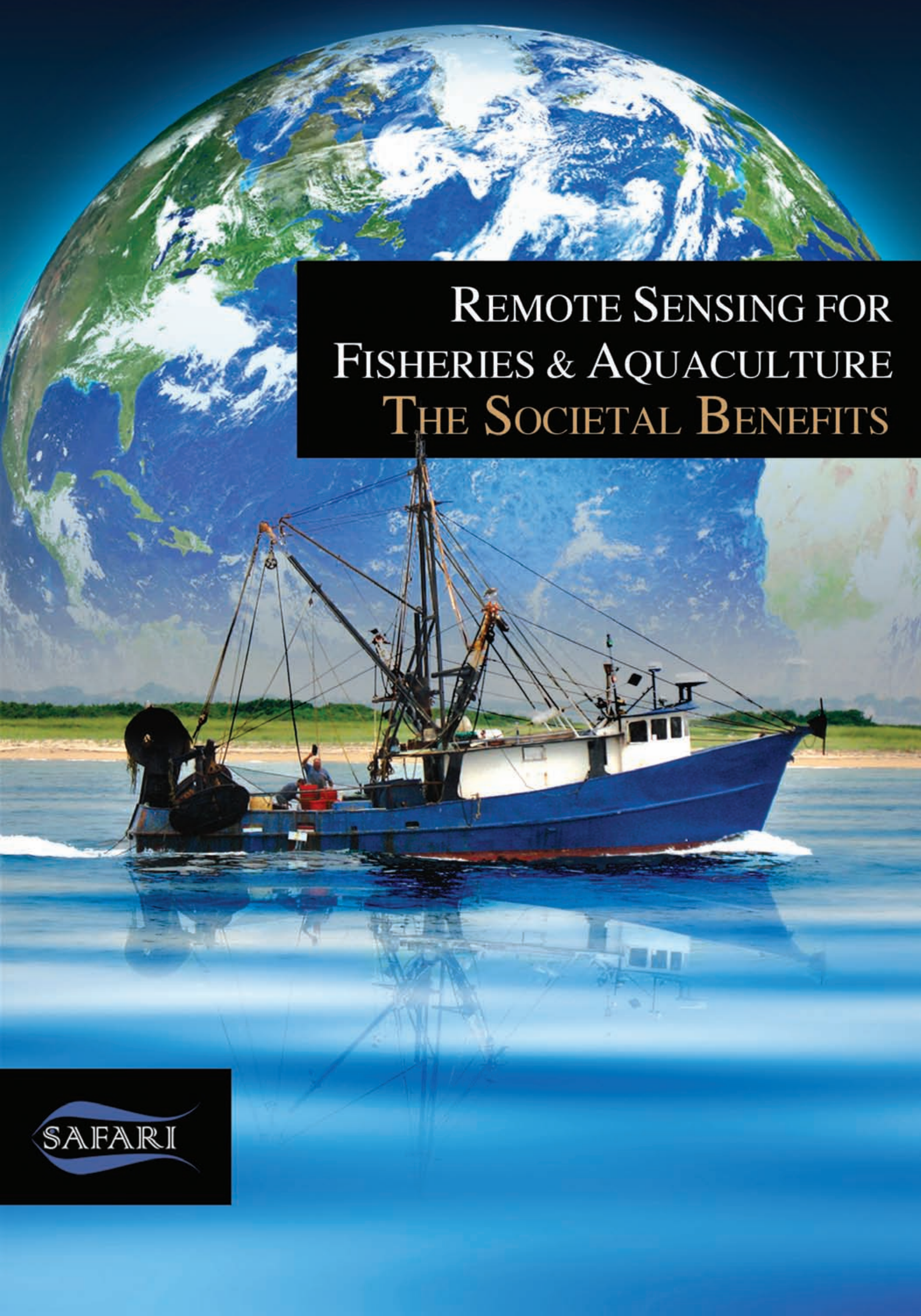
Remote Sensing for Fisheries & Aquaculture
The Societal Benefits



SAFARI

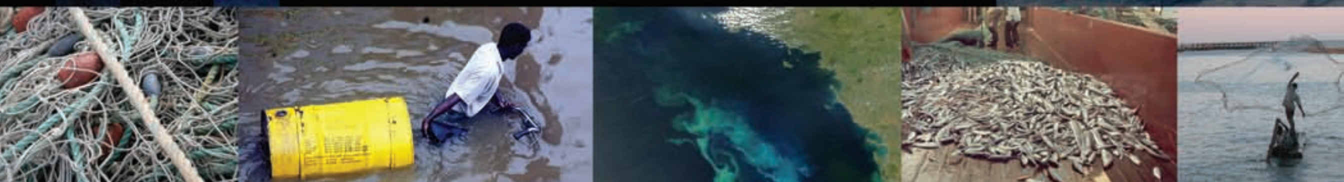
Earth observation by remote sensing is a technology that has demonstrated many benefits to society. SAFARI (Societal Applications in Fisheries and Aquaculture using Remotely-Sensed Imagery) is a new programme aimed at the application of remote sensing to the particular societal benefit areas of fisheries and aquaculture.

This brochure addresses the following important questions: What are the problems facing the fisheries on a world scale? What general strategies have been adopted by the society to meet the challenge? How can remote sensing help to make these strategies work?

World Fisheries Are Under Threat

The Number One Problem facing society today is **climate change**, a phenomenon that is truly global in scope. Environmental conditions in the ocean are changing in ways that are difficult to predict. We do not understand how fluctuations from year to year in the ocean environment affect the future fish stocks.

There is a growing problem of **overpopulation** in the world. The rate of population growth is highest at the margins of the continents, leading to acute human impact in the coastal fringes of the ocean, where the overwhelming proportion of global fishing effort is directed.



Coastal populations rely on protein from the sea, but there is mounting evidence that 75% of this food source may be overexploited or depleted. The developing economy of aquaculture is vulnerable to outbreaks of harmful algae, commonly known as red tides. Water quality in the coastal zone is of major concern for the world community as well as for the tourism industry.

Public awareness of the plight of species at risk, and of the necessity to maintain **biodiversity**, is at an all-time high. Illegal fishing and fishing outside allowed areas undermine efforts to conduct rational fisheries management. Some 65% of the oceans lie outside national jurisdictions and in these areas fisheries are difficult to control. This problem becomes more acute as fishing technology becomes more sophisticated.

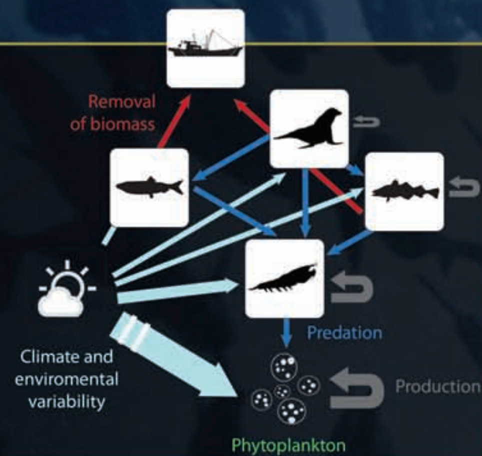
How is Society Coping With These Issues?

There is a maturing consensus between governments that stewardship of the oceans should be carried out through **ecosystem-based management** and an increased emphasis in the intergovernmental arena on **earth observation** (witness the formation in 2003 of the ministerial-level GEO, Group on Earth Observations). Moreover, **international governance** on the high seas is an issue of emerging importance. Finally, there is an increased interest that fish harvesting be **more efficient and more economical**.

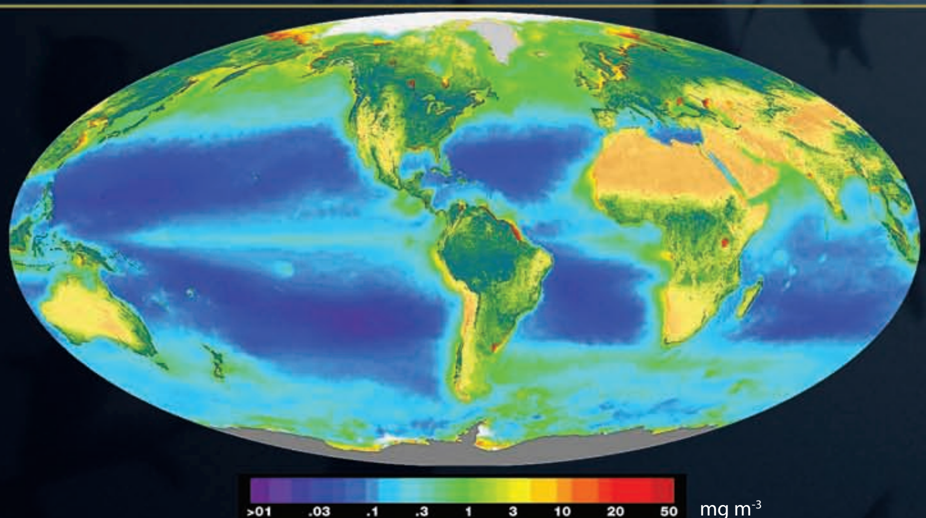
How can Remote Sensing Support our Efforts to Manage Fisheries and Aquaculture?

Marine Food Web

Remote sensing of ocean colour provides our only window into the ocean ecosystem on synoptic scales. It is the sole method we have available to take a global view of the marine biosphere. It can help us to learn how the marine ecosystem is responding to global warming and ocean acidification. It can also be used to provide essential ecosystem information in aid of international governance on the high seas.



Example of a marine food web. The dark blue arrows show the energy transferred up through the food web by predation, while energy removal by exploitation is shown in red arrows. The whole ecosystem is vulnerable to the effects of climate change and environmental variability (light blue arrows), the greatest and most direct effects being at lowest trophic levels (mainly on phytoplanktonic production). Remote sensing of ocean colour allows the estimation of the phytoplankton biomass and production at the base of the marine food web. Courtesy of Johanna J. Heymans (Scottish Association for Marine Science, UK).

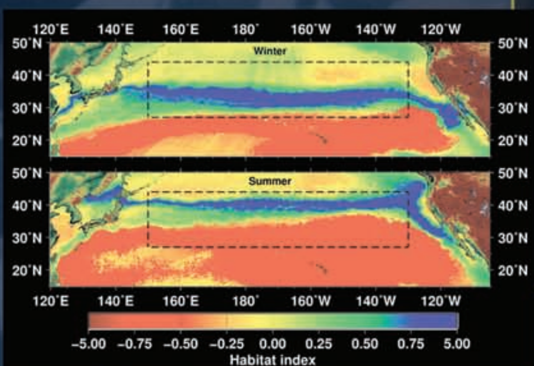


Climatology of the global estimates of chlorophyll-a concentration (a proxy for phytoplankton biomass) from SeaWiFS satellite imagery (1997-2000). Chlorophyll concentration is high in coastal areas (green to red areas) and low in the tropical gyres (deep blue). The ultra-oligotrophic gyres are considered to be the biological deserts of the global oceans. Satellite image provided by the Ocean Biology Processing Group, NASA/GSFC.

Marine Habitats

Remote sensing of ocean colour can be used to monitor water quality as a tool in coastal-zone management, for example to study the degradation of coastal habitats through removal of mangroves or intense sediment loads from river outflow. It also allows us to visualise and quantify the effect on the marine ecosystem of major perturbations at the regional level, for example El Niño.

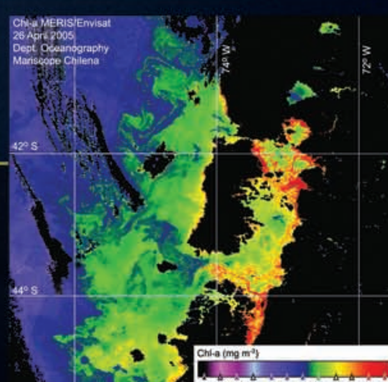
Remote sensing can be used to help delineate optimal sites for Marine Protected Areas and also habitats of species at risk. It can also be used to monitor no-catch areas. Finally, remote sensing of ocean colour can be used to monitor the onset, expansion and fate of harmful algal blooms as an aid to the aquaculture industry.



Climatological habitat map for pelagic loggerhead sea turtles in the North Pacific, based on a number of variables including satellite data (SST and SeaWiFS chlorophyll) for two different seasons. Blue areas represent a high probability of finding loggerhead sea turtles. Longline fisheries should be restricted from these areas to lower bycatch rates. Modified from Kobayashi et al. (2008), J. Exp. Biol. Ecol. 356: 96-114.

Sediment load from the Mississippi River. The increase in turbidity resulting from sediment load affects the water quality and marine habitat of the Gulf of Mexico. Satellite image provided by the European Space Agency.

Red tide event (Harmful Algal Bloom, HAB). Phytoplankton organisms forming the red tides often produce toxins which bio-accumulate in the local marine food web and can affect humans through consumption of contaminated marine resources. Photo credit - Grant C. Pitcher, MCM, South Africa



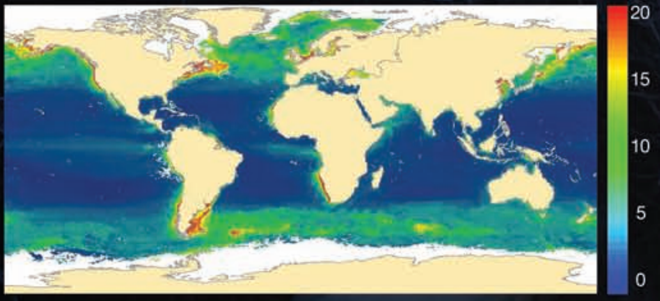
An extensive bloom of the dinoflagellate Gymnodinium chlorophorum in southern Chile, captured by the MERIS sensor on 26 April, 2005. This phytoplankton species is non-toxic but forms extensive blooms under specific environmental conditions. The decomposition of these organisms by bacteria results in anoxia (low oxygen levels) which represents a threat to the shellfish harvesting and salmon aquaculture industry. Satellite image provided by the European Space Agency under the Category 1 Project 1336.

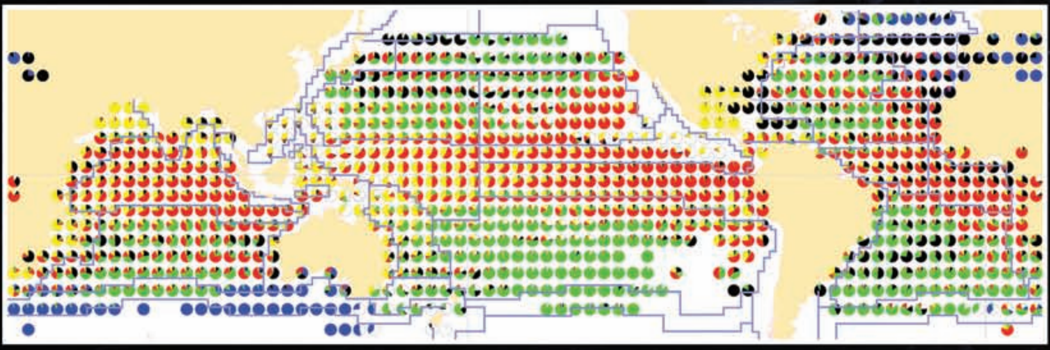
Fisheries Management

Remote sensing of ocean colour provides information on interannual variability in the marine ecosystem, helping to explain the effect of environmental fluctuations on the survival of larval fish and invertebrates. It may also be used to identify potential fishing zones, allowing fishermen to work more effectively and economise on fuel. This is certainly not to encourage overfishing, but merely to provide practical ways for sustainable management and more economical harvesting.

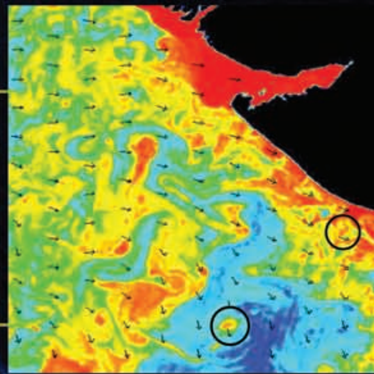
Remote sensing of ocean colour can provide cost-effective ecological indicators to apply serially and operationally in ecosystem-based management. The indicators also help to characterise ecosystem change following perturbations by natural or man-made causes. Ocean colour continues to provide priceless information, unobtainable by any other method, essential for researchers on a broad range of problems in fisheries oceanography.

Modelled distribution of global fish biomass (g m^{-2}) using remotely-sensed estimates of primary production on a 36 km^2 scale (white areas represent no data). Fish biomass is estimated to be high in coastal waters and at higher latitudes, matching the patterns found in chlorophyll concentration. Redrawn from Jennings et al. (2008), Proc. R.Soc. ,doi:10.1098/rspb. 2008.0192. Courtesy Rodney Forster (Centre for Environment, Fisheries and Aquaculture Science, UK).

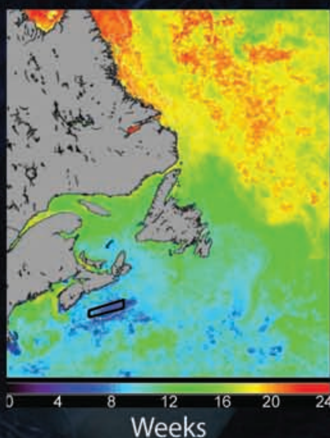


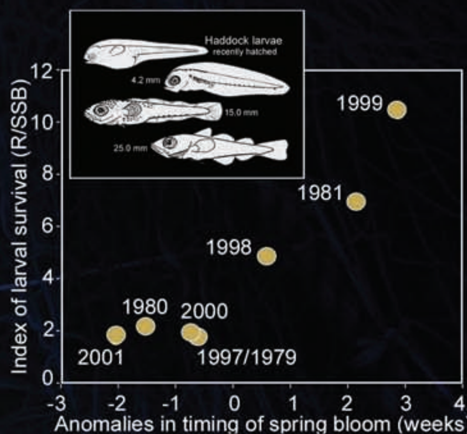


Average catches (1952-2003) of the global longline tuna fishery, represented as small pie charts according to tuna species (yellow-yellowfin; red-bigeye; green-albacore; blue-bluefin tuna; black-swordfish; white-others). Superimposed blue lines are the Longhurst provinces. It is clear that the species distribution of tuna is strongly related to the ecological structure (provinces) as revealed by ocean-colour remote sensing. Courtesy of Alain Fonteneau (Institut de Recherche pour le Développement, France).



Location of Potential Fishing Zones (PFZ) off the coast of India estimated from remotely-sensed data (chlorophyll concentration from OCM, temperature from AVHRR and wind from QuikSCAT-SeaWinds). PFZs are indicated by the black circles. Satellite image provided by R.M. Dwivedi (SAC/ISRO, India), under the IRS-P4 OCM Utilization Programme and SATCORE.





(left) Timing of the maximum phytoplankton biomass in the Northwest Atlantic from February to July, derived from SeaWiFS climatology (1998-2001).

(right) Relationship between larval haddock survival index (normalized to recruitment) and the local anomalies in bloom timing. Data from the continental shelf off east and southern Nova Scotia (see black rectangle on map) for the periods 1979-1981 and 1997-2001. Adapted from Platt et al. (2003) Nature, 423: 398-399.

Science and Outreach

Ocean-colour imagery has been of great significance in developing public awareness of ocean processes. Undoubtedly, these images are icons of our time. However, their striking beauty should not be allowed to obscure the reality that they are based on the most rigorous physical science. Ocean colour provides outstanding material for education at all levels. The images are readily available to the general public through the world-wide web, and in fact they are in very high popular demand. An informed public is a good ally to conservation of the fisheries. Ocean colour is one of the most useful missions, for both science and operations beneficial to society. We need a broad and secure commitment for an integrated constellation of ocean-colour sensors to continue to provide ocean-colour data of the highest quality, thus ensuring that this capability will exist uninterrupted into the future.

www.geosafari.org

The Societal Applications in Fisheries and Aquaculture using Remotely-Sensed Imagery (SAFARI) project was created to accelerate the assimilation of Earth Observation data into fisheries research and ecosystem-based fisheries management on a world scale. SAFARI has brought together an international forum of leading experts to facilitate the application of rapidly-evolving satellite technology to fisheries management questions through collaboration and networking. This initiative, funded primarily by the Canadian Space Agency, is also sponsored by the Group on Earth Observations (GEO), the Canadian Department of Fisheries and Oceans (DFO) and the International Ocean-Colour Coordinating Group (IOCCG).

The international secretariat for SAFARI is located in Canada at the Bedford Institute of Oceanography. SAFARI is directed by Dr. Trevor Platt (researcher at the Bedford Institute of Oceanography) and Dr. Venetia Stuart (Executive Scientist, International Ocean-Colour Coordinating Group), and the Executive Scientist for the SAFARI project is Dr. Marie-Hélène Forget.

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