Ocean Discovery Expedition 2009-10
Flag Expedition Report

Flag #73
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Ocean Discovery Project
Flag Expedition Report

Introduction:

The Ocean Discovery Expedition (ODE) purpose was to take a broad geographical look at a set of current highly significant threats facing the ocean today. Our intent was to add to the current fact base on these issues, and to refine methods that will be used by the same team and subsequent phases of work. We also believe that this work is important in developing working approaches that are less dependent on large-scale oceanographic research vessels and related funding levels. Following is a brief overview of the issues and conservation context, project methods, preliminary results and conclusions. Subsequent updates will be filed as data analysis progresses. In addition our two websites keep a current perspective on the overall work: http://panexplore.com/, and http://5gyres.org/.

Current Marine Conservation Context Related to the ODE

We face a significant and growing challenge to the fundamental health of the world’s oceans. This threatens not only the ecological fabric and biodiversity of 75% of the planets surface, but also the vast array of natural services to human society - e.g. climate moderation, rainfall, reef building, fisheries, and even our entertainment. The windows of opportunity to resolve these issues are limited and will require important, difficult near-term decisions. While the local face of these issues may vary, the underlying threats are common worldwide:

1. Chemical pollution and debris, ranging from low density toxins to the now famous “garbage gyres” of the open sea
2. Water temperature changes and acidification due to increased atmospheric CO$^2$ disrupting life-cycles in key marine species like corals
3. Sea level rise inundating coastal habitat (and land based pollution/ debris) and changing coastal marine habitat
4. Over exploitation and destructive harvesting techniques like bottom trawling severely depressing natural populations
5. Increasing separation between our daily lives and the health of marine ecosystems
Several factors have begun to dramatically raise the risk of an unhealthy ocean with serious consequences. First, our numbers and our conduct have pressurized the situation with an immense burden on marine habitats. Our world population will likely cross nine billion by 2050 – up 50% from current. More concerning, the rapid rise in living standards by most of these people, aspiring to reach western levels, will raise our footprint by another 2-300%. Second, the interaction of threats is pushing species and entire communities to the brink of collapse. The effects compound - severely depressed populations (>80% declines in most sharks, tuna and cetaceans), chemical and debris pollution interfering with foraging or breeding (high persistence plastics in seabirds), and physical destruction of the habitat through sedimentation, bottom trawling or the thermal bleaching of corals. What we once believed to be a vast, enduring sea of resources increasingly appears headed down a deteriorating and unstable trajectory.

Perhaps ironically, we do have powerful options and capabilities that could well create a path to restoration. There are very real choices in our daily lifestyles and consumer behavior. Technology for drastically reducing energy, material, chemical and habitat impact is also rapidly emerging. We also have the ability to improve ocean policy, governance, enforcement and resource management.

The fundamental challenge is not a lack of solutions, but our collective will to act. People around the world remain remarkably, tragically, un-informed and un-engaged. Despite living on our “blue planet” most of us have little direct contact with or understanding of the ocean. We may know some of the ocean’s wonders through our popular media or aquaria; the candid truth about the loss and risk going forward is generally not understood. We have the foundations of good science, resources and available options. Building a global mindset of marine conservation is far and away the greatest challenge. We believe share a strong belief with marine conservation leader J.Y. Cousteau- Il faut aller voir. We must go and see for ourselves.

The Expedition objectives focused on three principal areas:

1. Documentation of marine debris accumulation, particularly of a North Atlantic Gyre accumulation zone
2. Documentation of broad geographic evidence of persistent organic pollutant (POP) in fish
3. Field-testing of a new sensor type and combination for ocean acidity and CO2 absorption.
4. Field evaluation of a large sailing vessel to support marine environmental work.

This science team was also joined by a group of artists from the Netherlands. Maarten Vanden Enyde led a small team on the Bermuda-Azores leg to do field work for a large modern sculpture project based in Europe. Their art takes as a starting point, the recreation of natural life today, by a future culture that lives in a diminished world. In this case- imagine a world where coral reefs are gone and plastic debris is used to try to recreate the look of the now lost reefs. Despite our very different approaches, this was a very productive partnership.
During the seven months at sea the team also collected anecdotal observations on broader state of the oceans.

**Expedition Methods and Work**

**Expedition Team:**

Dr. Ron Ritter (FN07), Portia Ritter, Dr. Marcus Eriksen (FN10) and his wife Anna Cummins (FN10) led the Expedition. The full team complement varied throughout the seven-month project with each of us sharing roles on board the research vessel and working from shore.

The Full Complement of on-board crew are listed below:

<table>
<thead>
<tr>
<th>Ron Ritter</th>
<th>Dale John Selvam</th>
<th>Michael Atallah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portia Ritter</td>
<td>Gene Taoromina</td>
<td>Maarten Vanden Enyde</td>
</tr>
<tr>
<td>Marcus Eriksen</td>
<td>Ron Ritter Sr.</td>
<td>Lam</td>
</tr>
<tr>
<td>Anna Cummins</td>
<td>Pat Ritter Sr.</td>
<td>Mart.…..</td>
</tr>
<tr>
<td>Tim J. Longden</td>
<td>Stiv Wilson</td>
<td>Elton Joseph</td>
</tr>
<tr>
<td>Blythe Longden</td>
<td>Leslie Moyer</td>
<td>John Wright</td>
</tr>
<tr>
<td>Hugh Carthew</td>
<td>Clive Cosby</td>
<td>Diane DeWitt</td>
</tr>
<tr>
<td>Phoebe Cowen</td>
<td>Ian Buchele</td>
<td>Leah DeWitte</td>
</tr>
</tbody>
</table>
Several of our Advisory Staff played significant supporting roles during and after fieldwork:

1. Dr. Kathleen Sealey, University of Miami/ College of the Bahamas
2. Judith Landsberg, Greenrock Foundation, Bahamas
3. Dr. Peter Griffith, NASA Goddard Space Flight Center
4. Dr. Simone Alin, NOAA Pacific Marine Environmental Laboratory

Expedition Route

The ODE was based on a long oceanic route that traversed the North Atlantic twice and then longitudinally south to Brazil giving exceptional sampling to this large area. The overall route dates and duration are roughly as given in Table XX

The route included major stops in:

1. Lanzarote, Canary Islands
2. Tobago
3. Bermuda
4. Sargasso Sea
5. Azores Islands
6. Cape Verde Islands

The route plan is shown below:
The Expedition covered over 15,000nm (28,000km) of ocean travel, visited 15 countries, and traversed both the North Atlantic Gyre (Sargasso Sea), and the Equator. Total time from departure was approximately 190 days.

The Vessel and Supporting Equipment

The ODE was carried out on board our dedicated research vessel, Sea Dragon, a 72’ (22m), 90,000lb displacement steel hulled sailing vessel built in the UK in 2000. Formerly known as CB 37, she is one of 13 second generation yachts built for the Global Challenge Race - one of the longest, most demanding ocean voyages ever made with an “upwind”, west-about 32,000km circumnavigation. In her new role, the boat provides a superb platform of rugged capability, capacity and efficiency with a naturally low environmental footprint - perfect for this type of remote sailing expedition. The British Maritime and Coastal Agency rate Sea Dragon to the highest standard of “Category 0 – All Oceans”. Configured crew capacity was 14 (rated to 18).

Marine Debris Assessment - Coastlines:

Work on marine debris builds on the substantial research completed in the North Pacific Gyre and very limited, but important early data from other ocean regions. The team took two separate but supporting tracks to assess prevalence of plastic marine debris in the Atlantic.
First were a set of basic beach transects to give a rough indication of presence, density and type of debris on representative beaches. This follows the protocol set out by Algalita Marine Research Foundation (AMRF) for small-scale particles. In this, 1m\(^2\) observation squares are placed in the high tide accumulation zone of beaches. All sand within 2cm depth is removed and sieved through an H&C 12” frame, 2mm mesh sieve. Anthropogenic material is removed, counted by unit and weighed. Material is divided into X category types. Such data are useful in characterizing general occurrence and cannot be directly extrapolated to the larger beach or shoreline. In support of this, a series of longer transects were completed on beaches. These were typically 200m in length and 50m wide running down a beach. Actual width was calibrated to the particular beach profile and then averaged for purposes of determining the total sample area. All visible marine debris was collected, sorted by type and weighed on the transect. While still imperfect, these transects give a larger scale perspective of beach debris.

A total of 25 Fine Particle plots and 24 large item visual count transects were completed in Agadir Morocco, Lanzarotte Canary Islands, Cape Verde, Tobago, St. Lucia and Barbados. Numerous other beaches were inspected visually. In the vast majority of cases, anthropogenic marine debris was present and easily seen. There were several overall patterns:

1. Much higher concentrations on windward shores, and/or those facing the open sea
2. Localized concentrations due to either wind (e.g. Famara Beach, Lanazrote) or tide lines
3. Very low concentrations linked to regular beach cleaning (Agadir, Morocco)

Plastic fragments, followed by pellets, dominate the debris profile for smaller particles in plots. The latter are pre-manufacturing resin pellets that “escape” from supply chains and production processes. Total particle count ranged from zero to almost 5,000 per m\(^2\) with an average of 226. 17 Plots had 10 or fewer particles. Excluding these, the average particle count increases to 565. Counts by type for each transect are given in attached tables.
The large-scale visual transects give a similar profile with the dominant category being “other plastic”. This catchall category included a huge range of human debris—shoes (53 pairs in one case), toys, toiletries, utensils and fragments. Fishing gear (nets, line, buoys) was present in 16 of 24 transects.

There was also a high degree of variability in density ranging from 0 – 39,000 pieces with a median of 106 per 1000m$^2$. Values by type for each location are given in attached tables.
In summary, small particle and large visible piece marine debris was present on the vast majority of beaches visited by the team. The highest values were found in the main beach fronting Praia, Cape Verde Islands. This extreme case was a shocking example of river runoff, urban trash and likely some ocean arrivals. Also interesting was visual inspection of several samples under a 30x stereoscopic microscope. In both cases (Lanzarote, Canary Islands) apparent beach “sand” contained a noticeable fraction of plastic fragments (estimate 25-35%).

While useful as a qualitative, general indicator only, these data demonstrate again that the world’s beaches are being augmented by human debris. The term “plasticized” (R. Thompson, University of Plymouth pers comm.) seems increasingly appropriate. Particularly when looking at beaches like Bermuda and the Azores, it is also apparent that these shorelines are acting as giant natural nets that capture circulating debris.

Faial, Azores

Lanzarote, Canary Islands

**Marine Debris Assessment- High Seas Trawls:**

Spatial and Temporal Distribution of Plastic Pollution in the North Atlantic Subtropical Gyre: Results from Two Expeditions in 2010

Marcus Eriksen¹, Gwendolyn L. Lattin¹, Bonnie Monteleone², Anna Cummins³, Emily Penn⁴
INTRODUCTION:

This study presents data gathered from 35 surface net tows conducted during 2 expedition legs through the North Atlantic Subtropical Gyre in the winter of 2010. 6 months later, 6 sites were revisited to study seasonal variation.

In January 2010 the vessel “Sea Dragon” traveled over 4,850 kilometers from St. Thomas, Virgin Islands to Bermuda, and onward to Horta, Portugal. The Sea Dragon is a 50-ton, 72ft sloop-rigged sailboat, with long spinnaker poles easily rigged for towing neuston nets for sea surface sampling.

Previous studies of plastic marine debris in the Sargasso Sea span nearly 4 decades, yet have focused on the western region primarily. This study shows evidence of spatial distribution of plastic marine debris further than previously known, and a temporal change showing a summer increase plastic particle abundance over winter samples in the same area.

METHODOLOGY:

Sea surface samples were collected using a manta trawl with a 60cm x 25cm net aperture, a 333-μm mesh net, and towed at the air-sea interface. The net is towed off the starboard side using a spinnaker pole extended perpendicular to the boat, which extends the towline 5 meters from the ship’s hull, thus avoiding the ship’s wake. Tows were typically 3 hours long and traveled 6-8 nautical miles at 1.5-1.75 knots. To measure the area and volume sampled, we used a flowmeter, and recorded GPS coordinates of the start and stop locations. Samples were preserved in 10% buffered formalin for transport to the lab.
Plastic particle weight and count density was computed by multiplying the width and height of the net aperture by the length of water traversed according to flowmeter data, then this volume was divided into the total weight in grams, and also the total number of particles. Plastic particle count abundance was computed similarly, but with only net width, not height. GPS coordinates are used to validate flowmeter data.

Individual particles of plastic were then sorted into type categories (pellet, fragment, foam, film, and filament) and size categories (0.355-0.499mm, 0.500-0.709mm, 0.710-0.999mm, 1.0-2.79mm, 2.8-4.749mm, and greater than 4.75mm.)

**RESULTS:**

The first leg of the expedition began in St. Thomas, Virgin Islands and landed in Bermuda, representing the western region between longitudes (64.56W – 62.43W). The average plastic weight density is .0125 g/m$^3$, and the average particle count density is .4488 particles/m$^3$. The average plastic particle abundance was 68,446 /km$^2$. 
Leg 1 data

The second leg of the expedition began in Bermuda and traveled east toward to Horta, Portugal, with 15 samples collected between longitudes (64.25W – 33.23W). Plastic weight density was .0025 g/m³ and particle count density was .0342 particles/m³. Average plastic particle abundance was 46,393 particles/km².

Leg 2 data

On both legs, fragments far outweighed and outnumbered the other 4 types of plastic, by 80% or greater. The smallest size category (0.335-0.499mm) accounted for one third of the number of particles.
On Leg 1, the distribution of particles by size favored the smallest size class, 0.335 – 0.499mm, by 32%, with nearly half of the particles, 48%, less than 1mm. On Leg 2, the percent distribution of particles less than 1mm was 15%, with 59% of the number of particles in the 1 – 2.79mm size class.

During Leg 2, the expedition crew experienced a tropical storm with wind gusts exceeding 60 knots and wave heights over 8 meters. Samples were collected during sea states less than Beaufort Scale 4. What is unknown is the effect of sea state on the vertical distribution of different class sizes of particles, as well as the vertical suspension rate of microplastics after storms. This may explain the significant reduction in observed smaller class sizes between the two expedition legs.

Net tows 18, 19, 21-24 were repeated 6 months later in summer. The average weight density was .005g/m³. This is a significant increase compared to the average weight density of .0022g/m³ for the winter samples.

### Summer replicates of winter samples

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Date</th>
<th>Lat (N)</th>
<th>Long (W)</th>
<th>Surface Abundance #/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (repeats winter 18)</td>
<td>7/15/10</td>
<td>31.29.860</td>
<td>64.00.914</td>
<td>13,000</td>
</tr>
<tr>
<td>2 (repeats winter 19)</td>
<td>7/15/10</td>
<td>31.30.289</td>
<td>64.29.996</td>
<td>106,000</td>
</tr>
<tr>
<td>3 (repeats winter 21)</td>
<td>7/13/10</td>
<td>32.09.336</td>
<td>64.26.899</td>
<td>44,700</td>
</tr>
<tr>
<td>4 (repeats winter 22)</td>
<td>7/17/10</td>
<td>32.09.191</td>
<td>63.40.124</td>
<td>480,000</td>
</tr>
<tr>
<td>5 (repeats winter 23)</td>
<td>7/16/10</td>
<td>31.30.167</td>
<td>62.28.720</td>
<td>225,000</td>
</tr>
<tr>
<td>6 (repeats winter 24)</td>
<td>7/16/10</td>
<td>31.45.992</td>
<td>62.54.030</td>
<td>92,400</td>
</tr>
<tr>
<td>Mean =</td>
<td></td>
<td></td>
<td></td>
<td>160,193</td>
</tr>
</tbody>
</table>
CONCLUSION:

This study aimed to investigate the spatial and temporal distribution of plastic pollution in the North Atlantic Subtropical Gyre. Although only two samples were collected in the eastern region, these samples show evidence of plastic pollution further east than previously known. The data here suggests a decreasing trend eastward across the Sargasso Sea.

Further study is needed to examine plastic pollution in the eastern region, as well as the effect of sea state on the vertical mixing of microplastic particles.

REFERENCES:
Third, our art team led by Maarten Vanden Enyde collected bulk samples of marine debris in Bermuda, the Azores and from a small launch while in the Sargasso Sea. This material was cleaned and shipped back to their base in Europe.

**Toxins in Marine Fish**

Significant research has been done on the sources, occurrence and trophic dynamics of toxin accumulation in marine life. While the phenomenon is generally well known, the team sought to leverage the long expedition route to assemble a large-scale view of this phenomenon. Fish tissue samples were collected through a variety of means, multiple species, and in widely dispersed locations. This supports a broad picture view of the occurrence of these dangerous, anthropogenic compounds.

Fish were collected in three ways: a) rod/reel catch by team members when in International waters, b) samples from sport or commercial fishermen on docks, and c) fish purchased in local markets where point of origin could be verified. In each case a small 8cm$^3$ cube of flank muscle tissue was collected along with similar size of liver tissue. The fish weight and snout to tail length were measured. Species was recorded to best available detail along with catch location. Samples were frozen to -2C. Analysis for several known “Persistent Organic Pollutant” (POP) chemicals is underway completed using ELISA analyses at the University of Miami.

Based on the first phase of this work, we will now formalize the protocols for fish tissue analysis. Market source and crew caught (international waters only) fish will be taken on all legs and ports. These will now be sent to our partners at Örebro University, Sweden. As part of the UN Same Planet Campaign, future samples will be done using Gas Chromatography and Mass Spec analysis.

**Surface Water pH and CO$_2$**

Due to increasing concern about oceanic CO$_2$ absorption and subsequent acidity, researchers have been looking for ways to increase available data. Surface water data is currently restricted to large-scale research vessel expeditions and a limited number of offshore buoys. The US National Oceanic and Atmospheric Administration (NOAA) have been working to develop methods to augment this sparse data with private vessels. The Volunteer Observer Ship (VOS) program has done this for other water quality data for several years, and is now attempting to do so for CO$_2$/pH as well.

We fitted our research vessel with two sensors as a test and evaluation exercise to validate collection from smaller private vessels (i.e. yachts vs. commercial ships). This involved two sensors fitted in series. The first was a Hach MS5 water quality monitor unit capable of recording:

1. Temperature
2. Conductivity (salinity)
3. Turbidity (clarity)
4. pH

The second unit was a relatively new type sensor for measuring dissolved CO₂. This was a Sunburst SAMI flow-through sensor mounted inside the vessel.

The two units were set in series and fed with a 1.9lpm flow through pump. This pump pulled water from below the hull, through the two sensors and then overboard. Data were collected at 30-minute intervals. Position data was initially recorded in manual logs, and then with a later software upgrade, automatically on board. The system was initially installed in Bermuda in late January 2009. Tests were conducted crossing to the Azores with subsequent refinement. “Real” data were then collected on the first fully operational test from the Azores to landfall just south of Rio de Janeiro Brazil.

Anecdotal and Other Information

At each major port of call the team made an effort to “get out” and observe local marine conditions and other conservation issues. This was done through:

1. SCUBA diving and underwater video
2. Vehicle trips around the local area
3. Meeting with local people- particularly those working in the ocean-conservationists, fisherman, dive operators, other sailors

While anecdotal, this extra work did provide a number of interesting observations and overall trends. Some of this information has already proven useful in sharpening hypotheses and methods for future use. It has also been useful in public communications and education. A summary of our findings by area is found in the Appendix.

Communications

Supporting the entire ODE, communications supported vessel tracking, safety, logistics, education and external relations. A few of the principal means employed:

1. Multiple blogs from individuals on board to various websites
2. Media interviews on shore
3. SPOT GPS position tracking linked to individuals and website maps

We have now evolved to two primary blogs including:

1. http://panexploreshipsblog.blogspot.com/
2. http://5gyres.org/whats_happening_now/blog/
Crew members also did individual blogs available through our website – “communications” We have now transitioned to an improved blog based directly on our website – panexplore.com

Several thousand digital images have been taken – most easily seen on our two websites. Video was also filmed, both internally and externally. A representative collection is found on our website Gallery
The team “successful” announcement verifying the existence of a “north Atlantic Garbage Patch” resulted in substantial external media including multiple AP wire reports, Appearance (via sat phone and skype) on Good Morning America and Discovery Networks, NPR, The Late Show, and others. A sample of these can be found on our website as well.

Art Marine Debris Collection

Our art team, led by Maarten Vanden Enyde, collected debris at sea and on the shorelines of Bermuda and the Azores. Their total haul, not yet quantified was impressive as evidenced by photos taken on shore. This gives an excellent overall picture of the range of debris finding its way into our oceans.

The work will be shown on Vlieland, one of the Islands in the Netherlands in the beginning of September during a festival called INTO THE GREAT WIDE OPEN. It will be shown in a container, just like it was washed ashore. Latest details are on the blog www.plasticreef.com

Vessel Field Trials

An important part of the expedition was to set up and evaluate our vessel Sea Dragon for future work. As of this writing, she has been repositioned to Brazil and is scheduled to begin a new phase of work covering two oceans and over 24,000 miles of sea travel
through August 2011. The work will continue to focus on marine debris, toxins and acidification through CO$_2$ monitoring.

Positive Learning:

1. The exceptional seaworthiness and overall safety of the boat is critical. This allowed a relatively new crew to transit and work productively in the winter North Atlantic. At one point they worked through 72 hours of 60kts wind and 10m seas. This translates into overall mission reliability and crew well-being.
2. Light surface and mid-water net trawls work perfectly well from a sailing vessel of this size. We encountered no major problems working with various nets.
3. The close integration of the crew into one working team improved productivity and boat dynamics. People all shared evenly and took home a much broader experience (counter point below). Similarly incorporating initial sail training for all crew was a plus.
4. Fully operational alternative energy systems (wind turbines, solar panels) do significantly reduce fuel demands and costs
5. Artists are important crew. While dominated by scientists, our Dutch Artists made a strong case for their unique ability to interpret these complex issues in new, compelling ways.

Improvement Areas:

1. A higher speed plastic surface trawl is needed. There are important stretches where the boat must transit at higher speeds (>2kts). A new trawl has been designed and tested to do just this.
2. The Expedition should not plan for more than 150nm of travel per day when trawling.
3. Guest crew expectations must be set very clearly in advance. We had several cases where individuals believed their roles would be more specialized vs. working across the team.
4. Expedition leadership must invest time up front to ensure that the boat leads (Skipper, 1st Mate), Science lead and any other groups (artists) work smoothly from the start.
5. An advance party that meets the boat in key ports significantly improves productivity and connectivity when the boat arrives. In Bermuda we had tremendous support that led to perhaps the most effective leg of the trip.
6. Communications protocols must be established across sub-teams. We saw several cases of well intentioned but redundant blogs, video, photos and even identities.
7. Crew that is not well suited to the larger team and mission should be removed early.
8. Analytical equipment protocols and designs need to be absolutely bulletproof. These represent important data sources but must be easy to operate and record by “average” crew.
Expedition Summary

We count this first “Ocean Discovery” phase of our work as a broad success. Our progress has been highlighted by:

1. First ever transect of the North Atlantic Gyre and “discovery” of the “Atlantic Garbage Patch”. This important confirmation has, in one step strongly globalized the threat of marine debris.

2. Confirmation of oceanic islands as a major accumulation point for marine debris. The beaches of the Canaries, Cape Verde Islands, Bermuda and Azores are dramatic examples. This has not only local implications, but may be key to “cleaning up the gyre” as these shorelines act as natural nets collecting debris.

3. Testing and validation of protocols for ongoing documentation of toxin accumulation in ocean fish. This will expand under the UN partnership.

4. After a difficult teething period, a successful operational test of the onboard CO₂ sensor. We can now enter into the next phase of collecting acidification data for formal research. Publication of this work will encourage other private vessels to carry such sensors.

5. Field testing of the vessel and overall working model. This has positioned us well for extended, and in some ways more difficult, work in late 2010 and 2011.

6. Development of sound communication methods with blogs, twitter and short format video

7. Strengthened external partnerships- in particular invitation to formally work with the UN Safe Planet Campaign (related to Stockholm, Basel and Rotterdam Conventions).

As we go forward Pangaea Explorations and 5 Gyres have over 24,000nm of sailing planned ahead. This includes remote Ascension and St. Helena Island, three south Atlantic Crossings and a long run across the South Pacific to Hawaii. Our principal objective will be first documentation of marine debris accumulation in these two subtropical gyres.
APPENDIX 1: S/V SEA DRAGON OPERATING SPECIFICATIONS

Ship Systems:
1. Port of Registry: Cayman Islands, British Overseas Territory (No. 742307)
2. UK MCA Commercial Rating Category Zero - Unlimited
3. LOA 22m (72'). Beam 5.5m (20'), Draft 3.4m (10')
4. Gross registered tonnage 57.24
5. Hull construction steel with five watertight compartments and collision bulkheads.
6. Cutter rig, North G2 asymmetric spinnaker, storm sails
7. Perkins M130C main diesel engine, Northern Lights 6kw auxiliary generator
8. Berthing: 10 single pipe berths, 2 double berths
9. Evolution flex shaft coupling, Flexo-Fold prop
10. 400watts solar and 400 watts of wind turbine renewable power coupled with over 1,500Ah main battery storage capacity
11. Spectra Farrallon 75gph water maker 10. 560 gallons Fuel, 450 gallons water capacity (4 tanks each)
12. MaxSea Time Zero navigation software on dedicated computer
13. Maxwell VW3500 main windlass with three anchors
14. B&G instruments, autopilot and Interphase forward-looking sonar
15. ICOM HF radio with Pactor modem Iridium base phone with XGate email and software, SPOT Trackers
16. Large deck sun-canopy for use at anchor or in port.

Safety Systems:
1. 4x6 capacity Zodiac Xtreem offshore SOLAS life rafts
2. 406MHz Emergency Position Indicating Radio Beacon
3. Crew-overboard systems (4)
4. Furuno commercial AIS
5. GMDSS HF and VHF DSC systems
6. Musto foul weather gear and exposure suits for full crew complement
7. Deck work harness and tethers for all crew
8. UK MCA Offshore Medical kit and ongoing medical support via UK based medical professionals (MSOS)
9. DAN oxygen delivery system with 3000+ liters capacity

Expedition Support:
1. Avon 3.1meter and 4.65meter inflatable boats with 9.9hp and 30hp outboards
2. Bauer Dive Mate diesel air compressor to support SCUBA diving
3. Panasonic Tough book 52 laptop, salon video and audio support
4. 110VAC, 24 and 12V DC on board power
5. Hach MS5 water sensor with pH, Conductivity, temperature and turbidity sensor
6. Sunburst Systems flow through CO2 sensor with GPS logging
7. 30x Stereo dissecting microscope with camera port for Nikon D90
8. Twin spinnaker poles and powered main winch to support cargo lift and towing
needs
9. Dedicated freezer

APPENDIX 2: SUMMARY OF AREA SPECIFIC OBSERVATIONS

1. Transiting the English Channel, Bay of Biscay and Spanish coast we sailed through the main arteries of global trade. The living sea is now overshadowed by the mass of shipping traffic - we would sometimes have 15 or more targets on our AIS screen at once. Additional fishing boats scraped along the coast. Recent strikes by EU fishing fleets, including several harbor blockades, signal the constant spiral of over-hunting, quotas, subsidies and honest men trying to make a living.

2. Portugal where we witnessed first hand the difficult challenges of mass tourism along the country's southern coastline. The shore is crammed with development, the water is clear but seemingly sterile and the beaches are mechanically cleaned of any debris.

3. Agadir Morocco has so far done well in blending the deep history and heritage with the rapidly invading new world. However offshore fishing fleets, the arrival of plastic "everything", overgrazing by domestic stock and the growth in population present serious challenges ahead. We walked through the local fishing docks during an offload period. Bins of freshly taken sharks and other fish - all small – covered the dock. Fishermen talked openly about the greater effort in making a decent catch. Marine conservation awareness seems rare, but people are clearly cautious about development. From a sailing perspective we found the long arid coast much like Baja California. Khaki brown hills and distant mountains cut a coast of quiet desolation. Harbors are few, small and tricky to approach – we spent two hours anchored off El Mohammedia talking with the “port captain” as to whether we could enter with our draft – no dice. Casablanca appeared to have virtually no capacity for taking in sailing yachts – which cut out a night at the new “Rick’s Café.”

4. Lanzarote, Canary Islands. This volcanic outpost is exceptionally popular with European tourists seeking warm sun and clear waters. Tourism economy clearly visible, were also able to see how pressing environmental challenges are shaping the future. Significant amounts of marine plastic debris and, presumably, unseen chemicals make their way past these shores. Legacy over-fishing and human impacts have degraded the coastal waters making their beauty more like colorful but two-dimensional art. The water is clear blue from a distance; the hills are serene volcanic landscapes. But the sea is clearly breaking down. Look closely and the beaches become more plastic, the water surface holds the debris of Europe, and the large fish are gone. Most striking was the explosion of exotic sea urchins - harbingers of a damaged ecosystem’s uncertain future. These long-spine (Diadema) urchins are native to the Caribbean and apparently arrived in the Canaries more than 50 years ago. They have recently become a major problem, likely due to the collapse of
larger fish-stocks. During our stay, the ARC gathered here and on the other islands. We would meet up with these boats again in St. Lucia.

5. Schools of blue fin tuna, Atlantic common dolphin and a large beaked whale marked our entry to the Cape Verde islands. Smelling the wood smoke village fires at sea, stepping on to the ragged ferry dock and then wading into the vibrant masses of capital city Praia, we were now finally in Africa. The team split into two groups covering both Santiago and Santa Antao islands. Noted by Charles Darwin in the early 19th century for their ecological destruction, these islands have been in a long struggle to control environmental damage amidst development pressures. While our team could clearly see the marks of this battle in erosion, diminished forests and pollution. However, we were remarkably impressed with the resiliency and determination of the people to make the best of their inherited future. Ecotourism, diving and shore based enterprises were beginning to take hold. It will be interesting to watch these islands go forward. Sailing this southerly route also cuts almost 900 miles off our Atlantic crossing and better positions us to deal with late season Atlantic tropical storms. Closer to the equator we would have less trade wind air, but be able to duck under the ITCZ if systems developed.

6. After crossing the Atlantic in 12 days, dodging squalls, we were overwhelmed by our brief stay in Guyana. Seeing the depth rise to 50' some 50 miles offshore underscores the blended shape of this shoreline with the sea. The capital of Georgetown is, really, a town. With only 1 million residents in the entire country you feel as though you have, wonderfully, gone back to a simpler age. Mooring up against a thirty-year-old tug at the wooden customs dock I was in a Bogart film – Rick was in the shadows looking for a man. Later that night, the one they called the “fat man” guarded Sea Dragon against pirates that never came. We were officially the largest yacht to ever enter Georgetown. The city sits amidst a chocolate brown river, jungle shorelines and old colonial era wood buildings. We found, amidst the chaos of the streets, people who are aware and connected to the local environment. There is a national strategy to develop a low-carbon economy and protect the rainforest. A great example is the push to develop birding tourism by the Guyana Amazon Tropical Birding Society. One statistic says it all...over 850 bird species inhabit the inland forests. Several forest resorts up the nearby Essequibo River also appear to actively seek cruising yachts. For ocean sailors this is an intense coastline to approach. 200 miles out you get depth on the sounder after weeks of 14,000’ water. 10 miles out the bottom shoals up to 20’ where you must slot into the Georgetown approach channel. Milk chocolate water gives no sign of depth. There is no visible shoreline, and widely spaced markers. You have less than 6’ of water on either side of a lane just wide enough for two freighters. We had one crew manning our Interphase forward looking sonar and Maxsea plotter, two lookouts with binoculars on the bow, and another in the back keeping the charts close to the helm. This is the closest to instrument flying I ever want to be on a boat!
7. **Tobago** was the first real Caribbean stop. Here we observed first hand the condition and challenges facing this important coral reef region. Diving extensively and meeting with local conservation groups, we got a feel for the coral disease and bleaching and the repeated shortage of large reef fish. Many people and local organizations we spoke with clearly see it. Their frustration and sense of loss is deeply evident in their voices. Despite the oil wealth and international attention they have a tough road ahead. One example is the Buccoo Reef marine protected area. While good that it has been set aside, jet skis and human snorkel barges fill the lagoon and we could see little evidence of any organized management or interpretation.

8. **Barbados, Bequia and St. Lucia** along the route to the USVI provided more insights to the condition of coral and shoreline habitats. Traveling this area the team could also see first hand the powerful role that the Cruise Ship industry plays in the region. Every night watch involved monitoring the movement of these giant holiday ships. We were also able to approach within a few miles of Montserrat’s active volcano. Its summit was covered in a swirling mass of ash and steam pushing up against an overtopping thunderhead. Six hours later, off Nevis we had a fine ash fall on deck. It was good to feel the geologic life in the Caribbean.

9. While principally a holiday break and crew rest stop, our time in the USVI provided a very different perspective. St. Thomas and St. John are well developed, fully integrated into US environmental management, and heavily visited by tourists. In multiple discussions with local (cab drivers, tour operators, divers, tourists, and management staff at USVI National Park) there was near universal recognition that the health of the sea was important. Most would talk extensively about declines in fish populations, water clarity and reef conditions. However, the area is also clearly a leading example of progress. The National Park Service is strongly focused on managing these issues. All boats are either on fixed mooring lines or in carefully designated anchor zones. Fishing is controlled at all levels. There also appears to be significant effort to protect remaining coastal land- continued acquisition on St. John by the Trust for Public Land, The Nature Conservancy and others has been important. The USVI does however face major challenges. Their waste management practices focus on landfill disposal that is costly and imperfect. They have only recently been able to remove scrap vehicles for mainland recycling. Tires present another significant challenge.

10. **BERMUDA**

11. **AZORES**