Geo-ICT and the role of location in Science, part 3: Marine Biology

'Marine biologists are eager to explore the opportunities of Geo-ICT'

From the viewpoint of GIS, marine biology – the study of plants, animals and other organisms in the world's great waters – is a very attractive and challenging discipline. Within this discipline, ecology, which studies the interrelation between different organisms and their natural environment, is particularly prominent. To increase their understanding of the often complex relationships within these systems, marine biologists have been using 'location' for many decades. From the early 1970s, desperate attempts have been made to map *where* various organisms spend different phases of their lives. During the 1970s and 1980s extensive theoretical models were designed to represent the ecological relationships and to predict future developments within the systems. Although empirical testing already made up part of the research, marine biologists had limited tools to do so. They equipped sea birds with marked rings and fish with shiny metal plates, but only in the 'fortunate' case that the fish ended up in fishers' nets or if the birds happened to be spotted by bird-watchers were data produced.
Since then things have changed dramatically. With the introduction of advanced sensors (using GPS), it is now possible to collect much more reliable data on the habitat of the organisms. Within (marine) biological research, there are various examples of successful application of these sensors: grizzly bears in North America, otters in Friesland and Drenthe (North east of the Netherlands) and seals in the Wadden- and North Sea have all been equipped with such sensors.
The fact that the sensors are being used intensively by marine biologists is certainly no coincidence. To the researchers at IMARES* (a Dutch institute for marine research), the RFID chips that have received so much recent attention in the media concerning tracking of prisoners, are simply "old tools in a new coat". The most advanced sensors cannot only measure location, but also a wide range of environmental factors. This has already led to some significant breakthroughs, for example in the research on the habitat and dietetics of seals – more on that later. And the expectations for the future are high. Besides a tool for acquiring data, GIS also offers the possibility to visualise information in a dynamic way. In a scientific discipline in which analyses are often based on limited data, visualisation (in maps) is a vital tool. All of these factors stimulate a growing interest in spatial analyses within the discipline.

High expectations
That GIS is being used widely among scientists in marine biology and maritime conservation is clear from two collections of articles, published by ESRI in 2002. In *Under sea with GIS* and *Marine geography*, articles can be found on GIS applications in a range of research projects – from tracing the migration patterns of giant sea turtles in the Gulf of Mexico to realising the effects of nature restoration on the behaviour of dolphins in the Bay of Florida.
In the foreword to *Marine Geography*, Charles Convis, coordinator of ESRI's Conservation Programme, formulates his optimism about the results of GIS-use as follows: "In the same way as Newton's calculus allowed classical mechanics to become more predictive, we think GIS is the breakthrough tool that will allow the ecological

sciences to become more predictive, rigorous, and directly integrated into all manner of social, political, and resource decisions."
But what are the actual results of the use of spatial information in maritime research? To what extent have these high expectations already led to scientific breakthroughs? To answer these and related questions, we visited the research department of IMARES at Texel, which is affiliated with the University of Wageningen (the Netherlands).

Examples from the Netherlands
"Although most of our colleagues – 30 in total – only have a limited knowledge of the technical side of GIS, the use of GIS in IMARES has developed tremendously within the last few years", argue Han Lindeboom, head of the department at Texel, and his GIS-coordinator, Elze Dijkman. Since the late 1990s no measurement has been carried out by any of the researchers, without stipulating the x, y-coordinates through a GPS. This is largely due to Lindeboom, who was convinced that GIS could play a crucial role in marine research, especially with regards to visualisation and data-integration. The GIS-specialists in his department were given all the freedom to further develop their activities, to invest in the necessary technology and to design their own spatial data system. From only one part-timer, the 'GIS-department' has now grown to two full time positions, which are often supported by temporary staff.
These investments are already beginning to pay off. Lindeboom and Dijkman presented to us a few of their most exciting, ongoing projects. Firstly, there is the aforementioned research on the habitat and behaviour of seals. This research had been going on for decades but, because the seals, like most marine research targets, are so mobile, until recently it was extremely difficult to collect enough reliable data.
Now that twenty seals have been equipped with advanced sensors that can measure both location and depth ("our out-of-office staff", as Lindeboom calls them) this problem has partly been solved. By linking the sensors' information to data on fish stock, much more has been revealed about where the seals stay and for how long, and when and where they feed themselves. This has led to some interesting findings. For example, it turned out that two female seals that had been released in the waters of Zeeland (in the far south of the Netherlands) swam back all the way to the Wadden Sea just before they were about to give birth – they were attracted to an area which GIS identified as more quiet and with more food available.
A second example, which particularly indicates the importance of integrating spatial data from different projects, was a research on the recent and dramatic decline of fish stock in the Wadden Sea. From the fish that populated the Wadden Sea some decades ago, only 10% remain. Possible explanations are a gradual change of climate, eutrophication (often due to the use fertilizers), fishing and an increase in the seal population. Through overlay of spatial information on 'biological factors' and 'user factors', IMARES is trying to improve our understanding of this phenomenon. Earlier research always focused on either one of these factors or used extensive ecological models that were theoretically true, but not supported empirically. Neither of these methods produced satisfying explanations. But, partly due to GIS, Lindeboom believes to be able to break the deadlock.
A third example of the value of spatial information for marine research is an international project in which IMARES and other institutes have identified areas of special ecological value in the North Sea. Again for this project, the marine biologists at Texel have used a

GIS to combine different biological factors – such as biodiversity and the presence of underwater sandbanks.

Obstacles

Advanced tools, a spatial data system that is gradually filled up more and more and a number of clear 'success stories' – "it is time to celebrate"? According to Lindeboom and Dijkman, despite these positive developments, the marine biologists are not there yet. A number of serious obstacles have to be overcome for a further integration of GIS in their discipline, particularly in the Netherlands.

Firstly, it still is a problem to collect enough usable spatial data. Such data requires a controlled experiment: to be able to carry out a series of measurements, on one specific population, under fixed conditions. However, instead of a laboratory-like environment, the sea is in fact an extremely *dynamic* research field – due to the constant impact of tides, changing weather conditions and fluctuating temperatures and the constant movement of plants, animals and humans on, in and around it. Moreover, the underwater life, the most important target of marine research, is for the most part invisible.

Because of all this, although individual measurements may be *reliable* by themselves, they are still not *useful* for research purposes. This problem can be partly solved through the use of sensors, which keep track of an organism and reveal its routes – as was the case with the seals project. These sensors keep evolving and will soon be able to measure not only location (x, y) and depth (z), but also other factors and dimensions (such as temperature and salt levels). However, such instruments are costly, both in purchase and use. Per seal it costs approximately 5000 Euros.

And even if more and more useful data were collected, still, to visualise and interpret the information remains problematic. Because the sea is so dynamic, it is important for marine biologists to be able to show development and change over time. However, as we already saw in our article on the historical sciences (VI Matrix 101), it is particularly the temporal differences with which the current GI-systems are struggling.

An additional problem for the Netherlands is that here only one university offers a degree in marine biology – the University of Groningen. And within this programme, GIS plays only a minor part. According to Lindeboom, although the University of Wageningen is also considering offering such a course, it is not even sure that GIS will have a more substantial part in that degree. Lindeboom, who regularly appears as a guest speaker at his University, uses GIS to visualise his results, but he lacks the expertise to share the ins and outs of the systems with his students.

Hesitant

A third obstacle towards a more intensive and more productive GIS-use by marine biologists is that they are generally hesitant to share data with one another – which is crucial for the development of large scale databases. Spatial information offers the *opportunity* to combine data from different types of research; but to some extent in order to carry out sensible spatial analyses, it is *necessary* to do so. The merging of three marine institutes, each with their own expertise, into one organisation (IMARES = Institute for Marine Resources & Ecosystems Studies), would offer a great opportunity to improve the situation in the Netherlands.

But whether this will actually happen, still remains to be seen, says Lindeboom. Even within his own institute, many researchers are hesitant to share their data with colleagues in early stages of their research. In that sense the Dutch would do good to take the approach of their Australian colleagues, at the Australian Institute of Maritime Science (AIMS).
AIMS has also developed its own spatial data system: EGIS. According to AIMS-researcher Stuart Kinimonth the initiative was partly motivated by a desire to have one system with standard data that are useful to almost any research within the field (information on water depth, temperature, etc.) But it was also partly motivated by the acknowledgment that, because of the specialisation within the institute, there was hardly any exchange between different projects. This meant that researchers could hardly profit from useful data collected by others. Thanks to this new system, this problem seems to have been solved.
The Australian government, who finances the institute, stimulates AIMS to share their data with other organisations. To accomplish such a sharing and integration of information, the government has founded so called Cooperative Research Centers (CRC's). But Kininmonth argues that many of his colleagues are not to happy to take this next step. Agreeing on temporary protective status of data, a kind of temporary copyright, could be a possible solution.

Sensor-based approach
To what extent could marine biologists themselves contribute to the further development of GIS? Considering the limited technical GIS-expertise of most Dutch biologists a contribution in this respect is not likely. However, with their extensive experience of working with sensor based-GIS and dynamic visualisations, marine biologists could, in that respect, be a source of inspiration and expertise to scientists in other disciplines. Moreover, their interest in linking spatial and temporal variables and their desire to visualise dynamic processes could stimulate software producers to actually develop such advanced systems. We are convinced that the development of these sensors will have a tremendous impact on the development of GIS. All mobile sensors are now standard equipped with the possibility to "measure" location. It is no coincidence that, on our way to Texel, we received the following press release: Microsoft's plan to Map the world in Real Time (http://www.techreview.com/read_article.aspx?id=16781&ch=infotech)
The marine biologists consider this as 'yesterday's news', but the seals should be warned.

Niels van Manen, Henk Scholten and Rob van de Velde
SPINlab, Vrije Universiteit, Amsterdam

* IMARES consists of Alterra-Texel, RIVO in IJmuiden (Netherlands Institute for Fisheries Research) and the Ecological Risk Department of TNO in Den Helder.