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PAUL-ÉMILE VICTOR

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INFORMATION:
This English version of the activity report is shorter than the French version.

All photos without author's names belong to the French Polar Institute and were taken by the Institute's teams during their missions.

STORMS BUT A CLEAR AND STEADY ROADMAP

Editorial

JÉRÔME CHAPPELLAZ

Director of the French Polar Institute

With the emergence of the Covid-19 pandemic, the year 2020 did not spare our Institute in its organisation, which had to face an additional double challenge: (1) to avoid at all costs introducing SARS-CoV-2 into non-contaminated territories, (2) to ensure the transfer of essential expeditionaries via Australia which had closed its borders to foreign nationals.

This unprecedented situation forced us to significantly reduce the number of scientific projects deployed: of the 78 projects initially validated by the scientific committee in 2019, 40 were postponed. For the first time in its history, the Institute had to charter a plane that made it possible to transfer a total of 80 French expeditionaries from Paris to Hobart in Tasmania in a single operation in October 2020, thus avoiding any contact with other passengers for direct quarantine at the point of departure to Antarctica. Both Antarctic and Subantarctic expeditionaries spent between 14 and 27 days in strict confinement in Hobart or La Réunion. **I would like to underline the remarkable professional commitment of our staff to carry out their mission despite this very particular context and knowing that our Institute is under great pressure due to its lack of human resources.**

In Antarctica, the sea ice conditions proved to be very favourable throughout the 2020/2021 campaign. They enabled the supply ship L'Astrolabe to moor alongside Lion Island on each of the five logistical rotations (a rare event), delivering enough fuel to ensure the autonomy of the Antarctic stations even in the event of a blank year for supplies. The installation of important equipment at the Beyond EPICA European coring site could be brought forward by one year, and some of the scientific equipment to be sent to the South Pole during the EAIIST raid in 2019/2020 was recovered by plane. We were also able to provide significant logistical support to our Australian counterparts by resupplying Macquarie Island, a fitting return following the chartering of their icebreaker Aurora Australis in November 2019 to compensate for the damage to the Astrolabe. In the Subantarctic islands, the results of the campaigns were also excellent, both in terms of the deployment of the projects maintained and the maintenance of the many refuges under the Institute's management. Finally, in the Arctic, several projects were delayed, but those implemented in Ny-Ålesund were able to benefit in part from the relay provided by international volunteer staff, who were on site all year long despite the pandemic.

The year 2020 and the beginning of 2021 were characterised by the formalisation of several large-scale infrastructure projects for the Institute, with a major focus on the two Antarctic research stations, Dumont d'Urville and Concordia. With regard to Dumont d'Urville, the appointment of a new Prefect of the TAAF in October 2020 has strongly supported the momentum initiated by the Institute in 2019, aiming to propose an ambitious renovation/modernisation project for this ageing station to the relevant ministries. From November 2020, the technical services of the French Polar Institute and the TAAF, accompanied by a group of architects/engineers and a design office, have thus developed this ambitious project aimed at improving support for French research while ensuring environmental exemplarity. For Concordia, following the declaration of intent signed by the French and Italian research ministers in February 2020 and in support of a bilateral scientific foresight exercise, the French Polar Institute and ENEA-UTA technical teams have drawn up a multi-year action plan, including an emergency camp, a sanitary module, a new summer dormitory, new scientific facilities and the development of solar energy on site. The first two items have been financially committed from 2021. Following the same logic, the Institute also increased its investments in 2020 for the two Antarctic stations.

2020 was also the year in which the Institute established its Bilan Carbone® , a first for a polar operator. All of our activities in the six polar districts and at headquarters have led to an emission of 12,200 tonnes of CO2 equivalent in 2019 (considered as a typical year), the main source being maritime transport with the Astrolabe. A reduction in its average sailing speed would significantly improve the Institute's balance sheet, but this depends on the operational decisions of the armament provided by the French Navy. Finally, we would like to emphasise the Institute's strong commitment to communication and mediation (including new institutional films), particularly in preparation for the French presidency of the annual meeting of the Antarctic Treaty in June 2021.

At the Institute's headquarters, we continued the reforms initiated in 2019 (GPEC approach) by formalising the Management's vision for the Institute's strategic project and by setting up a new organisational chart including (1) an Operations department covering infrastructure, logistics and operations for all the districts where the Institute operates, (2) a human resources department, responsible in particular for leading the GPEC over the long term, (3) a "Quality - Safety - Environment" engineer position attached to the Management. The internal functioning of the Institute is now based on a management board and an internal council for social dialogue. This 2020/2021 period will have seen us carry out fundamental work from which the Institute can only benefit in the long term: revision of the job descriptions of all staff, continued work on the Institute's procedures and information system, setting up with the Board of Directors of a technical group responsible for evaluating the Institute's missions and resources and proposing solutions for improvement.

All these actions aimed at making the Institute more solid were accompanied by intense lobbying to strengthen the Institute's human resources, an essential point of vigilance in the short term. The good news in this respect was undoubtedly the increase of two units in the employment limit with the 2021 MESRI finance law. The CNRS has also done its utmost in a highly constrained context. The 2021-2022 financial year should mark the end of the tunnel in this respect so that the Institute can reach its target organisational structure as soon as possible.

The overall quality of French research in polar regions depends largely on a strong national operator. The roadmap is clear, the objective is approaching. If it is finally achieved, the known resilience of the Institute's staff in the storm will have largely contributed to it and I would like to salute them all for their courage and commitment.

Antarctic

1.4 times larger than Europe,
25 times larger than France.

14 million Km²

Subantarctic Islands

CROZET ARCHIPELAGO

Île aux Cochons ***Île de la Possession*** ***Île de l'Est***

Base Alfred Faure

46°25'S - 51°51'E
934 m altitude (Pic du Mascarin)
1st wintering in 1962
About 25 winterers
and up to 50 people in summer

KERGUELEN ARCHIPELAGO

Base de Port-aux-Français

48°27 -50°00 S, 60°27'-70°35'E
1800 m above sea level (Mount Ross)
1st wintering in 1949 About 50 winterers
and up to 100 people in summer

ÎLES AMSTERDAM ET SAINT-PAUL

Île Amsterdam

Île Saint-Paul

Base Martin-de-Viviès

37°50'S - 77°32
881 m altitude (Mont de la Dives)
1st wintering in 1950
About 25 winterers
and up to 50 people in summer

Antarctic Subantarctic

Concordia Station

75°06'S - 123°21'E
3200 m altitude
1st wintering in 2005
12 to 15 winterers
and 50 to 70 people in summer

Dumont d'Urville Station
and the Robert Guillard annex station
at Cap Prud'homme

66°40'S - 140°01'E
20 m altitude
1st wintering in 1952
25 to 35 winterers
and up to 100 people in summer

Arctic

Arctic Station AWIPEV

Position (79°N - 12°E)
Average temperatures:
in summer: + 4°C
in winter : - 12°C

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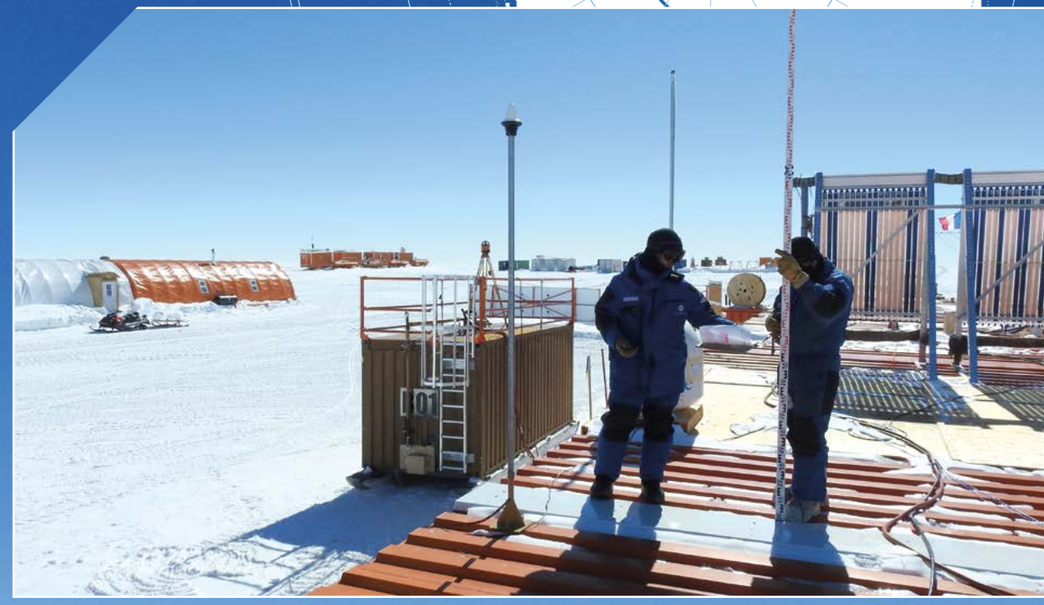
2020/2021 A YEAR IN THE FIELD

A CAMPAIGN UNDER **SOUS COVID** AT CONCORDIA

Interview
ARMAND PATOIR



I am the technical manager of Concordia in charge of the station's infrastructure and I joined the French Polar Institute two years ago, six months before the 2020-2021 summer campaign.
The station has to function in an optimal way. It seems obvious but it implies a lot of activities and also development with the construction of new infrastructures. In my job, there is also a part of logistics, the first mission is to supply the station with food and fuel to ensure the next overwintering and the replacement of the outgoing overwintering team and finally there is the big part of support to science.
My mission is to organize and orchestrate all the work that the technical team is going to do on site in order to meet all the needs of the station as well as possible, weighting them according to the importance of each. Otherwise, I turned 30 during the last campaign!

A campaign takes place during the summer in the southern hemisphere from November to February for Concordia. This is preceded by a 6-month preparation period at the Polar Institute headquarters. During the first months, we collect the wishes of the people involved in Concordia, first of all the scientists. Then we examine the technical urgencies correlated to the number of technicians that we can bring on site during the next campaign to carry out this work.

We then proceed to the various orders and organize the shipment of this equipment to Concordia: fuel for the production of energy, food, all the technical equipment to carry out our work, and of course the scientific equipment that must be sent to the field before the arrival of the researchers. Finally, we recruit the personnel necessary for the whole campaign but also the overwintering team which will ensure the succession of the outgoing team. **All this is done in collaboration with our Italian partner since Concordia is managed for half by the PNRA.**

Then comes September, the month of training for all the staff. The 12 overwinterers in particular must learn everything about the functioning of Concordia, life in Antarctica and our expectations during this 9-month period when they will be alone in the station. In November, everyone leaves for the field and the campaign starts.

The pandemic has caused a total change in all our activities. We created something completely new. The most important point came from *COMNAP*: the number one priority was to make sure that Covid not come to Antarctica. To do this, to reduce the number of people going to Antarctica and to go through a strict quarantine to eradicate the risk of bringing Covid to Antarctica.

THe implications were numerous and we asked ourselves many questions: **What is really important? What do we really need to ensure? In Antarctica, what job is strictly essential?**
Normally, during the three-month summer season at Concordia, people come and go: some come to work for three weeks and then leave, leaving their place to others. But this year, everyone arrived at the same time. There was no movement of people.
So we did much less scientific and technical activities than usual, because there were fewer people. At Concordia, we were half as many as usual!

COMNAP :
The Council of Managers of National Antarctic Programs

The AWACA project is one of the new projects that the Institute will deploy in 2021, not only for operational implementation but the French Polar Institute is also designing the autonomous structures that will be positioned along the logistics raid route so that the consortium's instruments can operate continuously and in total autonomy.

A PROJECT BASED ON VARIOUS EXPERTISE TO UNDERSTAND THE ATMOSPHERIC WATER CYCLE OF ANTARCTICA

AWACA (Atmospheric WAter Cycle over Antarctica: past, present and future) is a project funded by the European Research Council. It aims to better understand the water cycle in the Antarctic atmosphere via an unprecedented observation campaign. One of the objectives is to refine numerical models in anticipation of future climate changes and their impacts on the global sea level.

Little is known about the atmospheric water cycle in Antarctica. However, it is necessary to understand the meteorological processes that govern Antarctica. A team of researchers will be working on these questions to assess in what way a rise in the ocean level will be moderated by changes in snowfall in this region. Building on a synergy based on complementary skills, AWACA will begin with a technological and instrumental development phase. Specific devices will be deployed along a 1,100-kilometre transect between the Dumont d'Urville station, near the coast, and Concordia station, on the high plateau. This is a representative plot of the weather conditions in Antarctica. The measurement and observation campaign will provide an unparalleled dataset. It will be possible to use these data to characterise atmospheric surface processes, the isotopic composition of water in its various phases, as well as clouds and precipitation over the entire height of the tropospheric column. By understanding these mechanisms, we can improve their parameterisation in regional and global climate models. The key to improving climate projects is to improve the physical parameterisations in digital climate models. Through this, AWACA plans to reconstruct the climate variability of Antarctica over the past 1000 years, and to predict that of the next 100 years. The project will start on 1 September 2021 and will run for a period of 6 years.

the 4 project **leaders**

Christophe Genthon

CNRS Research Director and researcher at the Laboratory of Dynamic Meteorology (LMD)

A specialist on the climate of Antarctica, he brings his expertise in surface meteorology.

Valérie Masson-Delmotte

Research Director at the Climate and Environmental Sciences Laboratories (LSCE)

She brings to AWACA her knowledge of stable water isotopes and ice cores.

Alexis Berne

Director of the Environmental Remote Sensing Laboratory (LTE) and professor at the Swiss Federal Institute of Technology in Lausanne (EPFL)

A specialist in radar hydrometeorology, he will work on the remote sensing and microphysics of precipitation and clouds.

Thomas Dubos

Professor at the École Polytechnique

His research activity is based on the theme of atmospheric dynamics and its modelling. He brings to AWACA his knowledge of atmospheric dynamics and model design.

AWACA has received funding from the European Research Council (ERC) within the framework of the European Union's Horizon 2020 research and innovation programme. (Convention No. 951596 - AWACA)

AN OVERHAULED **RAID ORGANISATION**

Interview **ANTHONY** VENDÉ

I am in charge of mechanics at the Polar Institute. I manage the power units of the Dumont d'Urville and Concordia stations in Antarctica. I also manage the traverses (logistical and scientific) as well as the maintenance of the equipment at various sites.

There are two distinct phases in my job, the first is at the headquarters in Brest from March to October. We provide technical assistance to the overwintering staff on the Antarctic stations and monitor the work. This period is also the preparation of the next campaign, with the purchase of spare parts, equipment projects and the recruitment of personnels for the next campaign, in summer or wintering.

The second phase takes place in the field from November to February with the setting up of the wintering teams, the handing over of instructions and the monitoring of the work in progress.

As far as the traverse is concerned, it is more of a seasonal activity, with a first part of preparation of the equipment, the vehicles and the station that must be taken out of winter storage. Then, we have to prepare the convoys which, depending on the year, will be two or three in number. The preparation of the machines is done by the people of the traverse which implies that they arrive very early for the campaign around November 1st at Cap Prud'homme. **Historically, the first R0 rotation of the supply ship L'Astrolabe was created to allow for three traverses during the campaign, which was necessary at the time to resupply Concordia completely.**

The 1st traverse leaves around November 20th and returns between 22 and 25 days later. When it arrives at Concordia, the traverse personnel unload for about a day to a day and a half and then they often reload on a good day, so they stay at Concordia at Dome C between two and three days.

Today, thanks to the new, more powerful vehicles (a convoy "pulls" 11 or 12 loads compared to 10 years ago). We also have a better experience of the field, and we manage to transport what is essential for the functioning of the station in only 2 traverses. However, we sometimes make three traverses if there is extra equipment to bring up to the station.

When the last traverse is over in mid-February, it is time to order the equipment for the next season, to condition everything away at the station in order to prepare it for winter. The return of the personnel is done on the R3 and R4 rotations of L'Astrolabe in general.

During the pandemic, the first difficulty in the field was the late arrival of the teams and the early end of the campaign, which meant a shorter campaign which de facto prevented three traverses. In "normal" times, with the staff present at the Robert Guillard station in Cap Prud'homme, about 18 technicians are needed. Under Covid pandemic, there were two withdrawals and as the period was complicated for recruiting, the whole campaign was understaffed. Despite this, the two traverses were carried out and the SAMBA traverse, which is an observatory program, was maintained.

OCEAN SENTINEL

HENRI WEIMERSKIRCH

CNRS Centre d'Etudes Biologiques de Chizé, 79360 Villiers en Bois

Black-browed Albatross on its nest, equipped with a sputnik beacon, Kerguelen (H. Weimerskirch)

Pair of large albatrosses, Crozet (H. Weimerskirch)

ABSTRACT

In the oceans, the surveillance of fisheries is complex and inadequate, such that quantifying and locating nondeclared and illegal fisheries is persistently problematic. Given that these activities dramatically impact oceanic ecosystems, through overexploitation of fish stocks and by-catch of threatened species, innovative ways to monitor the oceans are urgently required. We describe a concept of "Ocean Sentinel" using animals equipped with state-of-the-art loggers which monitor fisheries in remote areas. Albatrosses fitted with loggers detecting and locating the presence of vessels and transmitting the information immediately to authorities allowed an estimation of the proportion of nondeclared fishing vessels operating in national and international waters of the Southern Ocean. We found that in international waters, more than one-third of vessels had no Automatic Identification System operating; in national Exclusive Economic Zones (EEZs), this proportion was lower on average, but variable according to EEZ. Ocean Sentinel was also able to provide unprecedented information on the attraction of seabirds to vessels, giving access to crucial information for risk-assessment plans of threatened species. This study shows that the development of technologies offers the potential of implementing conservation policies by using wide-ranging seabirds to patrol oceans.

1. BACKGROUND

Today, marine ecosystems are under threat from climate change and particularly from resource overexploitation and illegal fisheries, as well as from the accidental capture of non-target species. Fisheries are operating in all the world's oceans, in nation's Exclusive Economic Zones (EEZs) as well as in international waters. Knowledge about the distribution of fishing vessels is key for the regulation of fishing activities as well as for the conservation of oceans. Information regarding the location of fishing activities is usually made available to authorities or international agreements via a voluntary declaration or by using the Automatic Identification System (AIS), usually in EEZs.

In international waters, information about the fishing effort and distribution is not available or made available by Regional Fisheries Authorities in aggregated form on a large scale, making it impossible to have precise up to date/daily information. In addition, an AIS can be deactivated at any moment. As a result, information about the fishing location is fundamental for the conservation of marine ecosystems and species, especially species caught accidentally, some of which are threatened with extinction due to fishing. Among these accidentally caught species, albatrosses and petrels are the most endangered bird species, with hundreds of thousands of individuals killed each year, particularly by longline fisheries.

2. DETECTING BOAT RADARS

The idea of the Ocean Sentinel programme is to develop an animal-based system that would provide instantaneous information on the location of fishing vessels independently of current tracking systems. The concept was developed based on research conducted under the European Research Council (ERC) - Earlylife programme, the aim of which was to study, in seabirds, a critical period in the life history of an animal, the first months at sea after independence and to understand the reasons for the high mortality that occurs at this stage. Earlylife was based on an extensive juvenile animal tagging programme that had been implemented in 2013-2018, particularly in the Southern Territories with the support of the French Polar Institute as part of project 109. Given that longline-induced mortality was suspected to be a major cause of mortality for young albatrosses or inexperienced petrels, it was essential to find out when mortality occurred; in young albatrosses fitted with geolocation transmitters, mortality was detected when transmission stopped. It was necessary to be able to determine whether the death was natural or caused by a fishing vessel. It was obvious that, in the open ocean, no information exists on the precise instantaneous presence of fishing boats, with the exception of some information on boats equipped with an AIS, or (often confidential) on vessels equipped with a Vessel Monitoring System (VMS) operating in ***EEZs***.

We came up with the idea that, similar to how a boat at sea uses radar for safety and operational reasons, it would be possible to locate a locate a boat by being able to detect radar emissions. In collaboration with Dominique Filippi of the New Zealand company Sextant Technology, we have developed a logger that provides the location of the animal via GPS and also detects radar emissions from vessels[1]. We have called this type of logger, fitted onto an albatross, XGPS. The results of the first trials have shown that 80% of large breeding albatrosses fitted with XGPS in the Crozet Islands (the French Southern and Antarctic Lands (TAAF)) have detected boat radars. Half came from fishing vessels that declared they were operating in the Crozet EEZ, and which catch an economically valuable fish, the Sub-Antarctic toothfish. The other half of the boats detected by their radar were encountered by albatrosses in international ocean waters, outside of EEZs, up to 2,500 km away from Crozet[2] (Fig. 1).

French longliner fishing in Kerguelen waters (L. Fargier, TAAF)

1. Weimerskirch et al 2017 Cons Biol

2. Weimerskirch et al 2017 Cons Biol

EEZ :
Economic exclusive zone

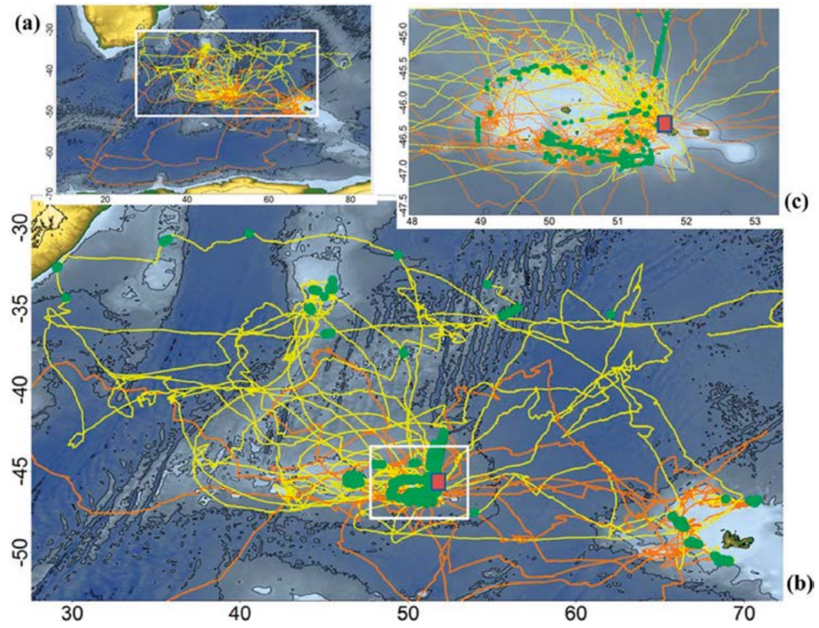


Figure 1 – a) and b)
Routes of large female (yellow) and male (red) albatrosses monitored from Crozet and fitted with XGPS beacons detecting ship radars (green dots)
b) enlargement of the Crozet shelf b).

Albatrosses are very useful patrollers of oceans because they are highly attracted to fishing vessels, which they can detect from over 30 km away[3], and they cover an enormous region of the ocean surface (10 million square kilometres with 50 individuals fitted in Crozet). We validated the performance of our system by omparing information from our logger and VMS data from declared boats. All declared boats encountered by the albatrosses were detected by their radar.

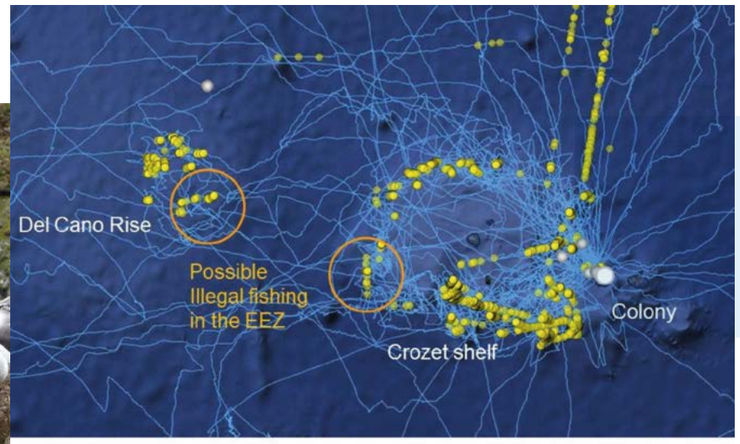
For this first phase, we used XGPS fitted on nesting birds that returned to their nests after a trip at sea: the information was provided to us several days or weeks after the encounters with the boats. The next step in our Earlylife programme was to develop a second generation of loggers, called XArgos, to track albatrosses without having to retrieve the devices in order to access the recorded data. This system is suitable for juvenile birds which leave their nests for several years and for which information cannot be retrieved from the logger. XArgos data (tracking and radar detections) is sent by the Argos system every hour, providing instant access to the detection and location of fishing boats via the Internet. In 2017-2018, XArgos beacons made it possible to follow the movement of young albatrosses and to know when exactly they encountered fishing vessels during their deployment from Crozet (Fig. 2).

3. Collet et al. 2017

Figure 2 – Deployment of a large juvenile albatross from Crozet, fitted with an XArgos beacon. The albatross encountered several vessels during its deployment (green dots), including one in the Amsterdam Island area, and several on the southern edge of the Australian shelf.

However, one very interesting result of the study was that it showed that albatrosses fitted with XGPS loggers also encountered undeclared vessels in the EEZ (Fig. 3). Naturally, this information attracted our attention, but more importantly it also attracted that of the French TAAF authorities where the French fishery targeting toothfish operates in the EEZ. These first results have shown that it is possible to detect and locate illegal fishing vessels.

Figure 3 – Routes of fitted large albatrosses (blue lines) from Possession Island - (White Point) in the Crozet sector and the Del Cano shoal. Yellow dots indicate the radar locations of reported vessels, and orange circles indicate the locations of undeclared vessel(s).



Weimerskirch et al 2017 Conserv Biology

Pair of black-browed albatrosses after a nest change, the bird on the left goes to sea with its beacon (H. Weimerskirch)

3. OCEAN SENTINEL

Based on the strength of this success and given the interest in being able to instantly detect fishing vessels and relay information by satellite, we have developed the Ocean Sentinel programme which aims to provide instantaneous information about the presence of fishing vessels in large ocean sectors worldwide, without going through conventional positioning systems, AIS and VMS, which can be turned off by ships, or RadarSat.

We were awarded a second round of funding from the ERC as part of its Proof of Concept (PoC) projects. These ERC PoC projects are intended to fund cutting-edge research activities as an extension of ERC funding. The aim of these projects is to provide funding, during the development phase, to research programmes with commercial or societal applications. They are intended to prove the feasibility of a new concept. The ERC PoC Ocean Sentinel project was funded in order to implement a societal application concept in 2018-2019. It draws together a team of researchers, PhD students, engineers and post docs from the Marine Predators team at the Centre for Biological Studies of Chizé[4], combined with the administration of the French Southern and Antarctic Lands (TAAF), the Sextant Technology company, a New Zealand Development Centre and the University of Liverpool. The programme was carried out as part of project 109 of the French Polar Institute.

4. CEBC, UMR CNRS University of La Rochelle

The aim of **Ocean Sentinel was to**

1 Develop a third-generation logger called Centurion which couples an XGPS platform and a satellite transmission system (Argos) which instantly sends the location of the detected vessels to a reception site as soon as a bird encounters a vessel. This logger was successfully tested in the field at Crozet in January 2018 and in France in July-September 2018.

2 Deploy 180 Centurions and XArgos on adult, immature and juvenile large albatrosses and Amsterdam albatrosses at the Crozet, Kerguelen and Amsterdam sites between December 2018 and March 2019, then in December 2019.

3 During the operational phase, to test the validity of the concept by comparing the Centurion localisations of the ships, with all data available elsewhere, AIS data (retrieved continuously between November and March 2019), VMS data obtained by the TAAF administration, and Sentinel RadarSat image frames that we can obtain thanks to the programme funding. This phase makes it possible to compare the effectiveness of the various systems that currently exist in relation to the Ocean Sentinel system and, in particular, to detect undeclared and illegal vessels that have turned off their AIS,

4 Lastly, to instantly make available the locations of all vessels detected by albatrosses on a website that can be accessed by researchers and the competent authorities. The benefit of the programme is that it will provide information about the distribution of fisheries in oceanic sectors where this information is not available. This mainly concerns remote ocean sectors such as the high seas of the Southern Ocean, as well as in EEZs where monitoring is extremely expensive. When undeclared vessels are found in French EEZs, the information is provided directly to the authorities (CROSS, Marine Nationale (French Navy) and TAAF) for information and potential interventions (Fig. 4)

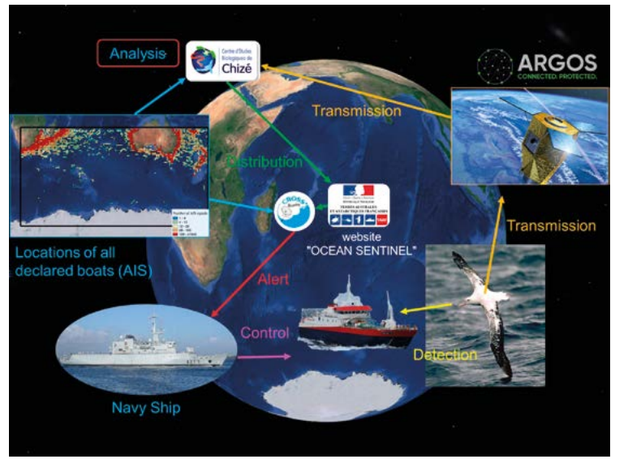


Figure 4 – Diagram of the Ocean Sentinel concept, detection by Centurion, transmission by Argos system Data analysis and integration of AIS data, provision of data on the TAAF website and alert in case of detection of undeclared activity, with potential intervention if a French Navy vessel is in the area.

From December 2018 to May 2019, 180 fitted albatrosses leaving from Crozet, Kerguelen and Amsterdam patrolled a gigantic surface area spanning nearly 50 million km² (Fig. 5). They encountered over 330 vessels, mostly fishing vessels, in the French, Australian and South African EEZs as well as in international waters from the tropics to Antarctica (Fig. 5).

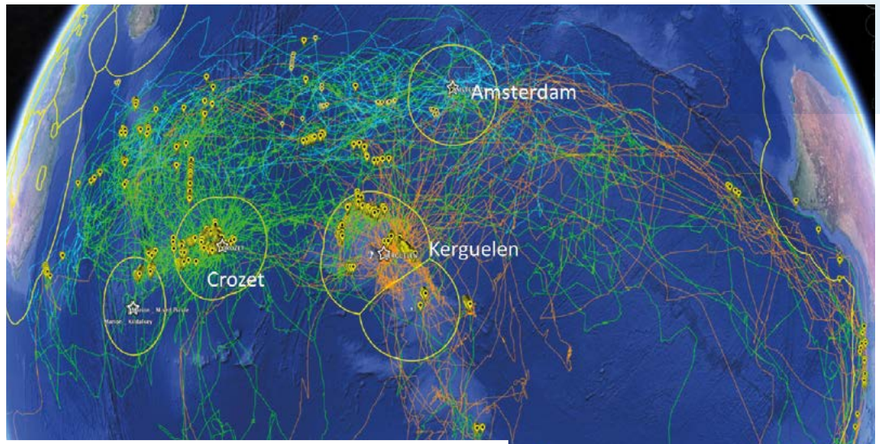


Figure 5 – Map of the southern Indian Ocean with the pathways of large Crozet (green) and Kerguelen (orange) albatrosses and Amsterdam albatrosses (blue). Radar detections are marked by yellow dots. The boundaries of the EEZs are shown as yellow lines.

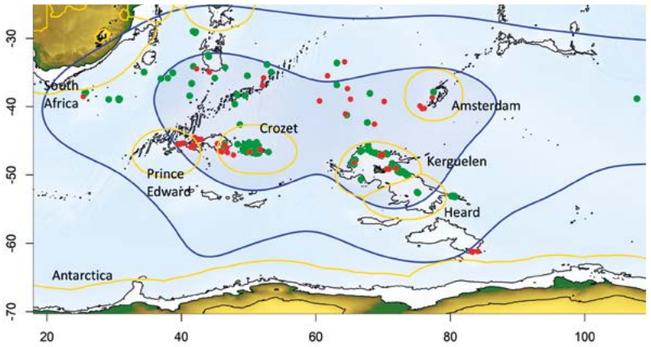


Figure 6 - Study area showing the overall distribution range (blue line; 90% nucleus of all birds tracked), central area (blue area; 50% nucleus) and location of radar detections with an associated AIS signal (green dots) and without an associated AIS (red dots). The EEZ boundary is shown in yellow.

Using albatrosses fitted with beacons detecting and locating the presence of vessels, and instantly transmitting the information to the authorities, it was possible to calculate the first estimate of the proportion of undeclared fishing vessels operating in national and international waters of the Southern Ocean. We were able to show that in international waters, more than one third of the vessels did not have an automatic identification system; in national exclusive economic zones (EEZs), this proportion was lower on average, but varied depending on the EEZ (Fig. 6). For example, in the EEZ around South Africa's Marion-Prince Edward islands, none of the vessels were declared.

Ocean Sentinel was also able to provide unprecedented information on the attraction of seabirds to ships, providing access to critical information on risk-assessment plans for endangered species. The attraction and time spent near a fishing vessel differed between species, age, and vessel activity. Fishing boats attracted more birds than other boats, and juveniles encountered half as many boats and showed a lower attraction to boats than adults (Fig. 7). Adult and juvenile Amsterdam albatrosses were much less attracted to fishing boats than larger albatrosses. This result makes it possible to understand why the Amsterdam albatross population is currently the only species whose numbers are increasing in the Southern Ocean, while other species such as the great albatross are in decline due to their attraction to fishing ships such as tuna or toothfish longliners which result in significant accidental deaths.

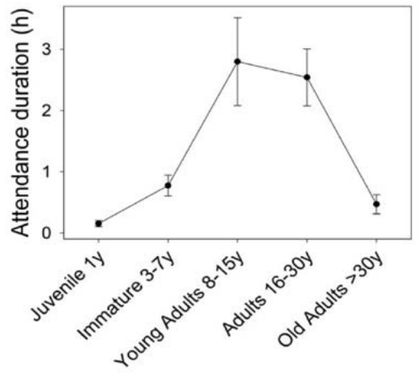


Figure 7 – Time spent associated with fishing boats for the various albatross age classes.

4. CONCLUSIONS AND PERSPECTIVES

This study shows that the development of new technologies offers the possibility to implement large-scale conservation policies using marine birds to patrol oceans. This programme is complementary to other efforts to provide independent information about the distribution of fisheries. It is a good example of how the development of new technologies applied to conservation makes operational conservation possible and could be used in other animal taxa such as sea turtles or sharks, where conservation actions and knowledge about independent bycatch locations is crucial in order to protect these endangered species.

In general terms, Ocean Sentinel has the potential to provide information that is very much in demand by the government, fisheries authorities and researchers today. It is based on technological development, combined with a concept of democratising access to data, making information about the location of fishing vessels instantly available to anyone. In the Kerguelen and Crozet EEZs (TAAF), vessels authorised to fish must always declare their position at all times. By inference, all other fishing vessels identified in the area are illegal. When their position is identified, it can be made available to the appropriate authorities, and if there are any Navy vessels or surveillance vessels in the area, an intervention at the location detected by Ocean Sentinel can be carried out.

The project also provided a new perspective on the relationship between seabirds and fisheries as well as on the extent of fisheries in areas where it is not possible to use conventional surveillance methods (boat or aerial patrol). Surveillance by boat, air and radar (e.g., RadarSat) is a very expensive method and costs make it difficult to consistently cover large areas. Ocean Sentinel also makes it possible to estimate the accidental mortality of monitored seabirds induced by fishing, to study the behaviour, time-budget, risk of animal mortality in relation to the presence of fishing boats and to compare them to natural situations in which fishing vessels are not present. Within the framework of international agreements or commissions for fisheries management, such as Tuna Fishing Commissions (IOTC, CCSBT, etc.) or for Conservation (such as CCAMLR or ACAP), Ocean Sentinel makes it possible to provide information on the fishing effort in specific sectors and their potential impact on marine resources. For example, in the IOTC or CCSBT sectors where mortality is very high among albatrosses and petrels, these bodies do not have the locations of the fishing vessels. The international ACAP convention, which partially funded the operational phase, has made it clear that they are interested in the potential of the Ocean Sentinel programme, especially in its effort to better identify and mitigate threats affecting the conservation status of albatrosses and petrels worldwide.

Great albatross at sea with a centurion beacon, North Kerguelen (C. Matheron, TAAF)

After this first operational phase, the Ocean Sentinel system was used at other sites, especially in the New Zealand EEZ in collaboration with the New Zealand Fisheries Department, which is trying to understand why a potentially threatened albatross population is declining. This decline could be due to an illegal fishery operating on the edge of the EEZ as well as in South Georgia by the British Antarctic Survey. A fourth generation more-compact radar detector logger, called sputnik, can now be used to equip smaller species. It was used successfully on black-browed albatrosses in Kerguelen in November 2020 and will be deployed in 2022 on two species of albatross in the Hawaiian Islands in collaboration with the University of California and the Wildlife Service.

In September 2021, Ocean Sentinel received the Horizon Impact Award from the European Commission. This award recognises programmes with concrete results among projects funded by the European Union that have a demonstrated impact on our societies in the economic, societal, political and environmental fields.

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THE USE OF WOOD FOR **SUBANTARCTIC ISLAND REFUGES**

Interview

ROMUALD BELLEC

I am a logistician in the Subantarctic Islands where I work on the setting up and maintenance of sites and infrastructures for the scientists.

Apart from the main station, each island hosts refuges located in isolated sites. They can be a few hours away from the base by foot or by boat. There are also camp areas where there are no inhabited structures. We provide watertight barrels, touques, accompanied by a tent allowing people who stay a few days to set up a light camp.

In the 60s and 70s, FILLOD brand arbecs, a model of metal shelters, were installed on various sites on the islands. But it was quickly realized that they were very constraining for the implementation and the maintenance compared to wood. Indeed, wood is easier to work with regardless of the technician on site. It is also easy to transport and to repair, we can even do carpentry inside the shelters to fit them out! So, as early as the 70s and 80s, wooden modules were built.

At the beginning, the idea was to install temporary structures, easy to assemble and dismantle, in order to find adequate study camps, close to animal colonies or remarkable geological sites for example. **With time, some sites became permanent because it was interesting to come back there to do a follow-up every year.** The Yellow-billed Albatross colony on Amsterdam Island is a good example, as it has been observed and studied for about 60 years.

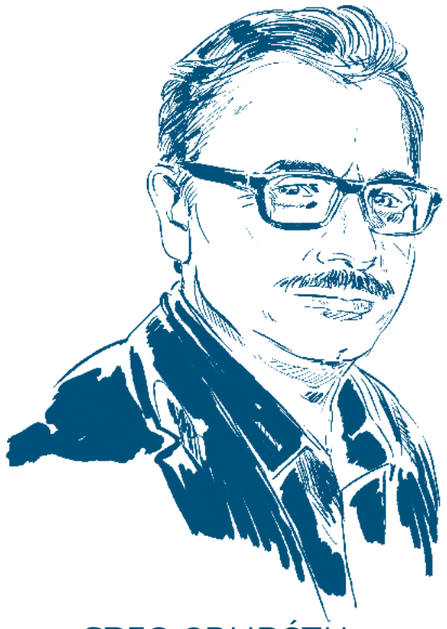
In the early 2000's, our teams continued to work on the viability of the refuges and the rehabilitation of all the lodging sites to meet the current needs. The use of computers and electrical equipment requires improving the comfort of people staying in these shelters. From now on, the energy is produced thanks to photovoltaic panels and the water treatment is also realized on each site. These huts offer better conditions for scientists to work, rest and eat!

We have not abandoned wood for other more "modern" materials because, for example, plastic materials require very good weather conditions to be assembled. It's amazing to think that you can make shelters sustainable from a wooden structure that may look breakable but in fact, wood breathes, it has plasticity and it responds well to outside conditions. **These are living, sustainable, biodegradable shelters and wood provides better insulation than other solutions.** An all-composite shelter looks like a refrigerator because it doesn't breathe and the accumulated condensation cools the interior down a lot. Finally, the quality-price ratio of wood is more interesting

The particularly harsh weather conditions of the sub-Antarctic islands damage the shelters and on average a complete renovation is carried out every 10 years.

HUMAN/ENVIRONMENT CO-EVOLUTION IN EASTERN SIBERIA

FROM THE FIRST CONTACTS WITH EUROPEANS TO GLOBALISATION



ERIC CRUBÉZY
PATRICE GÉRARD

UMR 5288 Centre for Anthropology and Genomics of Toulouse

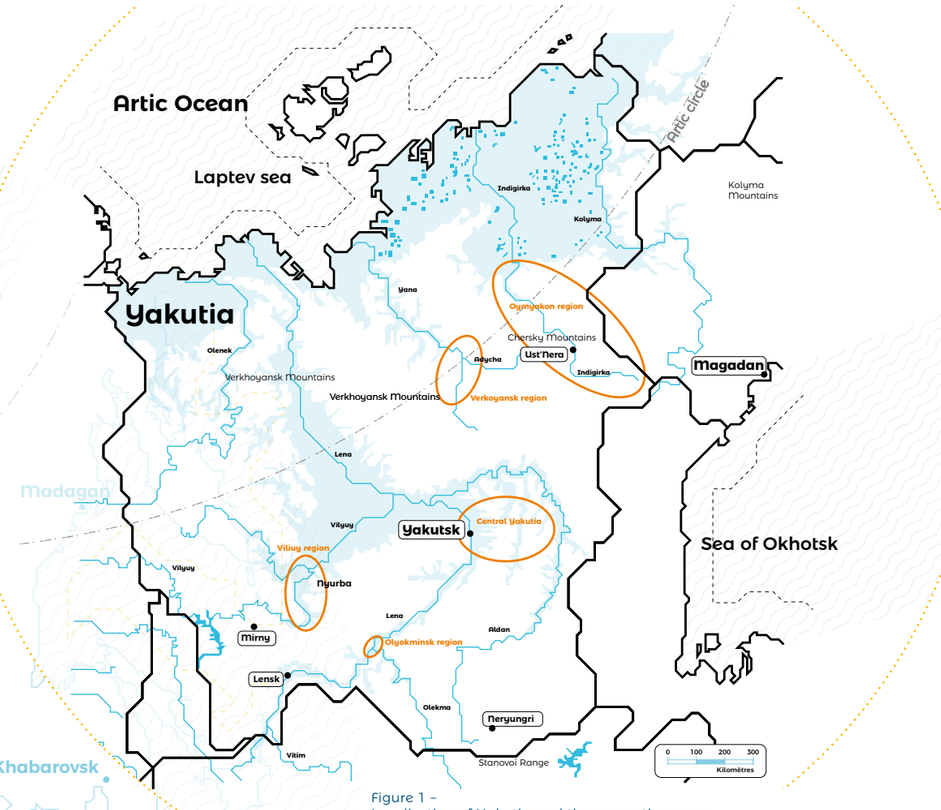


Figure 1 –
Localisation of Yakutia and the excavation areas.

ABSTRACT

Archaeological excavations, epidemiological and genetic surveys, and historical, ethnological and *palaeogenetic* work carried out since 2002 in the Sakkha Republic (Yakutia) have provided a new perspective on the recent history of this part of the world. Yakutia is a laboratory that compares these different sources of information and their respective contributions to the evolution of populations, their adaptations to diverse and changing environments and infectious diseases. After rethinking the complex history of this part of the world and the physical, cultural and political confrontation between hunter-gatherers, herders and Russian newcomers from 1632 to 1922 *AD*, we try to define a "total archaeology" combining palaeogenomics and cultural data.

Paleogenetics recovers and analyses DNA sequences sequences of organisms from the past from their fossil remains

Anno Domini: after Jesus Christ

Spanning three million square kilometres, the Republic of Sakkha (Yakutia) is the largest autonomous republic in the world and, with one million inhabitants, one of the least populated (figure 1). It is the world's largest producer of diamonds, it has all the known chemical elements in its territory and it has supplied the majority of intact mammoths in recent years in addition to producing close to around 40 tonnes of mammoth ivory each year. In addition to these classifications worthy of the book of records, the subsoil is permanently frozen throughout the whole of its territory and two cities, Oïmiakon on the Indigirka River and Verkhoyansk near the mountains of the same name, compete for the title of coldest inhabited place in the world outside the Arctic. For anyone interested in human variability, there is something that is even more astounding... The Yakuts, who represent the largest population in this area, speak a language affiliated with the Turkish languages and, for the most part, they are still cow and horse farmers. Their oral epic tales or

Olonkho which can be as long as 15,000 verses tell of the peregrinations of their mythical heroes who would have come from the south a long time ago...

Using these elements as a starting point, one of us (Eric Crubézy) established the first contacts with Yakut researchers 19 years ago. Two of these contacts were Anatoly Alexeev, the rector of the University at the time and Olga Melnichuk, director of the language department, and specifically French grammar[1]. At that time, we were carrying out the first palaeogenetic analyses with Bertrand Ludes[2]. Our experiences in Egypt and Mongolia had convinced us (long before the others and before this advance was beneficial) that there is nothing better than cold environments for good DNA conservation.

At the time, we thought that the collaboration between Eric Crubézy, an anthropobiologist specialising in funeral practices and the evolution of settlements, and Bertrand Ludes, a forensic pathologist specialising in kinship relations, would be a win/win situation (an unusual term at that time!). For our Russian colleagues, who are passionate about the history of their republic, this was a way to extend excavations that have been based on a long tradition initiated by, among others, the Russian archaeologist Okladnikov who had transported one of the oldest churches in the Arctic from Zachiversk over the Indigirka (67°27'N, 142°37'E) to Novosibirsk (southern Siberia) (figure 2).

For us, it was about developing methods at an experimental field site for archaeology since we would have access to well-preserved bodies and ethnographic and historical data that could act as a safeguard in our interpretations (figure 3). Through friendship, this programme expanded and with each passing year, COVID aside, led to increasingly more extensive field excavations and laboratory studies.

In almost 20 years, alongside a hard field core, over 300 Russian, French and European researchers and students have worked by our side in order to excavate more than 180 frozen graves. Initially supported by the Foreign Affairs Excavation Service, this program, which has become increasingly more focused on the biological side of things over the years, is now receiving funding from the French Polar Institute. The CNRS and its counterpart, the Russian Research Fund, have fostered the development of an Associated International Laboratory and soon an International Research Laboratory, greatly facilitating scientific exchanges and agreements.

Figure 2 – Zachiversk Church (1700 AD) in the open-air museum of the Institute of Archaeology at the Academy of Sciences in Novosibirsk. Initially in Zachiversk on the Indigirka River, it was dismantled and transported to Novosibirsk in southern Siberia in the 1970s under the direction of the archaeologist Okladnikov (1908-1981). This transport and restoration is one of the great achievements of Soviet archaeology.

1. Crubézy, Melnichuk, and Alexeev 2020

2. Actuel directeur de l'UMR 8045 BABEL

A BREAKDOWN OF THE ENCOUNTER

BETWEEN ARCHAEOLOGY, GENETICS AND HISTORY

Today, the past can be approached by several types of methods: historical, archaeological, environmental, genetic, etc. Several major questions linger in researchers' minds:

How are our samples and data biased or representative of a 'truth'? How can these different approaches be integrated? What were the factors or forces responsible for human and societal evolution?

With regards to history, current discussions on gender, minorities and slavery demonstrate that the awareness of a biased history that would have left out many actors is increasingly present in our societies. For archaeology, it is increasingly evident that statism societies with their large constructions and concentrations of populations have left more traces than non-statism societies with mobile groups, which have been somewhat forgotten by history. The development of genomics and palaeogenomics very quickly sheds light on the evolution of past populations; however, despite the power of genomics, the question of samples and their representativeness remains crucial. Who was buried? Are the funeral complexes or cemeteries of the past, what we sometimes call the 'world of the dead', representative of the 'world of the living'?

Figure 3 – To reach the excavation areas, helicopters and Russian all-terrain vehicles are needed in summer, whereas snowmobiles are used in winter to reach some of the indigenous populations for epidemiological surveys.

Obviously, environmental issues are currently of great concern, but the question of whether they caused the collapse of civilisations is still the subject of much debate. Weren't political, economic forces, infectious diseases much more important? If several factors were interacting with each other, how is it possible to identify these interactions and their modalities? Although more and more analyses are being performed, concordances between various data and various sample sources are generally not addressed and when they are, they often lead to 'storytelling' which more often reflects the prevailing 'mainstream' or the researcher's assumption than actual proof.

These are not new questions. For French researchers, they overlap with the questions asked by Fernand Braudel on the Mediterranean (1949) and those asked by Michel Foucault (1976) on power. Consequently, it is necessary to differentiate between the long-term history which is based on the links between geography and the adaptability of populations ('setting the scene'), cyclical time which is often punctuated by economics and politics and event-driven time of conventional history. Among the forces driving societies, often without their knowledge, how can we recognise the collective 'webs of significance' that make up a culture? Compared to Fernand Braudel and Michel Foucault, and to researchers in the second half of the 20th century, the novelty of these discussions is two-fold. First, they take biological evolution into account, which is becoming better understood through genetics and genomics and, second, they provide mathematical answers, not just discursive ones, by using advances in the powers of calculations and modelling which still need to be greatly improved in these fields.

Ultimately what we are missing are human models for a region of the world where we can carry out 'archaeology and a total history' given the sheer number of well-preserved documents that exist, and the various types of samples (past and present biological samples, historical and ethnological documents, geographic data) that can be compared with each other. This region exists: Yakutia. However, the fact that researchers feel, deservedly, that the region of the world where they are working is the best may come across as quite pretentious to readers! After all, the world is big and huge swaths of land are frozen, enabling the preservation of bodies – the truth is that Yakutia is only just one of these areas in the world. However, when the ground is frozen it is difficult to dig pits in order to bury bodies. Most of the populations who live in these types of places leave their dead on the surface under piles of stones or on platforms and it is therefore rare to find well-preserved remains... However, the Yakuts, for reasons still unknown, buried some of their dead well before the 19th century (figure 4). This was certainly because 'they came from areas where the dead were buried' but also because very early on, their leaders were in contact with Christianised Europeans. Other populations placed their dead on top of platforms, called arangas, which are sometimes quite large given that they would also bury one of the deceased's horses there. We know about these ancient arangas from photos taken by ethnologists at the late 19th century and early 20th century. Our team has excavated the remains of three arangas, which had collapsed in the middle of the woods (figure 5). However, it seems that forest fires over the last ten years have led to their almost total disappearance.

Figure 4 – A frozen tomb of a Yakut shaman along with the reconstruction of her outer garment.

Figure 5 – **Arangas**.
On the left, anonymous photo from the end of the 19th century, in the middle of the discovery of an aranga in the forest by the Franco-Russian mission (photo Jean-François Peire); on the right, its reconstruction using excavation data (Nicolas Sénégas).

Before the end of the 17th century, tombs were rare with the result that today's archaeologists and anthropobiologists struggle to find them, especially since the 'customs' guiding the burial sites seem to vary from one region to another. After 1689 AD and a whole series of political and economic events, the number of tombs increased and were easier to find. The development of private property under Russian influence pushed wealthy and polygamous families to bury the prestigious dead or those who were feared (figure 6), such as young shaman girls[3], on 'promontories' dominating alases: thermokarst lakes that form via the melting of the permafrost below (figure 7). It is possible to locate the tombs using satellite photos, Soviet maps detailing the human landscape and, in particular, the good field knowledge of our Yakut colleagues. After 1805 AD and the rise of Christianisation and a Russian Orthodox way of life, burial in community cemeteries for everyone became the rule until 1922. Always found in the middle of abandoned fields, they can be used to study population densities (figure 8). Certain isolated tombs from this time period, often thought to be older than they actually are by archaeologists before the excavation started, are a good source of subjects from this period. Currently, our studies are lacking information on the biology of Homo sovieticus...

In order to be able to compare ancient and recent subjects, genealogical and epidemiological studies are being conducted on contemporary Yakut populations from cities and the countryside, populations of northern fishermen, Evenki and Eveny reindeer herders as well as isolated populations of the last descendants of Russian settlers from the Siberian Arctic, living there since the 17th century, or perhaps even earlier than that according to certain hypotheses (figure 9).

Figure 6 – Kouranakh's frozen tomb (Verkhoyansk): young shaman with a metal sun-like circle on his chest.

Figure 9 – Lifestyle, diet and health studies are performed in winter when women and men are at home. Here, a Yakut anthropologist and joint supervisor, is asking an indigenous woman questions in Yakut (after the woman and the Ethics Committees gave their permission).

Figure 7 – An **Alaas**, a thermokarst lake in central Yakutia.

Figure 8 – 19th century cemetery (wooden superstructures).

Like much of Siberia, Yakutia, which had another name at the time, experienced the expansion of the Russian Empire. This expansion was driven by the search for furs, especially sable fur, also called 'soft gold', which accounted for up to 10% of Russia's gross domestic product in the 17th century. To do this, the model developed by the government was to tax native populations on furs and to tax private entrepreneurs on the importation of furs into Russia. The result was a flourishing, finicky, corrupt administration and a whole series of edicts issued by the Tsar of Russia in order to produce an elite class and leaders with whom his administration could have discussions and who would collect tax for the crown. Historians therefore have a very large number of archived documents, preserved and recorded for the most part, at their disposal which provide economic and administrative information as well as information about the daily life; this is because it was necessary to avoid internal wars as they were sources of bankruptcy for the government. In the 18th century, the goal of the major scientific expeditions organised by the Russians and including foreign scholars was to increase the encyclopaedic knowledge about these immense territories in order to assert the Czar's presence and power. The result was volumes of books about these expeditions, and on the way of life, food, and natural resources of indigenous populations. Lastly, starting in the 18th century and continuing throughout the 19th century, political exiles were sent to Siberia, especially Yakutia, and certain religious communities (Old Believers in particular) that were not especially welcome

3. Crubézy et Nikolaeva 2007

elsewhere also arrived in this region. This provided an influx of intellectuals who then encountered the indigenous populations; the many (never published) notebooks of these intellectuals, which included famous ethnologists or simply amateurs, can still be found in national or local museums. In 2019, we 'discovered' at the Oliokminsk Museum, in southern Yakutia, several hundred photos (currently being inventoried and scanned) on life in the region at the end of the 19th century. In the 19th century, a large community of Old Believers belonging to the Skoptsy sect lived in southern Yakutia, which was also known as Little Ukraine because of its agricultural potential. It was possible for Old Believers to have a sexual relationship at the start of marriage and to have one or two children before castration: the men had their testicles and sometimes their penis removed, women had their breasts and sometimes their vaginal lips removed. One influential person, Erofei Eresko, would order a camera and document life in the Oliokminsk region in an extraordinary way at the end of the 19th century (figure 10).

Figure 10 –
Photo of Erofei Eresko, photographer and Old Believer (Skoptsy) from Oliokminsk who, through his photographic work, leaves a unique testimony to what life was like in the region at the end of the 19th century (©Oliokminsk Museum). Note the Russian merchant with his abacus who is exchanging Western or Chinese products intended for indigenous women for furs, and the administrative staff responsible for making sure that the weighing is done properly.

4. Romanova et al. 2020
5. Crubézy and Nikolaeva 2017
6. Librado et al. 2015
7. Romanova et al. 2019
8. Biagini et al. 2012
9. Crubézy and Nikolaeva 2017
10. Zvénigorosky et al. 2020

FROM ONE PROGRAMME TO ANOTHER

After carrying out explorations in the heart of Yakutia, the famous country where alases are found and location of the Yakuts' homeland with its sheltered meadows ideal for herds and harvesting fodder, we headed for areas conquered by the Yakuts just before the Russians arrived in the 17th century. The Vilyuy region is a wet and marshy area. Here, the Yakuts had to adapt to the banks of rivers as well as to areas where it is difficult to move around on horseback (e.g., Verkhoyansk in the north). The Yakuts also learned from reindeer herders and borrowed some their adaptations. While they were far from their bases in the Indigirka region, in the northeast, they suffered terrible setbacks from the Tungus who forced them back towards the south.
In these areas, we have increased the number of excavations while developing the work and theses of Yakut historians and anthropologists[4] in order to learn more about the history and while increasing the number of palaeogenetic and genetic studies. The result is a new perspective on evolution in this part of the world[5]. The *long-term* history shows the supremacy of herders over hunter-gatherers. The Yakuts are the last wave of horse breeders, selected by the climate[6], who started to migrate northward long before our era began. During this migration, and due to a larger demography, the Yakuts were able to force back the hunter-gatherers, and who finally arrived at the Arctic Ocean in the 19th century by adapting their food and lifestyle to each environment[7]. With regards to the cyclical time of epidemics, we have shown how certain diseases[8] decimated the indigenous populations and from which the Yakuts recovered better than others because of ancient contacts with Europeans and links with the Russians which allowed them, through education and certain exceptional men, to become vaccinated against smallpox very early on[9]. In terms of the event-driven history, this ethnic group is divided into tribes and clans, some of whom took advantage of an alliance with the Russians to establish their supremacy over others, especially populations of hunter-gatherers and reindeer herders in the surrounding areas and who were either assimilated into the Yakuts or who disappeared[10]. Russian administrators were also unwittingly 'victims' of this supremacy which was at the origin of a veritable Yakut golden age from which the current autonomous republic descends. This begs the question of who were the victors and who were the defeated?

With the end of the ANR LifeChange project led by L. Orlando[11], it is now the genomic history of the Yakutia that is about to be published and which will provide a 'total archaeology' with kinship relationships between distant subjects, a comprehensive study on infectious diseases and epigenome changes. The works of L. Quintana-Murci[12] and both Yakut and French colleagues will form a 'bridge' between the 19th and 21st centuries in addition to describing the impact of globalisation and its lifestyle changes on the Yakuts and indigenous peoples. Lastly, this work will lay the foundations for a new Cultiak programme which will make it possible to better understand the biological, economic and cultural exchanges brought about by colonisation in fields as diverse as knowledge of mines or metalworking thanks to work with A. Nomine in particular[13].

CONCLUSION

In addition to their scientific interest, our works have shed new light on the Yakuts and their Republic is attracting more and more scientists and tourists who have heard about this region through documentaries, among other sources[14]. At a time when many parts of history are being rethought, the peculiarities of the Yakuts are increasingly being emphasised. In July 1776, when the thirteen British colonies in North America seceded from Great Britain after campaigning for several years, one of the slogans was 'no taxation without representation'. Thirteen years later, when the French Revolution began, the Yakuts demanded their autonomy insisting that the taxes they paid bring a lot of money to the Russian government. The difference between the British colonies and the Yakuts is that, in the first case, it was the colonisers who conveyed a message of independence and, in the second, it was the colonised who did so. This is an astonishing example to reflect upon at a time when indigenous peoples are trying to be recognised.

11. UMR 5288
12. Collège de France
13. UMR 7198
14. Jampolsky 2007; Molia and Lutz 2017

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ENERGY SUPPLY
ARCTIC STATION CORBEL

Interview
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I am responsible for the scientific operations in the Arctic, but also for the logistic organization of the Awipev station with my German counterparts of the Institute. Through the Ny Ålesund Science manager (Nysmac), I also participate in the evolution of the scientific and logistic organization of the international village of Ny Ålesund. Finally, I advise and act as a reference for the research projects that the Institute supports outside Svalbard but in the Arctic.

What is the specificity of the Corbel station in Ny Ålesund?

The Corbel station is the only French infrastructure in the northern polar zone, on Norwegian territory. It is a station located 5 kilometers from Ny Ålesund that can accommodate 8 people, ideally placed for studies on the Austre lovenbreen glacier located nearby. It is also an ideal station to host light sensitive studies compared to the Ny Ålesund village or other polar station but also ionospheric science, aurora studies, ... and atmospheric physics and chemistry.

The energy supply of the station was complex to set up

We wanted to make Corbel a clean station that uses green energy to allow us to host projects in atmospheric physics and chemistry in very good conditions. There is not much wind in general, so the biggest challenge is to produce energy during the polar night and to have enough storage capacity to compensate for the lack of wind.

What solutions have been chosen?

The first solution is the use of solar panels, of 7 Kw, very effective in spring and during the summer, associated with a consequent set of batteries. It autonomy without problem during these 2 seasons. The association of solar panels with a wind turbine of 2.5 Kw allows to extend the season with the same energy comfort. The solar panels and the wind turbine are relatively simple systems, which can be maintained in good condition easily with a reasonable installation cost.

The various fuel cells (hydrogen, methanol...) have not been retained until now because they present a certain number of disadvantages being difficult to manage in polar zone: complex maintenance, supply of fuels to be made regularly, storage...
Only a generator is used as a back-up in case of lack of energy and to recharge the batteries so that they do not freeze, which would destroy them.

The main problem is still the lack of energy in winter to accommodate more scientific projects during this period. One of the solutions is the setup of a second wind turbine allowing a more efficient recharging of the batteries during the windy periods.

What is laser data transmission?

The village is a radio silence zone, so WIFI transmissions are forbidden. The setup of a 5 km long cable on the tundra was not possible either. So, the transmission by optical beam was the solution adopted to obtain a computer network at the station Corbel working at high speed (1 Gb/s). The solution by satellite transmission would have been of a lower flow for a higher cost of use.