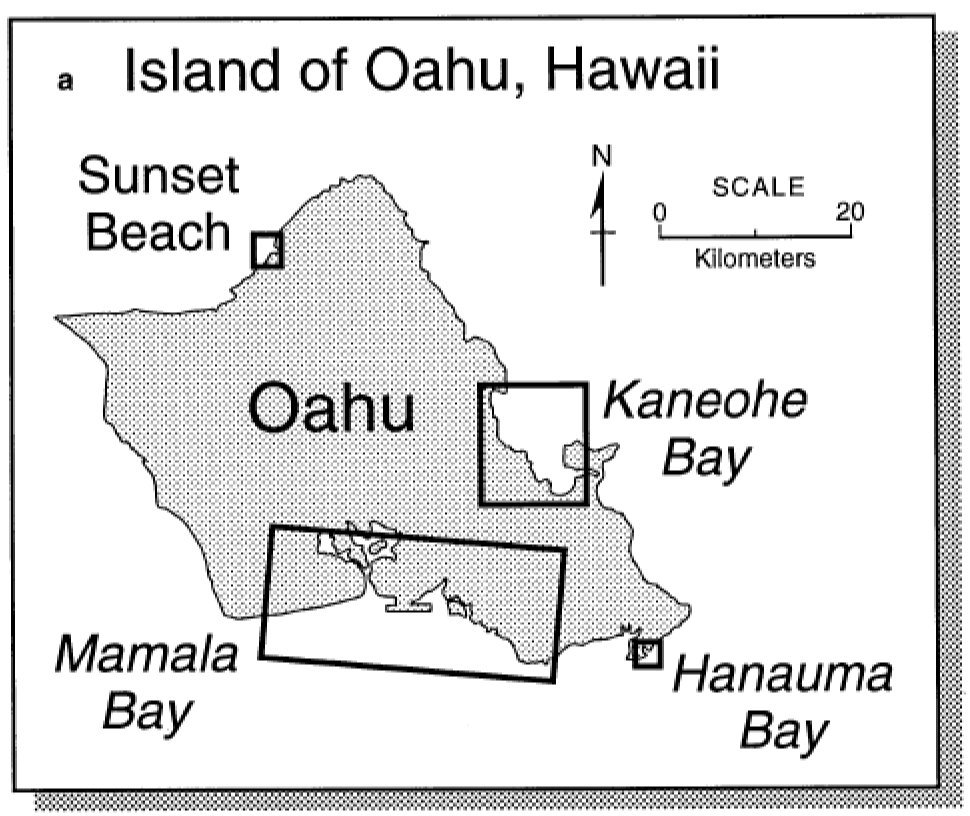
Coral Communities – Regional Patterns

Reef Accretion

In high Hawaiian Islands, significant accretion from coral reef growth limited by wave exposure and sea level change

Holocene coral growth and reef accretion measured at four sites on O'ahu, chosen along a gradient in wave energy from minimum to maximum exposures



Site	Depth (m)	Coral cover %	Coral diversity (H′)	Algal cover %	Bare limestone %	Sand %
Kaneohe Bay	1	2 ± 5	0.16	5	1	95
	2–5	69 ± 20	0.35	9	3	19
Hanauma Bay	1	< 1	< 0.01	90	10	0
	12	73 ± 14	0.87	0	5	10
Mamala Bay	1	6 ± 3	0.15	90	5	5
	12	10 ± 5	0.35	2	40	40
Sunset Beach	1	9 ± 8	0.53	60	20	0
	12	15 ± 13	0.68	20	65	0

(Grigg 1998)

Reef Accretion

(Grigg 1998)

Modern coral communities in wave exposed environments not thicker than a single living colony

Undergo constant turnover associated with mortality and recruitment or re-growth of fragmented colonies

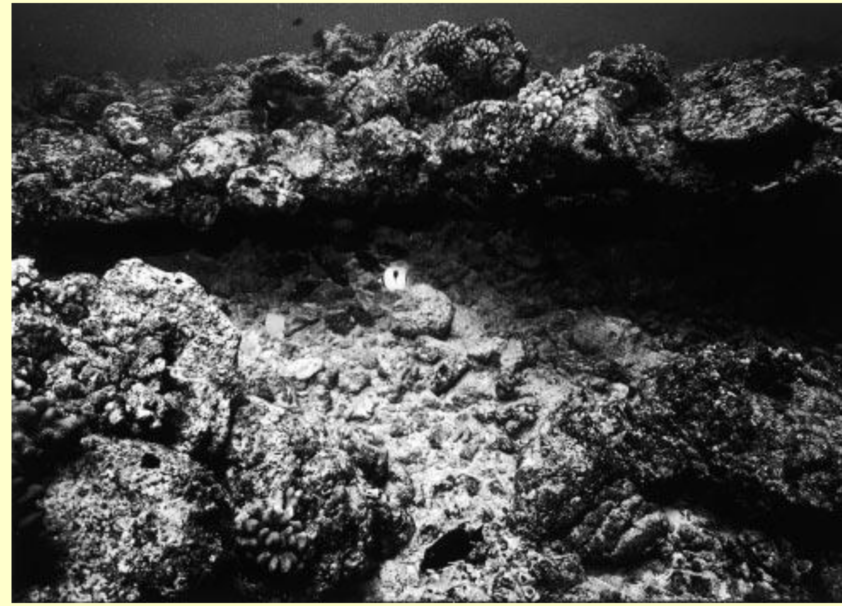
Breakage, scour and abrasion of living corals during high wave events is major mortality source and limits accretion to wave sheltered environments

The lack of coral reef accretion along shallow open ocean coastlines helps to explain absence of mature barrier reefs in the high Hawaiian Islands

Reef Accretion

Photograph of quadrat at 12 m depth in Hanauma Bay showing dominant species of coral: *Porites lobata* (lobe coral) and *Porites compressa* (finger coral)

Mean % Coral Cover = 73 +/- 14



Photograph of substrate at 12 m depth on Sunset Beach, where *Pocillopora meandrina (cabbage coral),* a fugitive species, is dominant. Approximately 65% of substrate covered by coralline algae

Mean % Coral Cover = 15 + / - 13

(Grigg 1998)

Reef Accretion

(Grigg 1998)

Coral growth of living colonies (linear extension) at optimal depths comparable at all sites (7.7 - 10.1 mm/y), but reef accretion only at wave sheltered sites

At wave sheltered sites (Hanauma Bay, Kaneohe Bay), rates of long term reef accretion ~ 2.0 mm/y

At wave exposed sites (Mamala Bay, Sunset Beach), reef accretion rates virtually zero in shallow (1 m) and deeper (optimal) depths (12 m)

At wave sheltered sites, Holocene corals 10 - 15 m thick. Wave exposed sites, thin living coral layer rests on antecedent Pleistocene limestone foundations

Wave Energy – Varies Spatially

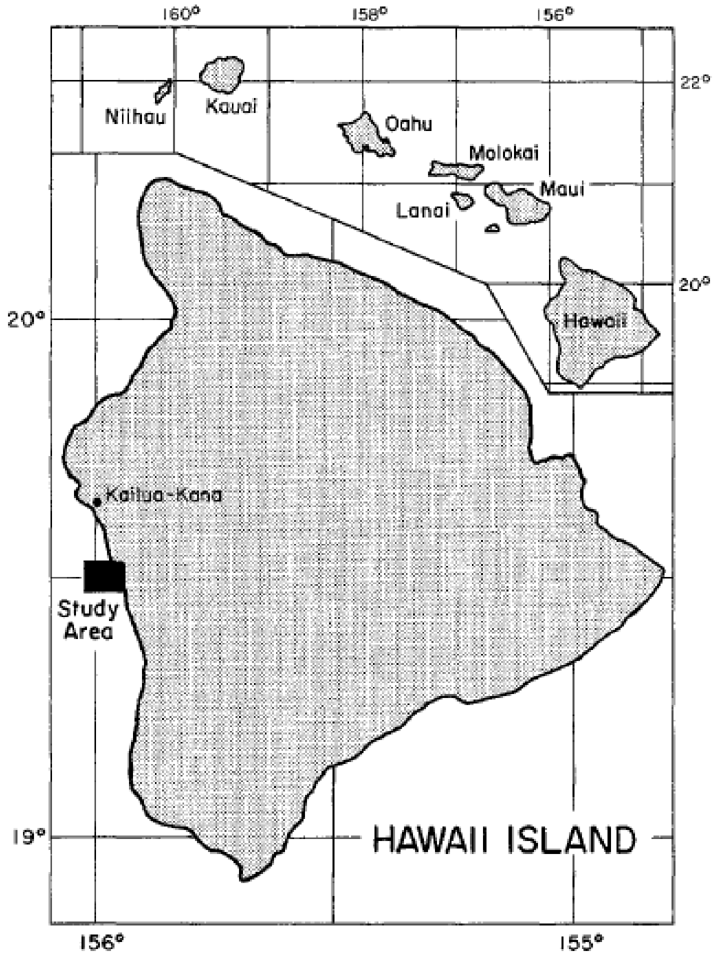


Fig. 1. Map showing location of study area on island of Hawaii and Hawaiian Archipelago

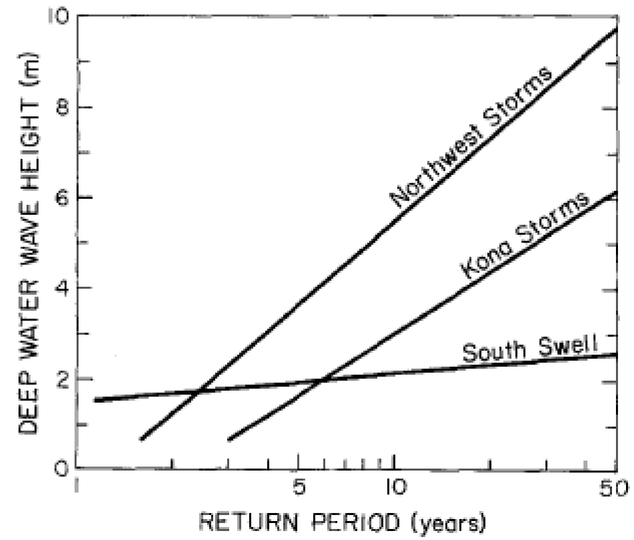


Fig. 3. Plots of deepwater wave heights (upper 10th) as function of average return period of storm events. (From Rochleau and Sullivan, unpublished data, 1981)

Wave energy varies by depth and by island location

(Dollar 1982)

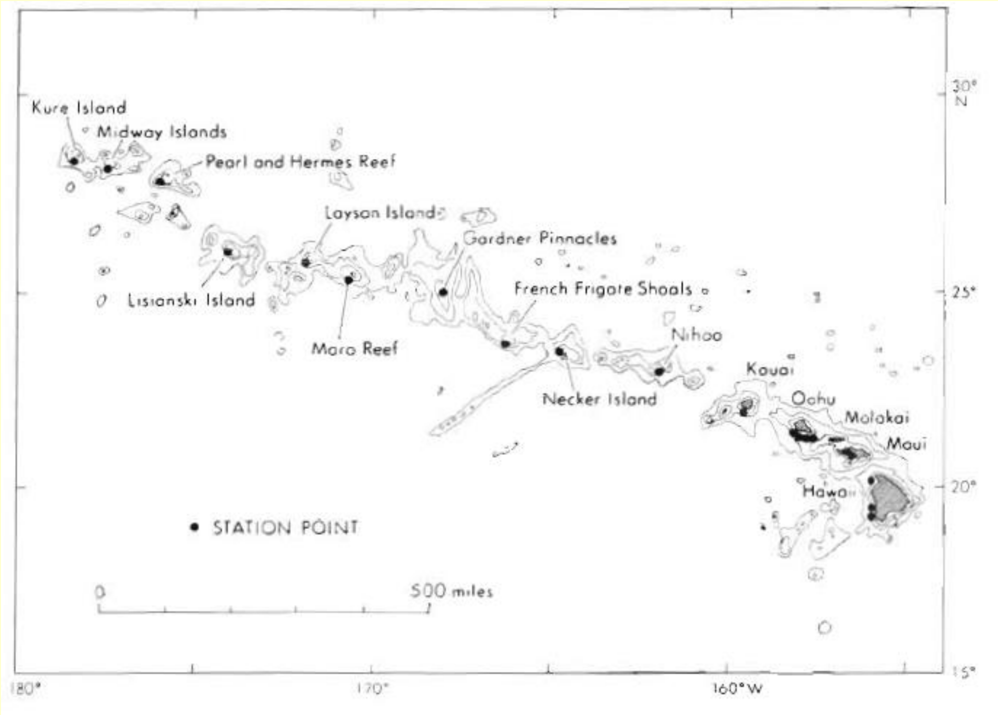
Corals on Evolving Hawaiian Islands

Reef building corals in the Hawaiian Archipelago consist of only 42 species belonging to 16 genera

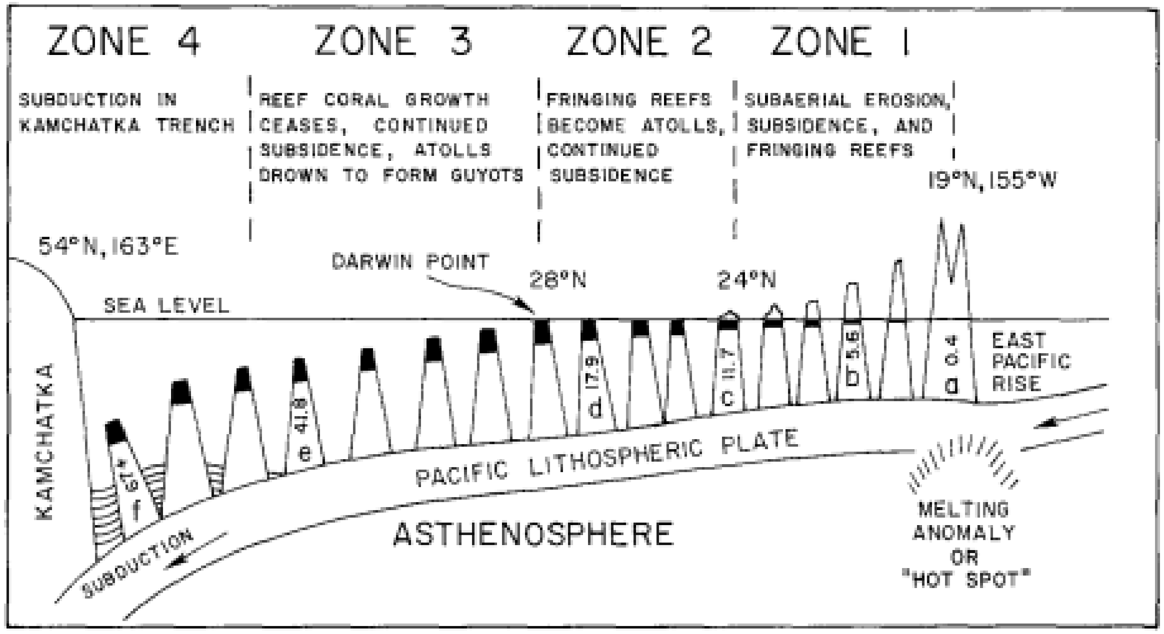
Hawaiian coral fauna is highly depauperate (low species) relative to Indo-West Pacific Ocean, due to isolation

Although impoverished, species composition of reef building corals remarkably uniform through archipelago

(Grigg 1983)



Corals on Evolving Hawaiian Islands



(Grigg 1982)

Fig. 1. Schematic representation of evolutionary history of the Hawaiian Archipelago showing location of the Darwin Point separating zones 2 and 3. Age of islands in millions of years shown for six geological features (*a–f*). (Modified after Rotondo 1980)

At Darwin Point, corals contribute only 20 % of calcium carbonate necessary to keep pace with sea level

Coralline algae play a more important role at high latitudes

Corals on Evolving Hawaiian Islands

Differences in species composition caused by varying patterns of disturbance and recruitment

While patchy distributions exist within islands, the differences in species composition between islands are small

Where adequate substrata prevail within euphotic zone most species are present

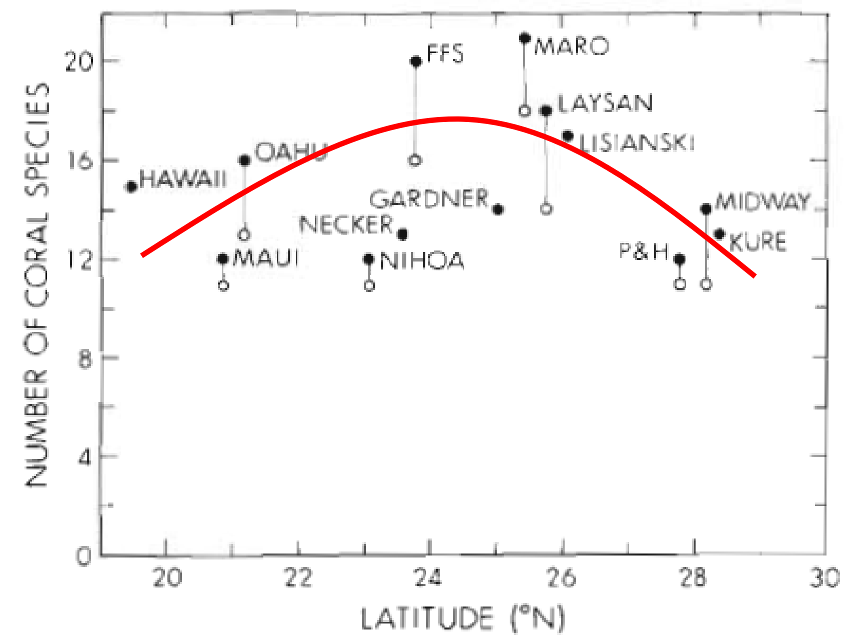


Fig. 4. Number of hermatypic coral species recorded at each island. Open circle: after 3 transects; solid circle: total transects (southwest sector)

(Grigg 1983)

Corals on Evolving Hawaiian Islands

Coral growth rates steadily decline moving northwest-ward within chain. This lengthens successional process and increases probability of intervening disturbances

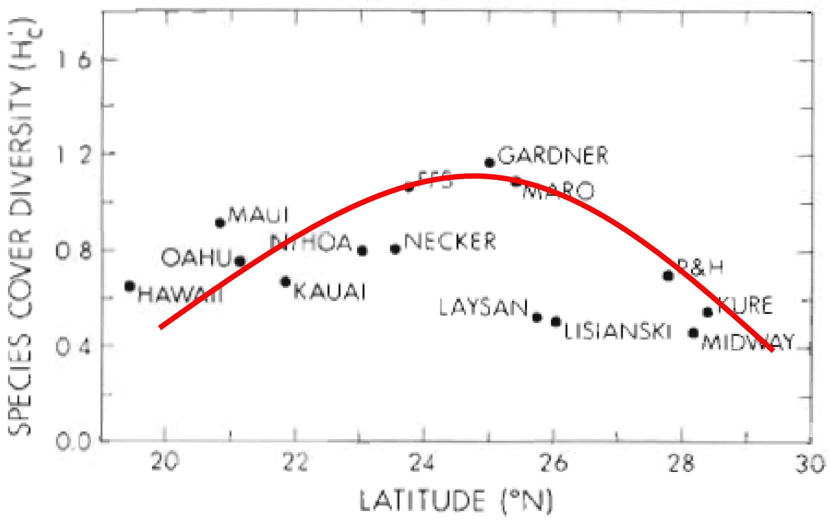


Fig. 6. Species diversity (H'_c) for hermatypic corals recorded at each island (southwest sector)

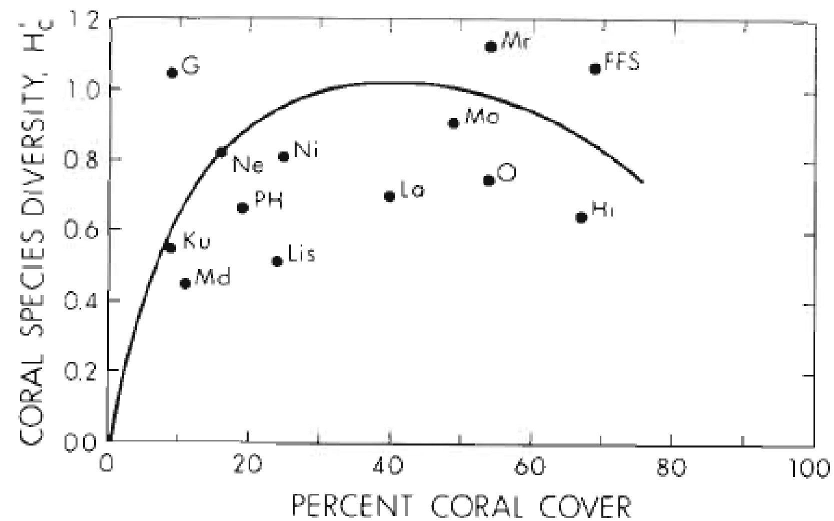
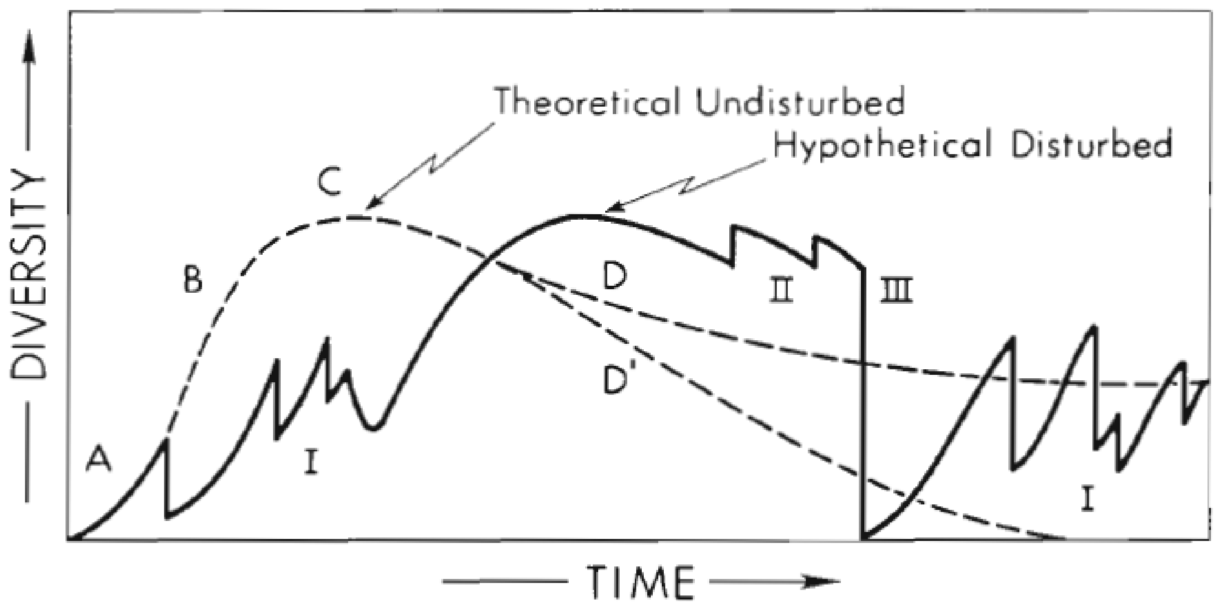


Fig. 10. Mean coral species diversity (H'_c) for southwest sector stations for all islands plotted against mean coral cover. Curve drawn by eye represents theoretical pattern of succession

(Grigg 1983)

Corals on Evolving Hawaiian Islands

In undisturbed case, *A-C* represent increasing diversity due to colonization. Diversity peaks at *C* after which space competition (and extirpation) reduces diversity

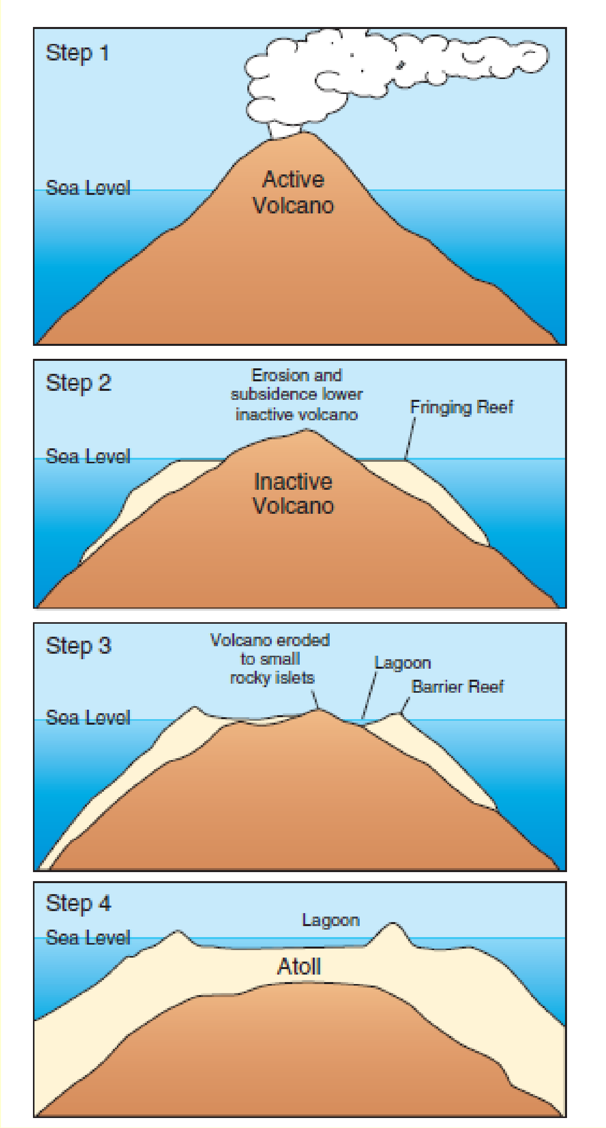


(Grigg 1983)

Fig. 11. Theoretical model of succession of coral reef communities and hypothetical case illustrating the effects of various intensities and frequencies of disturbance (see text for explanation)

(Disturbance Intensity: III > II > I)

Corals on Evolving Islands



Islands pass through various stages from the youth of volcanic eruption, to mature dormancy, to the old age and extinction

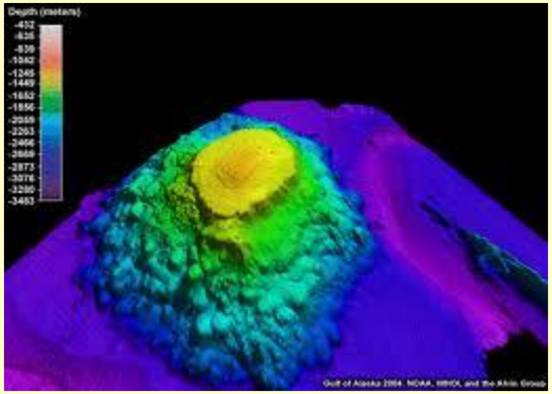
Atolls maintain the march to northwest and subside beneath the waves at the "Darwin Point"

(Fletcher et al. 2008)

Mature Coral Structures

Atoll - An annular (ring-like) oceanic reef system surrounding a central lagoon

Guyot - Also known as a tablemount, is an isolated underwater volcanic mountain (seamount), with a flat top over 200 meters (660 feet) below the surface of the sea



Corals on Evolving Islands

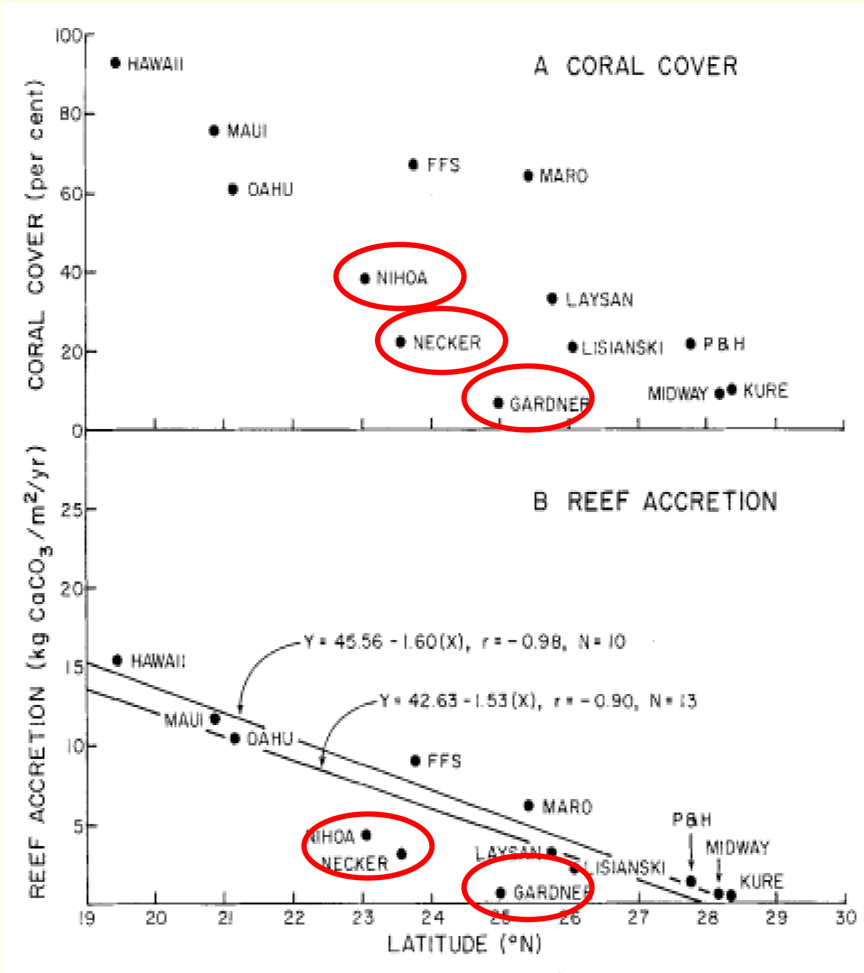
"Darwin Point" the geographic or depth limit (threshold) beyond or below which coral reefs drown. Reef drowning occurs when net production of $CaCO_3$ or vertical reef accretion does not keep up with relative sea level.

When $CaCO_3$ production rates due to coral growth are exceeded by rates of bio-erosion and physically-induced loss, and / or rates of island subsidence or sea level rise.

Both limits were conceived conceptually by Charles Darwin himself in 1837, while viewing the island of Moorea from the island of Tahiti (Darwin 1851).

(Grigg 1982, 2008)

Darwin Point – Across Latitude



Located north of Kure Atoll (29 deg. N), the Darwin Point marks limit of reef tolerance for northerly conditions: slow growth, slow recovery from disturbance, low cover

Beneath the waves, drowned atolls become seamounts, the oldest of which is 80 million year-old Meiji, at far end of The Hawaii-Emperor Chain

NOTE: Nihoa, Necker, Gardner

(Grigg 1982, 2008)

Darwin Point – At One Site

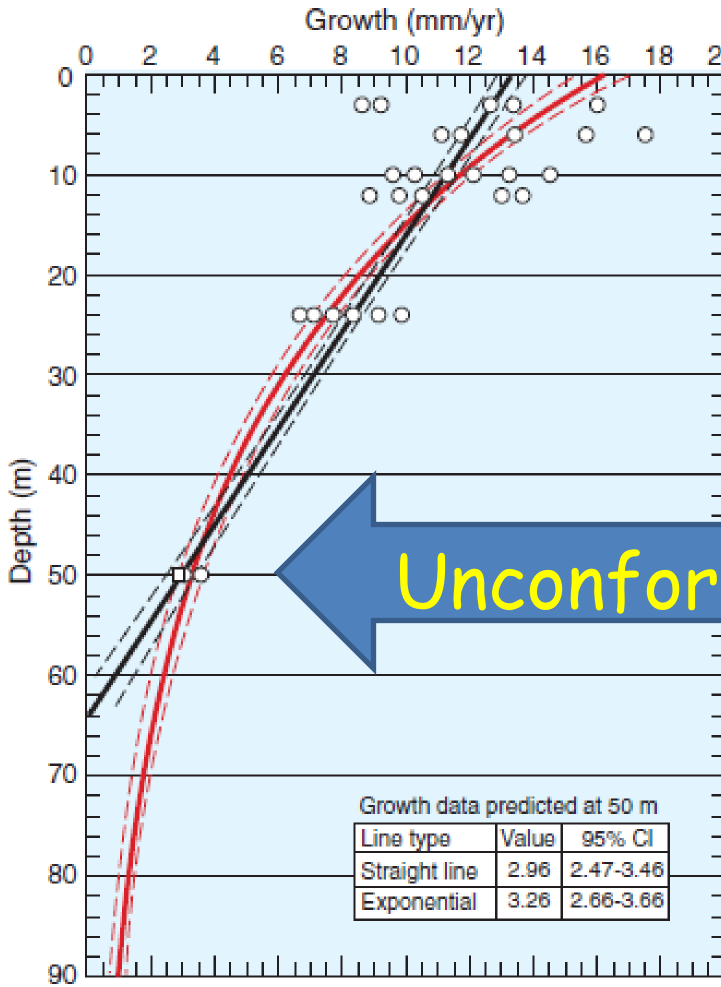


FIG. 11.26. This figure shows the growth rate (linear extension) of *Porites lobata* colonies vs. depth at stations off Lahaina, Maui in the Au'au Channel. Because colony age (*P. lobata* skeleton samples) jumps from modern to early Holocene at –50 m, this suggests that the rate of bio-erosion below –50 m exceeds the rate of present day accretion, and in this sense, the –50 m hiatus represents a vertical Darwin Point. These are best-fit regressions with 95% confidence limits (dotted lines) for *P. lobata* growth. The linear plot (black) includes all data points (n=384); r^2=0.64. The exponential plot (red line) excludes the data from 3 m (n=345); r^2=0.68. The open circles are the mean growth data for colonies. Values for growth predicted from both regressions at –50 m are shown in the box

Au'Au' Channel: 50m separates modern shallow coral growth from deeper limestone reef foundation from early Holocene and late Pleistocene epochs.

Unconformity:

Latitudinal threshold for reef accretion analogous to site-specific vertical Darwin Point: below 50m net growth is negative

(Fletcher et al. 2008)

What factors affect Coral Growth

Main Hawaiian Islands (MHI) have significantly greater cover of scleractinian corals than NWHI

Corals are found in deeper water in MHI than in NWHI

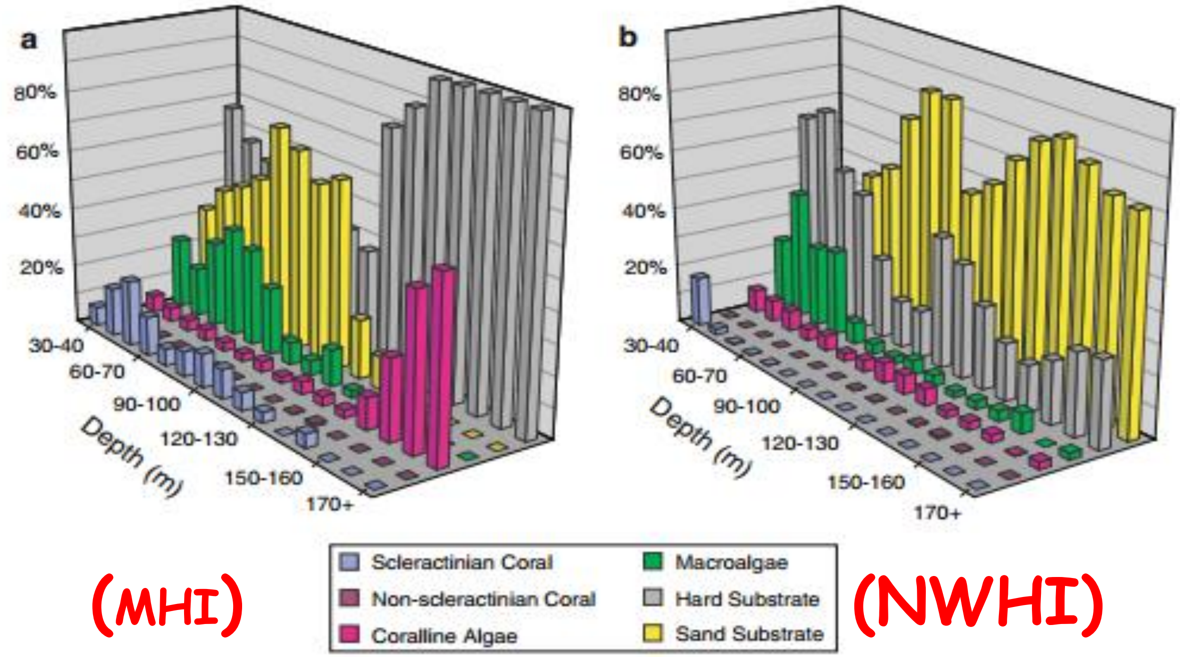
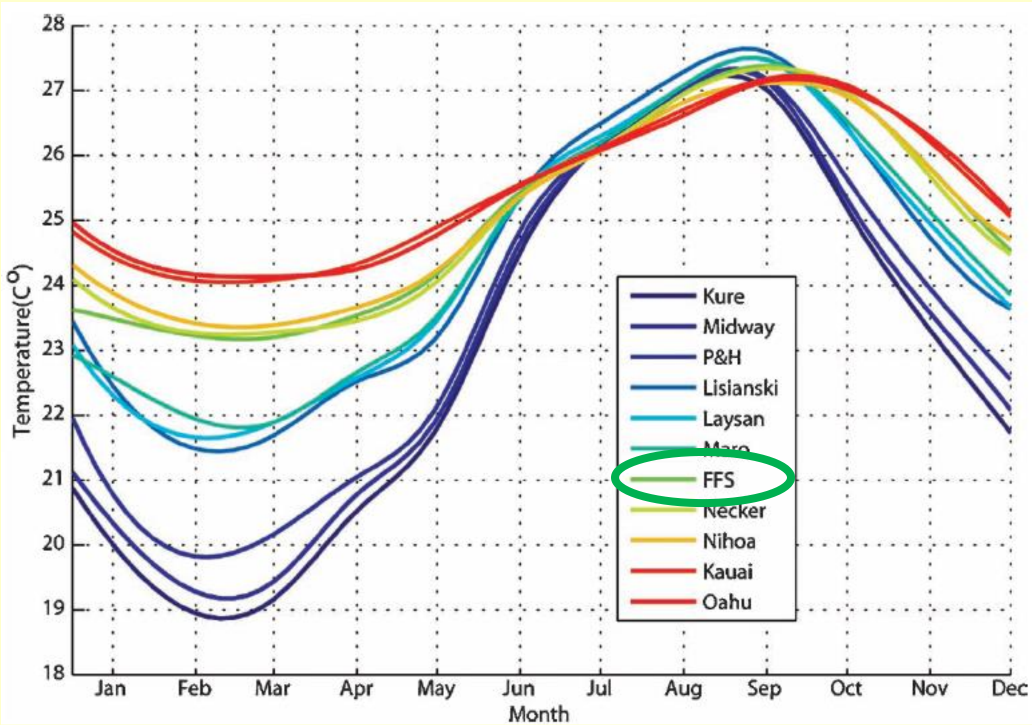
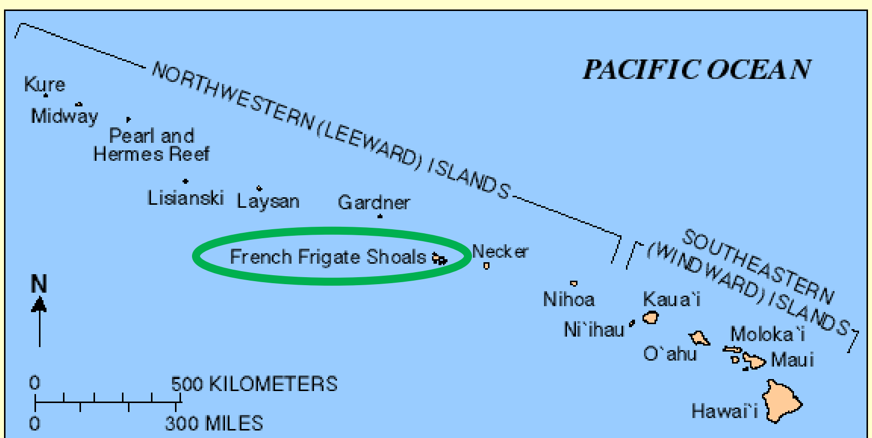


Fig. 1 The percent cover (shown on the *vertical axis*) of substrate type, scleractinian corals, and other megabenthic taxa from mesophotic depths binned into 10-m depth intervals, for: **a** Main Hawaiian Islands, **b** Northwestern Hawaiian Islands

Regional SST Patterns





SSTs have a strong north to south gradient, and a small annual cycle, being lowest around March 15, and highest around September 15.

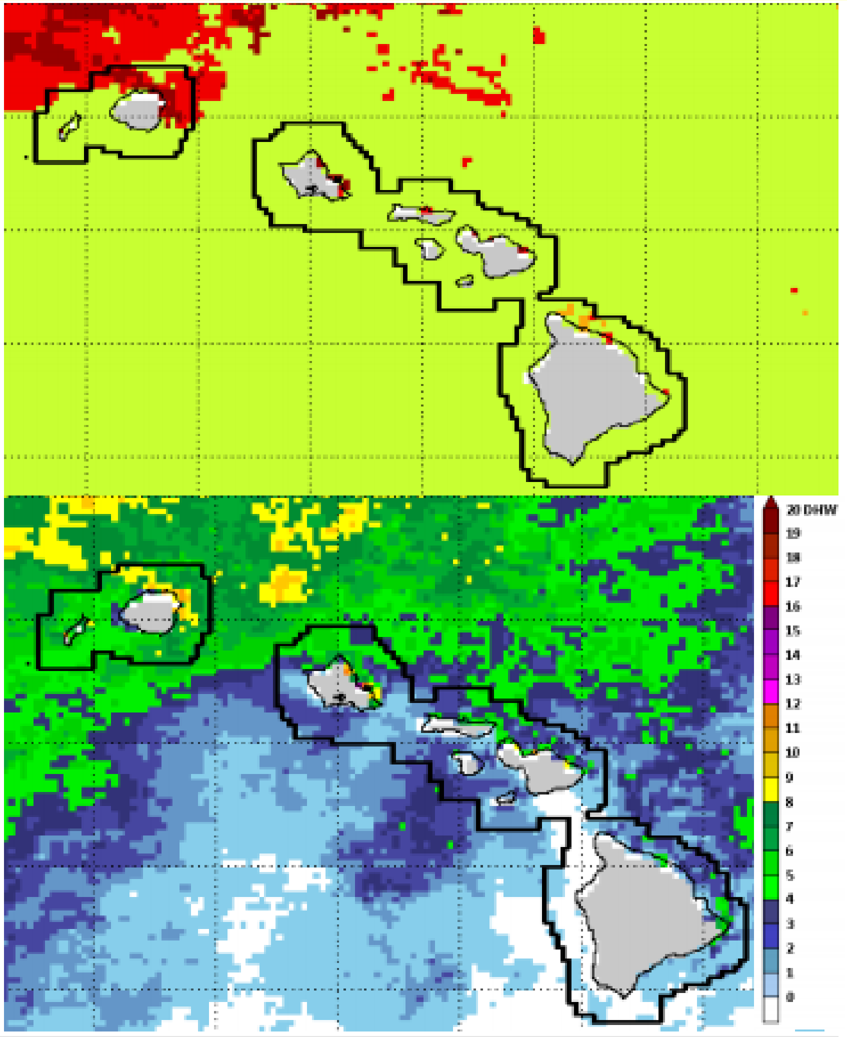
Temperature variations parallel the island chain, (i.e., surface waters cooler to northwest).

Thermal Stress - Coral Bleaching

Thermal stress linked with bleaching events

Fig 3. NOAA Virtual Station Thermal Stress Levels—10/27/2014

Kauai and Niihau	Bleaching Watch
Oahu	Bleaching Watch
Maui and Molokai	Bleaching Watch
Lanai	Bleaching Watch
Kona, Hawaii Island	Bleaching Watch
Hilo, Hawaii Island	Bleaching Watch



http://dlnr.hawaii.gov/reefresponse/

Coral Bleaching – What is it ?

Healthy corals appear tan, brown or green from the presence of the zooxanthellae within their tissues.

Coral bleaching is a stress response, describing the loss of color that results when zooxanthellae are expelled from the polyps or when chlorophyll in the algae are degraded.

When the zooxanthellae leave the coral, the white of the coral skeleton is then clearly visible through the transparent coral tissue, making the coral appear bright white or 'bleached'.

http://dlnr.hawaii.gov/reefresponse/coral-bleaching-2015/

Coral Bleaching – What is it ?

Primary cause of mass coral bleaching is warm water events (1-2 deg C. > normal).

Not all corals equally susceptible to bleaching:

Fast-growing branching and plate corals often first to bleach and more likely to die.

Slower growing massive corals take longer to bleach and survive bleaching better.

http://dlnr.hawaii.gov/reefresponse/coral-bleaching-2015/

Coral Bleaching – What is it ?

If normal water temperatures return quickly, corals regain the zooxanthellae and survive.

If stressors are prolonged, corals are more likely to die because they lack an important energy source.

Recovery is especially difficult for reefs in locations suffering from other stresses such as run-off and pollution.

http://dlnr.hawaii.gov/reefresponse/coral-bleaching-2015/

Coral Bleaching - Pervasive

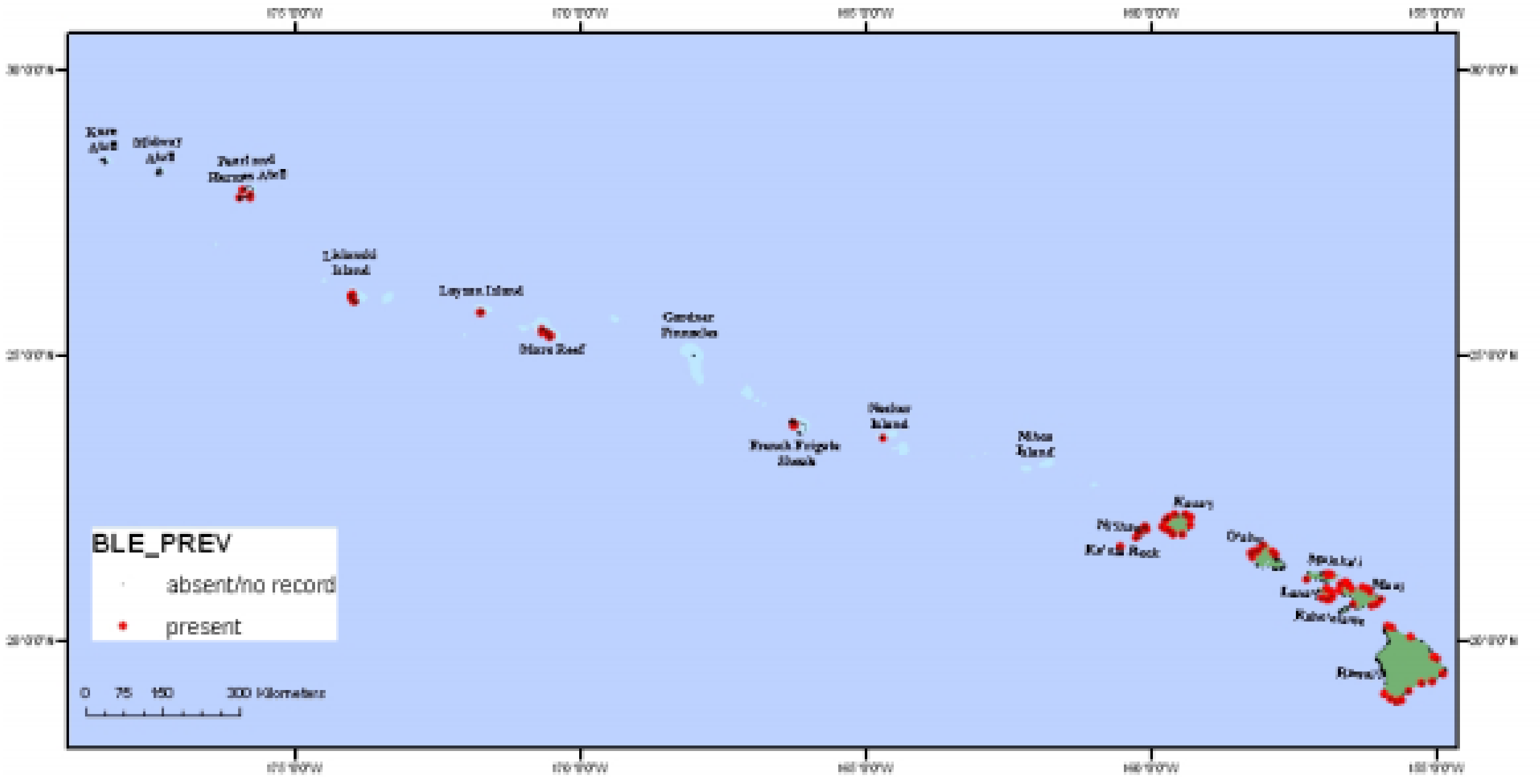


Figure 18. Survey sites with coral bleaching observed (red circles) during at least one survey between 1993-2008.

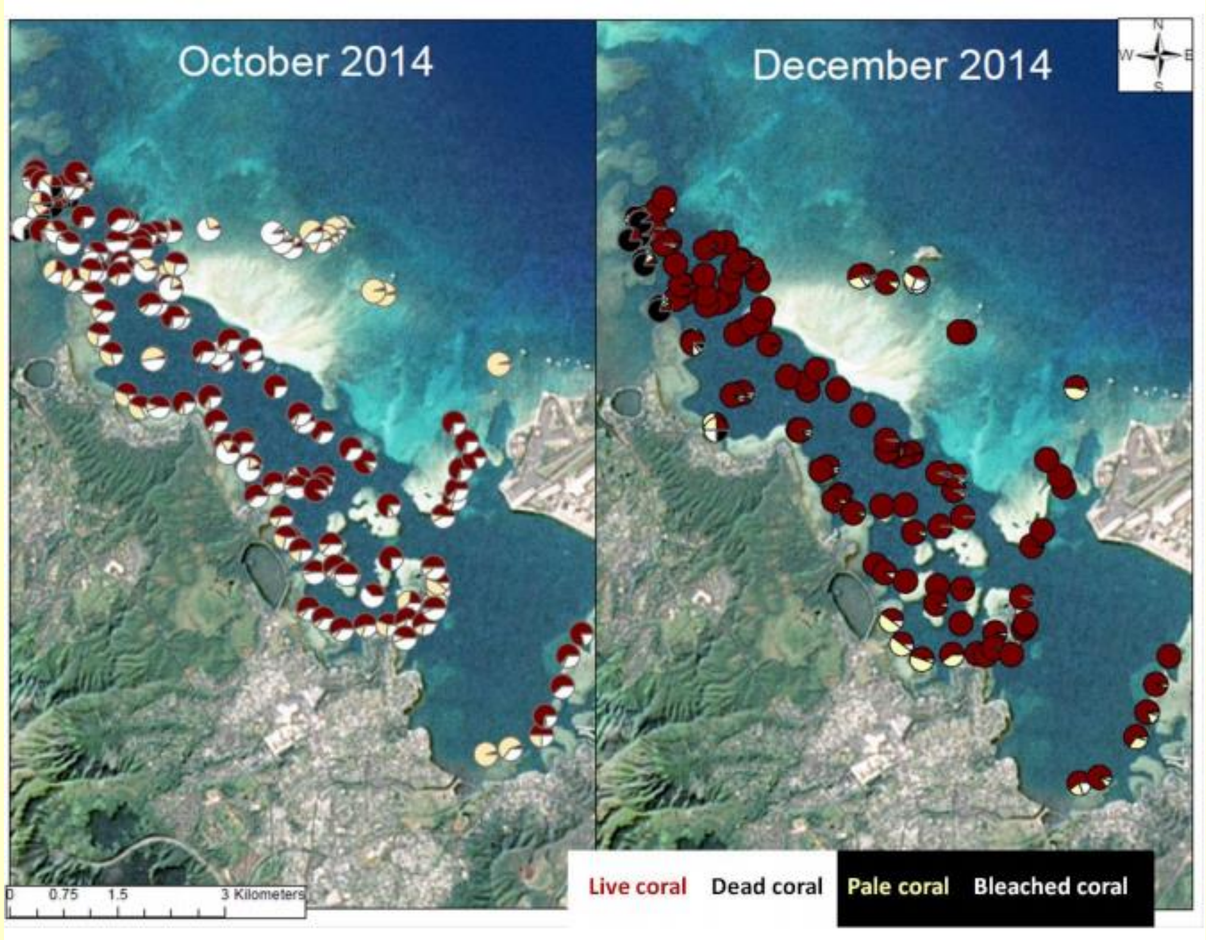
http://www.himb.hawaii.edu/HawaiiCoralDisease/download/CCMD_Project_Report_Final.pdf

Coral Bleaching – Localized

15 coral bleaching reports received by Eyes of the Reef Network from Nov 2014 to Jan 2015.

Monitoring will continue in 2015.

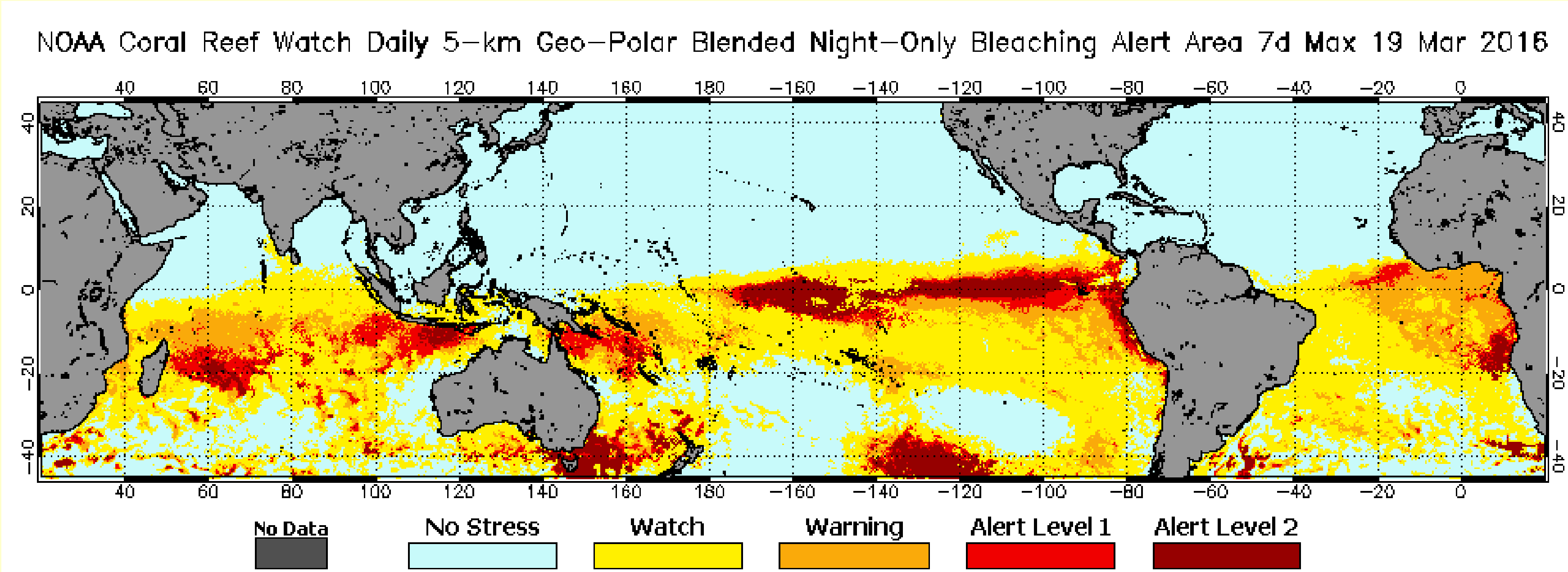
Severe bleaching predicted in 2015.



http://dlnr.hawaii.gov/reefresponse/

Coral Bleaching – Update

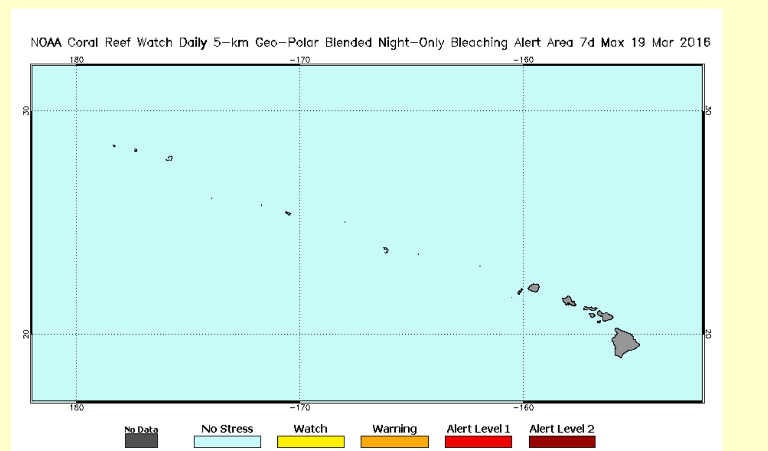
http://dlnr.hawaii.gov/reefresponse/coral-bleaching-2015/



Daily 5-km Satellite Coral Bleaching Thermal Stress Alert Area Product :

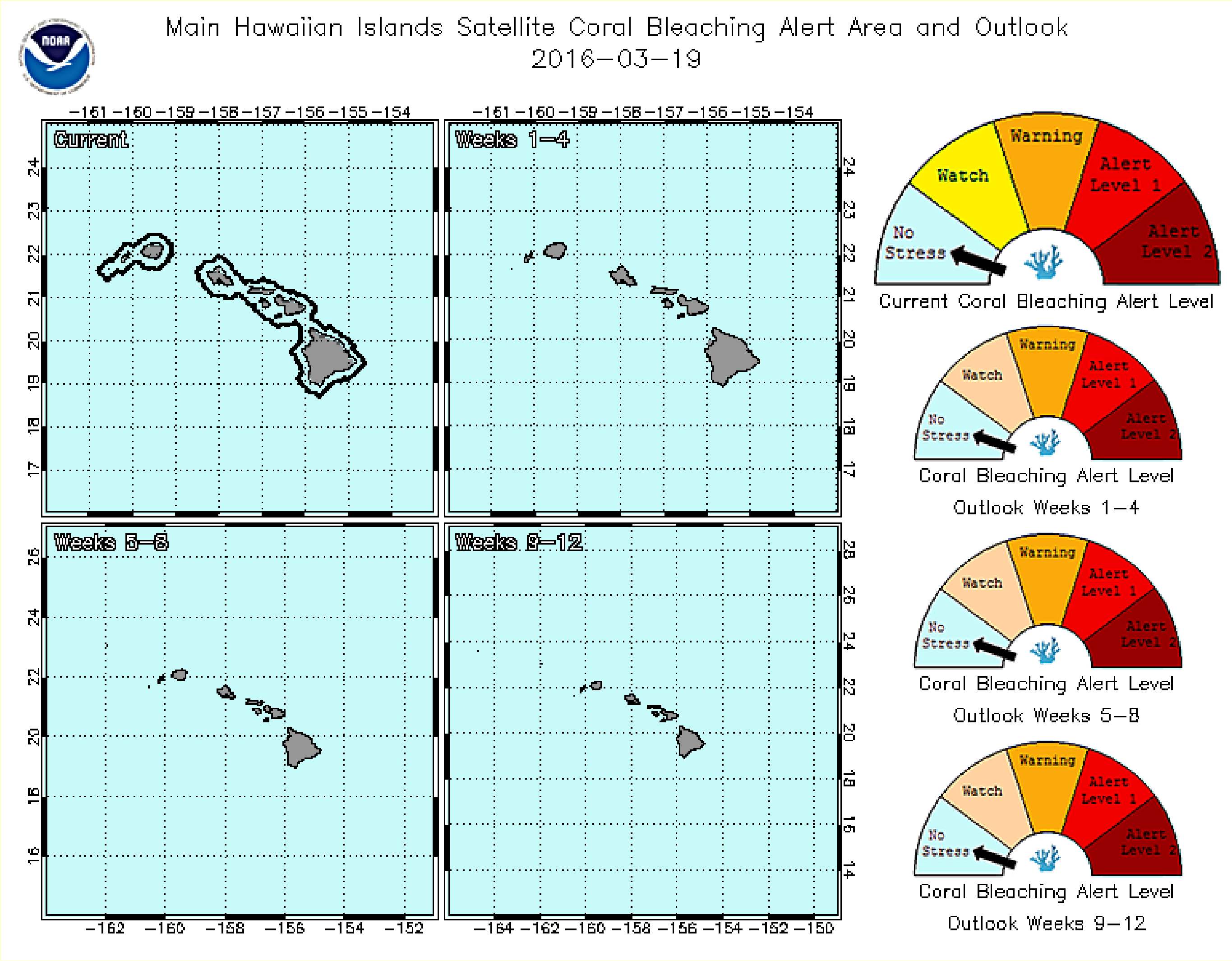
Global and Regional Predictions

Coral Reef Watch

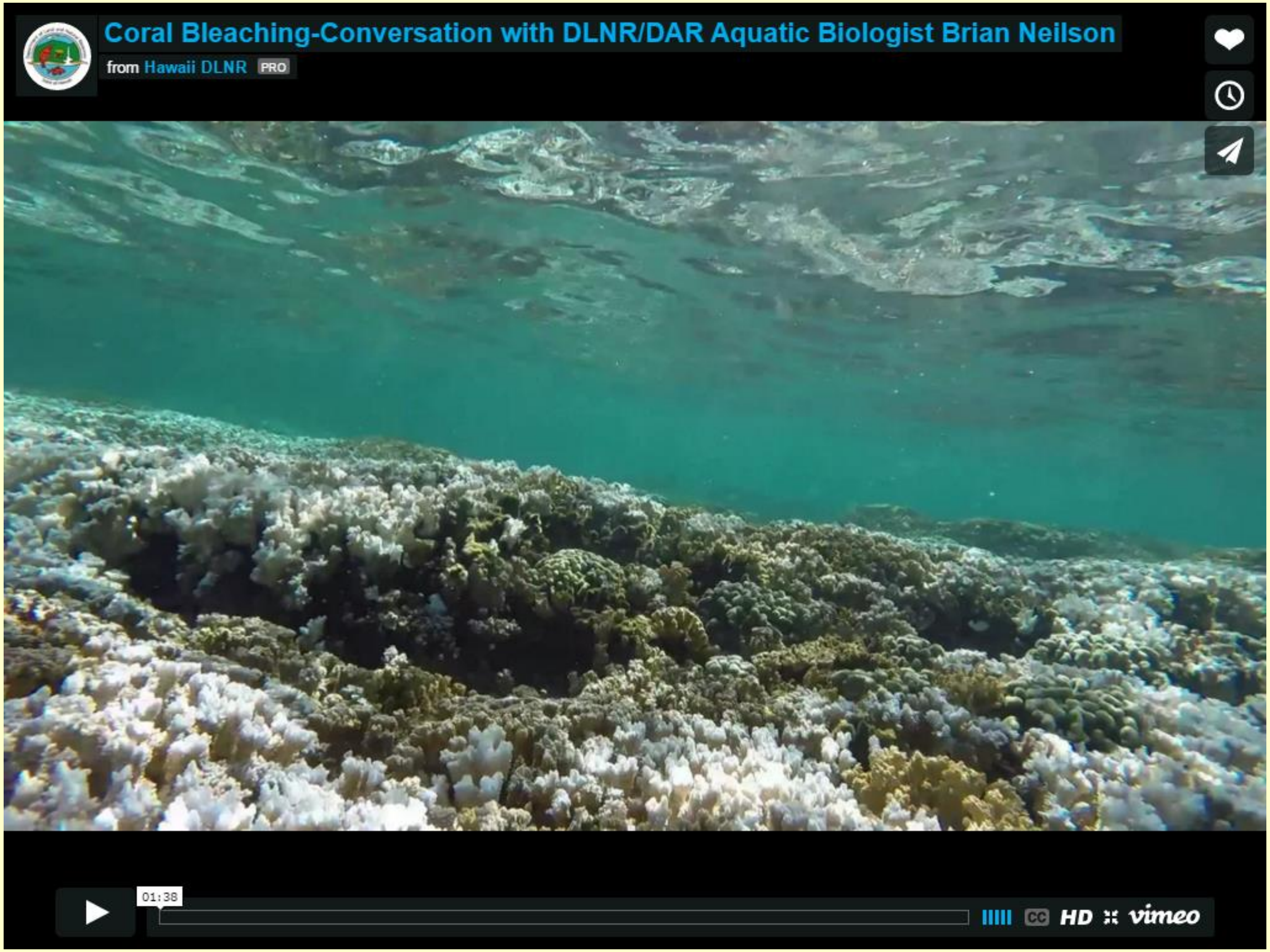


Coral Bleaching – Update

http://dlnr.hawaii.gov/reefresponse/coral-bleaching-2015/



Coral Bleaching - Pervasive



http://dlnr.hawaii.gov/reefresponse/coral-bleaching-2015/

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