



SCIENCE BRIEF (June 2004)

INDIRECT EFFECTS OF METALS IN AQUATIC ECOSYSTEMS

ISSUE

Metals, if present in bioavailable forms and toxic concentrations, can result in either direct or indirect toxicity to organisms. Direct toxicity can involve, for instance, death, reduced growth, or reduced reproduction. Direct toxicity to one organism can result in indirect toxicity to another organism. For example, if metals reduce the population of organism X, then organisms that prey (feed) on organism X will lose this food resource. However, organisms that are the prey (food) for organism X, or that compete with organism X for limited resources, will flourish – possibly beyond the carrying capacity of their environment. The indirect effects of metals on the environment may be even greater than direct effects but are not well understood.

SIGNIFICANCE

Very high levels of metal contamination in some eastern Canadian lakes have resulted in the elimination of certain species of benthic (bottom-dwelling) invertebrates (animals without backbones), an important food source for fish. These lakes also contain stunted fish (smaller perch) compared to lakes not impacted by metals. This research showed that the stunted perch are an indirect effect of metals in the lakes. The perch themselves are relatively resistant to metal toxicity. However, their preferred benthic invertebrate prey species are not. To survive, the perch have to switch to different, smaller food organisms, which take more energy to catch and eat. This "bioenergetic bottleneck" results in reduced growth efficiency for the perch and thus stunted growth. This research answered a specific environmental puzzle and provided the tools for investigating similar indirect effects at other locations and with other species.

BACKGROUND

Indirect interactions between organisms are relatively well known in the field of ecology, but are under-appreciated in the field of ecotoxicology (the study of the effects of stressors such as metals on organisms). Indirect effects on a particular organism due to stressors can be negative (loss of prey) or positive (loss of predators or competitors). Indirect effects due to stressors are less likely when there are direct impacts on most species in an ecosystem. They are most likely in cases where only some species suffer direct impacts.

FINDINGS

This research, carried out through the Metals in the Environment Research Network (MITE–RN) program, has shown indirect, food-web mediated effects of metals on yellow perch in some highly metals-contaminated lakes in eastern Canada. Yellow perch in these lakes begin life feeding on zooplankton (small, swimming creatures) in the water column. During their second year of growth, they shift to feeding on benthic (bottom dwelling) invertebrates. Later in life, their diet also includes smaller fish. Perch in the most metal-contaminated lakes did not undergo this normal sequence of diet shifts. Instead, they continued to utilize smaller prey throughout their lives because their primary prey species was absent from the lakes, presumably due to direct metal toxicity. A bioenergetic bottleneck developed because the perch's growth efficiency was reduced by the need to expend additional energy to catch and eat smaller-sized prey. Effectively, the following sequence of events occurred: metal exposure → reduced food abundance of certain dietary components → increased energetic costs of feeding → reduced growth efficiency.

The results of this research provide site-specific evidence for metals-related impacts on these aquatic food chains. They also provide the tools for assessing similar effects elsewhere and on other food chains, by considering food chain inter-relationships and closely examining situations where species are relatively tolerant of metals but nevertheless show reduced growth associated with a disruption of their normal feeding patterns.

FUTURE RESEARCH

Functional redundancy is a common feature of ecosystems, where more than one species can play the same energetic role, for instance, fixing incident light energy (photosynthesis) or breaking down detrital organic matter (respiration). It is sometimes assumed that, because of functional redundancy, protecting ecosystem function will protect ecosystem integrity. However, the present research clearly shows that this assumption does not universally hold. By changing ecosystem structure (the number and type of prey species present), metals have been shown to affect a higher consumer indirectly. The extent and significance of stressor-mediated indirect effects need to be determined, particularly relative to inter-relationships between ecosystem structure and function. Further, there may be indirect effects of reduced food availability for human subsistence fisherfolk such as northern First Nations populations, if they live in metals-affected areas.

ADDITIONAL INFORMATION

P. G. C. Campbell, A. Hontela, J. B. Rasmussen, A. Giguère, A. Gravel, L. Kraemer, J. Kovescs, A. Lacroix, H. Levesque and G. Sherwood. 2003. Differentiating between direct (physiological) and food-chain mediated (bioenergetic) effects on fish in metal-impacted lakes. *Human and Ecological Risk Assessment*, volume 9, number 4, pages 847 to 866.

<http://www.mite-rn.org/research/era/era.shtml>

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