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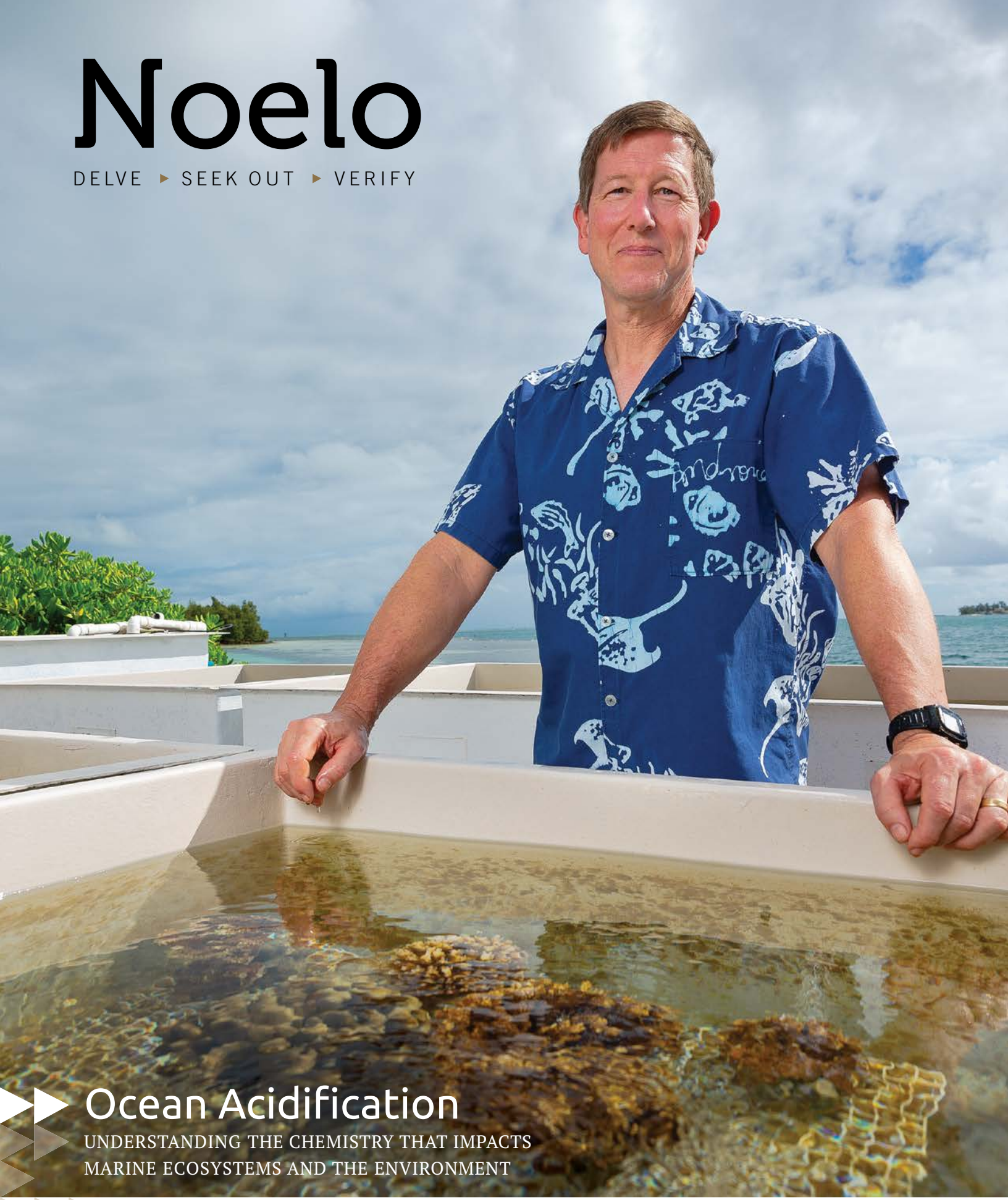
DELVE ▸ SEEK OUT ▸ VERIFY

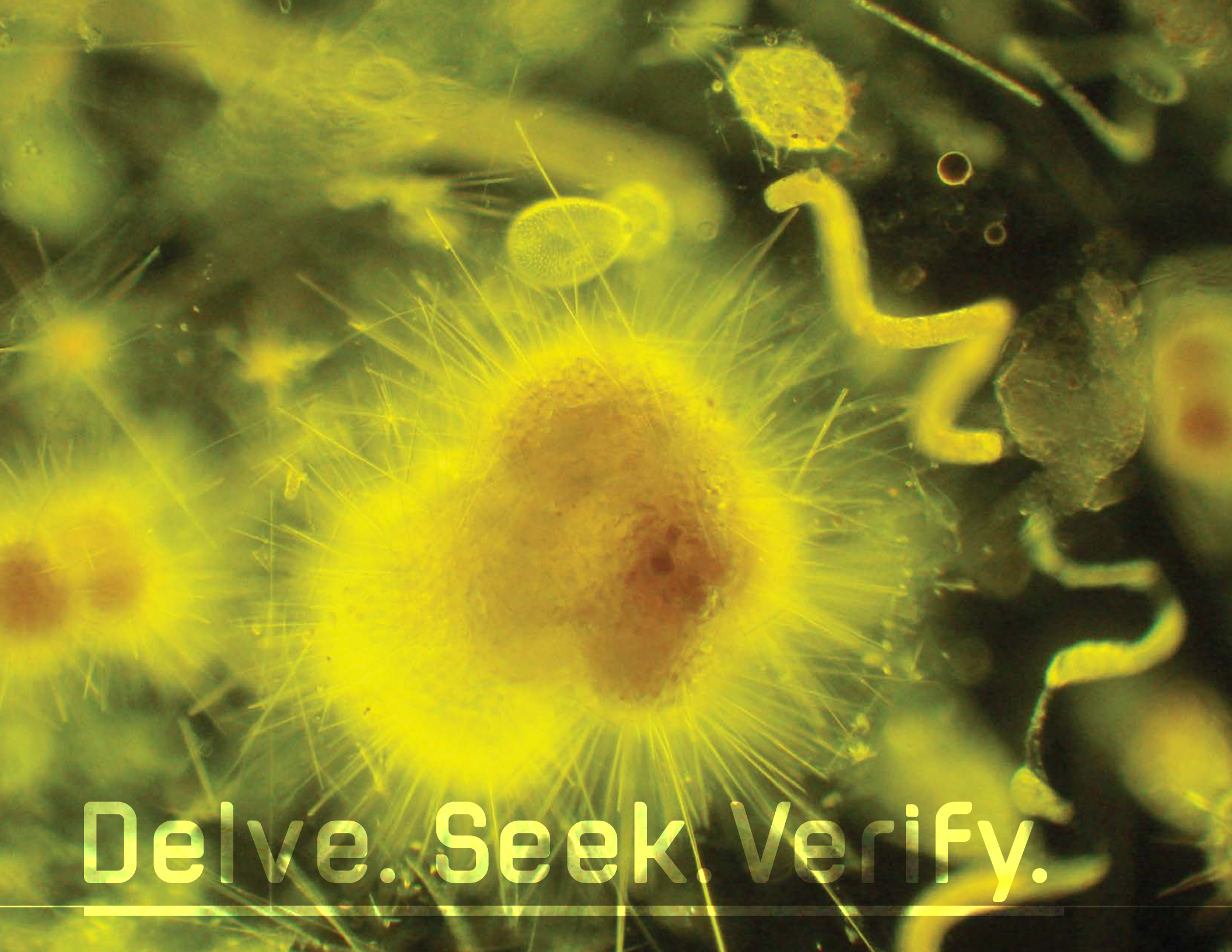


Ocean Acidification

UNDERSTANDING THE CHEMISTRY THAT IMPACTS MARINE ECOSYSTEMS AND THE ENVIRONMENT

RESEARCH AND INNOVATION AT THE UNIVERSITY OF HAWAIʻI - 2021

UNIVERSITY of HAWAIʻI® SYSTEM


Delve. Seek. Verify.

University of Hawai‘i System

David Lassner, PhD
President

Vassilis L. Syrmos, PhD
Vice President for Research and Innovation

***NOELO,* WHICH MEANS "TO DELVE, SEEK OUT OR VERIFY" IN HAWAIIAN, IS THE RESEARCH MAGAZINE OF THE UNIVERSITY OF HAWAI‘I SYSTEM PUBLISHED ANNUALLY BY THE OFFICE OF THE VICE PRESIDENT FOR RESEARCH AND INNOVATION.**

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LEFT: *Composite image of Radiolarians and Foraminifera, single-celled organisms usually less than 1 mm in size, that live on or within the seafloor sediment or float in the water column at various depths.*
PHOTO: ANGELICQUE WHITE

As we slowly begin to emerge from the global COVID-19 pandemic, we have borne witness to the importance of scientific inquiry and discovery in the fight to end this crisis. But research is much more than developing vaccines. It is also a driver of innovation, new discoveries, learning, workforce development and economic diversification.

In fiscal year 2020, University of Hawai‘i (UH) research expenditures totaled over $485 million and according to a recent report published by the University of Hawai‘i Economic Research Organization, those research expenditures generated $735 million in total business sales, $237 million in employee earnings and $42 million in state tax revenue; and supported an estimated 5,400 jobs in the islands. Our on-going efforts to grow a new, diverse and dynamic job sector based on the commercialization of UH-based research innovations will play a key role in the state's post-pandemic economic revitalization efforts.

Because Hawai‘i is an island state, often considered as one of the most geographically isolated population centers on Earth, it is extremely vulnerable to climate change and its increasingly catastrophic effects on our ecosystems and environment — with issues like extreme weather, ocean acidification, sea level rise, coral bleaching and a loss of biodiversity on land and in the sea that pose an even larger threat to our sustainability. To solve some of these problems, we sometimes need to look back at our past in order to shape our future.

In ancient Hawai‘i, a robust and fully self-sustaining ecosystem centered around a set of revered cultural practices that included mālama‘āina (care of the land) and kuleana (a person's responsibility to themselves and their community) that contributed to an efficient and effective natural resources management system. Today, UH researchers, staff and students are applying a similar set of core values in the field and in their laboratories as they collaboratively work to better understand the changes in our environment and to develop sustainable solutions to protect our shorelines, oceans, forests, freshwater sources and other natural habitats — not only in Hawai‘i — but around the world.

In the following pages, take a look at a sampling of our body of work and learn how our research makes the University of Hawai‘i — like no place else on Earth.

Vassilis L. Syrmos, PhD
Vice President for Research and Innovation
University of Hawai‘i System

In This Issue

COVER: *Professor Christopher Sabine conducts research on the effects of ocean acidification on coral at the Hawai'i Institute of Marine Biology*

Strengthening Foundations

UH'S STEWARDSHIP OF MAUNAKEA

AT 13,803 FEET ABOVE SEA LEVEL, MAUNAKEA ON HAWAI'I ISLAND, IS THE SECOND HIGHEST ISLAND PEAK IN THE WORLD AND THE HIGHEST POINT IN THE STATE. With its perfect combination of high elevation, dry environment, clean air and stable airflow — Maunakea is considered one of the best sites in the world for astronomical observation.

Modern astronomy on Maunakea began in the aftermath of the devastating 1960 Chilean tsunami that hit the northeastern coast on Hawai'i Island that resulted in the loss of over 500 business and homes, caused $75 million in damages, and killed 61 people. A new economic driver was needed to shore up Hawai'i Island's fragile economy from future disasters. Hoping to capitalize on Maunakea's almost-perfect attributes to attract the astronomy industry to Hawai'i and to establish the state as a worldwide leader in the field, then Governor John A. Burns authorized the Hawai'i State Board of Land and Natural Resources (BLNR) to enter into a 65-year lease with the University of Hawai'i (UH) to manage a 11,288-acre science reserve dedicated to astronomy in 1968.

A few years later, the completion of the first major telescope on Maunakea, closely followed by the creation of the Institute for Astronomy–helped to propel UH as a world-class leader in the field. Currently, Maunakea is host to several of the world's premier, ground-based astronomical observatories and is widely considered as the most productive astronomical research site in the world. According to a University of Hawai'i Economic Research Organization report in 2014, it is estimated 1,400 jobs statewide are sustained by astronomy, with an economic impact of $90 million per year on Hawai'i Island and $170 million per year statewide. These are numbers that Governor Burns would have been proud of.

However, much has changed since 1968. Although a strong and diversified economy remains paramount to the state, a strong Native Hawaiian cultural renaissance has ushered the state, UH, Maunakea observatories and other stakeholders in astronomy to reinforce the cultural significance of Maunakea and invite the voices of the community, particularly Hawai'i's indigenous community, into the planning and decision-making process.

In 2014, construction was to begin on the Thirty Meter Telescope (TMT), one of a new class of extremely large telescopes, on Maunakea. Featuring a 30-meter primary mirror and cutting-edge adaptive optics, TMT would be the most powerful telescope in the world—allowing astronomers to look deeper into space with a resolution 10-times sharper than the Hubble Space Telescope. Originally slated to begin scientific operations in 2022, this "crown jewel" of telescopes assured that Hawai'i would remain at the forefront of astronomical research.

Instead, the future of astronomy in Hawai'i has reached a crossroad.

After a number of protests and a well-publicized blockade of the access road to Maunakea by Native Hawaiians that halted construction in July 2019, the TMT project's future is now in limbo. There have also been calls for the state to not renew UH's master lease on the Maunakea Science Reserve, which expires in 2033, due to its past track record of the mountain's management.

In its pursuit of telescope development for the state, UH was admittedly not very balanced in its initial cultural, historic and environmental stewardship of Maunakea. Rocked by a critical state audit in 1998, UH used it as a "wake up call" to become more thoughtful and responsible stewards of the mountain, initiating a series of openly developed and inclusive management plans, resolutions, administrative rules and programs that have resulted in steady improvements over the years.

Management Plans

The turnaround began in 2000 with the creation of the Maunakea Master Plan (MP) that restricted future development to a 525-acre astronomy precinct within the reserve, shifted stewardship responsibility to Hawai'i Island, created the Office of Maunakea Management at University of Hawai'i at Hilo (UH Hilo) and two volunteer community advisory entities—the Maunakea Management Board and the Kahu Kū Mauna (Guardians of the Mountain). The subsequent development of the Maunakea Comprehensive Management Plan (CMP) in 2010 and its supplemental plans, provided overarching

LEFT TO RIGHT: *The endangered u'au or Hawaiian petrel was recently rediscovered on Maunakea*

Native plants like the māmane tree and the 'āweoweo are flourishing as a result of natural regeneration and invasive weed management

The Hawaiian Alpine Wēkiu bug was removed from the endangered species list in 2011

SPREAD: *A sweeping view of the Maunakea Science Reserve*

The Maunakea Rangers are an integral part of protecting Maunakea, as well as the people who work on and visit the mountain

Monitoring of an archeological/cultural site near Lake Waiau on Maunakea

Students in the A Hua He Inoa program named the Kamoʻoalewa and Kaʻepaokaʻāwela asteroids that were discovered in 2015 and 2016 by Pan-STARRS on Haleakalā

management guidelines for Maunakea to address public access, cultural resources management, natural resources management and decommissioning of observatories, as well as management of construction activities, education and outreach.

While not perfect, subsequent audits and evaluations acknowledged UH's efforts and progress. A follow up to the 1998 report by the state auditor in 2014 noted that: "…UH has developed several management plans that provide a comprehensive framework for managing and protecting Mauna Kea while balancing the competing interests of culture, conservation, scientific research and recreation." In 2020, an independent evaluation commissioned by the State of Hawaiʻi Department of Land and Natural Resources stated: "We heard many comments that the cultural and natural resources on the state conservation lands on Mauna Kea are some of the best managed and protected lands in the entire state."

Center for Maunakea Stewardship

The Center for Maunakea Stewardship (CMS) was established in August 2020 to create clear lines of responsibility for stewardship of the mountain under one umbrella with oversight of UH's cultural, scientific, and educational resources. The CMS combines the Office of Maunakea Management and Maunakea Observatories Support Services under the executive director for Maunakea Stewardship and formalizes the collaborative roles for the UH Institute for Astronomy and UH Hilo ʻImiloa Astronomy Center.

Telescope Decommissioning

As part of its promise to reduce astronomy's footprint on Maunakea, the UH Board of Regents approved a resolution in 2019 to decommission and remove five telescopes by 2033. Currently, the Caltech Submillimeter Observatory and the UH Hilo Hoku Keʻa teaching telescope have begun the process. Decommissioning means the complete removal of all man-made structures and the restoration of the site to its pre-construction natural condition to the extent possible. The decommissioning process is almost as complicated as that for construction, requiring environmental assessments, conservation district use permits and public hearings before any demolition work can begin.

Maunakea Rangers

The Maunakea Rangers program was established in 2001 to help protect the natural and cultural resources on the mountain and to provide public safety for visitors and observatory staff. In addition to informing visitors about the cultural, natural and scientific significance of the mountain, Rangers provide emergency assistance, maintain trails, remove litter and ensure that observatories are in compliant with their conservation district use permits.

Cultural and Natural Resource Management

Through an extensive archaeological survey of the Maunakea Science Reserve completed by UH, over 260 historic, archaeological and cultural sites, including ahu (shrines) and burial sites, have been identified and are regularly monitored and protected.

The University of Hawaiʻi's natural resources program for Maunakea includes early detection surveys, protocols and programs to prevent the spread and establishment of invasive species threats. Since 2012, over 2,400 garbage bags of invasive weeds have been removed by over 1,500 community volunteers. In 2019, native plant restoration began at the Hale Pōhaku mid-level facility. A greenhouse was recently completed to help with the propagation and outplanting of native fauna, including māmane, ʻāweoweo, pawale, puakala and heʻupueo.

Through UH's continued conservation efforts, the native wēkiu bug, first discovered on Maunakea in 1979, was removed from the endangered species list in 2011. In addition, the ʻuʻau, an endangered native seabird that has not been seen since 1954, was recently located on the mountain through research sponsored by CMS.

Educational and Cultural Outreach

The ʻImiloa Astronomy Center at UH Hilo is the only science center in the world created explicitly to promote contemporary science education to the public

BELOW: *Students in the Maunakea Scholars program experience life at the summit*

FACING PAGE, BOTTOM: *ʻImiloa Astronomy Center's interactive displays focus on Hawaiian culture, history and astronomy*

"Our goal is to ensure a future for astronomy on Maunakea and we feel the University of Hawai'i is in the best position to do so. We learned a lot over the years and have made significant changes to the way we do things, including what our responsibility is as stewards of the mountain and in our deeper understanding and integration of the values the community, particularly the Native Hawaiian community, into our plans and management."

GREG CHUN
Executive Director
Office of Maunakea Stewardship

within the context of an indigenous culture. 'Imiloa strives to elevate culture and education along with astronomy and land stewardship, including the development of educational materials for staff and visitors to Maunakea, as well as improving the educational and cultural experience at the Visitor Information Center and at the Hale Pōhaku facility. Since its inception in 2006, the center has hosted more than one million visitors, including over 120,000 Hawai'i students in grades K-12. 'Imiloa's A Hua He Inoa program is the first of its kind to weave traditional indigenous practices into the process of officially naming astronomical discoveries.

A number of outstanding educational outreach programs have also been developed over the years by the Maunakea observatories. Examples include the Journey to the Universe program and the highly successful Maunakea Scholars program where local high school students compete for telescope observing time that has resulted in some noteworthy astronomical discoveries.

Other Opportunities

With the transition to mostly remote operations of the telescopes on Maunakea, the Hale Pōhaku mid-level facility is now underutilized. The University of Hawai'i is looking into its potential to serve as a multi-disciplinary field station for itself and other institutions in areas such as geophysics, culture, and history, to name a few. With the planned decommissioning of the Hoku Ke'a teaching telescope, UH is also looking to house a 28-inch educational telescope at Hale Pōhaku that would be available for use by UH students and faculty, as well as the community.

The Future of Astronomy in Hawai'i

Currently, updates to both the MP and CMP are being discussed with stakeholders from the State, Native Hawaiian groups, Maunakea observatories, community members and UH that will offer an even stronger balance of cultural practice, recreation, educational and research opportunities on the mountain. Also, these plans will play a critical role in UH's master lease renewal request to the BLNR that will determine whether UH remains in its current stewardship role, has a reduced role or plays no role in Hawai'i astronomy beyond 2033.

"Our goal is to ensure a future for astronomy on Maunakea and we feel the University of Hawai'i is in the best position to do so," said Greg Chun, executive director of the Office of Maunakea Stewardship. "We learned a lot over the years and have made significant changes to the way we do things, including what our responsibility is as stewards of the mountain and in our deeper understanding and integration of the values the community, particularly the Native Hawaiian community, into our plans and management."

UH's Artemis CubeSat Project

MAKING SMALL SATELLITES AFFORDABLE AND ACCESSIBLE

WHEN PRESIDENT JOHN F. KENNEDY GAVE HIS FAMOUS, "WE CHOOSE TO GO TO THE MOON" SPEECH IN 1962, it helped to inspire a new generation of space explorers that culminated in the National Aeronautics and Space Administration (NASA) successfully landing the first man on the moon with Project Apollo in 1969.

Currently, the United States is planning for a series of return missions to the Moon beginning in 2024. With goals set to land the first woman and the next man on the lunar surface, NASA aptly named its new program after Artemis, the twin sister of Apollo.

To capitalize on the momentum generated by its groundbreaking program, NASA created the Artemis Student Challenges to build foundational knowledge and introduce students to topics and technologies critical to the success of Artemis. Through the program, NASA hopes to inspire the next generation of engineers, scientists and thinkers to become the "steely eyed missile men and women" that will enable humankind to take the next giant leap–sending astronauts to Mars.

Under this bold new initiative, NASA awarded $2.4 million to six space grant universities last year, including a $500,000 award to the University of Hawai'i at Mānoa (UH Mānoa) for its Artemis CubeSat proposal, which called for the development of a CubeSat kit that would check off many boxes on an impressive list of space flight goals, including:

- Undergraduate design and development
- Reducing the cost of space flight
- Development of an online course to supplement hands-on learning
- Outreach to states that have not flown satellites
- Establishment of a potential testbed for new aerospace technologies developed in Hawai'i

On point for the project is the Hawai'i Space Flight Laboratory (HSFL), a multidisciplinary research and education center at UH Mānoa's Hawai'i Institute of Geophysics and Planetology (HIGP) that brings together individuals from diverse backgrounds to work on the exploration and understanding of the space environment. Through HSFL and the Hawai'i Space Grant Consortium (HSGC), students throughout the University of Hawai'i's ten-campus system are able to design, build, launch and operate microsatellites in the 1-150 kg range that can be configured for a variety of science and educational tasks.

The principal investigator of the Artemis CubeSat project is HSFL's newest faculty member, Assistant Research Professor Frances Zhu, who joined HIGP in 2019. Zhu received her Bachelor of Science in mechanical engineering and PhD in aerospace engineering from Cornell University in 2014 and 2019, respectively. Her belief in science literacy and educational accessibility, combined with HSFLs expertise in small satellites, was a motivating factor in applying for the grant.

"Our goal was to create a foundational enabler in the form of a low-cost CubeSat kit and to develop an undergraduate course that transitions into an online course in the public domain," said Zhu, who also serves as deputy director of HSGC. "We are proving that CubeSats are absolutely within the realm of undergraduate education with development of a kit that contains all subsystems of a fully functioning small satellite, with a target cost of less than $5,000."

Traditionally, the lowest priced CubeSats run in the $500,000 range, placing it virtually out of reach for most high school and college aerospace programs. Cognizant of the need to balance cost with the necessary functions, the avionics, software and mechanical student teams carefully selected low-cost computer boards like Raspberry Pi Zero, BeagleBone Black and PyCubed; and often redesigned various components, such as solar panels, power distribution units, antenna and the payload, to fit their exacting requirements.

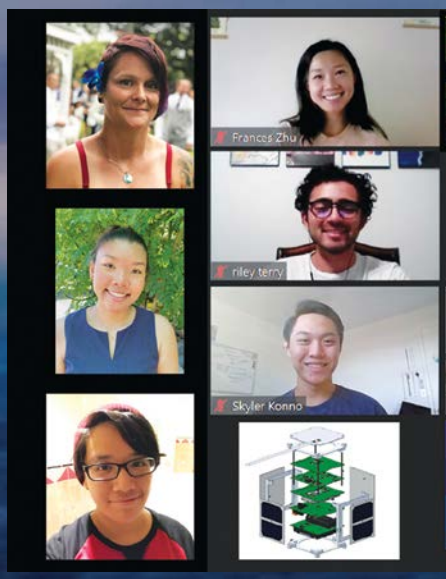
The general capabilities of the standard unit satellite, known as a 1U CubeSat, include onboard computing, radio communication, rudimentary dynamic sensors, a basic infrared camera and an electrical power system. Electrical and digital interfaces are designed to easily connect with the CubeSat Kit Bus for the altitude control system, additional science payloads or propulsion components.

The kit, which includes access to a standardized aerospace design program complete with online support, has been publicized to states that have not launched a small satellite under NASA's CubeSat Launch Initiative. The next phase of the program, already in progress, is focusing on the development of a classroom and online spacecraft mission design course utilizing the kit.

"The kit was not developed and designed solely for space flight," Amber Imai-Hong, HSFL outreach and engineer specialist. "It can be used as a tabletop sensor suite, avionics for a sounding rocket, payload balloon for a suborbital mission, sensor pack for a rover and more."

This flexibility allows HSFL to develop and test new technologies from its undergraduates.

"As a Native Hawaiian and lifelong Hawai'i resident, it is so important to diversify our economy and bring high paying jobs that are ecologically sustainable," added Imai-Hong. "By creating this foundation enabler, we can build a homegrown aerospace workforce in Hawai'i."



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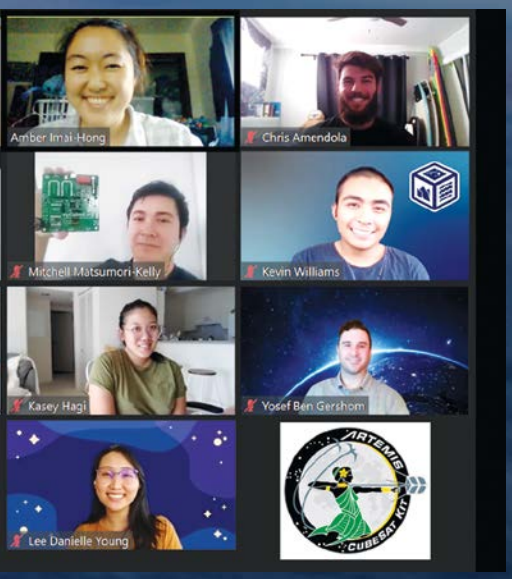
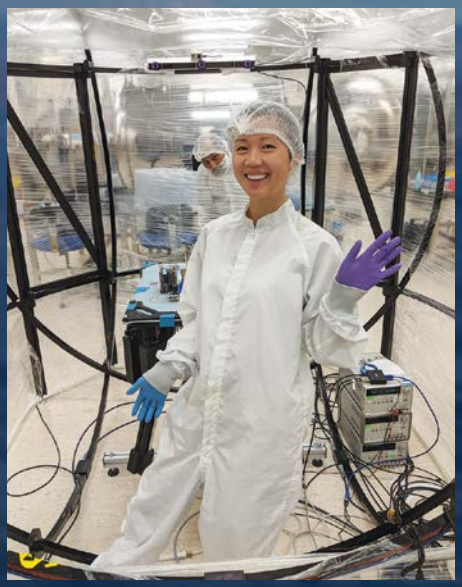
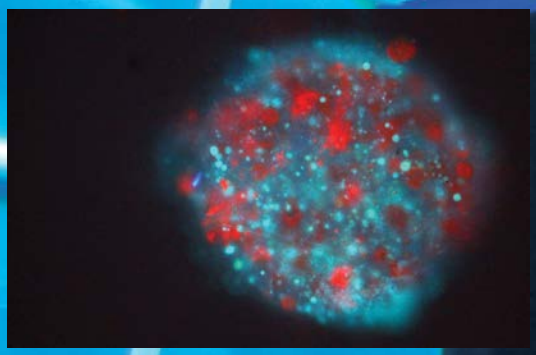


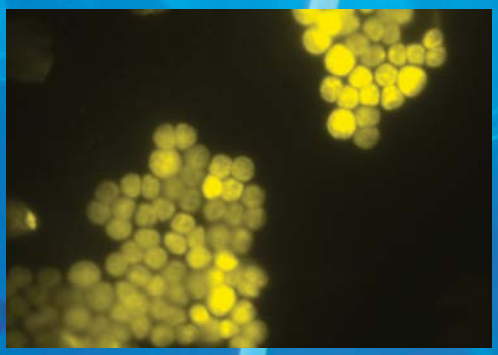


ABOVE: *Artemis CubeSat Kit Hardware integrated without solar panels*

FAR LEFT: *The Artemis team, comprised of undergraduate students, staff and faculty from UH Mānoa*

LEFT: *Dr. Frances Zhu in the Astrofein Attitude Control Testbed used to test satellite control systems*





A HOT Topic

UH'S VENERABLE OCEAN TIME SERIES ENTERS A NEW ERA OF LEADERSHIP

AT OVER 60 MILLION SQUARE MILES, THE PACIFIC OCEAN IS THE EARTH'S LARGEST AND DEEPEST OCEAN BASIN. In the middle of it all, lies a vast swirling system of currents known as the North Pacific Subtropical Gyre (NPSG). At four times the size of the Amazon rainforest, it is considered the world's largest ocean ecosystem.

However, unlike the Amazon, most of the plants and animals in the open ocean are microscopic. A single milliliter of seawater can contain more than 100,000 specimens and they come in a wide variety of shapes and sizes, colors and metabolisms. Some of these microbes produce oxygen, consume carbon dioxide and form the base of the food web upon which every other form of ocean life is reliant.

HOT/Station ALOHA

Since 1988 on an almost monthly basis, a dedicated and diverse team of University of Hawai'i at Mānoa (UH Mānoa) scientists have sailed into the NPSG, located 100 kilometers north of the island of O'ahu, to their field site known affectionately as Station ALOHA (A Long-Term Oligotrophic Habitat Assessment). This 33-year pilgrimage has been in support of the Hawai'i Ocean Time-series (HOT) program, one of the longest-running open ocean time-series on Earth, co-founded by world-renowned oceanographer David Karl.

"Decades of sustained ecosystem observations from HOT have revolutionized humankind's understanding of the ecology, physics, and biochemistry of the NPSG that surrounds the Hawaiian Islands and provides some of the only decadal-scale observations to gauge future changes in the ocean," said Karl. "The program is also a testbed for new technology and serves as an invaluable training ground that has attracted researchers from around the globe."

One of those researchers was Angelicque White, who took over for Karl as principal investigator of HOT in 2019.

Influential First Meeting/Early Work

White was first introduced to Karl in 2002 when she participated in a HOT cruise while working on her PhD in biological oceanography at Oregon State University (OSU), after earning her bachelor's and master's degrees in biology from the University of Alabama at Huntsville. In 2006, White was a student in the inaugural Agouron Institute course in microbial oceanography at UH Mānoa that was built on the scaffolding of HOT, and later became one of the course instructors in 2012. During her postdoctoral years and later as an assistant professor at OSU (between 2006-2012), she also was a part of Karl's acclaimed Center for Microbial Oceanography: Research and Education (C-MORE) program.

"Since then, Hawai'i and the HOT program have been an intellectual home for me in many ways," said White. "They were formative scientific experiences that built strong research ties and forged long-standing scientific collaborations for me with the state and UH."

White's work focused on the study of harmful algal blooms, remote sensing of phytoplankton and ocean acidification along the Oregon Coast, that included the utilization of a 20-year time series at OSU. At the same time, White built a rich funding portfolio with support from diverse sources, including the National Science Foundation (NSF), National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, and private funding sources such as the Simons Foundation. Her research, teaching and outreach efforts were recognized by a research fellowship from the Sloan Foundation in 2012; and prestigious early career awards from the American Geophysical Union in 2015 and the Association for the Sciences of Limnology and Oceanography in 2016.

FACING PAGE, ABOVE: *White during her TED Talk at the National Academy of Sciences in 2019*

FACING PAGE, BELOW (CLOCKWISE FROM LEFT): *Assortment of organisms collected from a net tow; Epifluoresence of radiolaria and symbionts Ross Sea, Antarctica; Squid larva; Colonial Cyanobacteria-epifluorescence*
PHOTOS: ANGELICQUE WHITE

SPREAD: *On location at Station ALOHA*

RIGHT: *Water sampling rosette aboard the R/V Kilo Moana*

BELOW LEFT: *White holding the cod end (collection bucket) after completion of a surface net tow*

BELOW RIGHT: *HOT Leadership Succession Day, July 31, 2019*

PHOTOS: SOEST

A Dream Job

Then, an opportunity arose to work with David Karl and the HOT team, in what she describes as her "dream job." Lured in no small measure by the chance to be a part of what she calls "an essential ecosystem service to our planet," White joined UH Mānoa as an associate professor in 2018. Similar to Karl, White's work is largely conducted in the natural laboratory of the sea, with her expertise focused on ocean optics and elemental fluxes.

Through HOT, researchers have documented the variability of ocean water masses and circulation; observed habitat variability; determined relationships between microbial community structure and function, including nutrient dynamics and carbon sequestration; and measured carbon dioxide levels in the upper ocean and quantified the capacity of the ocean to absorb it.

"It's not just a place of discovery. The important part about time series are that they provide us a sense of history, a sense of context," said White. "And with 30-plus years of data, HOT has allowed us to separate the seasonal change and see the emergence of humanity's fingerprints on the natural world."

Humanities Fingerprints

Unfortunately, this has included the rapid increase of carbon dioxide (CO_2) in the atmosphere. As CO_2 levels rise in the atmosphere, CO_2 also rises in the ocean, resulting in a fundamental change in the acidity of seawater. Known as ocean acidification, it has far-reaching impacts not only on the growth rates and metabolic interactions of small organisms, but also on large ecosystems like coral reefs.

"In the 33 years of the time-series, less than half the average life expectancy in the U.S., the HOT program has observed a clear and persistent increase in CO_2 and the decline in pH in the top 500 meters of the water column," said White. "What this signifies, is that the collective impact of everyday human activities from around the world has affected the water column in one of the most remote places on the planet. That should give us all a moment of pause to reflect on our actions as individuals and as a global society moving forward to curb this alarming trend. Our atmosphere and oceans have no geographic borders; they are for us all to protect."

Not All Doom and Gloom

Along with algal blooms and ocean acidification, other issues such as sea level rise, pollution, loss of biodiversity and overfishing also pose grave threats to Earth's delicate ecosystem. However, White is quick to point out that microbial ecosystems in the ocean are resilient.

"We know ocean ecosystems can be remarkably resilient. We just don't know when we will have gone too far and tipped the ecological scales beyond a point of return," said White. "Sustained observations have shed light on a changing ocean and now humanity must find a way to reverse its course and seek solutions to mitigate the rising levels of CO_2 and protect the microbes that sustain us."

A TED Talk Star is Born

In 2019, White got a chance to spread the gospel of HOT to a wider audience when she was selected as one of 14 speakers for the first science-centric TED Talk held at the National Academy of Sciences in Washington, D.C. Her presentation on what ocean microbes reveal about the changing climate captured the interest of 1.8 million viewers, making it into the Top 10 most watched TED Talks of 2020—and elevating her to "rock star" status in science.

"My short video pitch was made on the stern of a research vessel at sea with the sound of whipping winds and rolling waves drowning out most of my audio," said White. "It must've made an impression on the TED folks or maybe they just felt sorry for me having to brave the elements on that pitching deck."

The Future of HOT/Station ALOHA

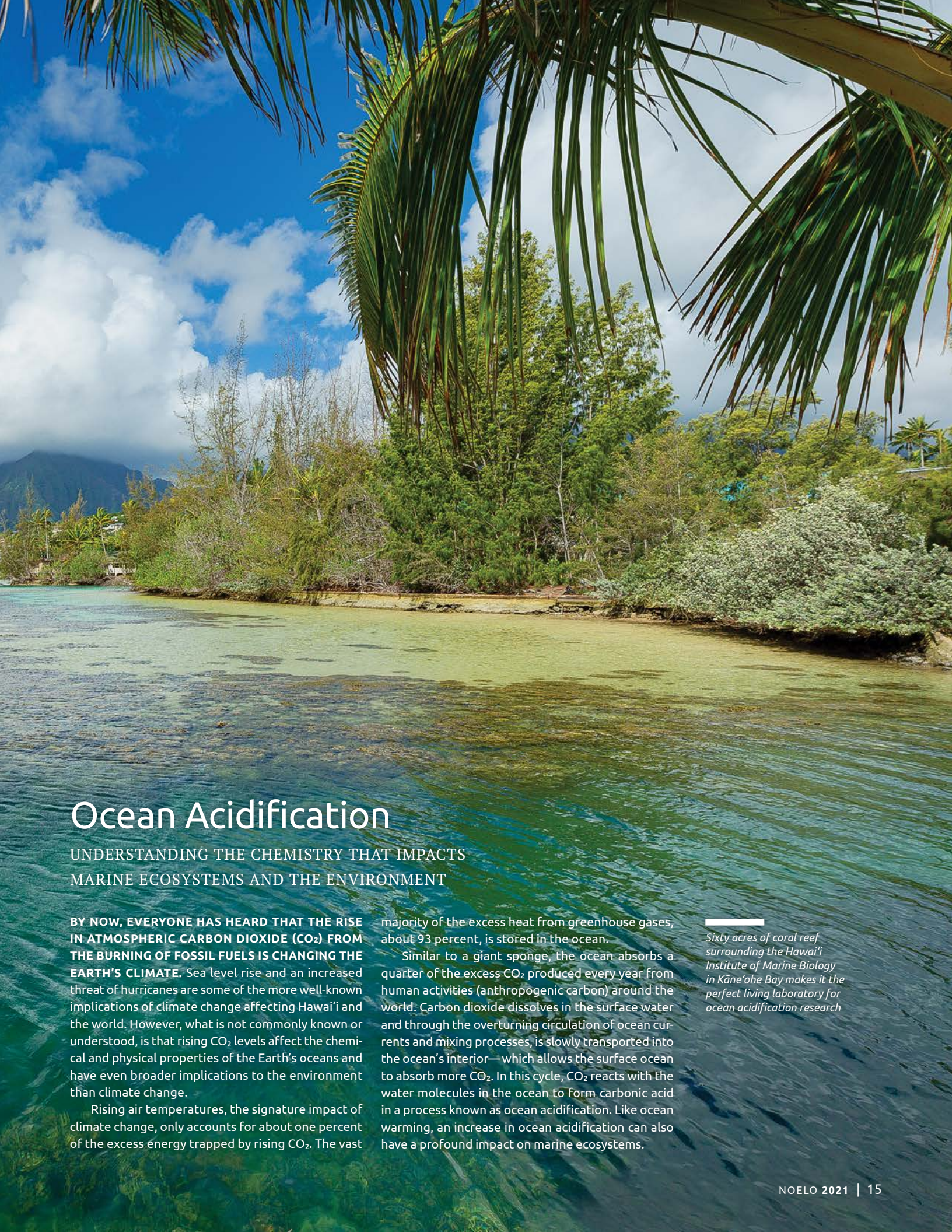
"The University of Hawai'i at Mānoa is a nexus for leaders in ocean observing with extraordinary access to the sea and seagoing infrastructure," said Brian Taylor, dean of the UH Mānoa School of Ocean and Earth Science and Technology (SOEST). "It is no small feat to study the largest ecosystem on the planet, yet we've made some amazing progress here at SOEST, which is a tribute to our researchers like Dave Karl, Roger Lukas and now Angelicque White."

Buoyed by a five-year $9 million award from NSF in 2018, HOT will continue to maintain a vigilant watch on the ecology, physics, and chemistry of the North Pacific. The venerable program will also continue as a testbed for new technologies and experimental approaches to help solve more of the enduring mysteries of the microbial ocean, document new organisms and discover new pathways for exchange of elements and energy.

"We will continue to be leaders in open data sharing that is so fundamental for time-series and to foster curiosity, creativity, openness and a sense of connection to our natural world," said White, who was recently promoted to full professor and is the recipient of the 2021 UH Regents' Medal of Excellence in Research. "I am proud to lead this program forward with an incredible team at my side, and to continue the indelible legacy of the great David Karl."

"The University of Hawai'i at Mānoa is a nexus for leaders in ocean observing with extraordinary access to the sea and seagoing infrastructure. It is no small feat to study the largest ecosystem on the planet, yet we've made some amazing progress here at SOEST, which is a tribute to our researchers like Dave Karl, Roger Lukas and now Angelicque White."

BRIAN TAYLOR
Dean of the UH Mānoa School of Ocean and Earth Science and Technology (SOEST)



Ocean Acidification

UNDERSTANDING THE CHEMISTRY THAT IMPACTS MARINE ECOSYSTEMS AND THE ENVIRONMENT

BY NOW, EVERYONE HAS HEARD THAT THE RISE IN ATMOSPHERIC CARBON DIOXIDE (CO_2) FROM THE BURNING OF FOSSIL FUELS IS CHANGING THE EARTH'S CLIMATE. Sea level rise and an increased threat of hurricanes are some of the more well-known implications of climate change affecting Hawai'i and the world. However, what is not commonly known or understood, is that rising CO_2 levels affect the chemical and physical properties of the Earth's oceans and have even broader implications to the environment than climate change.

Rising air temperatures, the signature impact of climate change, only accounts for about one percent of the excess energy trapped by rising CO_2. The vast majority of the excess heat from greenhouse gases, about 93 percent, is stored in the ocean.

Similar to a giant sponge, the ocean absorbs a quarter of the excess CO_2 produced every year from human activities (anthropogenic carbon) around the world. Carbon dioxide dissolves in the surface water and through the overturning circulation of ocean currents and mixing processes, is slowly transported into the ocean's interior—which allows the surface ocean to absorb more CO_2. In this cycle, CO_2 reacts with the water molecules in the ocean to form carbonic acid in a process known as ocean acidification. Like ocean warming, an increase in ocean acidification can also have a profound impact on marine ecosystems.

Sixty acres of coral reef surrounding the Hawai'i Institute of Marine Biology in Kāne'ohe Bay makes it the perfect living laboratory for ocean acidification research

University of Hawai'i at Mānoa (UH Mānoa) Oceanography Professor Christopher Sabine has devoted his life to understanding the connections between the ocean and anthropogenic carbon. After earning his PhD in chemical oceanography at UH Mānoa in the early 1990s, Sabine spent the next decade conducting high-quality carbon measurements in an effort to better understand where inorganic carbon is stored in the ocean.

"Initially, we were thinking that ocean storage of anthropogenic carbon was a good thing," said Sabine, who also serves as the associate dean for research at UH Mānoa's School of Ocean and Earth Science and Technology. "While producing the first robust, global synthesis of anthropogenic carbon based on direct ocean carbon measurements, we in the scientific community came to the realization that the accumulation of over 100 billion metric tons of anthropogenic carbon in the ocean would negatively impact marine organisms in ways not considered previously."

With this discovery, the field of ocean acidification research was created. Today, researchers have written tens of thousands of articles on ocean acidification, a term that did not exist 20 years ago.

Over the course of a distinguished 18-year career with the National Oceanic and Atmospheric Administration (NOAA) that began as an entry level oceanographer and culminated as director of the prestigious Pacific Marine Environmental Lab, Sabine helped develop the initial ocean acidification observing network in the waters around the U.S. He continued to focus his research on understanding ocean carbon cycling and the progressive development of ocean acidification around the world.

One of the initial concerns with ocean acidification was the impact it would have on calcifying organisms, that is, creatures that produce calcium carbonate skeletons or shells. Calcium carbonate is what forms the white sand beaches of Hawai'i. It is formed when corals, or other calcifying organisms, take a dissolved calcium ion and a carbonate ion and put them together to create a solid, calcium carbonate.

"As the ocean absorbs more CO_2 from the atmosphere, the concentration of carbonate ions decreases—nearly 20 percent so far," said Sabine. "With less carbonate ion in seawater, it becomes more difficult for corals and other calcifiers to form their critical skeletons and shells."

As research has progressed on ocean acidification, many other complicated effects on marine ecosystems have come to light. The changing chemical composition of the ocean has also been linked to hearing loss in fish due to enlarged otoliths (ear stones), disrupted reproductive cycles, increased frequency and toxicity of harmful algal blooms, and decreased sound absorption in the ocean.

Recognized as a pioneering leader in ocean acidification research, Sabine has significantly contributed to the growing body of national and international research programs over the last two decades. He has been a scientific advisor for a number of national carbon programs in the U.S. and internationally. He has won numerous awards, including the U.S. Department of Commerce Gold Medal Award for pioneering research leading to the discovery of increased acidification in the world's oceans and was recognized by the Intergovernmental Program on Climate Change (IPCC) for his contributions to the IPCC, when they were awarded the Nobel Peace Prize in 2007. He was also a coordinating lead author on the carbon cycle chapter of the IPCC 5th Assessment Report and in 2013, was made a fellow of the American Geophysical Union.

As time passed and the ocean's load of anthropogenic CO_2 increased by over 50 percent, Sabine realized that he was spending all of his time on administrative responsibilities and no longer had time for his passion—conducting research out on the ocean. When a carbon chemist position opened up at UH Mānoa's Department of Oceanography, Sabine literally jumped at the opportunity.

"It was a chance to refocus my career," said Sabine. "It was an opportunity to return to the ocean and look for solutions to the problems I had been studying for the last three decades."

Since starting as a full professor at the beginning of 2018, Sabine has been monitoring ocean carbon concentrations around Hawai'i using autonomous, buoy-based systems he helped develop as a researcher with NOAA. He is also working with colleagues to develop and test new instruments for measuring ocean acidification, as well as methods to better understand the impacts of climate change and ocean acidification on Hawaiian corals.

"Corals are a particularly vulnerable species because they are sensitive to rising ocean temperatures through a phenomenon known as coral bleaching, and they exhibit slower growth rates and increased fragility from ocean acidification," said Sabine. "These combined stresses, together with an increased risk of damage from a possible hurricane or drowning from rising sea levels, are a grave concern for Hawai'i's coral reefs."

Ultimately, Sabine hopes to explore more proactive ways to protect and restore Hawai'i's coral reefs. In the meantime, he also teaches a Global Environmental Change class in an effort to inspire the next generation of researchers to help find solutions.

"The ocean uptake and storage of human-produced CO_2 has significantly decreased the climate change effects the planet has seen so far," said Sabine. "Getting a handle on how much more the ocean can take is critical in predicting future climate change impacts."

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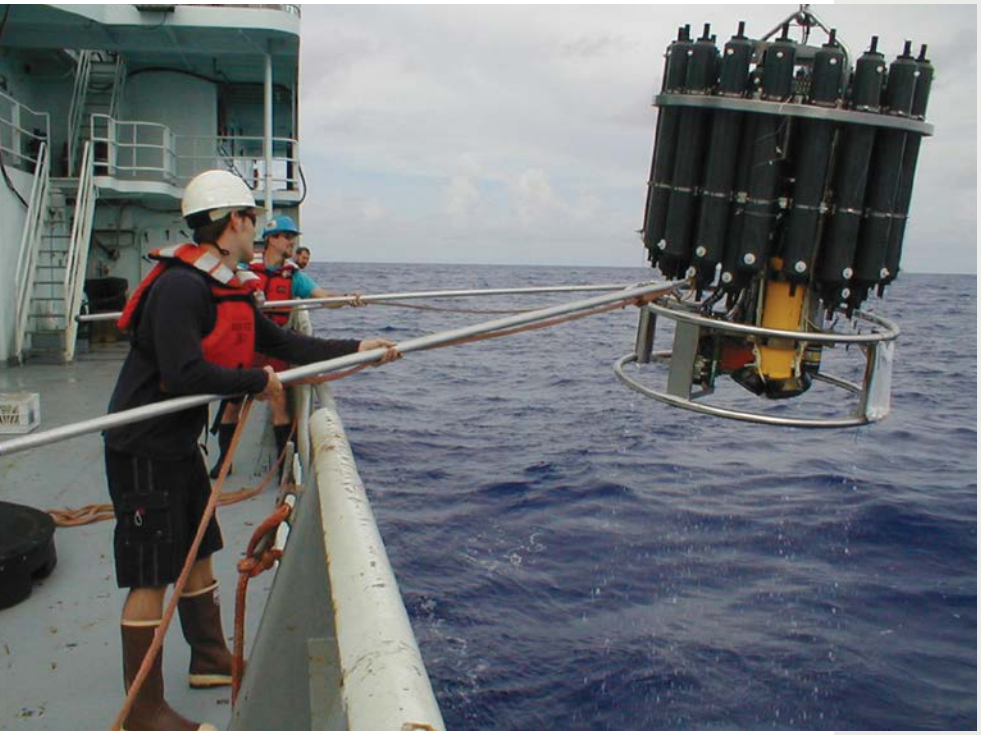
CHRISTOPHER SABINE
Professor, Oceanography
UH Mānoa

BELOW: *An ocean acidification mooring in Kāne'ohe Bay. The instruments on this buoy measure ocean acidification and other water properties to help assess the health of the coral reef system in the bay (http://www.pacioos.hawaii.edu/projects/acid/crimp2/)*

LEFT: *(Left-right) Adrienne Sutton, Remy Okazak, Christopher Sabine and Richard Feely on the back deck of UH's R/V Kilo Moana in May 2015. This team made the high-quality ocean carbon measurements used to evaluate which of the pH sensors would win the $2M Wendy Schmidt Ocean Health X-Prize competition.* PHOTO: NOAA/PMEL



ABOVE: *Helping to recover a water sampling package on a North Pacific research cruise*

LEFT: *Sabine evaluating a potential deployment site for a mooring in Palau*

RIGHT, TOP: *Explaining ocean carbon chemistry during a capacity building workshop in Fiji in October 2017*

RIGHT, BOTTOM: *An example of coral bleaching*

PBTRC

PROMOTING TELEHEALTH AND DIGITAL EQUITY

IN EARLY JANUARY 2020, NEWS ABOUT A DEVELOPING RESPIRATORY DISEASE IN WUHAN, CHINA BEGAN TO SPREAD AROUND THE WORLD. Within a matter of weeks, the COVID-19 virus itself went global — reaching pandemic levels that forced entire countries into lockdown to prevent its spread.

When the COVID-19 virus eventually reached Hawai'i, it forced healthcare institutions to find alternative methods of providing patient care to limit potential exposure to physicians, nurses, other healthcare providers, and of course the patients themselves. Telehealth, which is defined as the delivery of healthcare via telecommunications technologies such as computers or mobile phones, emerged as the frontrunner in similar fashion to how organizations gravitated to virtual meeting platforms like Zoom, Microsoft Teams or Google Meet to safely conduct daily business.

"Telehealth is a natural fit for our island state, where the majority of health specialists are in Honolulu, but need to service patients on the other islands," said Christina Higa, co-director of the Pacific Basin Telehealth Resource Center (PBTRC). "But even as recently as five to six years ago, the telehealth adoption rate was lagging with less than five percent of healthcare providers adopting the technology. The pandemic changed that. Now most health providers in Hawai'i have offered or contemplated telehealth services."

Much of the framework, guidelines and policies in support of telehealth in Hawai'i can be attributed to the behind-the-scene efforts of PBTRC, which was established at the University of Hawai'i at Mānoa (UH Mānoa) in 2010 to expand the availability of healthcare services in the state and around the Pacific. A collaboration between the UH Mānoa College of Social Sciences and the John A. Burns School of Medicine, PBTRC is one of 14 federally funded telehealth resource centers in the U.S. and is a member of the National Consortium of Telehealth Resource Centers.

During the pandemic, PBTRC immediately channeled its resources into helping the healthcare community focus on how to help people continue to have their healthcare needs met. PBTRC is currently working with the state Department of Health and Hawai'i State Public Library System to establish Hawai'i Telehealth Access Points at libraries, where internet connections and rooms can be used for telehealth consultations. Under the program, which just received $3.7 million in funding from the Centers for Disease Control and Prevention, libraries can also loan out MiFi units (mobile Wi-Fi hotspots) to people wanting to attend telehealth consults from the privacy of their own homes. The project will also enable health navigators and community health workers to assist patients with connecting to their telehealth appointments and accessing other health resources. As these support systems develop, PBTRC will continue working with healthcare advocates to promote supportive policies, payment structures and incentives for telehealth utilization.

"The collaboration that took place, and that is still taking place, is impressive," said Deborah Peters, PBTRC co-director and JABSOM senior scientist and research manager. "The urgency of the work that we were doing required us to break down silos, roll up our sleeves, and dive in. Everywhere you looked people were working together around the clock to immediately ramp up telehealth services — especially when the state went into stay-at-home quarantine orders."

As Hawai'i continues its transition in the area of healthcare delivery, the goal is to balance the conveniences and efficiencies of virtual care against in-person care. While some worry that the move may result in less personal connection, others believe it's an opportunity for better coordination of care and increased family engagement.

"Today telehealth has become a common means of delivery for healthcare, bringing increased conveniences and efficiencies to both physicians and their patients across the state. But some of Hawai'i's most vulnerable populations in rural areas still face challenges to widespread adoption," said Higa. "PBTRC is now pivoting its focus to utilize telehealth technology to bring more health equity to these groups. For rural areas, particularly on the neighboring islands, transportation to clinics or to O'ahu-based specialists are a challenge. Telehealth changes that dynamic by removing an important barrier to healthcare and bringing us a step closer to health equity throughout the state."

With a decade of experience to call upon, Higa is thankful that PBTRC was able to step into a significant leadership role in 2020. With technology becoming more sophisticated, mobile and integrated into daily lives, the stage is set for the continued use of technology to achieve true patient-centered care — with PBTRC continuing to serve as an important telehealth resource to help bolster Hawai'i's ability to deal with future pandemics and other crises.

"This is an issue of digital equity. The lack of access to broadband was highlighted during this pandemic, because if you didn't have a good Internet connection, your children couldn't go to school online, you couldn't telework or even get healthcare via telehealth," said Higa. "The good news is that federal and state governments are recognizing these issues and have developed many programs to address them. We are tracking these initiatives, building on them and moving forward in a big way."

Learn more about the Pacific Basin Telehealth Resource Center at https://www.pbtrc.org/.

With technology becoming more sophisticated, mobile and integrated into daily lives, the stage is set for the continued use of technology to achieve true patient-centered care — with PBTRC continuing to serve as an important telehealth resource to help bolster Hawai'i's ability to deal with future pandemics and other crises.

PBTRC Co-Director Christina Higa

ABOVE: *Entrance to the Early Phase Clinical Research Center will be conveniently located near parking areas*

RIGHT: *Study participants will check in with the reception desk upon entry to the facility*

BELOW RIGHT: *Patients will receive chemotherapy treatment in one of nine treatment areas within the center*

BELOW LEFT: *The Early Phase Clinical Research Center will be located at the Ewa end of the existing UH Cancer Center facility*

A New Cutting-Edge Clinic to Join the Fight Against Cancer

WHEN A CANCER PATIENT LIVING IN HAWAIʻI REQUIRES SPECIALIZED TREATMENTS FOR THE DISEASE, MORE OFTEN THAN NOT, IT MEANS TRAVELING TO THE CONTINENTAL U.S. TO RECEIVE IT. In addition to enduring a long flight and dealing with the expenses associated with travel, patients are often separated from their families and home for extended periods, leading to unwanted anxiety and additional stress during an already difficult time.

That scenario will soon be a thing of the past for many patients, as the University of Hawai' i Cancer Center (UH Cancer Center) will begin construction on an Early Phase Cancer Clinical Research Center (EPCRC), the first of its kind in the state, that will significantly improve patient access to experimental cancer treatments used in Phase 1 trials. These trials represent the first-in-human stage of developing new cancer treatments and are essential for patients not responding to existing therapies.

"Phase 1 trials represent the cutting edge of cancer treatments and are often considered for patients who have a particularly challenging form of cancer or when standard treatments are unsuccessful," said UH Cancer Center Deputy Director Joe Ramos. "Approximately, 7,000 people are diagnosed with cancer each year in Hawaiʻi and we estimate that our new center will serve an estimated 100 to 200 patients annually."

The EPCRC was made possible by a $6.5 million grant match from the National Institutes of Health (NIH) and $6.5 million approved by the Hawai' i State Legislature. The $13 million total will be used to construct the EPCRC within 17,000 square feet of existing shell space located in the state-of-the-art UH Cancer Center in Kakaʻako.

Program development and the recruitment of faculty, physicians, nurses and pharmacists to staff the EPCRC is being handled as a joint venture between the UH Cancer Center, University of Hawaiʻi (UH) and clinical partners in the Hawaiʻi Cancer Consortium — which includes Hawaiʻi Pacific Health, Kuakini Medical Center, the Queen's Medical Center, Adventist Health Castle, and Hawaii Medical Service Association (HMSA).

"We are extremely grateful for the tremendous support we have received from our collaborating physicians, the members of the Hawaiʻi Cancer Consortium, NIH, our donors and our Legislature," said Ramos. "I would like to especially give a call out to Senator Breene Harimoto, who was a champion of this project and unfortunately lost his battle with cancer last year."

The EPCRC will also facilitate new avenues for basic cancer research and complement drug development already in place at the UH Cancer Center that focus on identifying anti-cancer compounds derived from natural products unique to Hawaiʻi — creating an opportunity to translate basic discoveries into novel treatments for patients and further expanding the research capabilities of UH.

"We are also creating a 'tumor organoid' facility that will generate patient-based tumor models in the laboratory that are more representative of our unique population here in Hawaiʻi, and thereby develop and test potential new treatments specifically with our population in mind," added Ramos.

Organoids are the very latest in pre-clinical analysis of cancer and are derived from patient biopsies. A specialized technique for examining cancer cells, organoids are used to test new drug leads, to identify molecular differences that cause disparities in cancer, and to identify the specific mechanisms that drive the cancer in different patients. By having this capacity located in Hawaiʻi, there will be an opportunity to improve understanding of cancer and to better treat it specifically in the diverse ethnicities in Hawai' i.

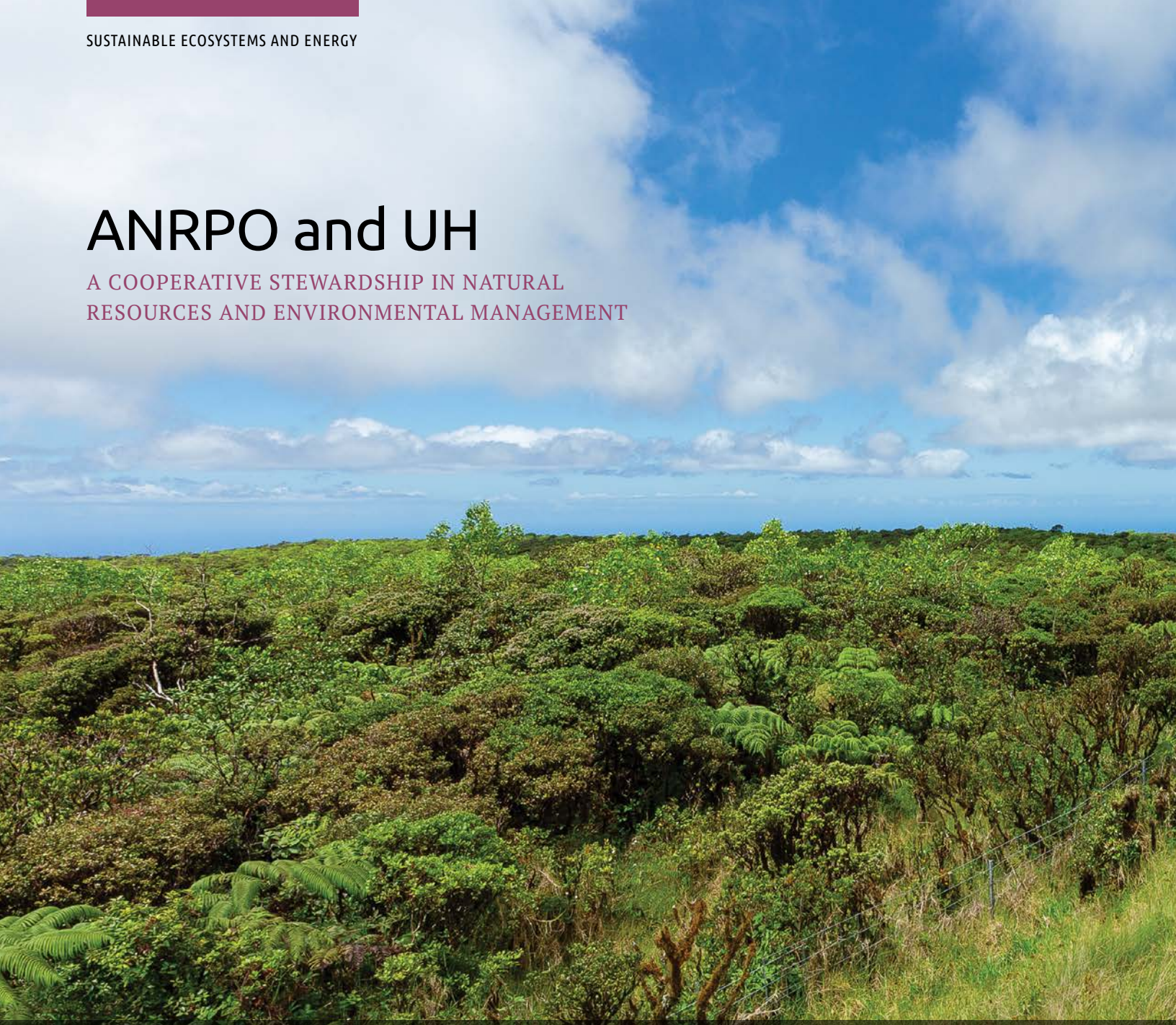
By expanding research capabilities and capacity, researchers who will benefit from the EPCRC include faculty and students at UH Cancer Center and John A. Burns School of Medicine, other researchers in the UH System, as well as other Hawaiʻi based institutions. More importantly, the resource will also provide substantial benefit to the people of Hawaiʻi, including Native Hawaiians and LGBTQ individuals, generate knowledge about the efficacy of novel agents in diverse populations, facilitate access to novel trials, and provide a resource for research on tumor-derived organoids from a racially and ethnically diverse population.

"Phase 1 trials represent the cutting edge of cancer treatments and are often considered for patients who have a particularly challenging form of cancer or when standard treatments are unsuccessful."

JOE RAMOS
UH Cancer Center
Deputy Director

ANRPO and UH

A COOPERATIVE STEWARDSHIP IN NATURAL RESOURCES AND ENVIRONMENTAL MANAGEMENT



U.S. Army Garrison Hawai‘i’s Schofield Barracks is home to an elite unit whose mission is to protect the island of O‘ahu from invasion.

They use helicopters and four-wheel drive vehicles; often rappel down steep mountainsides; and use their highly trained special skills to carry out their assigned objectives.

While the description certainly brings to one’s mind the famed U.S. Army Rangers, this group utilizes their specialized acumen and knowledge in conservation biology to protect endangered species and habitats on more than 50,000 acres of U.S. Army training ground on the island. They are members of the Army Natural Resource Program on O‘ahu (ANRPO), an approximately $21 million project funded through a cooperative agreement with the U.S. Army.

As a federal agency, the U.S. Army is required by the Endangered Species Act of 1973 to protect any federally listed endangered or threatened animals

and plants in their training areas and to ensure they are not negatively impacted. Additionally, they are bound by the Sikes Act that covers wildlife, fish and game conservation and rehabilitation on military reservations.

"In Hawai'i, the U.S. Army is responsible for over 120 endangered plants and animals, the highest number of endangered species for any Army garrison in the United States," said U.S. Army Garrison Hawai'i Natural Resource Manager Kapua Kawelo. "Through ANRPO, the U.S. Army is able to maintain compliance in their five O'ahu training areas, enabling service members from the Army, Marines, Navy, Air Force, National Guard and Reserve, as well as local law enforcement agencies, to successfully maintain their operational readiness."

The ANRPO team consists of two U.S. Army Garrison Hawai'i civilian employees and over 50 contract biologists and technicians who protect the native habitats via removal of pigs and goats from fenced units, invasive plant control and eradication, vegetation restoration, and rodent and slug control. In addition, ANRPO maintains and increases populations of endangered plants and animals through monitoring, cultivation and reintroduction. The program collaborates and consults extensively with conservation entities across the state of Hawai'i including the U.S. Fish and Wildlife Service, Hawai'i State Division of Forestry and Wildlife, Hawai'i State Department of Land and Natural Resources, the O'ahu Invasive Species Committee, the Hawaiian Seed Bank Partnership, the Hawai'i Rare Plant Restoration Group, and

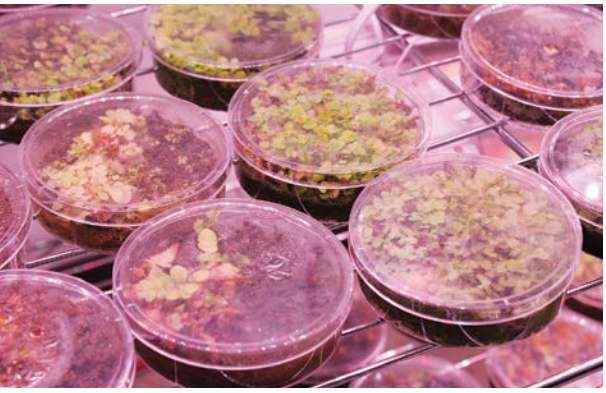
ABOVE: *(L-R) ANRPO members Clay Trauernicht, Samantha Shizuru, Kapua Kawelo, Jon Winchester, Jane Beachy, Deena Gary and Joby Rohrer*

the Honolulu Board of Water Supply, as well as many other municipal and private entities.

As new challenges and obstacles arise that often require innovative solutions, ANRPO regularly partners with researchers from various institutions and agencies from around the world. While the University of Hawai‘i has always been the defacto institution due to its location and expertise, a much stronger research relationship has developed when the University of Hawai‘i Office of the Vice President for Research and Innovation (OVPRI) entered into a cooperative agreement to administratively oversee ANRPO in 2018.

“The outstanding conservation work done by ANRPO is not only vital to the operational readiness of military forces in Hawai‘i, but also to preserving and maintaining the state’s finite natural resources and habitats,” said UH Vice President for Research and Innovation Vassilis L. Syrmos. “The partnership allows us to seamlessly integrate our excellent cadre of researchers to work collaboratively with ANRPO staff to find innovative solutions to constantly evolving issues in environmental stewardship.”

While ANRPO works with researchers from a variety of departments at UH, a strong partnership has developed with the Department of Natural Resources and Environmental Management (NREM) at the University of Hawai‘i at Mānoa’s College of Tropical Agriculture and Human Resources. At all levels, from professors to graduate and undergraduate students, NREM provides ongoing support to ANRPO.



Protecting the Endangered Kāhuli Snails

Decades ago, the large numbers of Hawaiian tree snails (kāhuli, genus *Achatinella*) made them look like ornaments on trees, causing shell collectors to come out in droves to snatch them up. Since then, the kāhuli have suffered dramatic declines and losses due to various introduced predators and the range of sites where kāhuli can be found has contracted to higher elevations.

“Unlike other snails, the kāhuli do not lay eggs,” said Melissa Price, a biologist and assistant professor at NREM, who studied under noted UH kāhuli specialist Dr. Michael Hadfield. “The snails give live birth to only one offspring at a time, which is another factor to their extinction level numbers.”

Price, who studied the effect of climate change on kāhuli (Price et al. 2021), has advised ANRPO on how to incorporate climate change considerations in kāhuli management, including selection of management sites. Translocating tree snails into predator fences at sites which are higher and cooler, is putting assisted migration into practice.

Other UH researchers worked with ANRPO on development of effective barriers to affix on predator-proof fences built to protect kāhuli in their native habitat. Electrical, cut copper-mesh, rolled metal hoods and angle barriers are the current combination employed to keep out the tree snail’s three major predators: rats, cannibal snails and Jackson’s chameleons. During the predator fence site selection process, many factors are weighed including terrain, accessibility, predator abundance, and habitat quality.

Controlling the Spread of Invasive Species

NREM guides and mentors numerous students pursuing higher-level degrees with a conservation focus. NREM graduate students have collaborated with ANRPO in the past on studies relating to vegetation mapping and classification, biology and distribution of the Hawaiian owl, and restoration of Hawaiian dry forests. Samantha Shizuru, a graduate assistant

ABOVE: *Assistant Professor Melissa Price, UH Mānoa NREM*

TOP, LEFT: *An endangered kāhuli tree snail (Achatinella mustelina)*

TOP, RIGHT: *Rare Snail Conservation Biologist Deena Gary shows the multi-barrier predator-proof fence built by ANRPO; the fence site was chosen based on research conducted by UH*

LEFT, TOP: *Native ferns are grown from spores in petri dishes in the ANRPO seed lab; once big enough, they will be used for restoration plantings in the field*

LEFT, BOTTOM: *Krista Lizardi pots up rare plant cuttings collected from the field; some of these plants will be planted back into the wild, while others will be maintained in the ANRPO greenhouse as a living collection to preserve genetic diversity*

funded by ANRPO, is currently working with NREM Professor Creighton Litton to study the noxious plant, *Chromolaena odorata* (devil weed). Devil weed was first discovered at the Kahuku Training Area where National Guard troops from Guam were training. Devil weed is abundant in Guam and likely hitched a ride on some field equipment transported to Hawai'i by the soldiers. Devil weed has since been moved around the Kahuku region of O'ahu due to unauthorized recreational vehicle use. Devil weed produces abundant, small, wind-dispersed seeds that have complicated ANRPO's eradication efforts. Thus, ANRPO is utilizing an integrated control approach which combines surveys, herbicide treatment, and biological control.

"Samantha is filling in gaps in ANRPO's knowledge about devil weed's life cycle, reproductive periods, and fecundity," said Kawelo. "She collects data in partnership with ANRPO staff and her research and analysis will feed directly into deploying the biological control most effectively."

Mutual Support Between ANRPO and NREM

Every year, ANRPO hosts a cadre of six to eight summer interns. NREM students are well represented in these coveted internships; in 2020, four of six interns were affiliated with NREM. In addition, ANRPO provides guest lectures to NREM conservation classes on topics ranging from the Endangered Species Act to rare and invasive species management. Also, ANRPO supports students conducting independent research. Krista Lizardi, an undergraduate in NREM and ANRPO summer intern alumna, selected one of ANRPOs rare plant taxa, Dubautia herbstobatae, as the subject of her structured decision making final project.

"Krista guided ANRPO botanical experts through a series of questions to assess staff comfort levels for outplanting this taxon outside of its current range in response to climate change," noted Kawelo. "The application of this decision-making approach was eye opening for natural resource managers at ANRPO because it provided a method for transforming qualitative expert opinion into quantitative actionable data."

Looking to the Future

NREM Associate Specialist Clay Trauernicht was recently hired as an extension professor to serve as liaison between NREM, ANRPO and other U.S. Department of Defense installations. Trauernicht has a strong background in botany, conservation and wildfire science. He has worked to feed wildfire data and lessons learned to natural resource managers so that they can adapt their native habitat management approaches. Trauernicht will track priority research areas/topics, facilitate communications between ANRPO managers, NREM faculty and students, and guide and review proposals and projects. His involvement will allow this budding partnership between UH and ANRPO to bloom into a productive and high-quality research-management collaboration.

Membership Has its Privileges

HAWAI'I-PACIFIC COOPERATIVE ECOSYSTEMS STUDIES UNIT

The University of Hawai'i (UH) plays an important role in Hawai'i in the care of its natural resources and the communities that rely on them. Through partnerships with federal, state, private and non-profit organizations, UH's collective resources bring world-class expertise and facilities to these collaborative efforts, providing rich and meaningful training opportunities for students.

Many of these collaborations involving UH are a result of its participation in the Hawai'i-Pacific Cooperative Ecosystems Studies Unit (HPI-CESU), a partnership program between 10 U.S. federal agencies and 14 non-federal members. HPI-CESU is one of 17 Cooperative Ecosystems Studies Units (CESU) across the United States that were developed to foster federal-non-federal partnerships to steward cultural and natural resources on public lands. As such, the HPI-CESU serves as the backbone of many successful and important conservation collaborations in the state.

Federal agencies can choose to work with a specific CESU, meaning that only HPI-CESU members are eligible to apply for projects targeting this CESU. Funds are provided to partners via a federal CESU cooperative agreement, which requires significant involvement of both federal and non-federal partners and emphasizes student engagement. The University of Hawai'i, as a key repository of research expertise and students, serves as the HPI-CESU host organization.

"Membership in the HPI-CESU provides a rich suite of opportunities for UH researchers to work with federal agencies in Hawai'i and the Pacific on important collaborative research that helps the state and its partners care for the natural and cultural resources in the region," said HPI-CESU Director Sharon Ziegler-Chong at the University of Hawai'i at Hilo.

Since October 2019, UH has received over $10 million from different agencies to work on a variety of projects. The Plant Extinction Prevention Program (PEPP), is a Pacific Cooperative Studies Unit (PCSU) project between UH Mānoa's Department of Botany, the U.S. Department of Interior's Fish and Wildlife Service and other partners. Another exciting project is a project led by Davianna McGregor, professor of Ethnic Studies at UH Mānoa's Center for Oral History with the National Park Service. The multi-year project is conducting an oral history project for all Region 12 parks, i.e., those in Hawai'i and the Pacific Islands, to capture the important stories and history behind these parks. Examples include the history of fencing on Haleakalā, the opelu boat traditions at Pu'uhonua O Hōnaunau, and the oral histories of internees, POWs and the community at large impacted by the internment camp at the Honouliuli National Historic Site.

The Army Natural Resources Program on O'ahu (see story), administratively managed by the UH Office of the Vice President for Research and Innovation, is a key partnership made possible through UH's HPI-CESU membership.

PIPES

FACILITATING MĀLAMA ʻĀINA PATHWAYS FOR THE NEXT GENERATION

OVER THE LAST 28 YEARS, THE PACIFIC INTERNSHIP PROGRAMS FOR EXPLORING SCIENCE (PIPES) HOUSED WITHIN THE OFFICE OF RESEARCH & COMMUNITY PARTNERSHIPS AT THE UNIVERSITY OF HAWAIʻI AT HILO (UH HILO), has been steadily working with partners across Hawaiʻi and the U.S. Affiliated Pacific Islands (USAPI) to provide undergraduate students with transformative summer internships focused on the care and stewardship of island resources.

The roots of the PIPES program can be traced to 1994 with the start of the Micronesia and American Samoa Student Internship Program (MASSIP), created in response to concerns that the youth of the territories were not returning home or were obtaining degrees with little relevance to their island community needs. The success of MASSIP led to the creation of the UH Hawaiian Internship Program (UH-HIP) in 1997, to address the low representation of kānaka maoli (Native Hawaiians) and kamaʻāina (born and raised in Hawaiʻi) in the natural resource management field. In 2003, UH Hilo was awarded its first of five National Science Foundation (NSF) Research Experience for Undergraduates (REU) awards to help underrepresented students with limited or no research background to explore the world of tropical conservation biology. Since then, these three programs have been run collectively as PIPES—a carefully designed program targeting students with interests stretching from research to natural and cultural resources management to environmental education and outreach who share a common commitment to the resources and communities of these islands.

Each summer, a cohort of 30 to 40 students are paired with mentors in an intensive, full-time, 10-week paid internship program with diverse projects that range from the implementation of outreach programs, outplanting, invasive species monitoring, geospatial analysis for water quality, and coral reef assessments. Host sites for these projects are agencies and organizations from across Hawaiʻi and the Pacific as well as UH research efforts. Examples of host sites include the U.S. Geological Survey's Pacific Island Ecosystems Research Center (PIERC), Mauna Kea Watershed Alliance, Paepae O Heʻeia, the National Park Service in Guam and American Samoa, and the State of Hawaiʻi Division of Aquatic Resources.

Since its inception, PIPES has evolved to be more than just an internship experience—it is focused on empowering its students who are deeply connected to these islands and their communities, often ancestrally, to identify their role and pathways to mālama ʻāina (care of the land). The PIPES program accomplishes this through a cohort mentoring approach with a foundation deeply rooted in Hawaiian cultural values. In addition to their internships, students participate in multiple activities that engage them with the ʻāina (land) and in discussions of their interests, values, and future objectives. By experiencing different ways of learning about places through names, moʻolelo (story), and participating in huakaʻi (field trips), interns connect to each other, new places and the people who care for them, and approaches to conservation in Hawaiʻi that bring these ideas together.

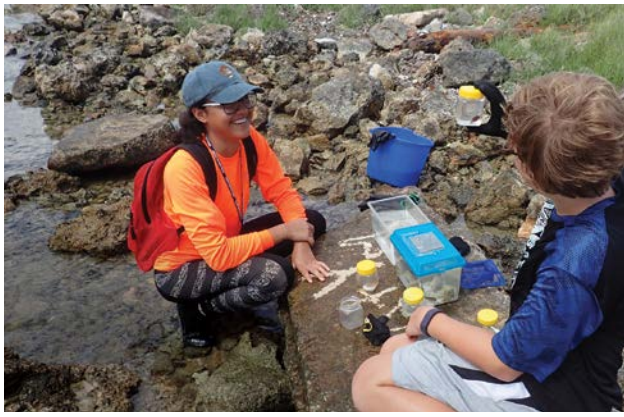
At the core of this teaching is the concept of kuleana or the responsibility to do work that is responsive to the needs of the community. It is this focus of PIPES that forms the quintessential glue that connects the students, staff, host mentors and the extensive community of program alumni across the islands–the importance of reciprocity to place.

"Exploring one's kuleana and roles in caring for these islands and the central role of indigenous and local knowledge are powerful frameworks often not included in conservation internships," said Sharon Ziegler-Chong, director of Research & Community Partnerships at UH Hilo, who also heads PIPES. "Interns in PIPES learn about themselves and gain confidence in their future roles in mālama ʻāina, in building community, and in ensuring that our island communities thrive."

For these mentors and supporting organizations, this program has influenced not only who is involved in caring for island resources, but how it is done. "Through our efforts and those of many others, the conservation community has experienced a marked increase in local representation and influence within a single generation, which, in turn, has shifted how conservation is done in Hawaiʻi and the Pacific," added Ziegler-Chong. This has perhaps become most obvious at the annual Hawaiʻi Conservation Conference (HCC), where the number of interns and PIPES alumni attending continues to grow. "PIPES Interns have helped change the face of HCC in terms of the demographics of conservation practitioners, bringing a whole new generation of researchers and managers into a conference that was once composed largely of older males," said Sam ʻOhu Gon, III, senior scientist and cultural advisor for The Nature Conservancy of Hawaiʻi.

> "PIPES has helped to root the University of Hawaiʻi within the mālama ʻāina field, bringing diversity and recognizing the role that kānaka and kamaʻāina play in Hawaiʻi's conservation field."
>
> **NOELANI PUNIWAI**
> Associate Professor
> Kamakakūokalani Center for Hawaiian Studies

BELOW: *Hannah White (PIPES 2018) interned with the U.S. National Park Service in Guam focused on developing outreach materials and programs on coral reef ecosystems*



"Our ecologists that have mentored PIPES interns have gained from their energy, dedication, and tremendous sense of connection to the environments that we work in," said Gordon Tribble, director of PIERC. "The perspectives and accomplishments of PIPES interns have added greatly to our biocultural awareness and shaped how our researchers view their work and its impact on the community."

Through its efforts, PIPES has created a strong network of kamaʻāina who are engaged in the stewardship of their islands and communities across Hawaiʻi to the broader Pacific. Over the past 28 years of creating summer internships for local undergraduates, PIPES, its alumni and partners have transformed conservation in Hawaiʻi by expanding local participation in resource stewardship efforts and fostering the long-term success of emerging professionals.

More than 800 internships later, the program continues to adapt to the needs of Hawaiʻi and the USAPI. The program continues through host program partnerships and with support from Kamehameha Schools, the Hauʻoli Mau Loa Foundation, and NSF. Today, PIPES' vision is to create a diverse and representative workforce that embodies and integrates mālama ʻāina innovations into ways of knowing, relationships, actions, and professions. Rooted in Hawaiʻi and based on best practice principles of education, mentoring, and building relationships, the PIPES program can be adapted for many efforts focused on ensuring that island places and people continue to thrive into the future.

According to Associate Professor Noelani Puniwai of UH Mānoaʻs Kamakakūokalani Center for Hawaiian Studies, who is a PIPES alumnus, mentor, and co-principal investigator on REU program — "PIPES has helped to root the University of Hawaiʻi within the mālama ʻāina field, bringing diversity and recognizing the role that kānaka and kamaʻāina play in Hawaiʻiʻs conservation field."

ABOVE: *UH Hiloʻs Jonathan Price showing UH Mānoa doctoral researcher and mentor Gina McGuire, Noe Puniwai, and PIPES 2021 interns Kaʻehukai Goin and Kaiʻinipuʻuwai Keliʻihoomalu-Holz what kind of plants are growing along the Kalapana coastline*

LEFT: *Kilaulani Kaawa-Gonzales (PIPES 2017) conducting research with the USDA Institute of Pacific Islands Forestry researching biocontrol of invasive Clidemia hirta*

FACING PAGE: *Marcel Jardeleza (PIPES 2017, CSU PhD student) worked with then UH Hilo researcher Dr. Jon Koch (PIPES 2007) on seasonal and elevational impacts on phenotype of Drosophila suzukii*

Agent of Change

UH STUDY RESHAPES HONOLULU'S URBAN CORE TO EMBRACE SEA LEVEL RISE

MIAMI. NEW YORK. TOKYO. LONDON. While the list brings to mind some of the world's greatest cities, it also doubles as a list of locations most vulnerable to future sea level rise. Unfortunately, an extension of this list would also include many other well-known cities across the world, including Honolulu, Hawai'i.

Over the next few decades, Hawai'i could face a rise in sea level of up to three feet, with some estimates predicting a rise of up to six feet. In Honolulu, it is estimated that the rise in ocean levels resulting from climate change could force over 13,000 people from their homes and result in $13 billion in economic losses.

"When you read all the reports on sea level rise, it's frightening," said Judith Stilgenbauer, professor of landscape architecture at the University of Hawai'i at Mānoa (UH Mānoa). "However, we have a real opportunity here on O'ahu and in Honolulu to get an early start on planning for the inevitable."

The opportunity that Stilgenbauer refers to is a comprehensive study released earlier this year by the University of Hawai'i Community Design Center (UHCDC) that proposes radical changes to Honolulu's south shore in response to sea level rise. Entitled, South Shore Promenade and Coastal Open Space Network Study: Resilience and Connectivity by Design, the two-year study was the result of an applied research, analysis and proof-of-concept planning and design project funded by the State of Hawai'i Office of Planning to serve as a visionary tool to stimulate dialogue among federal, state and city leaders on the future planning along the south shore of urban Honolulu, which stretches from Diamond Head to Pearl Harbor, and includes the world-famous Waikiki Beach.

The UHCDC approach utilizes speculative, nature-based living shoreline (soft) design solutions to embrace coastal flooding rather than trying to prevent it from occurring. For instance, the study proposes that the state make room for wetlands in order to increase its capacity to withstand flooding and improve overall environmental and water quality. Other more specific suggestions include converting the land currently occupied by the world-famous Ala Wai Golf Course into wetlands and areas for wetland farming; creating a "South Shore Promenade" on the Honolulu waterfront to connect a network of existing and proposed shoreline green spaces that is currently fragmented and highly vulnerable to a myriad of hazards such as sea level rise, flooding, groundwater inundation, erosion storm surges and

tsunami damage; and creating an elevated pedestrian promenade that would allow for unhindered water flow and protect wetland habitats.

"These catalytic sites will act as soft defense mechanisms against sea level rise, allow for indeterminacy, increase biodiversity, provide ecosystem services, and at the same time, create livable and accessible urban waterfront and place amenities for all people," said Stilgenbauer, principal investigator of the UHCDC study. "This study contributes to help merge the seemingly conflicting goals of economic development, ecological performance, and urban place-making into mutually beneficial, resilient relationships."

"In contrast to many scientific sea level rise and climate change studies, which often paint doomsday scenarios, our project highlights opportunities intrinsic to an inevitable need to plan for the adaptation of our coastal urban fabric throughout the remainder of the century," she added.

Headquartered at the UH Mānoa School of Architecture, the UHCDC is a collective of faculty, staff, students and allied professionals representing multiple disciplines. The group provides proof of concept services in strategic planning, city and regional planning, master planning, community engagement, landscape and ecological design, architectural design, development studies, engineering studies, interior design, furniture design, graphic design, service design, social science, and user research.

"I'm thrilled that Stilgenbauer's team leveraged the modeling that our researchers produced in 2018 depicting the footprint of sea level rise impacts on O'ahu this century," said Chip Fletcher, associate dean and professor in UH Mānoa's School of Ocean and Earth Sciences and Technology (SOEST). "It has always been our goal that experts in other disciplines would build on our products. Interdisciplinary thinking such as this, needs to be at the heart of solutions to protect our communities from the increasingly dangerous effects of climate change."

In Honolulu, it is estimated that the rise in ocean levels resulting from climate change could force over 13,000 people from their homes and result in $13 billion in economic losses.

TOP: *UHCDC's comprehensive two-year study serves as a visionary tool for federal, state and city leaders*

BOTTOM: *Professor Judith Stilgenbauer*

SPREAD: *Artist rendering of a climate-resilient, adaptive urban waterfront for Honolulu.* PHOTO: UHCDC/ STILGENBAUER ET AL.

Indigenous Innovation

RELYING ON THE PAST TO SHAPE THE FUTURE

THE AHUPUA'A WAS AN EFFICIENT AND SUSTAINABLE LAND MANAGEMENT SYSTEM USED IN ANCIENT HAWAI'I. Shaped by the island's geography, the ahupua'a was a wedge-shaped area of land running from the mountains to the sea, following the natural boundaries of the watershed. Each ahupua'a contained the necessary resources of the community, including fish and salt ponds, fertile farmlands to grow crops, and forests in upslope areas that provided wood. Villagers from the coast traded fish for other foods or for wood to build canoes and houses. Specialized knowledge and resources peculiar to a small area were also shared among ahupua'a. Amidst a belief system that emphasized a spiritual relationship between elements and being, stewardship of the land and its resources were enforced through the kapu (taboo) system that placed restrictions on fishing, harvesting and planting — creating a well-balanced sustainable ecosystem.

Since those early times, Hawai'i has all but moved away from self-sufficiency. Today, about 90 percent of the food and supplies needed to sustain the island population arrives by ship or airplane — and must be constantly replenished in a matter of days. Farming is now done on a relatively small scale, with most of the farms primarily catering to a small niche market of restaurants. Native Hawaiians, once stewards of the land and perpetuators of remarkable indigenous practices of sustainability, have lost most of their cultural and spiritual connection to it.

How might we utilize innovation when we start from an indigenous-centered approach grounded in a shared understanding of the science and technology that has been employed to manage Hawai'i's biosystems for over a thousand years? How might we move from being research subjects to equal partners? While these may seem like simple questions, they are fraught with scars and emotions, yet include a shared commitment to creating a better future for Hawai'i. In response to these questions and to address other issues brought forth in discussions with indigenous communities of practice and cultural practitioners, the University of Hawai'i (UH) created the Office of Indigenous Innovation (OII).

"The core premise of the UH Office of Indigenous Innovation is that the indigenous ancestral knowledge underlying precontact biosystems management in Hawai'i demonstrates a comprehensive application of science and engineering technologies, refined over millennia and optimized for calibration between human and natural system needs," said OII Director Kamuela Enos.

One of the organizations OII has closely partnered with is the Purple Mai'a Foundation, a technology education non-profit that works to educate and empower the next generation of culturally grounded, community serving technology innovators and problem solvers. Both organizations are assisting the Hawai'i Institute of Marine Biology and He'eia Natural Estuarine Research Reserve to restore resilience and abundance of the He'eia ahupua'a, including a (K)new Futures competition that has resulted in the creation of two UH startups. Recently, OII supported Purple Mai'a's hosting of an inaugural National Science Foundation biocultural restoration workshop that featured over 350 participants engaged in discussions on science and technology embedded within place-based ancestral knowledge systems.

Enos feels that the timing of OII's creation was incredibly important. Several months after the office was founded, the COVID-19 pandemic emerged. The turbulence of this time allowed his office to put forth a narrative to meet it, which it still centers on today — that of hulihia, where systems are destroyed they can be rebuilt stronger.

"In the kānaka maoli (Native Hawaiian) world view, we lived with and revered disruption. The extreme isolation of our ancestral society organically embedded

Amidst a belief system that emphasized a spiritual relationship between elements and being, stewardship of the land and its resources were enforced through the kapu (taboo) system that placed restrictions on fishing, harvesting and planting — creating a well-balanced sustainable ecosystem.

ABOVE: *UH Office of Indigenous Innovation Director Kamuela Enos*

ABOVE LEFT: *Purple Maia Ka Maka ʻĪnana visit to Kaʻala Farms (2020)*

LEFT: *Purple Prize initial kick off, Kānewai Loʻi (2016)*

FACING PAGE: *Purple Maia's Purple Prize Opening at Paepae o Heʻeia (2019)*

resilience to be the very core of the entirety of our political, economic, spiritual and social frameworks," said Enos. "This reality spurred our ancestral systems to optimize a collective, circular, and regenerative economy, with the end goal of accruing mana (life force or healing power)—which was measured as the bequeathing of abundance."

In alignment with Enos' statement, OII aspires to play an important role in helping stakeholders to continue to address Hawaiʻi's post-COVID recovery, especially in the areas of restoring a resilient food system and diversifying the state's economy.

"The pandemic has highlighted the need for an economy less tied to tourism and less vulnerable to global events," said Steve Auerbach, interim director of the UH Office of Innovation and Commercialization, under which OII is housed. "Through the UH Office of Indigenous Innovation and in partnership with the greater community, the University of Hawaiʻi is working hard to carve out the parts necessary to build a resilient and sustainable innovation economy."

Enos added, "Our ancestors have already proven our ability to be self-reliant, resilient, generative, and healthy on our own terms. I welcome the opportunity to work with the vast resources within the University of Hawaiʻi System and its many partners to demonstrate how we catalyze and scale our ʻike (knowledge) to meet the needs of Hawaiʻi and the world."

Hawaii Tech Bridge

A SOLUTION PROVIDER FOR THE U.S. NAVY

WITH SEVEN ACTIVE FLEETS COMPRISED OF OVER 290 COMBAT VESSELS, MORE THAN 3,700 OPERATIONAL AIRCRAFT AND OVER 336,000 ACTIVE DUTY PERSONNEL— the United States Navy is one of the most powerful fighting forces in the world. At a moment's notice, its forces can be rapidly deployed to cover any global hotspot.

However, a regional private sector company with innovative solutions looking to do business with the U.S. Navy might find the task of navigating a floating minefield easier than getting to the right decision-maker in the confusing and overwhelming layers of commands, departments and units.

To help bridge this gap, the Naval Agility Office (NavalX) was established to help facilitate the rapid adoption of proven agility enhancing methods for the U.S. Navy and to establish regional "tech bridges" in strategic locations across the country to better connect naval entities with the private sector. Since 2019, Tech Bridges have facilitated $45 million in project funding to solve problems facing the Navy, sponsored $37 million in small business innovation research (SBIR) for maintenance/sustainment, awarded over $2 million in prize challenges to non-traditional industry partners, and aided in the distribution of over $800,000 in COVID-19 response efforts. There are currently 15 Tech Bridges, with the recent addition of Hawai'i and the Gulf Coast.

"NavalX Tech Bridges are designed to increase collaboration, knowledge sharing and innovation with leading-edge tech companies and innovation partners to accelerate solutions for the U.S. Navy and Marine Corps," said National Tech Bridge Director Whitney Tallarico. "Tech Bridges serve within the growing ecosystem of the U.S. Department of Defense's innovation groups—Defense Innovation Unit (DIU), National Security Innovation Network (NSIN), U.S. Army Futures Command, AFWERX, SOFWERX—which helps to strengthen NavalX's overarching ability to connect people, companies, and technology solutions."

The Hawaii Tech Bridge is assigned to the Naval Information Warfare Center (NIWC) Pacific, Indo-Pacific Department Navy lab located in Pearl City, O'ahu. Led by Neal Miyake, director and local business deputy, the Tech Bridge is concentrating its efforts on the following focus areas: command and control, communications, computers/networking, intelligence, surveillance and reconnaissance, cyber defense, space systems and resilience—with a specific focus on energy resilience. Support will also be provided by the Naval Undersea Warfare Center Detachment Pacific (NUWC Pacific) based at Ford Island, Pearl Harbor.

"The vision of the Hawaii Tech Bridge is to establish an innovation ecosystem in Hawai'i where the Department of Defense, private industry, academia, state and local governments can collaborate to solve Navy and Marine Corps needs, while being mutually beneficial to all," said Miyake, a homegrown product and graduate of the University of Hawai'i at Mānoa College of Engineering. "Hawai'i is an ideal location for a Tech Bridge due to its proximity to the Indo-Pacific region, its major military commands, a flourishing local technology sector, and a world-class academic/research institution in the University of Hawai'i."

Miyake added that the efforts of the Hawai'i Tech Bridge will include collaborative sessions with partner organizations, prize challenge competitions, connecting small businesses with available opportunities and enabling local talent and technologies to actively participate in naval exercises and experimentation. Current partners include the University of Hawai'i Office of Innovation and Commercialization and the Hawaii Technology Development Corporation (HTDC)—whose 13,500 square foot facility known as the Entrepreneurs Sandbox, serves as the off-base, co-working space for Hawaii Tech Bridge.

"We are excited about our partnership with the Hawaii Tech Bridge and are pleased that our Entrepreneurs Sandbox is playing a key role in this program," said HTDC Acting Executive Director Len Higashi. "These are the types of programs and initiatives that we look for in our efforts to develop a technology industry that provides quality, high-paying jobs for Hawai'i's residents."

Future partnerships are in the works to include the U.S. Indo-Pacific Command; Commander, U.S. Pacific Fleet; and Marine Corps Forces, Pacific.

"Through our lens, the Hawaii Tech Bridge is a win-win situation for everyone involved," said Interim Director Steve Auerbach of the UH Office of Innovation and Commercialization. "A path has now been cleared for local companies, startups, researchers and students to apply their unique skill sets and technical knowledge to not only aid in our country's defense, but also to help diversify the state's economy through the development of a tech-based sector."

TOP: *Representatives from NavalX, HTDC and UH gathered for the inaugural meeting of the Hawaii Tech Bridge held at the Entrepreneurs Sandbox*

BOTTOM: *Hawaii Tech Bridge Director Neal Miyake outlines his vision of this new initiative*

University of Hawai‘i

UH RESEARCH

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