

# Kon-Tiki2 Expedition 2015-2016

## Scientific Cruise Report

By Torgeir Higrav, Cecilie Mauritzen, Pedro de la Torre and Håkon Wium Lie  
February 1 2017

### *Balsa Rafts *Tupac Yupanqui* and *Rahiti Tane**

**Leg 1:** Peru – Easter Island November 7 – December 19 2015

**Leg 2:** Easter Island – 39°33'S 096°01'W January 6 – March 17 2016



## Executive Summary

The Kon-Tiki2 Expedition was partly an anthropogenic exploration and partly an interdisciplinary oceanic and atmospheric research expedition. As a research expedition it was unique for three reasons: 1) The type of vessel used, 2) the timing of the expedition, and 3) the geographical location. The scientific program was run onboard the ancient design balsa rafts, powered by solar power only, with almost no possibility of stopping the raft, during a year with the strongest El Niño recorded in human history, in the midst of the center of that El Niño, namely in the area between Peru, Easter Island and the Chilean mid-latitudinal coast.

The scientific expedition planned and organized as a cooperation between the NIVA and NTNU in Norway. It was divided in two legs: the transect from Peru to Easter island and from Easter Island until the expedition concluded with the organized evacuation of the rafts. Instruments were brought on board the rafts and procedures were specifically developed for this cruise to study 1) climate change and ocean acidification, 2) marine litter, 3) El Niño and operational weather forecasting and 4) marine life.

The rafts were built following the designs of archeological studies on an Ecuadorian maritime culture known as the Manteno. They were built in Peru, with help from volunteers from all over the world as well as from the national Peruvian Navy. Building efforts were delayed by logistic issues, but Leg 1 departed Callao on November 7<sup>th</sup> 2015 and reached the Easter Island as planned 6 weeks later, on December 19<sup>th</sup> 2015. After a change of crew and a full overhaul of the rafts and equipment in Easter Island, Leg 2 departed Easter Island January 6 and ended March 17 2016.

The crew was multinational, gender-mixed, synergetic and multidisciplinary experienced. Each raft on each leg had 7 members on board. Only four members were present during both legs. There was a one scientist on board on each leg representing either of the organizing institutions.

Both rafts were instrumented for research. Each had an electrical installation with capacity calculated according to the payload of instruments that would be operated from it. Wind was the main source of energy to transport the vessels while photovoltaic cells transformed solar into electric energy for the electronics onboard.

The sensor payloads can be classified into three categories: atmospheric, oceanographic and ecological. Optical sensors to measure light, together with physical sensors to measure atmospheric conditions were combined with crew observations to describe the meteorological situation in the raft. A combination of echosounders and cameras were used to describe the macrofauna biodiversity present around the rafts. DNA and Chlorophyll a filtering aimed to study the microdiversity. The physical parameters like temperature, salinity, pH, levels of carbon dioxide described the climatic conditions in the region where the cruise sailed. Finally, both conventional and state-of-the-art technology were used to observe macro and micro plastics in this remote area of the world oceans.

Currently, the material collected on the cruise is subject of analysis in different laboratories. Kon-Tiki2, due to its unique nature, has been the subject of interest to a wide range of audiences. In addition to the general scientific interest, the expedition has given a much louder voice to the oceans than any regular research expedition could have given. For instance, the expedition coincided with the Climate Summit in Paris in December 2015 (COP21), a coincidence that we utilized to its fullest. The outreach efforts of the expedition participants have raised awareness about the science as well as about the

expeditions sponsors. Most importantly, it has promoted cultural awareness across many state borders.

The Kon-Tiki2 Expedition combined science with adventure and challenge. Its organization was not simple, however, the outcome is of highest value, both from a professional scientific point of view, for the originator and sponsors of the expedition idea and for each and every project participant.

Kon-Tiki2 aimed to double-down on Thor Heyerdahl's Kon-Tiki voyage (1947) by sailing two rafts from South America to Polynesia and then back. No one has done this in modern history. Kon-Tiki2 was an unparalleled voyage of survival, science and exploration.

Although one of the strongest El Niño ever recorded stopped us from sailing all the way to South America, Kon-Tiki2 substantiates the ancient Pacific pathway for both Polynesians and South Americans. We know both cultures had rafts. Polynesians probably used their superior double hulled canoe for exploration and rafts for migrations. Kon-tiki2 showed how Polynesians could have sailed to South America and back, and how South Americans could have done the same in the opposite direction.

# Acknowledgements

This report is prepared by Torgeir Higræff (who led the Tangaroa expedition in 2006, who originated the idea of the Kon-Tiki2 Expedition and planned, realized, led and sailed the expedition), Cecilie Mauritzen (Kon-Tiki2 Expedition scientific leader, Chief Scientist, Leg 1), Pedro de la Torre (Chief Scientist, Leg 2) and Håkon Wium Lie (Chief Technology Officer, Leg 1). Contact information is available at end of report. Scientific data is available upon request at the Norwegian Institute for Water Research. All photo credits of this report go to the Kon-Tiki2 Expedition.

The expedition would never have been possible without the generous, expert and volunteer help from the long list of people and institutions towards which **we would like to express our sincere thanks:**

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# 1 Raft design

The raft design is based on archaeological studies and historical sources. The Manteño were an Ecuadorian maritime culture that began around AD 800, and ended in AD 1526, when the Spanish Conquistadores arrived. The Manteño were a "league of merchants," using balsa wood raft to become a rich trading society. The Spaniards made drawings and written descriptions of the rafts and their sailing capabilities. The Kon-Tiki2 rafts were based on these designs.

Along the coast that was controlled by the Chíncha people (1300 - 1500) archaeologists have found hundreds of wooden boards in graves. Typically, these are 150-200cm long boards made from hardwood. In the past 100 years, archaeologist and collectors have put them on display in numerous museums and one is displayed in the Metropolitan Museum of Art where they are labeled as ceremonial of funerary staffs, or wooden sculptures, and visited by millions. In fact, these are centerboards used to steer rafts, called "guaras" by the conquistadors. These guara boards, i.e. centerboards, were built based on those found in the desert of Peru, basically from two cultures: the maritime Sicán culture on the northern Peruvian coast, conquered by the Chimú kingdom around AD 1375 (which, in turn, was conquered by the Inca by AD 1470) and the Chíncha culture on the southern Peruvian coast (conquered by the Inca by AD 1480).

The original 1947 Kon-Tiki raft was equipped with four such centerboards. However, they were fixed to the raft: Apparently, Heyerdahl had not seen sketches of people moving these guara boards up and down. He mentions that if he had known how to steer the raft with centerboards, he would never have smashed into the reef off the island of Raroia. But the whole point of this clever invention is to raise or lower the boards depending upon the winds and currents. When the wind is constant, the direction and course of the vessel can be changed if you move the boards to a higher or lower level.

The guaras on the 2006 Tangaroa Expedition were installed and used based on observations Heyerdahl made after completing the Kon-Tiki expedition: In 1953, he carried out an experiment together with Emilio Estrada in Ecuador with a small raft, using the guaras to understand how this mechanism worked.

Both rafts represented the cultures mentioned above. The rafts were named after the Inca Tupaq Yupanqui, with the logo of Thor Heyerdahl Institute on its sail, and after the Polynesian legend Rahiti Tane, with the AirexBaltekBanova logo on its sail (see front page photo).

An arrangement of 11 logs tied parallel next to each other provided floatation to the raft. Ten logs perpendicular to these and distributed evenly from the aft to the bow worked as structural elements to hold the floating elements together. The 15m tall mast and 90 square meter big sail was placed in the central fore part of the vessel. Spanish seamen noted (in the 1520s) that the rafts "carried sails like that of our own ships, and of equal quality". We know the Spaniard had both triangular sails and square sails, depending on the type of voyage. Squared sails were installed on the Kon-tiki2 rafts for two reasons: the first one was insufficient knowledge on the Peruvian raft rig, and the second is that skippers Ola Borgfjord and Signe Meling took part in the rigging. They knew well how to work on Norwegian Viking rigs and thus this type of sailing and rigging were used at sea. The rafts also had a bamboo hut that functioned as home for the crew and for storage and laboratory.

## 1.1 Building the rafts

The building should have been started in the end of September 2015, but due the delays of Peruvian custom, the actual building process started fully in the beginning of October 2015. It shortened the building time to a minimum and less. Instead of planned full six weeks the building team had approximately three and a half weeks to build both rafts. Working days started early in the morning and finished in the night every day.

The rafts were built in SIMA military shipyard in Callao, Lima, Peru. The building team and crew had enormous help from SIMA's workers, who were helpful and friendly thru the building process in SIMA. Builders had a small office changing room in SIMA and in the shipyard a container for equipment and supplies. The raft builders stayed nights at the Escuela Naval Del Peru in La Punta. The SIMA shipyard was in Callao, Lima, 5.6 km away. The building team was transported to SIMA and back with taxis and private buses. Refer to Figure 1 for an overview of the geographical location and installation of the building and deployment sites.

The second part of building was made after the rafts were launched, at the end of October, in the dock of Escuela Naval Del Peru. Because the builders and crew lived as well in the Escuela Naval Del Peru no transportation to work was needed. At Escuela Naval Del Peru the personnel of the school were very helpful and friendly. Without them the project would not have stayed on the desirable timetable.

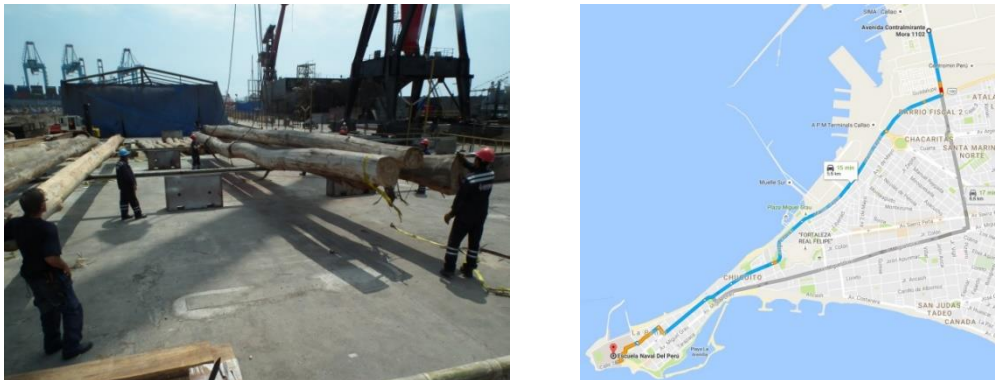


Figure 1 On the left, builders put logs together to build the rafts. On the right, a map shows the location of the accommodation of our team, at Escuela Naval, and the place where the rafts where built in La Punta, at the south end.

The building team had no major accidents during the construction. There was ongoing stomach disease circling on the group, which was probably caused by poor hygienic treatment of fruits and vegetables at the SIMA Shipyard.

The actual building process began when tools, part of the lumber and bamboos where bought and transported to SIMA. Also some ropes where handled to the shipyard. The logs for masts where also transported to SIMA shipyard. Only the longitudinal balsa logs where missing. They were held at Peruvian customs. The building process is scripted with respect of used time by numbers below:

1. The first task was to make yards for sails from bamboo. The four bamboos were tied together with tar handled rope. Modification, planning and making of masts started at the same time, few days before the longitudinal balsa logs arrived. The total construction of masts took

approximately two weeks. At the same time making of guara boards started. The total time required to make more than 20 guara boards was four weeks.

2. When the longitudinal balsa logs arrived, they were placed with the aid of SIMA's shipyard cranes 1.5 m above ground on railroad steel bars. The bars were placed above big cement pillars as shown in Figure 1. Balsa logs were modified to fit as tight as possible side by side. Work was done mainly by chainsaws and with the help of cranes. When fitting was roughly done, lines for the bandage ropes were measured, drawn and cut. The notches were made with hand circular saw, chisel and wood club. Fitting and notching continued until all the logs were tied together.
3. Refer to Figure 2. The bamboo structured decks for balsa rafts planned after there were clear image of the whole raft (placement of hut, mast, etc.). Each part of the deck was measured individually and made in specific manner which suited to the purpose. At the beginning some testing were made and after couple of days the suitable building manner for bamboo decks was figured out. The building was made with hand saw, machete, club, chisel and knife also with help of some newly developed tools to help the building. Bamboo decks were tied with sisal rope. The process continued until the rafts sailed on the journey to Eastern Island. Some decks were made on the sea, during the journey, because of the tight schedule on land.



Figure 2 The floor of the deck was made of bamboo logs tied next to each other (left). Skilled knot tiers and a hard-working building team assembled both the deck and the cabin with the same material.

4. At this time also rope work started fully. There was a huge demand of spliced ropes. Hundreds of different types of spliced rope were needed. The splicing was done in small groups and more people were instructed to do the work during the process. The biggest and strongest ropes were needed to tie the longitudinal and vertical balsa logs together. With ropes was also custom problems but it was avoided by buying ropes from local markets and shops. The ordered ropes arrived few weeks late to the shipyard.

When two longitudinal logs were fit the upper, vertical logs were placed, fitted and notched ready for roping. Also the vertical logs were compensated and leveled from the upper surface. This was done because decks should be at the same level, when placed over the log lines. Also it was made because the guara board and especially cabin floor mounting needed flat levels. The leveling was made roughly with a special chainsaw, club and chisel technique. At this period of time the rafts logs were cut to final size from fore, stern, port, starboard. On the fore also the fore angle of attack was made with chainsaw at estimation of 45 degrees. The heads of balsa logs on fore and stern were painted with tar and pitch.

5. The rope work for sail, mast and rig started. Also necessary timbles and all parts of sail work were made on the spot. This work continued to the end of construction process and some work were also made on sea-journey. At this time many other different tasks started. It was possible because many new volunteers arrived. The longitudinal and vertical balsa logs were tied together by spliced ropes. Here the SIMA workers helped a lot on tying the logs together with ropes. Work was done in two shifts.

The major woodwork for cabin (walls and roof) started. The spine of the cabin was made from natural wood. A hole was drilled to the upper balsa logs and the wood bars were fit to the hole. The cabin walls were strengthened by wood rods, which were tied to the main wood bars. The spine of the cabin roof was made from bamboo. The cabins were almost ready during the launching, but lot of work was done in Escuela Naval Del Peru's dock.



Figure 3 On the left, Gunvor reinforces the sail of Tupac Yupanqui. Builders on the right test the guara setup on the deck of a raft.

6. Just a week before launching the building team started to tie up the sails. Also the Thor Heyerdahl institute logo was painted in Escuela Naval Del Peru's sports hall. After this the masts were ready and they were lifted to the rafts with help of the crane. The equipment for wind speed and direction measurement were mounted to the top of the masts. The yard and sail were attached together and then attached to the mast with suitable ropes and lines.
7. The cabin floors were made from straight wood blanks. The 10 guara boards were mounted to raft as follows: Between vertical balsa log a wooden blank is mounted and attached with wooden large nails. In the blank is a hole, where the guara board can be placed. Another support for the guara is between longitudinal balsa logs made from two wooden blanks which also are attached to logs with large wooden nails.

On the deck started during this time mounting and preparing the safety fence to the outer sides of balsa rafts. Guardrail was done from wood bars (total height of approximately 1.80 m) and safety line (sisal rope). Also to Tupac Yupanqui was made and mounted mechanical winch as a backup for the electrical assembled winch. Ongoing operation was to modify ready/unready bamboo decks because of diverse reasons (shroud, mast, rails, cabin, etc.)

8. At the end of October on SIMA Shipyard was held rafts launching ceremony. The rafts were moved to the Pacific and after the ceremony towed to Escuela Naval Del Peru's Dock. The final building and modification was mainly made there. The moving was done by SIMA's cranes and towing was done by tugboat.

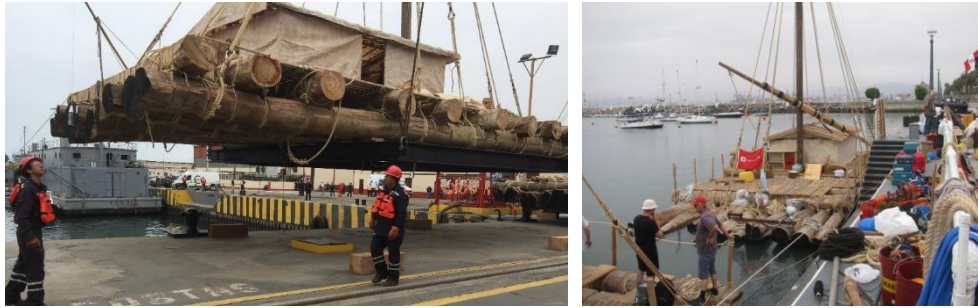


Figure 4 Launch of rafts at SIMA shipyard. The rafts are being lifted from the dock (left) into the sea (right).

9. The last tasks were made in Escuela Naval Del Perú's dock. All the major work was already done in SIMA shipyard, but still numerous targets need modification, adding and finishing. One of the main tasks were electronics and electrics (solar panels, circuitry, batteries, measurement devices, computers, etc.). Also more bamboo decks had to be made and modified. The attaching structures for scientific and communication devices also had to be made and partly change. The sail ropework was also finished on this dock. On the dock was noticed a termite problem, which was rapidly increasing and jeopardizing the bamboo and wood structures. The problem was solved quickly and effectively with sea water and insecticide.
10. The final part in building process was to move all the equipment, crew supplies, food and water to the rafts before leaving to Eastern Island. What could not be done in Escuela Naval Del Perú's dock, due the extreme short timetable, was done during the sea journey.

## 1.2 Electrical system

The electrical system consisted of solar panels, solar charge controllers, a fuse panel, and 12V battery banks. Rahiti Tane had two systems, each comprising of four 145W solar panels and three 12V 100Ah batteries. Tupaq had one. Electrical energy was drawn from the battery banks through 220V inverters, 12V connections and 5V USB chargers. The fuse panel protected the electrical devices connected and provided ON/OFF switches to save electrical power. Refer to Figure 5

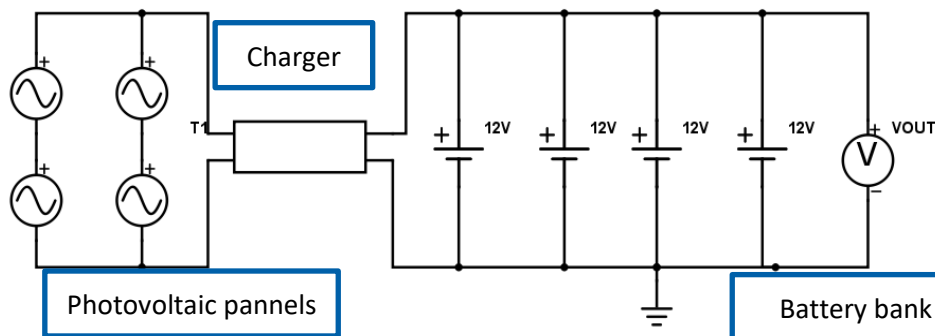


Figure 5 Electrical schematic of the power generation system installed on Tupac Yupanqui.

For backup purposes, each raft had a gasoline-powered generator. Additionally, a mobile solar panel with USB outlets for charging communication devices was present. The solar panels that charged controllers and batteries worked well throughout the journey and the backup systems were never



used. However, due to a more overcast than expected sky, power had to be preserved and units turned off when not in use. We experienced some problems with short circuits, probably due to salt water and humidity.

Rahiti Tane had two energy systems, each comprising of 4 solar panels, one solar controller and three 12V batteries. Tupac Yupanqui had one such system due to being equipped with less scientific instrumentation. There were four 145 Watt, 19 volt solar panels organized in two pairs. Each pair was wired in series, so that they delivered around 38 Volt at peak. If one solar panel was damaged during the trip, the solar panels could be reconfigured to deliver 57V. The solar charge controller charged the 12V batteries in a safe way. Wiring was done with MC4 connectors, which are waterproof and easy to reconfigure. The 12V batteries were wired in parallel.



Figure 6 Solar panels were mounted on both rafts and provided the vessels with electrical energy. The solar charge controller, fuse panel and a voltmeter protected the electrical installation.



Figure 7 Raft Rahiti Tane (left) doubled Tupac Yupanqui's (right) power generation and storage with 8 solar panels installed and 8 batteries storing energy.



Figure 8 The 12V battery bank on Tupac, consisting of four 12V batteries is shown on the left; the white box is the inverter for the three-stage sampler and the most energy-demanding device on board. The rafts had a payload composed of electronic equipment for navigation and communication, shown on the right. The science/electronic desk on Tupac. On the table, a stack of PCs can be seen, including a

Panasonic Toughbook (which was used with the Kongsberg equipment) and a Lenovo Thinkpad (which connected to the internet). On the wall is the Iridium Pilot control box, the handheld Jotron VHF radio, the power supply for the Toughbook, the Iridium GO, various inverters and USB outlets, a silver WiFi router, the Iridium GO (over the silver box), and controllers for the Kongsberg sonars.

### 1.3 Communication and navigation

Communication was vital to ensure the safety and well-being of the expedition. State-of-the-art satellite communication equipment was installed on both rafts, and VHF radio allowed voice communication between the two rafts.

Both vessels were equipped with Iridium GO transceivers, which connected onboard smartphones and tablets to the internet through the Iridium satellite network. All crew members could read and write emails at no per-message charge.

Each GO sent a message with the current position to the expedition web server every 30 minutes. The position was plotted on a map on the web site so that everyone could follow our progress. Several radio stations called the expedition on a regular basis, and we were also in phone contact with Chilean authorities during the voyage. The GO was lightweight and USB-powered, with a built-in battery so that in an emergency, it could be easily detach from the raft.

The GO units enabled the crew members to send and receive text messages on a regular basis to the expedition email accounts. `science.Kon-Tiki2@myiridium.net` was the designated address for divulgation of research on board. Pictures could be transmitted through Iridium GO although the bandwidth was very limited. As a rule of thumb, pictures up to 100kB were possible to transmit. The system was overall stable and only seldom down.

In addition to the GO units, Rahiti Tane had the Isatphone 2 backup phone which uses the Inmarsat satellites. Tupac had an Iridium Pilot, which supports higher data speeds and was used to upload web pages, high-quality images and video snippets.



Figure 9 The Iridium Pilot antenna was installed on Tupac Yupanqui for faster satellite internet access

VHF radio transceivers were used for voice communication between the expedition vessels. It had a range of about 20km and the crews could talk to each other regularly for most part of the trip. These radios were critical to communicate with the Armada vessels that towed the rafts out of port and the rescue aircraft and ship that helped in the evacuation process.

Each raft had two automatic identification systems (AIS) on board (Kongsberg and Jotron). During leg 2, none of them were successful in providing constant, reliable positioning information due to hardware damage. The Jotron units provided GPS position, course over ground (COG) and indicated

the position of the other vessel. The position transmitting function of the AIS on both rafts failed, due to lack of proper connectors between the antenna and the processing unit. The cables on both rafts were damaged by the mast motion.

## 2 Cruise track

The Kon-Tiki2-expedition was divided into two legs. The first one began at Callao, Peru, where both rafts were built. The rafts sailed from this port city to the Easter Island in 42 days, from November 7th 2015 to December 19th, 2015.



Figure 10 The crew members of the first leg about to set sail from Callao, Peru

An interval of two weeks in between expeditions allowed for end of year celebrations, shipping samples to different laboratories and preparations for the next expedition part. The second leg departed from the Easter Island. Both rafts were towed away from the island by a Chilean Armada's towboat and then they set sail on January 06th, 2016. After 72 days in the sea, without having reached the continent and after having sailed a distance that in total was more than 4000nm, the expedition was called to an end.

The expedition concluded with the organized evacuation of the rafts. Several factors were discussed to come to an agreement among the expedition crew members. These included the expected time of arrival of the rafts to South America, water and food stocks and the rafts' structural integrity among others. The decision of calling for help was made by consensus. The expedition leader T. Higruff had been in contact with the Chilean navy every day during the return voyage, as agreed during a meeting in Valparaiso in October 2015, a month before the voyage from Peru. On March 14th the expedition leader called the Armada for rescue.

The distance to the nearest armada ship was several hundred nm. The nearest vessel available was the Japanese freighter Hokuetsu Ushaka, on its way to southern Chile. This ship was asked to assist. On March 17th, both crews climbed a 17m rope ladder onto the big ship. During this operation, Lisa's foot



was injured (the only major injury throughout the cruise), and she was treated immediately by expedition doctor Sergey Goltsov, and later, in Chile, doctors found no fractures in her leg.

On March 19th, 2016 both crews moved into the Chilean Armada's offshore patrol vessel *Piloto Pardo*. The expedition members landed safe and in good health condition on the port of Talcahuano, Chile on March 21st, 2016. Figure 11 show the route sailed by the Kon-Tiki2 expedition.

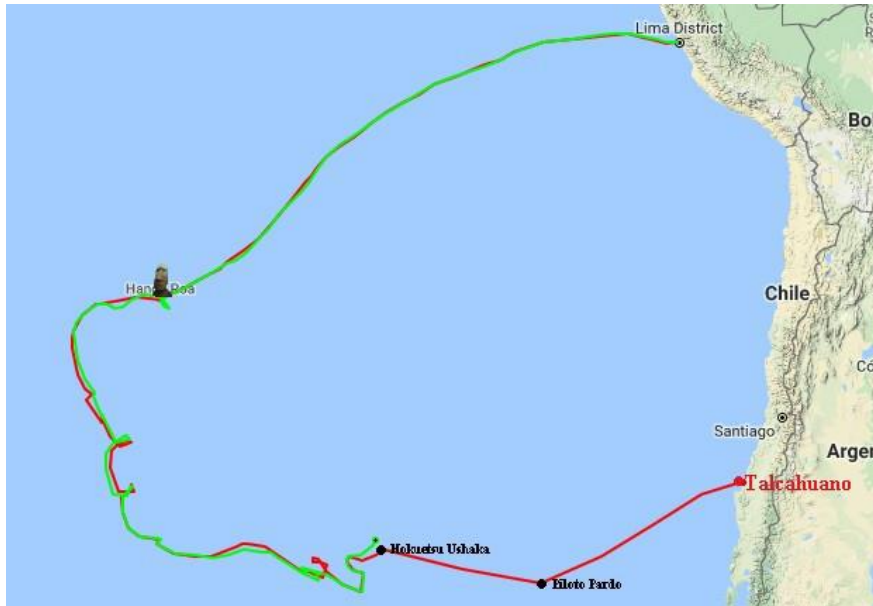


Figure 11 The Kon-Tiki2 expedition route. Leg 1, from Callao, Peru on November 6th 2015 to Easter Island, Chile on December 18th 2015. Leg 2, from Easter Island on January 6th 2016 to 39°33'S 096°01'W on March 17th 2017. The green track corresponds to Rahiti Tane while the red one to Tupac Yupanqui.



Figure 12 Captain Borgfjord and crew Erik Clasen fix a wall on challenging sea conditions. This state was prevalent during the last month of the expedition.



Figure 13 On the right, the crew of MS Hokuetsu Ushaka assists in the evacuation process of the Kon-Tiki2 rafts. On the left, expedition leader Torgeir Higravf climbs the ladder to the safe deck of the rescue vessel.

## 3 Life on board

Although the main scope of this document is to report the scientific activities of the expedition, this section describes some of the daily life aspects relevant and related to performing such activities. They are mentioned because they affected in a great extent the way the expedition was performed. Some other factors that affected the program was weather and raft integrity state.

### 3.1 Safety and watches

The watch system depended on the raft and the weather conditions. Rahiti Tane ran a 4 hour on, 8 hours off watch system on both legs. A similar scheme was implemented on Tupac Yupanqui, except that the watching couple had the option to choose if they divide the 4hours period into two hours each.

Safety procedures were observed always. Regulations varied depending on the raft. On Rahiti Tane, the use of life vests and life lines was compulsory when on watch or for everybody on rough weather conditions. Lines were to be attached to the vessel when swimming by the raft if sailing speeds could compromise the safety of the crew. Safety harnesses were used on both rafts when climbing the masts for maintenance. An extended 50m long line with a floating beacon at the end (on Rahiti Tane) and a floating buoy (on Tupac Yupanqui) were towed by the aft of the vessel always. This line was retrieved only for fishing purposes and the crew were notified every time.

### 3.2 Food, sleep and leisure

Skilled cooks on Rahiti Tane posted their weekly menus on the web site, and the content was also copied to Facebook. Eager readers therefore learnt about the Pacific delicacies prepared on the raft. For example, on Monday the 17<sup>th</sup> of November 2014, dinner on Rahiti Tane was quinoa with red pesto and mango salsa. The next day, falafel with pan fried bread and orange salad was served.

The somewhat more relaxed attitude towards food preparation and preserving on Tupaq resulted in all peanuts being consumed during the first two weeks. On December 11<sup>th</sup>, 2014, the crew sent a

request for help from onshore chefs; what could they make from the only remaining ingredients: peas, onions, garlic powder, wheat flour, ketchup, and boxes of tomato. No tasteful answers were found.



Figure 14 Kari making Ceviche from an unexpected barracuda (*Sphyraena* spp) catch by Esteban onboard Rahiti Tane.

## 4 Sailing with "guara boards". Case studies from the expedition

As noted above, the guara boards were the secret to the sailing successes of the old Chincha culture, and the key element in this expedition's plan to sail westward from Easter Island to South America.

Based on the 2006 Tangaroa expedition (Higraff, 2010) and the experiences from this expedition it can be reasonably assumed that if one of the boards in the aft is raised 20 centimeters, the course can change 20 degrees towards the wind. If we did the same with one board in front of the mast, the raft went 20 degrees from the wind. By lifting them up and down, we learned how to steer the raft the way ancient men did.



Figure 15 Signe sailing with the guaras. She and Gunvor mastered this skill and could outsail anyone else.

Kon-Tiki2 also shows that the force is just as important below water as above. High sails need a representative keel area to be effective. Vessel speed is another major component. If it is doubled, the effect of the keel increases by a factor of four. If you have more speed you can raise the keels on the raft, which again gives you higher speed because of less friction, and then the remaining keel

area is even more effective (optimized in the modern “trimaran-design”). The following case from the raft Rahiti Tane enlighten the description aforementioned.

## **Case study A: daily sailing, high up towards the wind**

This is how raft Rahiti Tane sailed the first four weeks: with winds from southeast, and sailing southwest, as far up in the wind as possible. To sail this far up into the wind requires very active guara maneuvering. In general, guaras down in front, up in back, as far up as possible without getting the wind behind the sail. When the wind is about to go behind the sail, the helmsman must quickly lower the quaras in the back. The raft typically responds quickly to such a maneuver, and only very seldom is it necessary to work with the guaras in the front. Due to the constantly changing combination of winds, waves and ocean currents, the helmsman must constantly watch the sail, and keep the guaras in back as high up as the sail at any given time permits.

Main lessons learned, Case Study A:

- 1) We can't sail closer than 100 degrees from the wind, 90 degrees is not possible, no matter how we position guaras and sails.
- 2) when guaras are down in front they may easily break if the wood is not strong enough, due to the enormous forces from the combination of waves and current). A solution, utilized by Rahiti Tane, was to lift the front guaras half way up.

## **Case study B: daily sailing, semi-downwind**

This is the most relaxed form of guara sailing. No quick changes are necessary, and it is perfectly possible to bring the compass to the front deck and join the social activities there. One can even steer by the front guaras exclusively. The most common error is to fall off so much from the wind that the wind hits the sail from the back. In that case a quick guara response is required. But to fall so far off requires long-term lack of concentration on behalf of the helmsman.

## **Case study C: large change of course with sail up**

**Rahiti Tane, leg 1, December 6th, 2015, ~100° clockwise turn**

At the start: wind from east, raft headed southwest (200 deg), currents NA (probably westward), sail tied down on portside, elongated far back on starboard side.

Our plan is to perform a jibe (“kuvending”), i.e. turn to the opposite direction by falling AWAY from the wind, i.e. towards starboard, i.e. clockwise.

- Step 1: all guaras down in back (to lock down this part of the raft), all guaras up in front (to release this part of the raft to follow the wind. Within minutes, the raft points westward (270 deg), the wind directly from behind.
- Step 2: fixed the sail to be symmetric across raft. Still wind from behind.
- Step 3: took down guaras in front as well AND tightened the sail to starboard. Now raft was sailing northwest. Wind still in from the east.

### **Rahiti Tane Leg 1, December 13th 2015, ~80° clockwise turn**

At the start, wind from east, raft heading southwest 235 deg

- Step 1: All guaras down in back, up in front. Nothing happens. Direction still 240.
- Step 2: switch sail ("hals") from port to symmetric. Now raft stabilizes at 270 deg, i.e. straight downwind.
- Step 3: lower guaras in front half way. Stabilizes at 310-320 degrees
- Step 4: attach sail ("hals") on starboard side: we keep sailing on new course 320 degrees.

Main lessons learned, Case Study C: We have a 160 deg sailing range, given any wind direction. From plus 100 degrees to minus 100 degrees, relative to the wind.

### **Case study D: 360 turn with sail down**

#### **Rahiti Tane, leg 1, Saturday December 12th, clockwise turn**

At the start (15.45 UTC): Wind from east, sailing towards southwest. Estimated the direction of the current to be roughly east-west (specifically 60-80 deg). Method: released limes, pieces of wood and paper, plus compass. Our plan is to perform a 360 turn, clockwise, starting with raft pointing southwards. The trial took 1 hour.

- Step 1: lower the two guaras on port side front and aft (rest up). Raft turns to south. (NOTE: this is one of the few times we have noticed a left/right asymmetry)
- Step 2: lower all guaras aft, all up in front. Raft turns to west (270, 280 deg)
- Step 3: lower guaras starboard side both front and aft (rest up). Expected raft to turn to north, managed only 340 deg.
- Step 4: To push further to north, we lifted the starboard-most aft guara. Now raft stabilized in north.
- Step 5: Lower all guaras in front, lift all in aft. Raft stabilizes in direction 030 after 3 minutes, i.e. just a little bit eastward. but then falling back to north
- Step 6: lift all guaras in front, lower all guaras in back. Now we reach 070, i.e. almost eastward.
- Step 7: lift one guara portside aft. Then raft turns to 150, "almost" south.

#### **Rahiti Tane, leg 1, Saturday, December 12th: Anticlockwise turn**

At start: wind from east (less strength than clockwise attempt), raft points southwards

- Step 1: lower guaras on starboard side, both front and aft. No movement, stabilizes at 180 deg
- Step 2: lift guaras front starboard. Raft stabilizes at 175 deg
- Step 3: lower aft guara starboard side. It works, it stabilizes at 130. But not straight up to the wind.
- Step 4: try drifting anchor in addition to help the turn. Works, stabilizes at 75 deg. But can't manage to get it further northward

- Step 5: last attempt to pass through the wind (from east) and move the raft towards north: lift guaras on port side both front and aft. Not even this works.

In summary, weak winds, or small guaras are not enough to maneuver. The largest range of possibilities is obtained when combining guaras with all the adjustment possibilities of the sail and using the drifting anchor actively.

## 5 Scientific investigations

### 5.1 Scientific program in short

The Scientific Program of the Kon-Tiki 2 expedition was developed as a collaborative work between the Norwegian University of Science and Technology (NTNU) and the Norwegian Institute for Water Research (NIVA), and it focused on four research themes:

#### 1: Climate change and ocean acidification

Oceans play an important role in global climate dynamics. Oceans have absorbed more than 90% of the heat that has accumulated in the atmosphere due to global warming. About a quarter of all the carbon dioxide (CO<sub>2</sub>) emitted from the burning of fossil fuels has been absorbed by oceans, making the oceans an efficient buffer of global warming. When the algae are done with their "carbon capture and storage" – absorbing CO<sub>2</sub> to create oxygen, then dying and being buried at the sea floor – the remaining CO<sub>2</sub> turn into its evil alter ego: ocean acidification. In addition, oxygen content in the oceans is dropping. All these changes pose risks for marine life and may affect the oceans' ability to perform the wide range of functions that are vitally important for environmental and human health.

#### 2: Marine litter: Plastic and microplastic litter

The expedition was to cross one of the five gigantic garbage accumulation zones of the world oceans (so-called "gyres"). High and low-tech instrumentation was brought along to identify and quantify macro and micro plastics. Micro plastics are regulated by UNEPs Stockholm convention, a global treaty to protect human health and the environment from persistent organic pollutants (POPs), and information from remote regions is highly valuable.

#### 3: El Niño and operational weather forecasting

In the equatorial Pacific, the ocean and atmosphere are strongly coupled. There is strong feedback between changes in the atmosphere and the ocean. The "normal" state can last for several years, but during an El Niño year, like the one the expedition sailed, the surface ocean in the eastern Pacific becomes significantly warmer and the winds, surface currents and precipitation patterns also change. The marine ecosystem responds strongly: collapse of the coastal fishery along the Peruvian and Chilean coasts was probably the first, ancient, indicator of this strong climate signal. To read more on El Niño, check this interesting article on Wikipedia: [https://en.wikipedia.org/wiki/El\\_Ni%C3%B1o](https://en.wikipedia.org/wiki/El_Ni%C3%B1o).

The expedition depended on high-quality weather forecasts, so we transmitted data directly to the World Weather Watch, the core program of the World Meteorological Organization, from our own weather station every three hours. Weather forecasting centers around the world depend on meteorological observations from voluntary ships to make good forecasts, and considering how few ships sail in the southeast Pacific we felt certain we could make a difference.

#### 4: Marine Life

The marine ecosystem is under tremendous threat due to the many changes happening to the marine environment: marine litter, toxic chemicals, ocean warming, ocean acidification, ocean de-oxygenation to name a few. This multitude of stressors is having a major impact on marine habitat all around the world and the Kon-Tiki2 expedition carried instrumentation to monitor the entire ecosystem, from the smallest phytoplankton to the grandest of sea animals. Standard procedures were adapted were necessary to facilitate the use of the instrument or the collection of the sample on a non-conventional research vessel.

## 5.2 Logistics

A special area of the cabin on each raft was dedicated to the scientific activities. Some of the instruments, literature and the scientific computer were located here. A Panasonic Toughbook provided by NIVA concentrated data from different instruments on board. The LabVIEW Data Center (LDC) software was designed at NIVA to concentrate the readings from multiple instruments and store them systematically in the computer's storage drive. The following sections describe the scientific equipment used on the expedition to make observations or take samples *in-situ*.

The rafts instruments can broadly be grouped into three categories: those that observed the physical characteristics of the atmosphere, those that monitored the physical state of the seawater and those that were used to sample biological activity. A combination of transducers and recorders were taken on board with the objective of better describe objectively the conditions present on the place where the rafts sailed.

## 5.3 Atmospheric observations

Among this set of instruments, optical sensors were used to measure the amount of sunlight reaching the surface, of atmospheric aerosols limiting the energy from reaching the surface and the conditions of the prevailing winds around the raft, i.e., wind temperature, strength and direction.

### **Atmospheric aerosol optical depth (AOD)**

A Microtops II sun photometer was taken on board to measure marine atmospheric aerosol size distribution. It has five collimators that measure aerosol optical depth (AOD) in five wavelengths spread across the light spectrum [1]. Measurements with the Microtops were taken only on cloud free days. Each measurement consisted of 10 consecutive samples within 90 seconds. The data collected was regularly downloaded into a computer. The comma separated values files were small in size, less than 100kb, and therefore it was possible to transmit them through the Iridium GO modem.



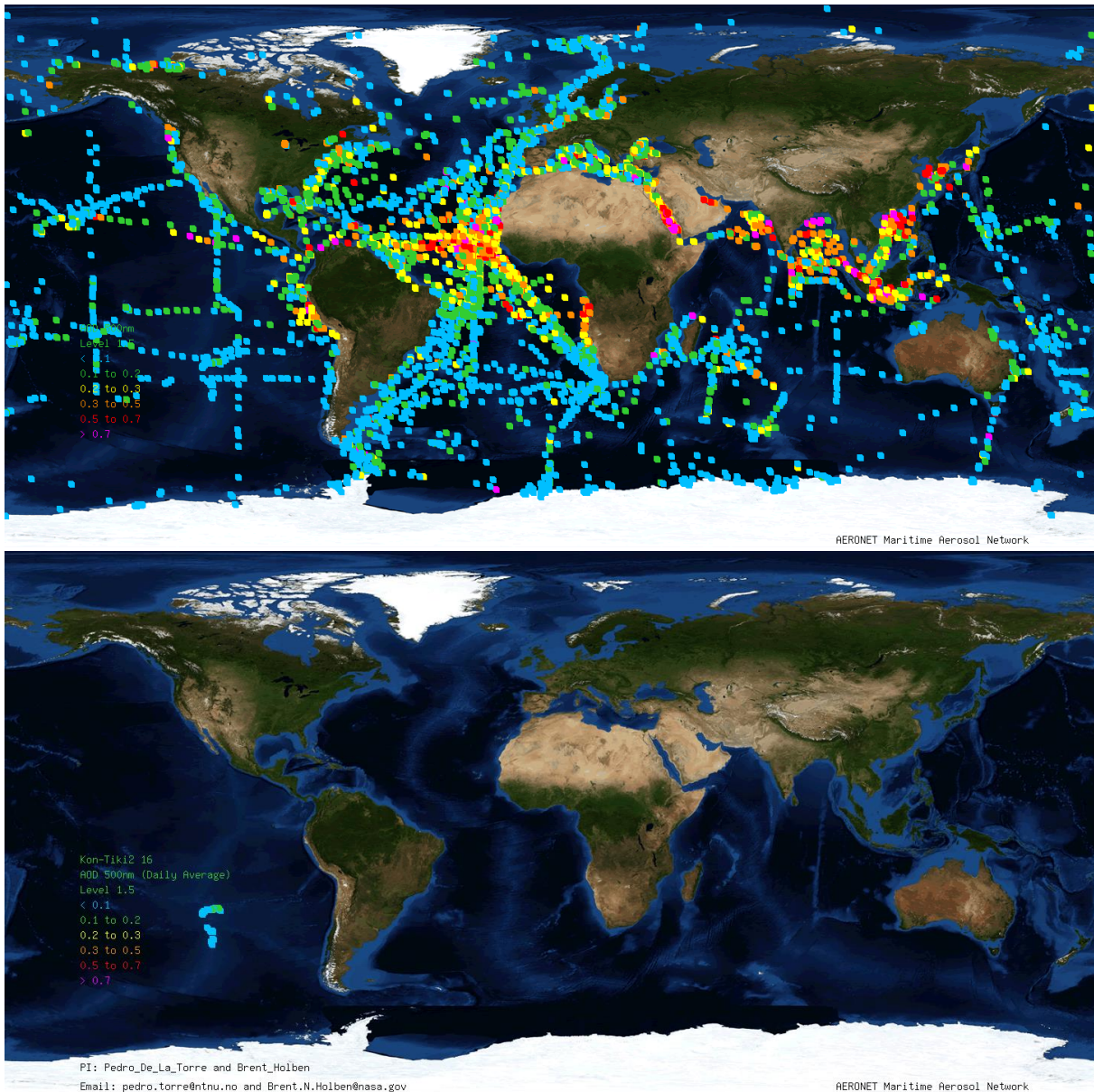


Figure 16 Aerosol optical depth, size and distribution were monitored on the expedition. The map on the top shows how scarce measurements on the southeast Pacific are. The bottom map filters the contribution of the expedition to the knowledge of aerosol distribution and demonstrates a low content aerosol in the open sea that is slightly higher by the Easter Island, where there is anthropogenic activity.

## Light measurements

There were two LiCOR units on Rahiti Tane. They measured light density reaching the Earth’s surface. One recorded automatically from the rooftop. Caution was taken to avoid the sail and rigging from shading that sensor. The other was used manually in connection with the 6-hour meteorological observations.



## Weather reports

The expedition depended on high quality weather forecasts. With the assistance of the Norwegian Meteorological Institute and JCOMMOPS at IOC data was transmitted directly to the World Weather Watch, the core program of the World Meteorological Organization, from Rahiti Tane's weather station every six hours. Its call sign was LF5983.

Observations were transmitted through the Iridium modem to the World Weather Watch. They were registered using a combination of instruments and bare eye observations. These include information on the conditions of the sky and the ocean. Date, time and GPS coordinates were read directly from the Jotron navigation unit. Air temperature and humidity values came from an environmental thermometer installed on the rooftop at the aft of the cabin, as shown in Figure 17. Atmospheric pressure and trend readings came from a barometer installed inside. The sea state was observed and compared to reference pictures while sea water temperature was measured from a CTD. The percentage of the sky covered by clouds, as well as their types, were estimated from direct observations. Levels of precipitation were included in the report on a regular basis.

The software used to gather data was Turbowin. This produced a string of digits with the data encoded in it. This string was then sent to the WMO.



Figure 17 Weather station components are shown on the left. The equipment was provided by Aslaug Mariolijn van Nes from the Norwegian Meteorological Institute. The weather station installed on Rahiti Tane was used to report meteorological information every six hours.

## 5.4 Physical properties of the sea surface

NIVA has developed a system for automatic collection, analysis and presentation of water quality data from “ships of opportunity” called the Ferrybox System. This system is in place, for instance, on the ferries running from Oslo to Kiel, on the mailships running from Bergen to Kirkenes and on regular ship passages from Tromsø to Longyearbyen. Once every minute, the Ferrybox system measures temperature, salinity, oxygen, chlorophyll and particle content at a depth of four meters along the fixed route of a vessel and transmits the data to shore using the environmental satellite ENVISAT. Emanuele Roberto Reggiani (NIVA) installed the Ferrybox System on Rahiti Tane in Callao. These measurements include salinity, temperature, chlorophyll A levels, turbidity, pCO<sub>2</sub>, pH and oxygen. In addition, we observed the surface ocean current condition, using an acoustic current meter attached to the Rahiti Tane as well as autonomous surface drifters.

## CTD

A SAIV CTD was installed permanently on the bow port side of Rahiti Tane. A wooden housing was built around the instrument to protect it from impact and it hung from a 3m long rope. The depth of the instrument varied with the speed of the vessel between 1m at the maximum speed of the vessel and 3m when the vessel was stopped. This instrument logged data with a regular interval. During the leg 2 the CTD stopped transmitting data, the reason being low battery power. External power fixed temporarily the issue, but we linked the instrument to the raft's electric grid.



Figure 18 Cecilie demonstrates the wooden frame built to protect the surface CTD that was permanently deployed under the Rahiti Tane raft.

## Carbon Dioxide

An in-situ partial carbon dioxide pressure sensor (Franatech pCO<sub>2</sub>) was towed on the aft of Rahiti Tane. The sensor was submerged between 2 to 3m under the raft in order to avoid turbulence caused by the wake of the vessel. Through a cable, the sensor transmitted measurements to the manufacturer's data logger. This sensor required a warm up time of approximately 5 minutes before it was ready to take measurements. The instrument stopped working during the second leg of the expedition and, although the exact reason is unknown, it could be attributed to mechanical damage due to constant impact with the raft's aft or a broken wire.

## pH

There were two instruments on Rahiti Tane to measure the pH of the water: Pharo (pH analyzer for oceanography) and a SeaFET Ocean pH Sensor (Satlantic). The former was an instrument in development stage that measures total pH based on the optical absorbance measurement from a sample of water reacting with a suitable indicator. Pharo is based on the Automated Flow-through Embedded Spectrophotometry (AFtES) layout developed by NIVA within EU projects like NexOS and supported by Skattefunn as a possible industrial product. The system is fully automated and has an internal memory, but it also transmitted data to the LDC. The part of the LDC software that stored pH data for this sensor was completed on the raft while leg 2 was ongoing, giving the chance to scientists on board to verify the status of the instrument.

Both Pharo and the SeaFET sensors were connected to the seawater flow pipeline installed on the raft. Water pumping was activated regularly to enable measurements of pH where the raft was located. The SeaFET, however, could not transmit successfully any data into the LDV. When Pharo was brought back to NIVA laboratories in Oslo, it was in power down mode. When the instrument was switched on again it was able to communicate and perform sampling regularly. Data have been retrieved and provide the absorbance spectra of surface Pacific water for the whole cruise. Data quality analysis in order to achieve a pH evaluation down to 0.005 uncertainty is ongoing. The cruise, despite the many difficulties,

has confirmed the possibility to use such system for a reliable, unmanned, extensive remote monitoring of ocean surface pH using low power sources.

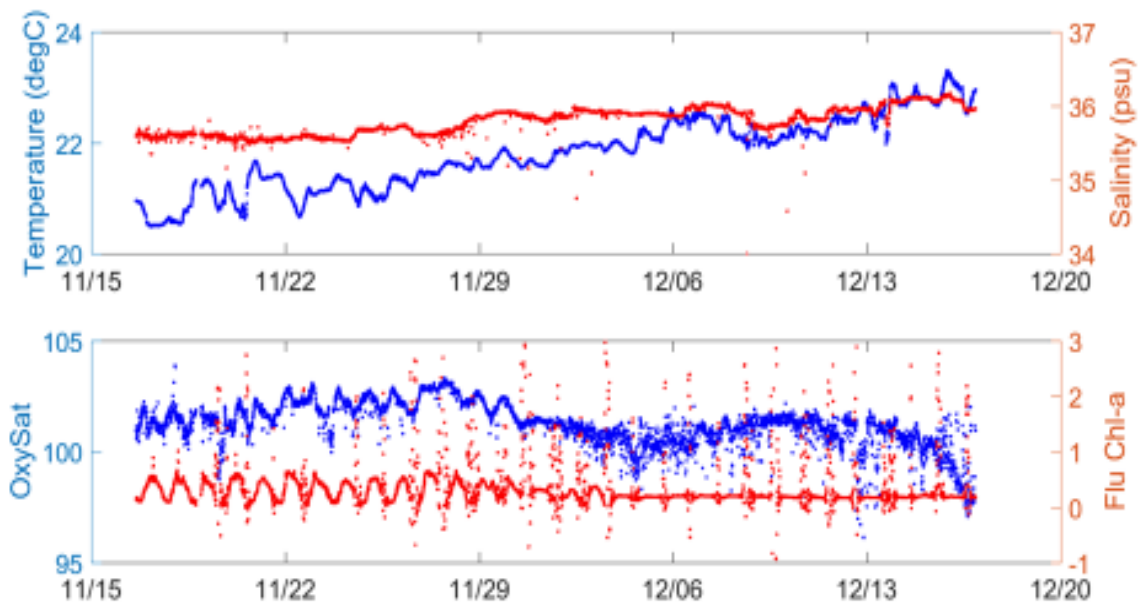


Figure 19 Preliminary results from the leg1 Ferrybox data, by Kai Sørensen (NIVA)

## Surface currents

Seawater current speed and direction were measured with a Nortek Aquadopp current meter. The acoustic transducer was mounted on the aft port side of the raft Rahiti Tane. It was connected to a Nortek Autonomous Online System (AOS) that transferred regularly a data subset through its own Iridium satellite channel. Based at Nortek's offices in Oslo, Jardar Maatje, provided technical support to operate the instrument.



Figure 20 Nortek Aquadopp instrument mounted on Rahiti Tane to measure seawater current strength and direction. It was installed inside a bamboo for protection.

## Surface drifters

We deployed 16 surface drifters from the Global Drifter Program **in pairs** (see locations in appendix). Historical data collected by the drifter program, provided a fairly good idea of the mean surface currents before we left port (see below), though we were uncertain what El Niño would do to the system. The previous strongest El Niño occurred in 1997/1998 before the start of the drifter program.

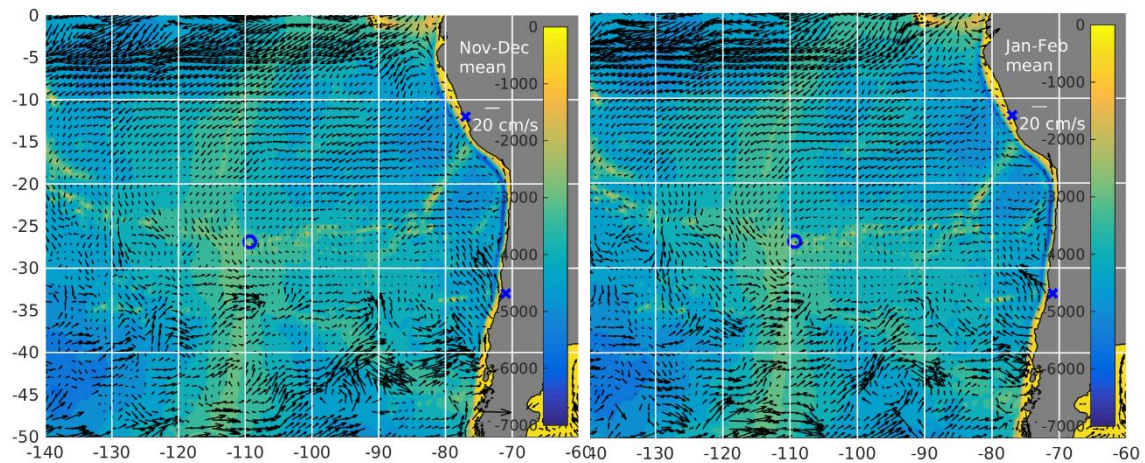


Figure 21 Mean surface current for November and December (left, relevant for Leg 1) and January and February, (right, relevant for Leg 2). Easter Island is indicated with the blue circle. Courtesy of the Global Drifter Program and Pål Erik Isachsen.



Figure 22 The surface drifters were stored under the walking deck until deployment. Kari is ready for deployment on the picture of the right.

## 5.5 Biological sampling from the surface

### Water transparency and color

Measurements of water transparency in the Pacific Ocean were performed using a Secchi disc and a pallet with the Forel-Ule scale for water color. The disk was deployed when the raft sailed at very low speeds, i.e., under 0.5 knots. Otherwise, the drift of the disc with respect to the raft made it very difficult to observe the disc at the depths that were possible to attain, usually over 30m. A stone was attached under the disc to sink it as much as possible right under the vessel. Always two crew members helped in the determination of the depth at which the disc was not seen anymore. This depth was recorded as the Secchi depth. Then the disc was pulled up to half the Secchi depth and the Forel-Ule scale was obtained against the disc using the colors palette.





Figure 23 On the left, Gunvor sets up the Forel-Ule Scala plate. On the right, the Secchi disc is deployed to quantify ocean transparency.

### Chlorophyll A and DNA sampling

Water samples (phytoplankton) were collected and filtered on to polycarbonate filters and stored in ethanol along the way on both legs of the expedition for the purpose of DNA extraction and barcoding. Those samples collected in the first leg were shipped from the Easter Island to NIVA, Chile before the second part of the expedition sailed. They were transported from the freezer at the raft, to the island and further to the continent on a polystyrene box with 10kg dry ice. DNA was filtered out of the water using GFF filters. A constant amount of water was forced through these filters and aided by a vacuum. A similar procedure was followed to sample Chlorophyll A. Volumes of filtered water were adjusted to obtain a visible sample on the filter, i.e., a green stain. Chlorophyll A samples were fixed in alcohol. Both types were preserved in the freezer at -17C. At the end of Leg 1, the freezer content was transported to shore on Easter Island and flown to Chile mainland, then to NIVA Oslo on dry ice. On Leg 2 the freezer stopped working when it was immersed in water during a storm event. The samples were refrigerated once they reached the continent and transported to NIVA, Oslo afterwards.



Figure 24 On the left, Cecilie filters Chlorophyll A and DNA from sea water on the first leg of the expedition. Pedro De La Torre on the right continued this procedure and a sample with Chlorophyll A is shown in the middle.

### Surface plankton filtering

Plankton was filtered from the water using a plankton net with a 10 $\mu$ m mesh. An average speed of 2kn was desired to ease the deployment of the net. The time of the trawl and how long the net was deployed for were adjusted to target higher concentrations and plankton biodiversity in the sample. Iodine was used to fix the collected material. Details on the trawl characteristics were logged.



Figure 25 Pedro deploys the plankton net from the aft of Rahiti Tane to sample the upper 5m of the water column.

## 5.6 Acoustic studies of fish and plankton

Two echosounders were installed on the port aft of Tupac Yupanqui. They were Kongsberg EK80 systems for 70 and 200kHz. This is a broadband system. Operation of this equipment happened only after the second half of leg 2 as none of the crew members on the raft transporting the instrument were trained to operate it. Frank Reier Knudsen provided assistance in setting up the echosounders to optimize data gathering. Broad band processing produces larger amounts of data, in comparison with single frequency processing. Storage capacity became one limiting factor to use this instrument. This challenge was overcome by testing with different sampling rates and processing depths along the course. Another factor that prevented the continuous operation of the echosounders was power on the rafts batteries. Even after a sunny day of battery charge, the acoustic instrument will display a low voltage alarm during the night and stopped operating early in the morning. Voltages were under approximately 11V at these times.

Diel Vertical Migrations were observed through the cruise, as shown in Figure 26 The diel vertical migration of plankton from a layer located at 400m ascends to 200m. Data was collected with two Kongsberg EK80 echosounders.. Biological activity moved in a vertical range exceeding 200m. The dataset contains wide band acoustic fingerprints for species in the Pacific Ocean. Considering that wide band technology in the field of marine biology research is relatively new, these fingerprints provide the basis for a modern library for acoustic identification of species. Although the procedure does not include ground proofing, the material gathered provides a reference point of the state of the ocean during the cruise.

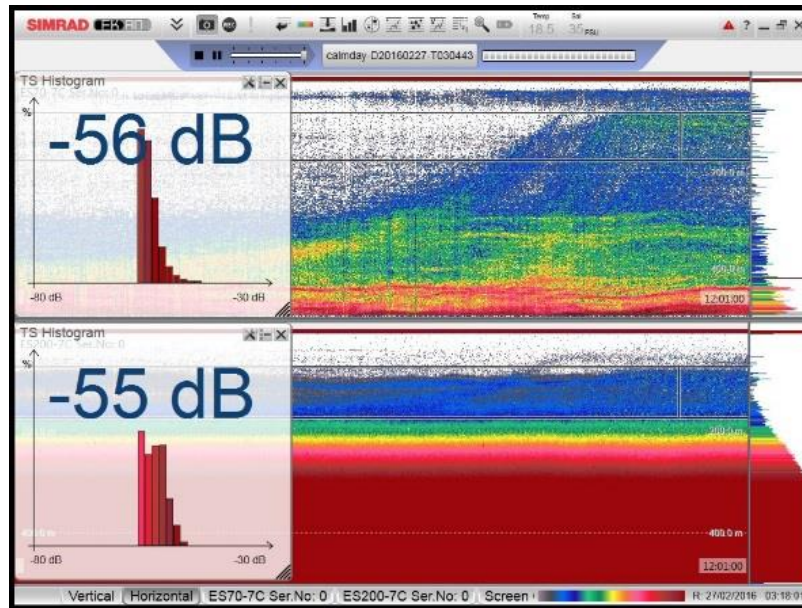


Figure 26 The diel vertical migration of plankton from a layer located at 400m ascends to 200m. Data was collected with two Kongsberg EK80 echosounders.

## 5.7 Marine litter

Bert van Bavel (NIVA, Oslo) provided Kon-Tiki2 with a Manta trawl and a three stage sampler (TSS). Both were transported as part of Tupac Yupanqui's scientific equipment. Sampling happened in both legs. The 300  $\mu\text{m}$  net was thrown from the aft of the raft and towed for 1 hour in every deployment. Andrey Chesnokov and Jimmy Blom at the end of leg two observed the samples and separated with tweezers what they considered was plastic. The sample was then stored. Deploying the trawl became more and more difficult as damage to the raft's deck occurred and as algae grew on the deck rendering the area slippery and unsafe.

The Three-Stage sampler had, as the name suggests, filters of three different sizes: 500  $\mu\text{m}$ , 300  $\mu\text{m}$  and 50-100  $\mu\text{m}$ . It takes in a large volume sea water: 10 000 L/hour. Sampling with the Three-Stage sampler was a very demanding activity. The equipment was heavy and voluminous. Transporting it from the box inside the cabin, where it was stored, to the aft for deployment required the assistance of at least two crew members. Usually, E. Clasen and T. Higrav would perform this task. The sampler consumed a large amount of energy from the batteries. Electrical energy availability limited in a large extent the use of the sampler during leg2. However, when the sampling was successful, the filters contents were stored together with their metadata for post processing.



Figure 27 The Manta Trawl (left) and the three-stage sampler were installed on Tupac Yupanqui to collect micro plastic samples throughout the cruise. In the right, Håkon assembles the filtering water pump for the sampler.

## 5.8 Marine contaminants

A passive sampler was used to study the type and concentration of contaminants in the sea. Ian Allan (NIVA, Oslo) was the point of contact regarding this equipment. An aluminum frame and a collection of low density polyethylene (LDPE) and silicon sheets were available on the raft. During the second leg, the frame was modified to include both LDPE and silicon elements to be deployed in a single exercise. Special care was taken to avoid contact between strips and raft at any point, to minimize the interaction with the wind and to assemble the sampler when no fumes were present (see Figure 28). Metadata and blank samples were put together and stored in the freezer. Samples collected during leg 1 were successfully transported to NIVA Chile at Easter Island and then to Oslo.

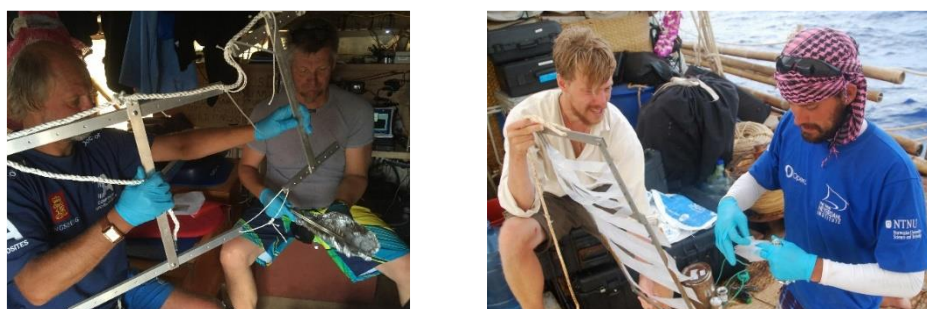


Figure 28 Deployment of passive sampler.

## 5.9 Equipment that was not used during the expedition

For the first leg, all instrumentation arrived safely, though this required two weeks of constant attention to the customs and shipping agencies at Lima Airport. The last piece of equipment, the three-stage sampler, arrived the evening before departure.

An attempt was made to bring additional scientific instrumentation onboard for the second leg. However, transport logistics, local government customs and regulations, the remoteness of the island in terms of transport and communication, and departure dates that overlapped with Christmas and New Year's celebrations, complicated the arrival of this equipment on time. Among the equipment that did not arrive were an underwater hyperspectral imaging camera (UHI, Ecotone), a Wetlabs ecotriplet sensor, spare parts for the Kongsberg AIS units and navigation maps, tools and parts to fix



the electrical installation on the rafts. A Kongsberg underwater surveillance camera was taken on board Tupac Yupanqui. Nevertheless, lack of an appropriate monitor and connecting cable made it impossible to display what the camera could have observed. It was, therefore, never used.

## 5.10 Data

The scientific data are stored at NIVA and are available upon request. The AOD data are stored and publicly available at the Marine Aerosol Network (MAN, [https://aeronet.gsfc.nasa.gov/new\\_web/cruises\\_new/Kon-Tiki2\\_16.html](https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Kon-Tiki2_16.html)), administered by the National Aeronautics and Space Administration (NASA). Likewise, the surface drifter data are available at NOAA's Global Drifter Program Data Assembly Center: <http://www.aoml.noaa.gov/phod/dac/dacdata.php>.

## 5.11 Publication plans

The Kon-Tiki 2 research program was made on a volunteer basis, with many scientists and institutions providing instruments and expertise. In order to maximize the scientific output, Table 1 has been made to identify interesting interdisciplinary cross-institution and inter-scientist topics that can be pursued, namely distribution and circulation of plastic during the El Niño 2015/2016 (see orange field in Table 1); Carbon and aerosol loading in the Southeast Pacific (blue field); and Life in the Southeast Pacific during El Niño 2015/2016 (green field).

	Met	drifters	currents	plastic	passive	Ferry box	pH	Aerosols	DNA and plankton	chlorophyll a	echosounder	Sechi disk	Light
Met obs (T, P, humidity)	Aslaug												
Surface drifters		Shaun											
Surface currents			Morten										
Plastics & Microplastic				Bert									
Passive contaminant sampling					Ian								
Ferrybox (T, CO2, S, P, O2, turbidity)						Kai							
Ferrybox pH							Emanuel						
Aerosols								Alexander					
Phytoplankton									Wenche				
Chlorofyll										Marit			
Echosounder											Frank		
Sechi disk, camera												Pedro	
Light													Kai

Table 1. Interdisciplinary publication plans.

## 5.12 Kon-Tiki2 scientific presentations to date

The expedition has been of interest to general and scientific audiences. The following is a list of Kon-Tiki2 scientific presentations to date:

### **Pedro De La Torre:**

1. The crew of OPV Piloto Pardo, March 2016.
2. Welcome presentation to the employees and students at the Trondheim Biological Station, March 2016.
3. The crew of R/V Gunnerus on May during the Integrated Autonomous Operations cruise 2nd May 2016.
4. The Plenary session of NTNU Oceans Week 2016, Thursday May 12th 2016.
5. The Department of Marine Technology (IMT) Miniseminar on Friday, May 27th 2016.
6. The crew of R/V Helmer Hanssen during the CAGE expedition on June 20th 2016.
7. European Union Hi Resolution Ocean Color meeting, Monday, September 19th 2016.
8. The Department of Biology (IBI), NTNU, “Forsker Lunsj” on Friday, October 21st 2016.
9. A presentation is planned for March 21<sup>st</sup> at Dokkhuset, Trondheim as part of the “NTNU Kveld” program.

### **Cecilie Mauritzen:**

1. Universitetet i Oslo, seksjon for meteorologi og oseanografi, Oslo, januar 2016
2. NIVAs instituttsamling, Sundvollen, februar 2016
3. NORMAN conference on marine contaminants, Oslo, mars 2016
4. CIENS, Oslo, mars 2016
5. Majorstuen Rotary, Oslo, mars 2016
6. The Plenary session of NTNU Oceans Week 2016, Thursday May 12th 2016.
7. United Nations Environmental Assembly - Side Event on Marine Litter, Nairobi, mai 2016
8. Norsk Bremuseums 25-års jubileum, Fjærland, juni 2016
9. Norway’s MIT Club, Oslo, juni 2016
10. Universitetet i Oslo, institutt for geofag, juni 2016
11. Utenriksdepartementet, klima og miljøseksjonen, Sundvollen, September 2016
12. Norges Rederiforbund, Oslo, September 2016
13. Thor Heyerdahl International Day, Oslo, oktober 2016

### **Bert van Bavel:**

1. Hold Norge Rents konferanse om marin forøpling, Oslo, 2. februar 2016
2. Norske Havforskeres Forenings Årsmøte, Bergen, november 2016

## 6 Contact Information

### 6.1 Expedition contact information

	Leg	Name	Role	e-mail	telephone
Tupac Yupanqui	<b>1</b>	<b>Øyvin Lauten</b>	Captain	o-lauten@online.no	
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## 6.2 Science program contact information

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## 7 Appendices

### 7.1 Abbreviations list

AOD - Aerosol Optical Depth LDC - LabVIEW Data Center LDPE - low density polyethylene

COG - Course over ground

CTD – conductivity, temperature and depth.

GPS – Global Positioning System

MAN - Marine Aerosol Network

NASA - National Aeronautics and Space Administration

NIVA - The Norwegian Institute for water research

NTNU - The Norwegian University of Science and Technology

OPV - Offshore Patrol Vessel

RV, R/V - Research vessel

TSS - three stage sampler

UN - The United Nations

WMO - World Meteorological Organization

## 7.2 Cecilie Mauritzen's log for leg 1

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Sea Surface Temperature	Sea Surface Salinity	CTD Pressure	CTD Oxygen	Flu	Turb	CO <sub>2</sub> (fish sensor)	Lys (Licor)	Notes
7112015	21:28													turn on CO2
10112015	19:15													CO2 franatech deployed behind vessel, measuring ~365
11112015	12:00													full reboot of ferrybox ctd. Wiring problem; Pharo up and running
12112015	13:00	11	29	80	38									Drifter deployment 1 & 2. Forgot to write down ID numbers.
14112015	23:00	11	44	82	53									Deployed first passive sampler, with chain as anchor. Some rust, but Ian says ok. Strips had to be folded when attached so we probably made some mistake in assembly. Deployed front, starboard. (in retrospect: possibly too close to crew's "spa site")
15112015	20:00													Took off main fuse for battery pack A (supplying ferrybox system) in attempt ot stop the regular fuse breakdown at sunset.
15112015	21:30													Lowered surface CTD 30 cm
16112015	02:35	11	52	84	0,3									Drifter deployment 3 & 4. ID numbers 139563 and 139799
16112015														Rewired battery packs A and B

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Sea Surface Temperature	Sea Surface Salinity	CTD Pressure	CTD Oxygen	Flu	Turb	CO <sub>2</sub> (fish sensor)	Lys (Licor)	Notes
16112015														Discovered that turbowin downn't save data locally so started to religiously note down met data. Luckily conditions have been fairly steady: winds from south, southeast, sat ~21, wetbulb ~17, air pres~1013
18112015	14:42	12	11,4	86	1,6	20,8	35,5	0,26	101,07	0,09	0,02	315		Samles taken: chrol and DNA (used 1,15 l each), CO2, Tur, Oxy, phytoplankton, salinity
19112015														Tried the plankton net, messed up, no samples
20112015	00:00	12	41,66	87	28,5									Drifter deployment 5 and 6 (from Tupac). ID numbers 139895 & 139619
20112015	12:24	12	55	87	50	20,81	35,6		101,73	0,21	0,02			Plankton net in at 13.10. Took plankton net and plankton, with 1,5 ml iodine; Filtered chlor and DNA with 1,1 l each.
22112015	14:00	13	40	89	48	20,7	35,6			0,21	0,02			Filtered Chlor, 1,1 l
	22:00													Discovered that aquadrop current meter had broken off. Brought on deck in lieu of new solution
23112015	14:00													Passive sampler up. Looked miserable
	16:00	14	1	90	40									Passive sampler deployed. In front, middle to port side to avoid shampoo from crew members.



Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Sea Surface Temperature	Sea Surface Salinity	CTD Pressure	CTD Oxygen	Flu	Turb	CO <sub>2</sub> (fish sensor)	Lys (Licor)	Notes
	17:00													Current meter deployed, this time only with rope
24112015	05:00	14	7,4	91	45									Drifters 7 & 8 deployed. ID numbers 139562 & 139617
	16:00													Took debubbler off the pump system. It got broken because I took off hose to get water for filtering. The glue doesn't work. Hopefully not too much bubbles in pump system.
25112015	12:55	14	27	92	7									Plankton net deployed, brought in at 13.33 UTC
	13:35					21	35,7	0,69	102,06	0,16	6,05			Took chlor & dna (1,1 l); CO <sub>2</sub> , turb, ox, chlor
	14:22	14	28	92	5	20,99	35,7	0,82	101,95	0,19	0,03			End of water sampling 1 today
	18:20	14	32	92	12	21,2	35,7	0,81	101,2	0,08	3,45			Filtering no 2: Chor & dna. End 18:45 UTC
	22:00	14	34	92	20									Aeronet, 8-10 hits
	23:00	14	35	92	22	21,37	35,7	0,46	102,68	0,16	0,02		24	Filtering no 3, just chlorophyll. Partly clear sky during the day, so satellites should be able to see something.
27112015	13:20	15	26	93	56	21,47	35,6	1,19	102,08	0,3	0,02		30	Chlor and DNA, 1,1 liter each
28112015	15:15	16	11	95	4									Surface drifters deployed. ID numbers 139565 & 139564
	22:30													Aquadrop current meter on deck; it was hanging by a rope
	23:20	16	20	95	25									CO <sub>2</sub> water sample

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Sea Surface Temperature	Sea Surface Salinity	CTD Pressure	CTD Oxygen	Flu	Turb	CO <sub>2</sub> (fish sensor)	Lys (Licor)	Notes
29112015	14:30	16	53	95	59	21,71	35,9	0,6	101,95	0,29	0,02		95	Chl and DNA filtered, 1,1 liter for each. DNA fell down on floor by mistake
30112015	13:14	17	19	96	46	21,56	35,9	0,6	101,2	0,22	0,02		65	Plankton net out at 13:14 UTC. CTD values read at 13:30 . Chl & DNA (1,1 liter each). Water samples: OX, CO2, Turb, plankton, plankton net. Done at 14:26. Light 38 @ 12UTC; 65 @ 14:30
1122015	15:30													Cleaned CTD, tightened rope 20 cm; Tried CO2 sensor with new inverter, worked for a few hours, then started blinking; Mounted aquadrop current meter for the fourth time, this time inside a bamboo.
1122015														2 drifters deployed on Tupac
2122015	14:45	18	35	98	45	21,94	35,9	0,59	101,06	0,12	4,98		52	Chl (1,1 Liter); DNA (1 liter), CO2, Turb; done qt 15:10 UTC
3122015	13:30	19	15	99	21									Passive sampler turnaround. Only silicone strips came back, no LDPE. Used blanks (handled like the others but not deployed). Redeployed with rig (strip-attachment) only on one side
5122015	12:55	20	13	100	1									Plankton net out
	13:25													Plankton net back in

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Sea Surface Temperature	Sea Surface Salinity	CTD Pressure	CTD Oxygen	Flu	Turb	CO <sub>2</sub> (fish sensor)	Lys (Licor)	Notes
	13:55	20	13	100	3	22,03	35,9	0,52	100,39	0,18	0,19	350	322	Clor & DNA (1,1,liter each), plankton & plankton net. With Pål's inverter we have reached a steady state where CO2 is monitored continuously during the day, and the n the fish-box blinks all night
	15:50	20	13	100	6									Aeronet measurements (more than ten)
6122015														Guara-board-sailing-testing
7122015	13:06	21	17	101	2	22,27	36	0,65	100,73	0,18	0,02	357		Plankton net out
	13:36													Plankton net back up
	14:28	21	18	101	3	22,19	36	0,67	101,79	0,17	0,02	356	90	DONE with: Chlor&DNA; ox, co2, turb, plankton sample, plankton net
9122015	13:45	22	39	102	23	22,01	35,7	0,35	101,38	0,17	0,02	387	250	Chlor & DNA, 1,1 liter each. Done at 14:15 UTC. Light measured 650 at that point.
10122015	19:10	23	41	103	18	22,1	35,8	0,52	101,76	0,15	0,02			Passive sampler turnaround. Done at 20:00 UTC
11122015	13:40	24	14	103	51	22,19	35,9	0,35	100,88	0,16	0,08	430	50	Filtering chlor & DNA. Done at 14:10 UTC
12122015														Guara-testing
13122015	13:33													Plankton net out
	14:00	25	8	105	4	22,45	36	0,8	100,88	0,17	0,02	447	510	Plankton net back in
	15:15					22,61	36,1	0,57	101,89	0,15	12,48	428	1400	All done: Chlor&DNA (1,1 liter each), plankton net, planktpn sample, ox, co2, turb, salt

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Sea Surface Temperature	Sea Surface Salinity	CTD Pressure	CTD Oxygen	Flu	Turb	CO <sub>2</sub> (fish sensor)	Lys (Licor)	Notes
	18:20	25	11	105	12									Aeronet sampling. All done at 18:30 UTC. Guara board testing
16122015	13:05	25	59	106	54	22,57	36	0,9	97,64	0,52	8,37		122	Chl & DNA, 1,1 liter each
	17:13	26	4	107	3	22,63	36	0,72	98,67	0,17	12,48	415	21	Chl, 1,1 liter
	21:00					22,9	35,9	0,87	98,34	0,18	0,11	419	1900	Chl, 1,1 liter
	21:10	26	9,18	107	11,3									7-10 aeronet samples
17122015	00:50	26	12,6	107	18,4									Chl, 1,1 liter
	14:00	26	27	107	47									Passive sampler on board, samples frozen
	16:00	26	28,12	107	50,9									7-10 aeronet samples
18122015	22:30	26	53	108	59							409		Turning off CO2 fishsensor
	22:45													Turning off pharo and seafet
	23:00													Turning off CTD
	23:15													Turning off ferrybox computer
19122015														Arrival Easter Island

### 7.3 Pedro De La Torre's log for leg 2.

Entry no.	DATE	TIME	latitude	longitude	CO2	alkalinity
	YYMMDD	UTC	S	W		pH
1	160104	2123	27°08.304'	109°26.078'	700.2	
2	160107	2106	27°15.163'			
3		1954	27°15.163'		947	
4	160108	1600	27°15.163'	109°17.372'		
5		1716	2716.10698	10918.26037	550.3	
6		2217	2720.23071	10919.8026	553	
7	160109	0746	2725.148	10913.44309	542	
8		1346	2724.47768	10911.37238	457.2	
9		1553	27°24.76'	109°11.01'		
10		1846	2726.4803	10910.48021	488.7	
11	160110	1319	27°34.289'	108°57.75'		
12	160110	1401	27°34.234'	108°57.794'	511	
13	160115	1648	27°38.15'	112°09.83'		
14	160116	0245				
15		1751	27°26.57'	112°38.02'		
16	160117	1000			411	
17	160118	1228	27°31'	113°49'		
18		1422				
19		1430				
20	160119	1440			479.1	
21	160120	0000			477.6	
22		1100	28°36.62'	114°47.33'		
23		1813	28°54.57'	114°54.94'		
24	160121	1510			481.4	
25		2050			427	
26	160122	1136	29°56'	114°43'		
27		1345	30°05.01'	114°42.87'		
28		1942			521.1	
29	160123				421.7	
30	160124	2347			465.3	
31	160125	1553	32°12.34'	113°29.38'		
32	160126	1600				8.01

Entry no.	water temperature	oxygen	turbidity	Salinity	Pressure	Fluorescence	LI189	LI1000	air temperature	humidity	Atmospheric pressure	Secchi depth	Forel Uje
	°C			PSU	dbar		umol	umol	°C	%	mbar	m	
1	23.68	104.04	0.25	36.05	3.51	0.01	1894.7		25.7	86	1016		
2	24.266	99.22	0.1	36	3.32	0							
3													
4							1523	1260					
5	24.61	100.22	0.16	36.04	3.26	0	2038	1188					
6	24.562	98.71	0.17	36.02	3.31	0	381.5	386					
7	24.977	98.21	0.11	36.04	3.44	0							
8	25.075	98.29	0.11	36.06	3.42	0	572.2	450					
9												44.7	1
10	24.942	99.29	0.12	36.08	3.23	0	1370.9	1324					
11													
12		96.13	0.02	36.02									
13													
14													
15													
16													
17							168.37						
18													
19													
20							604.5	440.4					
21													
22													
23													
24													
25													
26													
27													
28													
29													
30	22.58	94.77		35	1.95								
31													
32												28	3

Entry no.	SAMPLE TYPE	SAMPLE LABEL	raft speed (kn)	notes
1				
2				
3				
4				
5				
6	passive sampler			deployment
7				
8				
9				
10				
11	plankton net	1A,1B	1	
12	ctd sensors ctrl	E162,		
13	passive sampler	PS1	0.9	
14	deepbot	3m		30min
15	CHIA 10l, DNA 2l	2C,2D		
16				
17	plankton net	3A		30min
18	CHLA 10l, DNA2l	3C		
19	sensor ctrl	2T,2S,2CO2		
20				
21	deep ctd cast		2.1	30min down, 1hr up
22	plankton net		1	
23	passive sampler	PS2	1.2	deployment
24				
25				
26	plankton net		0.7kn	retrieved at 1302UTC
27	CHLA6l	5C, 5D		broken vacuum pump; no DNA veil
28				
29				
30				sal=34.8, watertemp=22.65, oxy=100.34, press=1.9 measured with the deep ctd for comparison
31	CHIA10l, DNA2l	4C, 4D		
32	secchi			28m, forel Ule3, overcast.

Entry no.	DATE	TIME	latitude	longitude	CO2	alkalinity
	YYMMDD	UTC	S	W		pH
33	160127	1634				
34	160128	0110	33°27.71'	113°35.59'		
35	160130	1748	34°41.28'	112°22.47'		
36	160131	0100	34° 45.69'	112°11.76'		
37		2000	34°40.65'	111°20.04'		
38		2143				
39	160201	1800				
40	160203	1500	35°06.8'	112°44.81'		
41	160209	0530	36°58.17'	111°23.63'		
42		2130				
43	160210	1500				
44		2143	36°57.57'	111°17.4'		
45	160211	0538	37°03.56'	111°13.68'		
46	160213	0515	38°38.59'	111°43.6'		
47		1730	38°51.85'	111°37.25'		
48	160214					
49		1627				
50		1900				
51	160215	0021	39°24'	110°43'		
52		0609	39°27.17'	110°32.85'		
53		1800	39°27'	110°01'		
54			39°31'	109°46'		
55	160216	0003	39°30'	109°24'		
56		0618				
57		1400				
58			39°29.8'	109°16.41'		
59	160217	0745				
60		1607				
61		1823	39°37.81'	109°46.24'		



Entry no.	water temperature	oxygen	turbidity	Salinity	Pressure	Fluorescence	LI189	LI1000	air temperature	humidity	Atmospheric pressure	Secchi depth	Forel Uje
	°C			PSU	dbar		umol	umol	°C	%	mbar	m	
33							1311.3	517.6					
34													
35													
36													
37													
38		98.56	0.09	34.58									
39	21.774	97.95	0.08	34.78	2.97								
40							375.4	215.8					
41													
42												32	3
43													
44													
45													
46													
47													
48	19.02	97.6	0.02	33.82	3.31	0.34							
49	18.58	83.91	0.1	33.79	2.75	0.38							
50		88.58	0.07	33.79									
51													
52	18.7												
53	18.4	90.91	1.51	33.82	2.45	0.04							
54	18.5												
55	18.93	90.91	0.2	33.79	2.4	0.3							
56	18.95	91.2	0.12	33.79	2.52	0.24							
57	19.01	91.78	0.12	33.75	3.07	0.08							
58	18.8												
59	18.617	93.78	0.14	34.15	3.35	0.34							
60	18.596	98.88	0.03	34.09	3.45	0.15							
61	18.539												

	SAMPLE TYPE	SAMPLE LABEL	vessel speed	notes
			kn	
33				
34	deep ctd cast			and deepbot, 2411.51m, retrieval at 0515
35				
36	plankton net ChIA10I,DNA2I	5A, 6C, 6D		retrieved 0252UTC, 1hr 50min
37	passive sampler	PS2		retrieval, 3LDPE, 4silicion packed in 2 and 2
38	ctd sensors ctrl	2O2,3T,3S,3CO2		
39				sal=34.66, watertemp=21.8, press=3.13, Oxy=100.54
40	plankton net, chIA,DNA	7A, 7C, 7D	1	1hr30min trawl, NOTE, I skipped 6A so that it matches the filtering samples numbering.
41	deepbot			30m deep deployment, low wind
42	deep ctd cast		1.5	1.5hr down, 2hr up NOTE Fvalue 0.2 at 0m, 0.9 at approx 100m, 2nd peak at approx 250m, 0.4
43				
44	deepbot			bait and water splash
45	plankton net, chIA10I,DNA2I	8A,8C,8D		1.5hr tow
46	plankton net	9A		3 tows 10min each into 600ml bottle covered w black plastic, note, carved 8a erroneously but crossed in the bottles cap
47	passive sampler	PS3		deployment, line entanglement during Tupac exchange *was never retrieved
48				
49				
50	ctd sensors ctrl	2O2,3T,3S,3CO2		microtops backup
51			1.5	
52			1.5	air temperature 19.2C, wet bulb 18.6C, 1025.14hPa
53			2	
54			2.5	air temp 19.4, wetbulb 19.0, atm pressure 1021.4hPa, tendency -1.4, 7
55			2.5	ait temp 19C, wetbulb 18.9, atm pressure 1021.11hPa,
56				
57				
58			2.2	air temp 16.6C, wet bulb 15.6C, 1020.4hpa tendency 1.8
59				
60				
61			1.8	ait temp 18.2, wet bulb 14.2, 1026.55hPa, * transferred to Tupac

## 7.4 Meteorological observations, Rahiti Tane, leg 1

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Air pres	Air Temperature	Wetbulb T	Cloud cover (x/8)	SST	Salinity	pressure	oxygen	Flu	Turb	CO2 (fish)	Lys
18112015	00:00	12	1.0	85	32	1010,6	19,8	17,9	7	20,6						324	
	06:00	12	5	85	50	1012	20,3	17,3	8	20,6						319	
	12:00	12	7	85	52	1012,5	20,1	17,8	8	20,8						305	
	18:00	12	14	86	8	1012,9	21,4	18,1	6	21,3	35,62		101,7	0,07	0,54	300	
19112015	00:00	12	14	86	8	1012,3	20,4	18	7	21,2	35,6	0,87	101,6	0,3	0,28	310	
	12:00	12	29	86	48	1015,4	19,4	17,7		21	35,63	0,6	101,4	0,26	0,02	291	
	18:00	12	30	86	51	1016	20,7	17,8	7	20,9	35,57	0,6	99,9	0,07	0,02	309	
20112015	00:00	12	38	87	17	1013,8	20,2	18,2	8	21,3	35,54	0,4	100,1	0,33	0,96	296	
	12:00	12	44	87	31	1014,1	20,6	16,9	7	20,8	35,57	0,34	101,8	0,34	0,02	330	100
	18:00	12	56	87	51	1013,8	21,3	18,6	8	21,46	35,52	0,72	101	0,08	0,47	363	94
21112015	00:00	13	10	88	15	1011,6	20,8	17,9	7	21,6	35,53	0,75	102,2	0,27	0,02	330	9
	12:00	13	19	88	42	1013,6	19,7	17,4	7	21,4	35,56	1,15	101,1	0,27	0,88	343	70
	18:00	13	23	88	54	1014,6	19,5	17,8	7	21,4	35,54	0,78	101,8	0,14	0,02	313	120
22112015	00:00	13	28	89	9	1012,5	20,2	17,9	4	21,2	35,52	0,58	102,6	0,36	0,11		22
	12:00	13	38	89	42	1014,1	19,4	17,5	8	20,7							
	14:00	13	40	89	48	1015,4	20			20,8	35,63		102,4	0,23	0,03	449	60
	18:00	13	44	89	56	1015	21,2	18,2	4	21	35,61	0,69	102,36	0,07	3,62	294	20
23112015	00:00	13	49	90	8	1013,3	19,4	18,2		21,1	35,59	0,34	103,1	0,36	1,22	301	40
	12:00	13	58	90	34	1013,9	20,5	17,5	8	21,2	35,55	0,5	101,6	0,32	0,65	305	90
	18:00	14	0	90	43	1014,5	21,4	18,6	8	21,3	35,54	0,42	101,9	0,07	0,02	317	115
24112015	00:00	14	4	90	56	1012,6	20,1	17,9	2	21,4	35,54	0,63	102,6	0,25	0,02	280	60

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Air pres	Air Temperature	Wetbulb T	Cloud cover (x/8)	SST	Salinity	pressure	oxygen	Flu	Turb	CO2 (fish)	Lys
	12:00	14	12	91	20	1014,4	20,2	17,6	6	21,1	35,6	1,1	101,7	0,26	0,02	304	83
	18:00	14	17	91	29	1014,2	21,5	18,3	1	21,1	35,67	1,31	102,2	0,07	2,53		20
25112015	00:00	14	19	91	38	1012,6	20,7	17,4	5	21,2	35,68	1,1	102,5	0,32	3,99		40
	12:00	14	26	92	0	1014,1	20,2	17,8	7	21	35,71	1,05	101,8	0,32	4,94		50
	18:00	14	32	92	11	1015,4	20,7	18,2	4	21,2	35,69	0,88	102,33	0,12	6,06		100
26112015	00:00	14	36	92	23	1013,6	20,5	18,6	5	21,3	35,69	0,83	102,63	0,21	0,02		70
	12:00	14	49	92	52	1015,6	21,3	17,4	7	21,2	35,7	0,56	101,7	0,29	0,03		46
	18:00	14	59	93	7	1017,4	21,8	18,9		21,3	35,6	0,94	101,83	0,09	0,04		25
27112015	00:00	15	7	93	22	1014,7	20,9	18,7		21,4	35,61	0,72	102,7	0,3	0,35		100
	12:00	15	24	93	53	1015,8	19,7	18,3	7	21,4	35,61	0,58	102,8	0,41	0,04		33
	18:00	15	34	94	9	1016,8	21,9	18,6	5	21,6	35,61	0,12	103,2	7,49	1,58		170
28112015	00:00	15	45	94	24	1014,9	21	18,3	5	21,6	35,64	0,18	103,1	0,29	0,02		72
	12:00	16	6	94	56	1015,2	20,7	18,4	8	21,5	35,78	0,28	102,2	0,31	0,02		21
	18:00	16	14	95	13	1016,9	20,7	18,7	7	21,6	35,71	0,19	102,3	2,49	0,12		150
29112015	00:00	16	21	95	25	1013,7	21,1	18,8	1	21,7	35,85	1,03	102,5	0,31	0,02		42
	12:00	16	39	95	53	1014,5	20,3	18,1	8	21,7	35,89	0,59	101,57	0,46	0,06		14
	18:00	16	47	96	6	1015,6	21,9	18,9	8	21,8	35,9	0,27	102,3	0,23	0,02		
30112015	00:00	16	57	96	17	1013,9	20,8	18,1		21,9	35,91	0,45	102,4	0,39	0,02		110
	12:00	17	18	96	43	1014,9	21,4	17,9	8	21,6	35,87	0,74	101,1	0,27	0,02		38
	18:00	17	28	97	0	1016,6	19,9	18,5	8	21,6	35,86	0,29	101,4	0,23	0,02		110
1122015	00:00	17	38	97	15	1014,8	21,2	18,3		21,6	35,85	0,19	102,42	0,29	0,02		185
	12:00	17	54	97	47	1016,3	21,3	17,9	8	21,6	35,82	0,54	101,3	0,3	0,02		47
	18:00	18	1	98	1	1016,9	20	18,5	8	21,8	35,89	0,1	101,25	0,27	9,3	369	120
2122015	00:00	18	12	98	14	1014,8	21,2	18,6		21,9	35,83	0,53	101,3	0,16	2,76		122
	12:00	18	30	98	39	1015,8	21,3	19	7	21,9	35,97	0,026	100,8	0,22	0,02		52

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Air pres	Air Temperature	Wetbulb T	Cloud cover (x/8)	SST	Salinity	pressure	oxygen	Flu	Turb	CO2 (fish)	Lys
	18:00	18	41	98	52	1016,8	22	19,2	8	22	35,94	0,32	101,2	0,14	0,32		76
3122015	00:00	18	52	99	1	1015,5	21,6	19,3	7	22	35,93	0,71	101,1	0,25	0,29	370	145
	12:00	19	12	99	18	1018	19,3	18,7	8	21,9	35,9	0,76	100,6	0,15	0,17		33
	18:00	19	24	99	26	1018,2	21,7	19,3	5	21,9	35,92	0,51	100,9	0,1	0,13	400	1300
4122015	00:00																
	12:00	19	51	99	47	1017,5	18,9	18,2	7	21,8	35,88	1,14	99,94	0,18	0,23		26
	18:00	19	53	99	51	1018,4	22	18,9	2	22	35,88	1,22	99,38	0,21	0,23	354	22
5122015	00:00	19	59	99	54	1016,2	20,6	19,1	5	22,2	35,9	1,3	100,14	0,19	0,43	385	80
	12:00	20	12	100	0	1016,1	20,8	18,7	5	22,1	35,89	1	100,1	0,19	0,24		
	18:00	20	16	100	9	1018,2	20,9	18,9	6	22,3	35,86	0,26	101,16	0,16	0,37	366	21
6122015	00:00	20	26	100	12	1016,6	21,4	19,5	2	22,5	35,88	1,14	101,2	0,19	0,26	351	650
	12:00	20	40	100	23	1018,3	20,1	19,2	7	22,5	35,98	0,99	100,1	0,2	0,27		29
	18:00	20	50	100	33	1019,4	22,5	18,9	5	22,5	36	0,66	100,48	0,15	0,66	385	20
7122015	00:00	20	57	100	40	1017,3	21,9	18,9	6	22,5	35,97	0,76	101,09	0,21	0,26	389	70
	12:00	21	15	100	59	1017,2	21,6	18,6	7	22,3	36,01	0,92	100,73	0,18	0,02	389	14
	18:00	21	24	101	9	1018,5	23,7	19,7		22,4	36	0,83	100,89	0,17	0,56	375	155
8122015	00:00	21	35	101	20	1017,2	22,2	19,1		22,5	36,03	0,57	100,8	0,2	0,22	370	88
	12:00	21	51	101	38	1017,2	21,8	19,7		22,1	35,9	0,61	101,13	0,19	0,02		9
	18:00																
9122015	00:00	22	14	102	0	1017,6	22,1	20,3	1	22,2	35,73	1,09	101,5	0,19	0,07	410	85
	12:00	22	36	102	19	1019,2	20,8	19,4	3	22	35,72	0,28	101,7	0,19	0,05		27
	18:00	22	50	102	31	1021	22,6	20,2	4	22	35,73	0,34	101,6	0,14	0,03	394	25
10122015	00:00	23	3	102	41	1019,4	22,1	20	3	22,1	35,73	0,48	101,63	0,17	0,02	386	250
	12:00	23	28	103	4	1019,9	21,8	19,8		22,3	35,92	0,46	101,29	0,16	0,18		1,5
	18:00	23	38	103	16	1021,8	22,4	20,1		22,2	35,87	0,31	101,5	2,46	0,03	400	19

Date (ddmmyyyy)	Time (UTC)	Lat (degrees south)	Lat (minutes)	Lon (degrees west)	Lon (minutes)	Air pres	Air Temperature	Wetbulb T	Cloud cover (x/8)	SST	Salinity	pressure	oxygen	Flu	Turb	CO2 (fish)	Lys
11122015	00:00	23	51	103	27	1019,8	22,1	20,1	8	22,2	35,82	0,58	101,31	0,17	0,02	425	180
	12:00	24	11	103	48	1020,4	21,6	19,1	7	22,1	35,81	0,73	100,73	0,15	0,02		
	18:00	24	21	103	59	1021,3	22,9	19,8	7	22,4	35,96	0,48	100,68	0,13	0,15	460	1130
12122015	00:00	24	32	104	10	1019,2	22	18,1	5	22,4	35,92	0,75	101,42	0,16	0,22	456	50
	12:00	24	52	104	30	1019,9	21,4	19,1	3	22,4	35,93	0,75	101,26	0,15	0,25	444	9
	18:00	24	55	104	38	1021,7	22,7	18,2	7	22,5	35,96	1,01	99,62	0,15	0,02	441	1490
13122015	00:00	24	57	104	44	1019,6	22	18,6	7	22,7	35,94	1,2	99,76	0,18	0,02	455	35
	12:00	25	6	105	1	1020,6	21,4	18,1	7	22,5	36,03	0,65	101,16	0,16	0,02	435	9
	18:00	25	11	105	12	1021,8	22,2	18,1	1	22,1	35,74	0,42	101,15	0,19	9,11	445	22
14122015	00:00	25	6	105	18	1019,7	23	19,6	3	23	36,06	1,16	101,11	0,17	0,71	442	70
	12:00	25	12	105	33	1019,7	21,7	19,8	7	22,7	36,09	0,81	100,15	0,17	0,14	452	1,6
	18:00	25	18	105	41	1021,4	22,6	19	6	23	36,11	1,09	100,72	0,16	0,16	426	30
15122015	00:00	25	24	105	48	1019,9	21,9	19	7	22,8	36,11	1,08	98,31	0,2	0,16	433	35
	12:00	25	32	106	4	1019,1	21,3	17,3	1	22,7	36,05	0,66	99,63	0,11	0,11		3,6
	18:00																
16122015	00:00	25	44	106	26	1019,6	22	18,2	3	23,2	36,14	0,87	99,17	0,18	0,11	440	195
	12:00	25	58	106	52	1020,2	21,7	18,8	5	22,7	36,01	0,75	99,65	0,18	0,1		6,5
	18:00	26	5	107	4	1022	23,1	19	1	22,7	35,95	0,75	97,68	0,16	3,08	419	22
171122015	00:00	26	12	107	17	1020,5	22,2	18,5	4								250
	12:00	26	25	107	41	1021	21,8	19,1	3								0,4
	18:00	26	30	107	56	1022,9	23,2	19,3	1							417	21
18122015	00:00	26	37	108	9	1022	22,6	19,6	3							439	
	12:00	26	43	108	33	1022	22	19,6	2								0
	18:00	26	48	108	49	1022,6	23,2	20,8	3	23,1	35,75	0,93	100,72	0,22	0,22	400	23
19122015	00:00	26	55	109	1	1020,9	22,6	19,9	2								

## 7.5 Statement of the expedition's conclusion from [www.Kon-Tiki2.com](http://www.Kon-Tiki2.com)

«(2016-03-17) The Kon-Tiki2 Expedition has decided to end the expedition after 114 days and 4500 nautical miles in the South-East Pacific. The goal of the expedition has been to show that balsa rafts can sail from South America to Easter Island, and back. The Expedition reached Easter Island after 43 days at sea, but the return voyage has proven more difficult due to atypical winds.

We have shown that balsa rafts can sail to Easter Island. This is a first, in modern times. We have also made good progress on the return journey, but this is an El Niño year and the weather patterns we have encountered have been atypical. We realize that reaching South America will take too long and we prefer to evacuate to ensure safety for all, says Expedition leader Torgeir Higræff.

The Expedition consists of two balsa rafts that left Lima in Peru on Nov 7th, 2015, and arrived on Easter Island just before Christmas. On Jan 6th, 2016, the rafts started the demanding return voyage.

In a normal year, we would have reached South America by now. Instead, we are still 900 nautical miles from land and the weather forecasts are not promising. The crew is at good health and spirit, and there is no emergency situation. These rafts have proven to be exceptional vessels at sea. They have impressed us by their seaworthiness in all sorts of weather, over enormous and remote waters. Needless to say, it is sad to end the expedition without reaching South America, says Higræff.

The Kon-Tiki2 Expedition has done important scientific research on climate change, marine life, plastics, and pollution in the Pacific.

The rafts are rigged as floating research vessels through a unique collaboration between NIVA, NTNU, Kongsberg Maritime, Norwegian Meteorological Institute, Nortek, Sperre, Opera, and the American research organizations NASA and NOAA, says Cecilie Mauritzen, Chief Scientist of the Expedition. We have gathered large sets of data on climate change and pollution. From a scientific point of view, it has been particularly interesting that the expedition took place in one of the strongest El Niño years recorded, even if El Niño now contributes to the termination of the expedition. As research partners, we look forward to receiving and analyzing these data sets, says Mauritzen.

The Expedition is supported by Thor Heyerdahl Institute, 3A Composites AirexBaltekBanova, and the Ministry of Foreign Affairs. The Expedition is discontinued in close collaboration with the Chilean Navy, which have assisted us in a highly professional manner. The Norwegian Embassy has also communicated closely with the Expedition, says Ambassador Hege Araldsen at the Norwegian Embassy in Santiago, Chile.»



Figure 29 Left. Hege Araldsen, Norway's Ambassador to Chile and Admiral Larrañaga met to express gratitude to the Chilean Navy for the rescue operation. On the right, the crew members of OPV Piloto Pardo and expedition leader Torgeir Higræff.



## 7.6 Statement of Fact for Rescue operation

To ; Sato steamship  
 To ; NYK Tokyo / Trampfff  
 Cc ; Concerned part  
 Fm ; Master of Hokuetsu ushaka  
 Date ; 17<sup>th</sup> Mar 2016

### Statement of Fact for Rescue operation

Dear sir,

I, master of the MS Hokuetsu Ushaka hereby inform you that en route to Loadport Calbuco, Chile from Niigata, Japan where my ship left on 20<sup>th</sup> Feb 2016, the said vessel has received instruction for Marine Rescue operation from MRCC Chile on 16<sup>th</sup> Mar 2016 as follow, and Have successes Rescue operation as follow.

1. Received telephone call from MRCC Chile tel no. 4711111111 on 1855/16<sup>th</sup> Mar 2016 UTC (1355/16<sup>th</sup> LT). and received Rescue in struction by phone.
2. In order to confirm, master called MRCC Chile no. 56-32-220-8637, and confirmed their instruction on time 1918/16<sup>th</sup> Mar 2016 UTC (1418/16<sup>th</sup> LT).  
 MRCC Chile asked to master telephone no. of Owner & Operator, and e-mail address too.
3. Master called Owner Sato steamship, & NYK PIC on 1922/16<sup>th</sup> Mar 2016(UTC)(1422/16<sup>th</sup> LT).  
 Have contacted Sato steamship/N. Isogai, & NYK /Hirofumi Izumi by phone.  
 And reported present emergency condition.  
 Contacted time ; 1926/16<sup>th</sup> Mar 2016 UTC(1426/16<sup>th</sup> LT)  
 Duration ; 1 m 26 sec.
4. Master received a call from NYK/Hirofumi izumi on 1935/16<sup>th</sup> Mar 2016 UTC(1435/16<sup>th</sup> LT).  
 NYK/Hirofumi Izumi instructed to master to follow MRCC Chile instruction by phone,  
 And ordered to master to be follow Shota Takehira instruction.  
 contacted time ; 1935/16<sup>th</sup> Mar 2016 UTC (1435/16<sup>th</sup> LT).  
 Duration ; 3 m 34 sec.
5. MRCC Chile asked to master to rescue, & divert to Emergency area by E-mail.
6. Master changed co to emergency area from 1950/16<sup>th</sup> Mar 2016 UTC(1450/16<sup>th</sup> LT).  
 Ship's position ; 3606S 09452W. BROB FO/1310.62 mt MGO/277.7 mt.  
 Distress position ; 4021S 09601W.  
 Raft name ; Tupac Yupanqui 7 person.
7. Received e-mail from NYK/Shota Takehira who asked to be update position.
8. Received e-mail from NYK/Shota Takehira who asked picture of Rescue operation.
9. Timely updated ship's position, and sent to MRCC Chile, NYK Tokyo/Trampfff.



- And Sato steamship, and agent too.
10. Found out 1<sup>st</sup> Raft, named Rahiti Tane ; 171035 LT(171435 UTC)  
Made fast Raft on ship's Stbd side ; 171200 LT (171600 UTC).  
Prepared material & rigging.  
1<sup>st</sup> Person came on board ; 171216 LT(171616 UTC).  
Last person came on board ; 171244 LT (171644 UTC)  
Released the Raft Rahiti Tane ; 171245 LT (171645 UTC).  
Position of the raft Rahiti Tane ; 3933S 09601W.  
Took material & baggage on board from the Raft as satisfy of person of the Raft.  
(Raft's movement ; direction NE, spd 1.0 kts.)  
1 person of the Raft got injury during her came up pilot ladder.  
(touched leg to ship's shell plate due to her heavy rolling).  
Now 1 doctor who is one of them gave treatment, no serious condition.  
Checked health condition of them are in good health condition.
  11. Proceed to 2<sup>nd</sup> Raft Tupac Yupanqui.
  12. Found out 2<sup>nd</sup> Raft, named Tupac Yupanqui ; 171630 LT(172030 UTC)  
Made fast Raft on ship's Stbd side ; 171730 LT(172130 UTC).  
Prepared material & rigging.  
1<sup>st</sup> person came on board ; 171741 LT(172141 UTC).  
Last person came on board ; 171839 LT(172239 UTC).  
Released the Raft Tupac Yupanqui ; 171845 LT (172245 UTC).  
Position of the Raft Tupac Yupanqui ; 3959S 09552W.  
Took all material & baggage on board from the Raft as satisfy of person of the Raft.  
(raft's movement ; direction N, spd 1.0 kts)  
Checked health condition of the new 7 person are in good health condition.
  13. Completed Marine Rescue operation ; 171850 LT (172250 UTC)  
And left rescue position. (3959S 09552W).  
BROB FO/1280.1 mt MGO/277.2 mt  
Reported all of the above statement to MRCC Chile, NYK Tokyo/Trampiff, Sato steamship  
And concerned part timely with picture attachment.
  14. Now we have the rescued total 14 person on board in good health condition

Yours,

Capt Yun Sun Bug  
Master of MS Hokuetsu Ushaka.

