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PROMOTING THE HEALTH AND SUSTAINABILITY OF CORAL REEF HABITATS

# New Mapping Techniques Help Assess the Health of Hawai'i's Coral Reefs

***More than 60% of coral reefs in U.S. waters are found in the extended Hawaiian Island chain. These complex and diverse marine ecosystems are not only ecologically important but also provide hundreds of millions of dollars annually to Hawai'i's economy. Elsewhere in the world, corals are dying at unprecedented rates, and the reefs of Hawai'i may also be at risk. To monitor and protect these reefs and to help understand what is threatening coral-reef habitats worldwide, U.S. Geological Survey (USGS) and other scientists are using new techniques to create detailed maps of Hawai'i's coral reefs.***

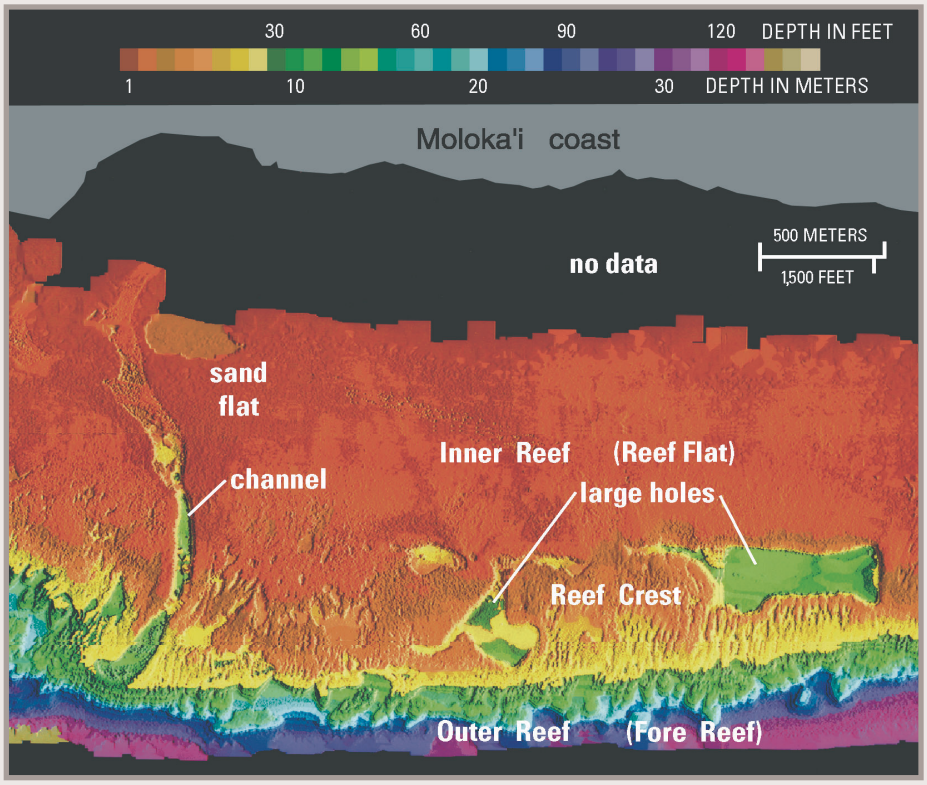

*A rich diversity of life inhabits Hawai'i's coral reefs, complex ecosystems that are being affected by both natural processes and human activities. The U.S. Geological Survey is using a combination of techniques to map these reefs in a step toward evaluating their overall health.*

More than 5,000 square miles (14,000 km$^2$) of coral reef habitat is found in the Hawaiian Islands from beyond Midway to the Island of Hawai'i, constituting more than 60% of coral reefs found in U.S. waters. Hawai'i's reefs are of great importance both environmentally and economically to those who visit or live on the islands. These reefs shelter and provide nursery grounds for many commercially and culturally important species of fish and invertebrates, they protect the islands' harbors, beaches, and shorelines from erosion and wave damage by storms, and they are vital to Hawai'i's marine tourism industry.

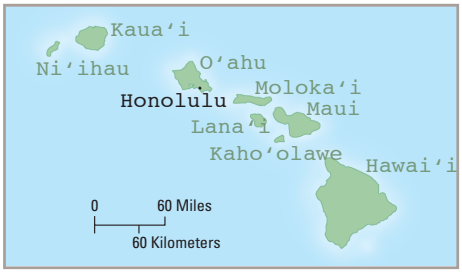
The world's coral reefs are home to 25% of all marine species, yet it is estimated that 75% of these reefs will be destroyed or significantly damaged in the next 20 years. Hawai'i's coral reefs still appear to be relatively healthy, but some areas of dead and dying coral have been found in recent years. The causes of this degradation are poorly known, but are probably in part related to human activities.

The U.S. Geological Survey (USGS) is working closely with academic institutions and state and Federal agencies to assess the factors that affect the health of Hawai'i's and our Nation's coral reefs. In order to establish a basis from which scientists can objectively detect changes in reef health, the USGS and its cooperators are applying many new techniques

## MAPPING CORAL REEF LANDSCAPES




*Many different types of information are gathered to assist in mapping coral reefs. The map (above) shows a portion of the coral reef off the south-central shore of the island of Moloka'i. Very detailed bathymetry (see color scale) was obtained using lidar, a laser-ranging technique that can penetrate shallow water. The oblique perspective view of the same portion of reef (below) was created by digitally draping an aerial photograph on the bathymetric model. By using such detailed maps and images that show prominent features, including channels and large holes, scientists can better understand the structure and development of coral reefs.*




*Map of the eight main Hawaiian Islands. More than 60% of coral reefs in U.S. waters are found in the extended Hawaiian Island chain, which stretches another 950 miles (1,500 km) northwestward from the island of Ni'ihau to beyond Midway Island.*

to the mapping and monitoring of coral reefs in Hawai'i.

Mapping of coral reefs provides important information about a number of reef characteristics, such as overall structure and morphology, abundance and distribution of living coral, and distribution and types of sediment. No single approach is effective for evaluating the overall health of a reef. It is only through combining techniques that scientists can establish the most complete view of a reef, one that can be used for evaluating reef health and for future monitoring.

## New Mapping Techniques

Lidar (light detection and ranging) is a laser-ranging technique that can penetrate shallow water to depths as great as 120 feet (36 m) to create precise bathymetric maps that are accurate to within a few inches (15 ± cm). These maps show details of reef structures and zonations that cannot be revealed using traditional sonar technology, which requires deeper water for successful operations.

Lidar data from the island of Moloka'i, digitally combined with aerial photographs, are resulting in a better understanding of shallow-water coral reef development. Moloka'i's reefs, like many reefs elsewhere in the world, consist of nearshore inner reef flats that slope to deeper water fore reefs farther offshore. The reef crest, between the inner reef flat and outer fore reef, lies in extremely shallow water and may be exposed during the lowest tides. Waves commonly crash against or break on the reef crest.

Lidar also reveals details of channels that cross Moloka'i's reefs. These channels were originally valleys formed by streams that cut across and eroded the reefs when sea level was much lower about 18,000 years ago. The channels across the reefs typically contain sediment that is a mixture of calcium carbonate ($CaCO_3$) debris (derived from the breakdown of reef material) and silt and other sediment eroded from the island. The role of these channels in transporting sediment and their relation to coral reef health are poorly understood and are one focus of USGS investigations in Hawai'i.

## Other Mapping and Monitoring Techniques

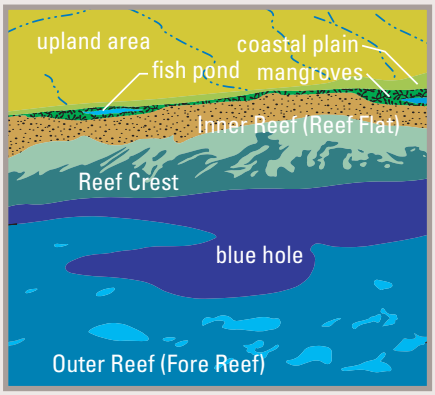
Although lidar maps provide "snapshots" that reveal the large-scale structures of a coral reef, other techniques provide greater detail on the biological and physical composition of a reef and can document changes on a scale of months to decades. For example, large-scale maps showing changes in the distribution of coral, algae, and sediment are compiled from sequences of aerial photographs taken over decades. Such maps may show changes that identify groups of coral colonies stressed by

sediment influx or encrusting algal overgrowth.

Hyperspectral imagery, collected from aircraft, is being used in Hawai‘i to map coral reefs and potentially identify areas of dead coral. Hyperspectral imagers measure reflected sunlight in many narrow wavelengths, ranging from ultraviolet to near infrared. This spectral information allows for detection of subtle variations in the reef substrate that are not visible to the naked eye. To calibrate and help interpret the remotely collected imagery, a hand-held hyperspectral sensor specially outfitted for underwater data collection is used by divers. The divers collect spectra from healthy coral colonies, stressed coral colonies, and other sea-floor substrates.

Another technique being used by scientists to map coral reefs in Hawai‘i is acoustic mapping. Dual-frequency sonar technology is used to map areas of coral reefs in water depths ranging from 25 feet (8 m) to 120 feet (35 m). By processing data from two frequencies, it is possible to identify the acoustic signatures of different types of material, such as soft sediment deposits or hard coral. Observations from scuba dives are used to help confirm these interpretations.

## MAPPING CORAL AND SEDIMENT DISTRIBUTION

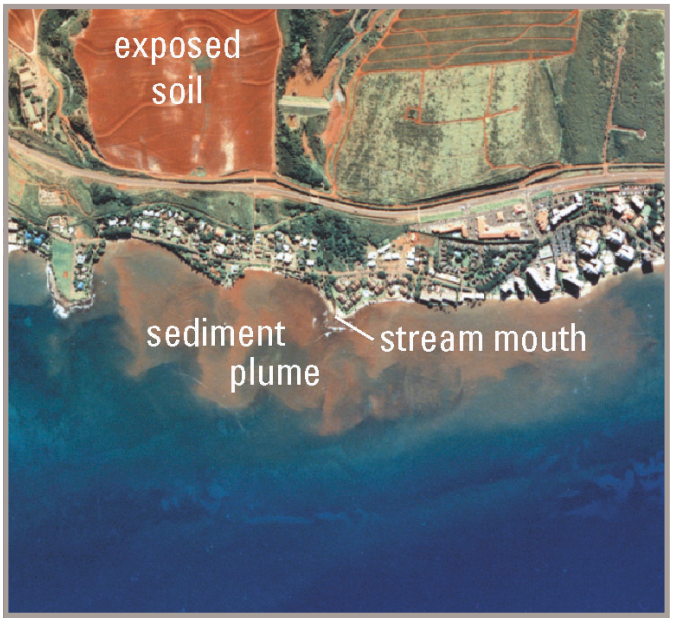



*This oblique aerial photograph (above) shows a portion of the reef tract on Moloka‘i. The map of the same area (right) shows the percentage of live coral and types of sediment. This style of mapping requires direct observations from snorkel and scuba dives. The shoreline in the photo is about 0.7 mile long.*

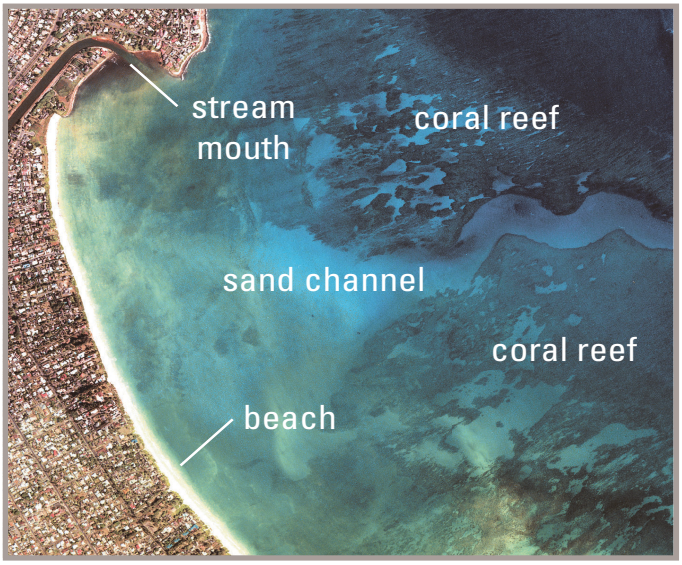
**MAP EXPLANATION**

- Land-derived mud and sand
- Mixed carbonate and land-derived sand
- Coralline algae and 5 to 60% live coral
- Carbonate mud and sand
- 90% live coral
- Carbonate sand

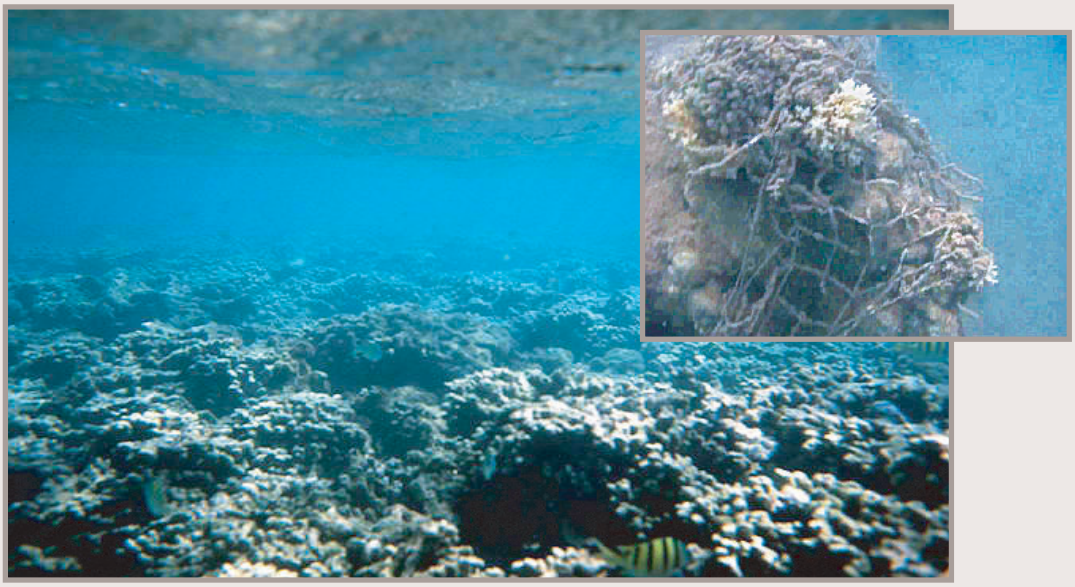
Scuba and snorkel dives also allow scientists to directly identify coral species and make estimates of living coral coverage and biodiversity. Underwater photography and video transects made by divers provide a record that can be used to map and understand subtle changes in the reef ecosystem. For example, University of Hawai‘i scientists are taking photographs of 1-square-meter plots at selected locations on Hawai‘i’s reefs to assess changes over time within individual colonies of coral.




*A sediment plume obscures the coral reef in this aerial photograph of the western coast of Maui. The sediment was transported by stream runoff from fields where soil is exposed. (Image courtesy of National Oceanic and Atmospheric Administration.)*




*Growing urbanization and development of coastal areas are a concern for the long-term sustainability of coral reefs. This aerial photograph of Kailua Bay, O‘ahu, shows an area of well-developed and healthy coral reefs. University of Hawai‘i and U.S. Geological Survey scientists are studying these reefs for their role in producing calcareous sand and in protecting beaches from erosion. (Image courtesy of National Oceanic and Atmospheric Administration.)*

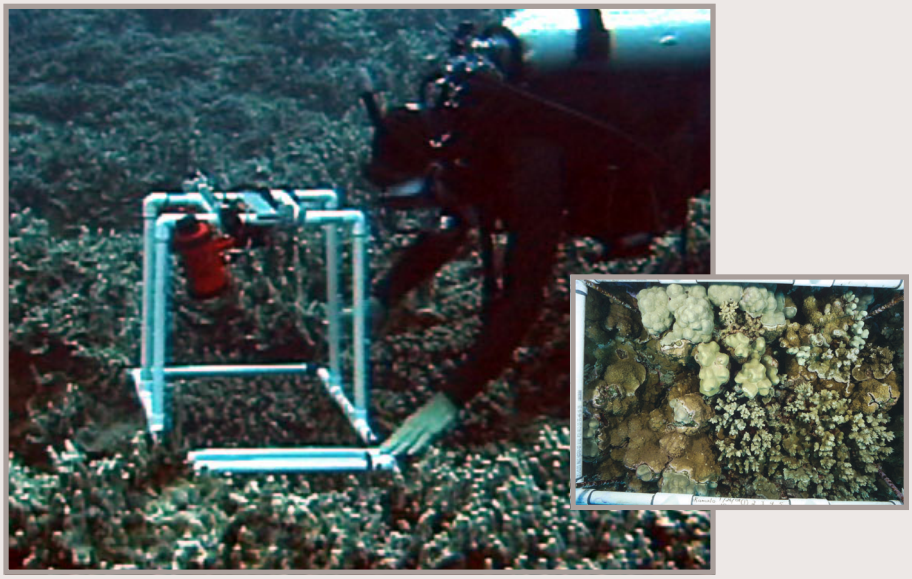


*These broad, healthy thickets of the coral* Porites compressa *thrive in unpolluted, sediment-free water off the southern coast of Moloka'i. The health of Moloka'i's reefs varies locally—other areas appear to show signs of degradation from both natural and manmade causes. Inset shows an unhealthy coral colony off the coast of Moloka'i that is entangled in an abandoned fishing net. This colony's productivity is also impaired by suspended sediment that is making the water cloudy or turbid.*

Historical patterns of sedimentation are important for determining the role of human activities and their impact on a coral reef. On shallow reef-flat areas in Hawai'i, scientists are using sediment probes (graduated stainless steel rods) to measure sediment thickness. Maps of sediment thickness made using these measurements, combined with sediment ages and compositional data, provide a detailed record of the history of deposition.

Maps of coral reefs help scientists better understand changes brought about by activities on land. Sediment eroded from land as a result of both natural processes and human activities can pose a serious threat to coral reef health by (1) reducing the area of sea floor suitable for growth of new corals, (2) creating cloudy or turbid water that diminishes the amount of light available for photosynthesis by symbiotic algae that live within individual coral animals, and (3) in extreme cases, burying coral colonies. For example, in the past 100 years, a large amount of sediment has accumulated on some inner-reef areas of Moloka'i, and ongoing studies indicate that this has had an effect on reef health.

Many of the world's coral reefs already have been severely damaged by human activities. In order to protect and preserve the health of our Nation's coral reefs, it is essential to monitor these treasured and important ecosystems. Mapping and understanding the history of the coral reefs of Hawai'i is a large step toward this goal. The work of USGS scientists studying reefs in Hawai'i is only part of the ongoing efforts of the USGS to help protect people's lives and property from geologic and environmental hazards in the coastal zones of the United States.



*Detailed mapping of coral reefs requires direct observations in the water for identifying coral species and collecting samples. This scientist is documenting changes through time in a group of coral colonies (inset), visited a year earlier, by rephotographing them using a precisely positioned frame. (Inset photograph courtesy of University of Hawai'i.)*

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