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Satellites and fisheries: a personal view

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Satellite remote-sensing data have become indispensable in fishery oceanography, but are rarely used in applied fishery science, i.e. stock assessment. However, they are likely to be a key data source in the implementation of ecosystem approaches to fisheries management.

Keywords: fisheries, remote sensing, satellites.

> "If all you have is a hammer, you tend to see every problem as a nail."
>
> Abraham Maslow

It has been my privilege to have worked on some of the most innovative projects and with some of the most influential researchers in both fields under discussion in this issue of the *ICES Journal of Marine Science*. As such, perhaps I am qualified to comment on its contents from several perspectives. I began with the Controlled Ecosystem Pollution Experiment (CEPEX), an international effort to understand the effect of very low levels (ppm to ppb) of anthropogenic materials (heavy metals, hydrocarbons, radioactive elements, etc.) on marine ecosystems, one of the first of many "mesocosm" programmes. This was attempted by simultaneously capturing three, relatively large (1500 m^3) parcels of seawater *in situ*, or more precisely in plastic, which were then used as control or experimental (pollutants added) mini-ecosystems. Early on, it became clear that things were not quite that simple. In an initial run without pollutants, the mesocosms went off in all directions—one turned into jellyfish, another into a monoculture of a copepod rarely seen. If unperturbed mesocosms did not replicate, it would be impossible to draw conclusions from any observed differences between controls and experimental treatments. The replication problem was quickly solved by methodological improvements, including more simultaneous capture and pumping between mesocosms to homogenize any initial differences between them. Interestingly, and to my point, despite many groundbreaking discoveries relevant to the original objectives, the name was eventually changed to Controlled Ecosystem Population Experiment, an effort to address basic ecological questions, although retaining the funded acronym.

This bold attempt to determine humankind's sublethal impact on the oceans influenced my views on the practicality of controlling (managing) them, and my subsequent approach to applied fishery science on the Scotian Shelf (Koeller, 2008). However, it was not the published results, but the initial replication problem that stuck with me. In many ways, the problems of fishery science and management parallel the mesocosm experience; for example, in the difficulty of separating anthropogenic from natural causes, even in relatively controlled situations. However, it took the fishery establishment many decades to come to essentially the same conclusion—things are not that simple. Enter the ecosystem approach to fisheries management (EAFM), under intense discussion for more than a decade, but with little real progress, at least not where the rubber hits the road (at the short-term, local, and species levels). There are many good reasons for this, including the necessarily conservative nature of stock assessments and fishery management. Moreover, those tasked with the problem of determining the number of fish in the sea, predicting their future numbers, and convincing fishers how few they should remove, hardly have time to implement such grand visions. Then there is the enormous complexity of the vision itself—the ecological "known unknowns" and "unknown unknowns". This is where satellite remote sensing (SRS) enters the picture.

For those who appreciate the known or unknown complexities of the stock–recruitment problem, arguably the Holy Grail of fishery science, a quick look at a sequence of ocean-colour images is a revelation—you can actually see the complexity, so you can no longer ignore it. One can see the spring bloom advancing from lower to higher latitudes in the North Atlantic, repeated annually on the grand scale, but infinitely variable locally, and how a species must adapt to survive throughout its range (Koeller *et al*., 2009). One can see the patchiness and motion, drill down into it like a Mandelbrot set image, and understand why some year classes are more successful than others, and why those mesocosms went astray; three isolated ecosystems, initially identical to the instruments of the day, ending in completely different regimes. No doubt there were differences at capture—patchiness is apparent at all scales in both physical and biological properties—but they were small and undetected. One can easily imagine, without the formality of chaos or complex systems theory, these differences accumulating, one small action-response at a time until, in the fullness of time, they add up to a bumper year class, or something entirely unexpected. Unfortunately, this is where satellites cannot help us in the recruitment issue, because, alas, they only reveal differences in the initial conditions resulting in the success or failure of a year class, and only at the surface, though more comprehensively than ever before. What lies below and happens later must still be observed at great expense; or imagined and modelled.

Nevertheless, for species trophically close to the primary producers, such as shrimp and small pelagic fish, or for shallow-water systems, the phytoplankton–fishery link is often manifest; here, SRS might be more useful in management at the local and species level. In any case, the potential fishery applications of SRS are myriad and certainly not restricted to ocean colour, small or large scales, or recruitment problems, as the highly diverse subjects of this special issue and the review papers will testify. SRS data can provide invaluable information during the process of formulating fishery management frameworks, as exampled herein by Patagonian scallops (*Aequipecten tehuelchus*). They can help solve difficult management problems, such as loggerhead turtle (*Caretta caretta*) bycatch in tuna (*Thunnus* spp.) fisheries. They can help us elucidate the complex recruitment mechanisms of northern shrimp (*Pandalus borealis*), classify the suitability of a coastline for marine plant aquaculture and, of course, find fish to be caught. In fact, SRS data are so pervasive in fishery oceanography today that it would be difficult to find a paper in the field without some reference to them or to do their contribution justice here, or even in this whole suite of papers. It is in applied fishery science and management where they are rarely encountered and, as alluded to above, not through any fault of their own.

If there is a fault, it is perhaps in the heady generalizations that often follow the first blush of discovery with a new and groundbreaking methodology. True, all fish come from phytoplankton, and it all starts at the surface. However, too much emphasis on measurements from a single instrument invites trouble. Fishery assessment biologists are (or ought to be) the most sceptical of all marine scientists—their theories and applications have been tested too often by bitter experience. They will move forward slowly, methodically, and with all the available data, including SRS. Give them time, but not too much.

References

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