JIJI PRESS/AFP/GETTY IMAGES

Brown seaweed, usually harvested off the coast of Japan (above), is absorbing radioactive iodine.

RADIOECOLOGY

Radiation release will hit marine life

Researchers call for extensive surveys to gauge ecological effects of Fukushima.

BY QUIRIN SCHIERMEIER

As radioisotopes pour into the sea from the crippled Fukushima Daiichi nuclear plant, one reassuring message has been heard over and over again: the Pacific Ocean is a big place.

That the isotopes will be vastly diluted is not in question. Nevertheless, scientists are calling for a marine survey to begin as soon as possible to assess any damage to ecosystems in the area around Fukushima. Although the contamination is unlikely to cause immediate harm to marine organisms, long-lived isotopes are expected to accumulate in the food chain and may cause problems such as increased mortality in fish and marine-mammal populations.

"Just because you can measure it, doesn't mean it's dangerous," says Ken Buesseler, a marine geochemist at the Woods Hole Oceanographic Institution in Massachusetts. "Even so, this is the biggest man-made release ever of radioactive material into the oceans. We haven't yet seen enough data to assess what's going on, so anything that can be done in terms of further monitoring would be very welcome."

The past two weeks have seen extremely high concentrations of radioactive iodine-131 (with a half life of 8 days) and caesium-137 (which has a half life of 30 years) in samples of sea water collected near the Fukushima reactors, and even as far as 30 kilometres offshore. By late March, levels were tens of thousands of times higher than before the accident (see 'Radioisotope contamination'). Many other radioisotopes, both long- and short-lived, are also likely to have been released.

FUKUSHIMA CRISIS

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But the total amount of radioactivity that has entered the ocean is unknown, and discharges — both accidental and deliberate — are continuing and may even be substantial if any further problems occur at the Fukushima plant (see page 146).

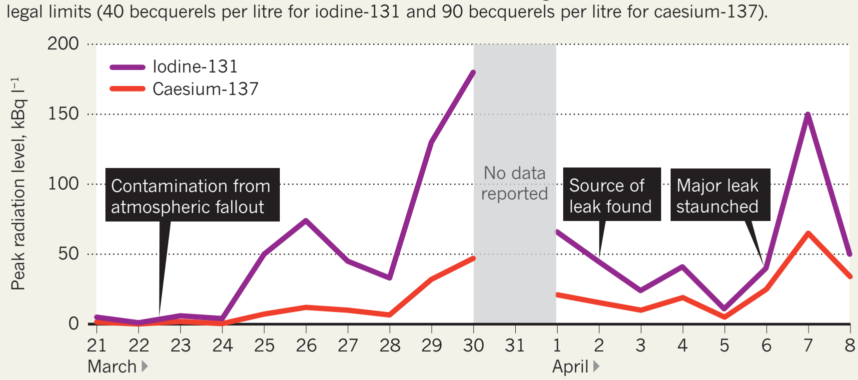
Despite these uncertainties, scientists at the National Institute of Radiological Sciences (NIRS) in Chiba, Japan, are designing studies aimed at monitoring the accumulation of radionuclides in the muscles, organs, eggs and bones of marine organisms. They also plan to model the long-term behaviour of radioisotopes in the marine environment, and the overall radiation doses to which marine organisms will be exposed. "We need to obtain specific concentrations of caesium and iodine isotopes to assess their effects in different marine organisms," says Tatsuo Aono, an expert in marine radioecology at the NIRS.

A team led by Dominique Boust, director of the French Institute of Radioprotection and Nuclear Safety (IRSN) in Cherbourg, is now predicting the level of contamination in marine organisms and sediments using estimates of the quantity of radioisotopes released from Fukushima, and the ratios of those isotopes calculated from available sea-water measurements.

The team calculates that about 50 radioisotopes contribute to an overall concentration of roughly 10,000 becquerels per litre in the sea water within 300 metres of Fukushima. Before the accident, caesium-137 concentrations there were about 0.003 becquerels per litre, and iodine-131 was not detectable. On the basis of these figures, the IRSN researchers suggest that sediments in the region could now contain 10,000–10 million becquerels ▸

RADIOISOTOPE CONTAMINATION

Levels of caesium-137 and iodine-131 in the sea close to the damaged Fukushima reactors have shattered legal limits (40 becquerels per litre for iodine-131 and 90 becquerels per litre for caesium-137).



SOURCE: IAEA/TEPCO/IRSN

per kilogram; fish could carry 10,000–100,000 becquerels per kilogram; and algae, some of which are particularly susceptible to iodine uptake, could contain up to 100 million becquerels per kilogram. Japan has legal limits of radioactivity in fish for human consumption of 500 becquerels per kilogram for caesium-137, and 2,000 becquerels per kilogram for iodine-131.

"Doses will decrease very quickly with time and distance from the facility, if no further leaks occur, but there could remain a persistent low-dose component in the local marine environment for many years," says Thomas Hinton, deputy director of the IRSN's Laboratory of Radioecology, Ecotoxicology and Environmental Modelling in Cadarache, France. "The impacts are best addressed through an international long-term assessment."

Ward Whicker, an environmental and radiological health expert at Colorado State University in Fort Collins, agrees that a survey would be worthwhile. "It would require a great deal of sampling effort, near the discharge point as well as at locations farther away," he says. "Concentrations of radionuclides in water, sediments, plankton, molluscs, crustaceans, seaweed and fish would need to be measured, and the health of the ecosystem monitored."

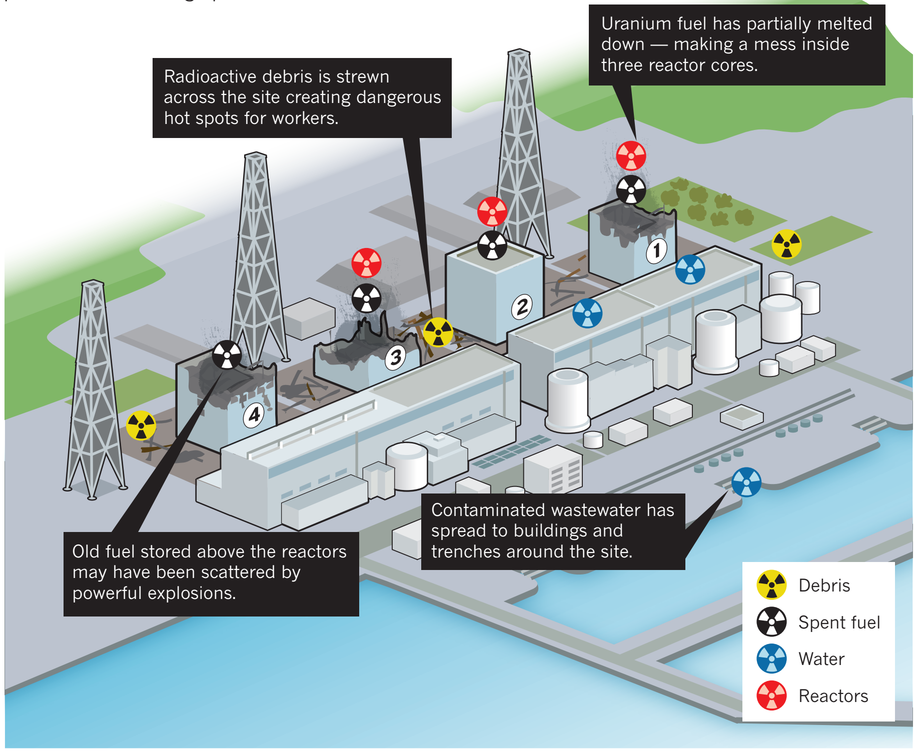
Although radioisotope concentrations in fish, shellfish and seaweed could exceed limits for human consumption for weeks, Whicker thinks that it is unlikely that scientists would be able to detect any genetic effects on marine life. Any affected creatures would probably disperse into the Pacific, or die more quickly, he says. Moreover, teasing out radiological effects from other stresses, such as conventional water pollution and the damage caused by the tsunami, would be extremely difficult.

An alternative approach could be to focus on a suitable proxy species. "In my opinion, brown seaweed should be the number one research priority," says Bruno Fievet, a radioecologist at the IRNS in Cherbourg. The brown seaweed *Laminaria digitata*, ubiquitous in the coastal Pacific waters off Japan, absorbs iodine to help defend itself against environmental stresses such as pollution. It can have iodine concentrations some 10,000 times greater than the surrounding sea water. "This species is the world champion in iodine uptake, and it would be a good indicator of the radioactive labelling of other marine organisms," says Fievet.

But sampling may be hampered by the danger that remains at the Fukushima plant. "Any survey would be welcome," says Ulf Riebesell, a biological oceanographer at the Leibniz Institute of Marine Sciences in Kiel, Germany. "But I certainly wouldn't ask my students to do field work off Japan amid this ongoing crisis." ■

FUKUSHIMA'S RADIOACTIVE WRECKAGE

Radioactive contamination takes many forms at Japan's stricken nuclear reactors. Each source creates its own problems for cleaning up the site.



NUCLEAR ACCIDENT

Fukushima set for epic clean-up

Latest data suggest a Chernobyl-like effort will be needed.

BY GEOFF BRUMFIEL

As the immediate threat from Fukushima Daiichi's damaged nuclear reactors recedes, engineers and scientists are facing up to a clean-up process that could last for many decades, or even a century.

Experts on previous nuclear accidents say that the sheer quantity of nuclear material that needs to be removed from the site, together with the extent of the damage, makes Fukushima a unique challenge. The plant's damaged reactors are home to just under 1,000 tonnes of nuclear fuel and thousands of tonnes of radioactive water (see graphic).

Last week, the Toshiba Corporation floated a rough proposal to clean up the site in a decade. But veterans of clean-up operations at sites such as Three Mile Island in Pennsylvania say that it will probably take much longer. The removal of the radioactive material will require a carefully planned and technologically sophisticated programme, made all the more challenging by the devastation left after partial core meltdowns and explosions.

No clean-up can begin until the reactors are stabilized. Radiation around the plant is beginning to wane, but the threat of further releases has not yet passed. On 7 and 11 April, severe aftershocks struck nearby, raising fears that the three crippled reactors could be damaged further. The Tokyo Electric Power Company (TEPCO), which manages the plant, says that no additional damage has been detected.

A 26 March report from the US Nuclear Regulatory Commission (NRC), leaked to *The New York Times*, says that massive explosions at the plant in March scattered fuel from the reactors' spent-fuel pools around the site. NRC officials also believe that a portion of the uranium fuel inside the unit 2 reactor may have escaped its stainless steel containment