surface vehicle made by Liquid Robotics. The vehicle is loaded with high-tech listening and monitoring gear that contain sound triggers and satellite uplinks to collect, record and transmit data. JRF programmed Europa to store all recordings on an onboard solid-state drive, although they can request audio files at will. If JRF hears something of interest, they can command Europa to survey that area before proceeding.

The mission is a little like searching for a needle in a haystack. However, the humpbacks' song has a vast range of frequencies and amplitude; therefore, it is a large needle in a haystack. The data they collect are critical to studies of behavior and abundance of humpback whales in the North Pacific Basin.

The HUMPACS mission, covering more than 2,000 nautical miles, is the first survey of seamounts from Hawaii to the Baja California Seamount Province searching for these humpback whales. Ships, satellites and submarines have surveyed the Pacific; however, never at the slow pace of 1.5 kt. over several months while recording the acoustic soundscape 24/7, collecting sea surface temperatures, salinity levels, ocean currents, weather data and taking above and underwater photos, and certainly never from an unmanned surface vehicle.

Soundscapes, Marine Ecoacoustics

Ecoacoustics is a relatively new field of science. It is the study of sounds and their relationship with the environment over a wide range of scales (both spatial and temporal). Scientists investigate sounds to understand their evolution, functions and properties under environmental stressors and changes. They use these sounds as tools to monitor ecological factors, such as biotic and abiotic relationships, animal behavior, diversity, abundance and distribution.



Scientists have gained much knowledge and a better understanding of the ocean and how humans are affecting it by using hydrophones to record marine acoustics. JRF's acoustic data may contribute to ecoacoustics by establishing a benchmark of the soundscape patterns along Europa's path, which could support marine conservation and resource management efforts.

Building the Acoustic Payload

To be able to detect whales from miles away and ensure no recorded data were lost, JRF's acoustic payload required significant software and hardware engineering. They acquired a "smart" digital hydrophone called the icListen HF, made by Ocean Sonics of Nova Scotia, Canada. The icListen can record a wide range of frequencies and target most cetaceans.

During the design phase, and anticipating the perils of an ocean journey, they attached the hydrophone to Europa's subsurface component, or "sub," to prevent loss due to entanglement or predation. However, being directly connected, the hydrophone picked up self-noise from the platform, which interfered with acoustic sampling. Therefore, JRF embarked on a design to decouple as much of the self-noise as possible from the hydrophone and enlisted the help of a veteran acoustician, Michael Holt, who has designed devices for similar purposes. Holt helped them create a mount that would be durable but not too heavy, biofouling resistant and still enables sound transference. To construct this, JRF used a thick-walled 3-in. type K copper pipe, which is an excellent biofouling deterrent and provides mounting strength. They mounted it to the center of the sub to avoid drag or any change in the sub's performance.

To mask mechanical noise, Holt first designed an inner casing tube out of low-density polyethylene to house the hydrophone. To keep it from hitting the bottom or the sides of the tube, they manually cut 15 circles of polyurethane open-cell foam to encase the hydrophone. JRF then sealed the tube and filled it with medical-grade castor oil, which closely matches the acoustic impedance of seawater. After testing it for leaks, they slid the inner casing into the outer copper pipe modified with 250 drilled holes, which reduced interference within the frequencies of interest.

Data Analysis

During the mission, which started in January and ended in April 2018, the JRF team was periodically transmitting short sound files back to shore via satellite as a contingency for system loss or failure. The Ocean Sonics hydrophone allowed them to set five "triggers" (or epochs) that detect sounds above desired decibel levels and within the desired frequency ranges of whales. The triggers were also used to help filter out specific frequency ranges, such as self-noise.

When the epoch detected a whale, JRF would request a fast Fourier transform (FFT) text file that displayed the relative strength of frequencies sampled over time. Subsequently, they would download the FFT into the Ocean Sonics' software program Lucy, where they could view it as a spectrogram (a graphical representation of the audio). If JRF confirmed there was something of interest from the FFT, they could request an actual mp3 audio file via satellite. Using specialized software, they had the ability to detect humpback whales' sounds by listening to and looking at the different frequencies in the mp3. For reference, baleen whales' frequency range is 20 Hz to 22 kHz, and the humpback whales' song is thought to be 80 Hz to 4 kHz.

The team is currently processing more than 800 surface and underwater pictures, sea surface temperature and salinity data, as well as analyzing more than 2,000 hr. of acoustic data. So far, the data have revealed some unusual sounds, which have yet to be substantiated. Conclusive results will be published in a scientific journal.

A Second Payload: HF Voyager

The HF Voyager is an entirely autonomous high-frequency (HF)

radio station integrated onto Europa. It is a project of the Jupiter Research Amateur Radio Club (JRFARC), a group of amateur radio operators affiliated with JRF. HF Voyager is designed to allow two-way communications with amateur radio operators worldwide and supports a new communication mode that has taken the amateur radio world by storm: FT8. With shorter transmit-receive cycles making for quicker contacts, FT8 is the ideal mode for communicating with this remote station in the Pacific Ocean. Ham operators call the Voyager on the 20-m amateur band, and (if propagation permits) the Voyager will respond with telemetry, including location and other data. The Voyager's responses occur from areas that are rarely occupied by human sailors.

JRFARC has taken off-the-shelf components and customized and integrated them for this application. Additionally, the system supports other digital-mode HF protocols: PSK-31 for two-way communications, and WSPR (transmit only), which will allow them to create a propagation study based on the contacts received over the course of this transpacific mission.

You can visit the JRF website to track Europa's progress, receive updates and view the HUMPACS data portal at www.jupiterfoundation.org and the JRFARC HF Voyager portal at www.jrfarc.org.

Acknowledgments

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Beth Goodwin, a U.S. Coast Guard-licensed captain, has spent more than 30 years identifying marine mammals throughout the eastern tropical Pacific. She is a co-founder of Liquid Robotics and has an M.A. in physiology and behavioral biology from San Francisco State University and a B.A. in marine biology from University of California, Santa Cruz.

Kurt A.F. Kiesow III is a co-founder of both Jupiter Research Foundation (JRF) and Liquid Robotics. He has integrated numerous payloads and sensors in the maritime environment and currently manages several technical programs at JRF. Kiesow is an active amateur radio operator and serves as the president of the JRF Amateur Radio Club.