THE ECOLOGICAL SOCIETY OF AMERICA

Frontiers in Ecology and the Environment

Issue No 9 Volume 10 November 2012

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Fukushima disaster indirectly threatens lake ecosystems

After the March 2011 tsunami, the Fukushima Daiichi nuclear accident contaminated large portions of Japan's Honshu Island (Yasunari *et al.* 2011), affecting both human livelihoods and the environment. Elevated radiation levels have already triggered changes in surrounding ecosystems (Møller *et al.* 2012). Strict thresholds for human access within contaminated areas were implemented, resulting in widespread changes in land-use patterns. Whether the radioactivity has impacted fisheries is still under debate. Although there is growing evidence of the Fukushima disaster's direct effects on biota and ecosystems (Yasunari *et al.* 2011; Møller *et al.* 2012), management strategies to address radioactive contamination on a wider scale have yet to be established.

Before the Fukushima event, central Japan's freshwater ecosystems and fisheries were already imperiled by the establishment of several invasive fish species. Japan's second-largest lake – Lake Kasumigaura – is located approximately 160 km southwest of Fukushima Daiichi and is home to one of the country's most important inland commercial fisheries. However, invasive species, such as channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and silver carp (*Hypophthalmichthys molitrix*), have historically threatened this fishery as well as the native fauna and ecosystem. In particular, channel catfish are thought to be one of the major causes of native fish declines and have been implicated in serious damage to commercial fisheries (Matsuzaki *et al.* 2011).

To prevent further ecological and economic damage by invasive species, Ibaraki Prefecture initiated invasive fish removal efforts in the late 1990s, by paying local commercial fishermen for invasive fish incidentally captured as bycatch (Figure 1); these fish were then processed into fishmeal for livestock feed. According to an Ibaraki Prefectural Kasumigaura-Kitaura Fishery Office report, in the years before the Fukushima disaster, up to 400 metric tons of invasive fish had been removed annually through such efforts.

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Figure 1. *Caught by local fishermen at Lake Kasumigaura in 2006, these invasive fish will be processed into fishmeal for consumption by livestock.*

However, one year after the Fukushima disaster, this project was discontinued because radioactive cesium levels in fish exceeded the legal limit for use in livestock feed. As of May 2012, radioactivity detected in some invasive fishes in Lake Kasumigaura now even exceeds human health threshold levels (100 becquerels per kilogram), precluding human consumption (National Institute of Environmental Studies unpublished). The distribution of livestock feed pellets derived from these fish has thus been restricted. As a result of these restrictions and the absence of appropriate disposal techniques, local fishermen have discontinued catching invasive fish. Studies on the long-term effects of radioactive contamination through the food chain are largely absent (von Wehrden *et al.* 2012). Yet, over time, the program's termination and eventual cessation of fishing for invasives will likely lead to (1) increased abundance of invasive fish; (2) changes in the distribution and abundance of native fish, macroinvertebrates, and plankton, leading to ecosystem-wide effects (Maezono and Miyashita 2003); and (3) cascading negative impacts on biodiversity and related ecosystem services.

In this context, safeguarding the survival of native species will require combustion of contaminated invasive fish into highly concentrated ashes, construction of waste disposal fields, and development of effective remediation methods. Another potential management option could rely on efforts to interrupt the reproductive cycles of invasive fish species.

To restore contaminated lake ecosystems and their fisheries, we urge the national Japanese Government, in cooperation with local governments, to design and implement management plans that take a long-term perspective. Once contamination levels decrease, the objective must be to promote viable populations of native species, which are not only crucial for local fisheries but also a vital component of these unique ecosystems.

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doi:10.1890/12.WB.022

