The world’s coral reefs are in decline. Some areas such as the Caribbean have lost as much as 80% of their coral reefs. The causes are thought to range from global climate changes to local human disturbances such as pollution, silt runoff and overfishing. In studying these causes, one problem lies in what is known as the “changing baseline phenomena”. When there is a continuous decline, an observer will always remember their first observation as the “best” despite the fact that this state may have occurred decades before he arrived.

The purpose of the 2010 Northern Line Island Expedition was to find remote coral reefs that were still at their most pristine and compare them to reefs in the geographic vicinity that were under the influence of human populations. The Northern Line Islands in the equatorial mid pacific are composed of densely populated Christmas Island, lesser populated Fanning Island and three remote uninhabited atolls, Washington, Kingman and Jarvis. The latter two atolls are closed the general public and are under the protection of the US government requiring permits to enter.

The scientific hypotheses centered on the theory that the corals and fish life on Christmas and Fanning would be less abundant than those on the remote atolls. The science team was composed of four teams from four of the most prestigious academic marine science programs: Scripps Oceanographic Institute, University of Hawaii, University of Queensland, University of California Santa Barbara and the University of San Diego.

The science objectives of each team were as follows:
Fish: Through fish counts, specimen collections and dissections, the biomass and abundance of species would be recorded across the visited atolls. The working hypotheses was that these numbers would increase the further from the populated atolls of Christmas and Fanning island.

Benthic: The Benthic team was concerned with the health and abundance of the coral and algae and would deploy three different sets of experiments on each reef and then compare the results across all five atolls. These experiments were set up as:

1- Reef Tent Study: one meter triangular closed plastic tents were place over sections of reef and then were monitored for pH, salinity, temperature and oxygen levels. Higher levels would suggest healthier and more productive coral.
2- Algae Growth Cages: Algae was collected and placed in small cages to protect it from the algal consuming reef fish. It would be collected after several days and weighed and analyzed.
3- Coral/Algal incubated collected samples: Coral and Algal samples were collected at each site, brought back onboard ship and placed in incubation chambers where water chemistry could be measured

Paleo: The only way of looking at the past history of a coral reef is by drilling core samples out of the reef. These samples can then be analyzed for evidence of sea temperature, bleaching and other changes. The paleo team would select specific sites at each atoll and then drill core samples.

Microbes: Only recently scientists have discovered that sea water contains over a half a million bacteria per ml of sea water. These microbes appear to influence the health of the coral reefs. It is thought that when there are more nutrients introduced onto the reefs that toxic microbes increase and injure and weaken the corals. The microbe team would take water samples and analyze microbe content across the atolls. The premise being that on the populated atolls more pathogenic microbes would be found.

The Expedition.

It is difficult to imagine an expedition that can come closer to the ideals of remote field scientific exploration. The NLIs are situated in the equatorial pacific with the closest civilization being Hawaii 1000 NM to the northeast. The first challenge was getting to the staging area of Palmyra Atoll. The scientific team gathered at Honolulu airport and boarded a citation I turboprop for the 5 hour flight to Palmyra. The flight itself was an adventure in that it involved flying through the intertropical convergence zone (ITCZ) which lies over the equator and is the home of notoriously bad weather. We were lucky able to circumnavigate several large storms and landed at Palmyra uneventfully.
Palmyra atoll is now managed by The Nature Conservancy and the US Government and entry is restricted. It’s major function today is to house living quarters and laboratories for scientists studying the reef and marine ecology of the island.

We met our vessel that was to be our home for the next three weeks the MV Hanse Explorer. The ship was 150 feet long with enough deck space to conduct scientific and diving operations. After five hours of loading we departed Palmyra for our first destination Kingman Atoll.

Kingman Atoll is a ten by ten mile triangular atoll with only several small sand spits and no structures, vegetation or inhabitants. Historically it was used as a flying boat refueling station lagoon during the early days of the Pan AM Clipper service. Today it is a protected marine park managed by the US Park Service with severe restrictions on who can visit. We had permits but were not permitted to go ashore. In fact our captain who was an avid kite surfer requested permission to kite surf off the back of the vessel in the lagoon. He was denied. Fortunately we could dive and as planned, Kingman along with Jarvis, was the most pristine of all the reefs we visited.
The coral and fish abundance was prolific because of its protection. Along with Jarvis Island it had the highest observed numbers of predators indicating a healthy marine environment with no sign of disturbance. Actually there was one. A commercial fishing boat had wrecking on the outer reef and had either been carried over the reef or entered through the inlet and was found on the inside of the reef (also called the back reef). The coral at the wreck site was completely overgrown and actually smothered by thick filamentous green algae. This type of reef disturbance had not been observed before and was speculated to be form the added iron in the water from the deteriorating wreck.

There was a large population of Grey Reef sharks present both inside and outside of the lagoon – another indication of the health and uniqueness of this atoll. At night the sharks were attracted by the boat lights and were present in numbers as high as 30-50 on each side of the boat. In fact we had a mystery of why some sharks we saw during our daytime dives had blue snouts which grey reef sharks clearly do not have. Evidently they were hitting the blue painted underside of the Hanse Explorer during their nightly feedings. We were disappointed to find we did not discover a new species of grey reef shark after all.
The daily scientific began and remained the same for the remainder of the expedition. After an early breakfast tanks were checked for fill and nitrox percentage and loaded onto the four zodiacs – one zodiac per team.

The Paleo team had their own zodiac since it contained the generator for their drilling tools. The first day on site was a deployment day for the Benthic team. They deployed their tents and algal cages. The microbe team readied their sampling equipment. The fish team had the least amount of gear consisting of spears, catch containers that they wore hanging from their BCs. They would also take down a tape measure and waterproof slate to record fish counts.

The dive sites were either outside or inside the barrier reef and designated the fore or back reef respectively. At Kingman the first day, the fish and Paleo teams went to the outside reef while the Microbes and Benthic teams stayed inside the lagoon which for the Benthic team provide more protection from open sea conditions.

The outside reefs at Kingman are as one may expect – spectacular with coral cover approaching maximum and a multitude of species. The fish diversity and abundance was also the highest seen on the atolls visited and is one the highest recorded in the Pacific. The sharks we saw at night were present outside the reef and a half dozen or more were our constant companions. They were
curious but showed no aggressive displays. It is a incredible experience to swim with these “wild sharks” that have never seen a diver before as compared to frequently dived recreational sites in tourism areas where - if there are any sharks - are completely acclimated to divers and almost domesticated.

The Fish team starts their dive by unreeling 25 meters of tape for their fish count. Starting at one end two divers will travel along the tape counting the number and species of fish encountered in a line 4 feet off the tape. Once this is done they will start their sampling portion of the dive by spearing fish for later measurement and dissection. These fish would be then placed in the carry container. While the samples are not exposed as they would be in a bag net, the sharks still know by smell they are there. Once spearing begins in a area where there is a large shark population the team members know that they have only a limited time to get their samples before the sharks get too excited. When this happens it is time to end the dive and leave the water. This proved to be the case on the first dive at Kingman.

Alan Frielander of the Fish Team points to the business end of his high tech “data recorder”. 
The Paleo Team also dove outside the reef just down the reef from the fish team. Their first task is to identify a site that contains a large amount or Porite coral – typically the most massive hard coral found on any reef. Then the largest specimen is selected for drilling. A pneumatic drill with a 4 inch bit is used to drill down through the center of the core to extract a 2-3 inch core that will be analyzed back in the laboratory. This is hard work and it takes the whole dive for the two divers to get a sample and can be made even more arduous when there is a heavy surge or current running.

Inside the reef but out in the lagoon are areas of reef that have grown on the lagoon floor called patch reefs, the Benthic team is starting to deploy the first of their several experiments. The largest and most complex are their cBat tents. These are one meter triangular plastic enclosure that is secured to the bottom covering a patch of coral. Sensors are place inside the tent to measure the water chemistry that will reflect the respiration of the coral inside. This requires a whole team of 4 divers to set up a series of 4 tents per site. One deployed the additional water samples are periodically taken and the sensors checked.
An easier deployment are the caged algal boxes. These are placed secured to the bottom and algae sampled placed inside them. Protected against grazing by algal eating fish they will be collected after several days and weighed. By comparing these growth data across atolls the health of the coral/algal community can be determined.

Fanning Atoll

After spending three days at Kingman the next stop was at Fanning atoll which is part of the country of Kiribati. This was our port of entry into Kiribati and is often the case, our passports were collected and brought ashore while we followed the expedition routine of setting up the what needed to be done.

Fanning has a population of 2000 that was impossible to see from our position off shore – only two or three structures were visible. With this size population it was thought that there would be visible local impact on the reefs. On the first dive this was immediately evident with few large fish seen. There was also more algae on the reef. The coral was not as abundant as on Kingman but compared to Caribbean reefs it was certainly spectacular.
As on Kingman there was a shipwreck on the Northwest reef which decimated the reef. Though there was little of the wreck left there was a dead zone of more than a quarter mile on each side of the wreck. Water sand algal samples were taken and the fish team investigated the species and numbers that were found there.

Further up and down the reef the coral and fish life return to normal. An interesting observation is that no one is seeing any sharks on any of the dive sites. We do not see any evidence of a large fishing presence by the native population. In fact we see no one fishing at all! So what is going on here? Where are all the sharks? We get an answer the next day when we go ashore to retrieve the passports.

We talk to some of the village elders who state that the previous year a fishing boat arrived and requested the right to fish for shark fin. The vessel offered the equivalent of 300$ US and the deal was done. In less than three months there were no sharks left. This was dramatic and discouraging evidence of the damage one vessel could do in a short period of time. There could be a no more dramatic comparison between Kingman Atoll just 100 miles to the north with its healthy and prolific shark population and Fanning with none. Conservation and protection works.

We spend another two days at Fanning and then prepare to head North to Washington Atoll.

**Washington (Teraina) Atoll**

Just 100 miles north of Fanning we arrive early in the morning and see it upon rising as a small 3 mile long by one mile wide lushly wooded island. This is due to the extra rainfall the island gets compared to Fanning and Christmas to the south. It is inhabited by only a few hundred Kiribati natives. There is no lagoon or easy landing site so we stay onboard during our stay here.

The routine is by now old and quickly set up. All our diving is done mainly on the westward (leeward) slope in thirty feet of water. The fish team will do a count at 60 feet but no deeper. This makes me happy since the odds of anyone coming down with decompression sickness are significantly reduced at these shallow depths.
The coral and fish life are good but do not approach what we saw at Kingman. Though it will be a long time before all the data is analyzed back at each respective institution, what we are observing at least supports the working hypothesis of the expedition.

The last day on the atoll is as busy as the first as the tents and other experimental enclosures must be picked up. Though the fish team does not have this responsibility this day they have their own worries. Each site involves logging and collection of a number of species and one of the more valuable - Lutjanus bohar - has not been seen. This involves another trip back out in the inflatable but despite all efforts still no bohar. In desperation the Island fisherman are approached and offered a bounty for every bohar caught. Offer good for 12 hours till the boat leaves. Later that evening one boat approached with a catch of 4 bohar. This is a disappointing number but the fishermen say they are not common. This observation can't count as data but at least the fish can be used for dissection.

Another mystery develops when the benthic team starts retrieving their tents. One is missing – a seemingly impossible occurrence. The tents are secured to the bottom with long lengths of steel anchor chain and they simply cannot move or become dislodged. When checked all the other tents where in place with no sign of disturbance. So what happened to tent number 4? The fact that we saw no boats or other native activity on this side of the island eliminates any possibility of a human cause plus they are not marked by any surface markers. Currents, heavy surge or rough ocean conditions? We saw no evidence of this and the adjacent tents were undisturbed. A large tiger shark up from the depths at night? You can take your pick.

The next and most remote atoll of the expedition will be Jarvis atoll.

**Jarvis Atoll**

Jarvis Atoll is a small one mile by one mile dry atoll less than 25 miles south of the equator. Like Kingman it’s administered by the US fish and Wildlife Program and requires a permit to visit. It receives scant rainfall and has never been inhabited. With such an isolated location and history it would be logical that it could prove to be the most pristine atoll on the itinerary.

We crossed the equator early in the morning and arrived before breakfast. In the process many on board shed their designations as pollywogs and became shellbacks.
Spectacular coral formations and an abundant shark population greeted us at Jarvis Island.

As soon as we dipped beneath the surface we knew we were privileged to be diving on this island. Here was a perfect example of a pristine reef environment, free from human influence and protected from this negative impact for the future. The coral cover was at its maximum exposure and there were large numbers of grey reef sharks, red snappers and other schools of fish. These last few days were a fantastic culmination and even the most seasoned reef scientist stops and looks about in wonder.

My feeling was that I was experiencing the closest to what it must have been like to dive these reef three hundred years ago. On one dive I have never seen as many grey reef sharks as we saw on this particular dive. This particular dive was to retrieve cameras deployed the day before. I was the first in the water and as soon as I started to descend I was astounded to see at least 80 grey reef sharks below me and beginning to approach me on all sides. This is simply too many to safely dive among and I rather quickly degeared (I think I set some sort of record) and was back on board the zodiac before anyone else entered the water. The other problem was that the zodiac had drifted slightly too far from the sloping reef wall that would at least protect our backs as we descended to the bottom. You do not want to be exposed on all sides and descend in open water with that many sharks. We repositioned the zodiac and went back in – but this time close to the reef now at our back. Dr. Forest Rohwer retrieved the cameras in the midst of a dozen curious grey reef sharks.
Homeward Bound to Christmas Island

After Jarvis we headed north to our disembarkation port of Christmas Island. Some of us would return on the first flight out and the remainder would stay on for another day and do more work on sites on Christmas Island.

Christmas Island

The final Island on the expedition was also our disembarkation point. Christmas Island is by far the largest and most populated of all the Line Islands. It has a population of over 5000 in four villages. The island served as a nuclear test site for both the US and UK in the 1950’s and 1960’s. It has the only jet runway in the Line Islands and receives a single international flight once a week.
Due to these logistics we separated into two departure groups with the first group departing the next day. The second group would do another few days of diving and then depart. Scientific Expeditions are always one part science and one part adventure as we found when at our scheduled pickup for the airport the next morning. Instead of two large pickups there was only one small pickup. Making quick selections we had to leave 800 pounds of equipment behind in order to pack in the bare essentials (scientific specimens and ourselves). Probably the most hazardous situation of the entire expedition occurred when Christian McDonald agreed to travel spread eagles across the cases in the back truck bed on a harrowing ride across the island to the airport. After a minor mix-up at the airport when we were told we could not board our flight and with some kindly intervention from the Quantas pilot we were allowed to depart.

**Safety and Medical Issues**

For an expedition of this size and length there are likely (and there were) several cases requiring medical support. From a safety perspective there were no dangerous incidents or safety breeches. This was the result of planning and having experienced personnel involved. There were no diving related accidents or incidents.

The most serious potential risk was that of a diver becoming separated and lost from the boat. There is no search and rescue support in these remote waters. To insure a prompt recovery should this occur, all divers carried a VHF manually activated alarm/alert. Once activated this would activate an alarm in the wheelhouse and give a bearing. The system was tested but was never needed to be activated.

Each dive team also carried a tourniquet that could be applied in water to control hemorrhage due to a shark bite or prop strike. Most deaths from hemorrhage are preventable. The reason for loss of life is too much blood is lost during the first few minutes before first aid can be applied. The average time between in water hemorrhage and retrieval is likely to be between 5 minutes ten minutes or longer. During this time in severe wounds, 1-2 liters of blood loss could occur. Considering the evacuation of being 24 hours or longer this amount of loss, while survivable with close medical evacuation, could be fatal in these remote areas. Military use has confirmed the value of these devices and each solder now deployed in US forces abroad now carry one. They should be considered mandatory in remote expeditions such as these.

In tropical environments infections are common. On this expedition, six individuals required antibiotic therapy for infections. One had a severe oral abscess and almost required evacuation but responded to
antimicrobial treatment. One member of the crew required minor surgery for an imbedded coral fragment. Other minor medical conditions included sea sickness and ear infections.

Preliminary Results and Conclusions

To find answers to the questions on the etiology of coral reef decline a number of variables must be controlled for. These variables are global climate change and local changes. Global change is another topic and cannot be controlled for, however local changes can. Among the causes of local (human) change are excess inorganic nutrients, excess organic nutrients, microbial changes, temperature and seawater chemistry changes. Studying reefs that have the least amount of human population can be used to control for these variables. The Northern line Islands provided this gradient from most human impact to most pristine in this scale: Christmas>Fanning>Washington>(Kingman=Jarvis)

This was confirmed on preliminary observations. The best coral and highest fish populations were observed on Kingman and Jarvis islands – both protected reefs. Both Christmas and Fanning with the highest human populations had the least amount of coral coverage and the highest algal growth rates.

This also supports a theory as to the cause of coral death. It is thought that overfishing eliminates the herbivores and grazers that consume algae. Without grazing to keep growth rates down, algae increases and becomes dominant on the reef. Algae produce dissolved organic carbon which promotes excess microbial growth and is toxic to coral. Pristine reef systems have low algae growth and low dissolved organic carbohydrates with low microbial population and healthy coral.
The results of the ten individual experiments and results of observational data will begin to be released for publication later in 2012 and 2013.

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