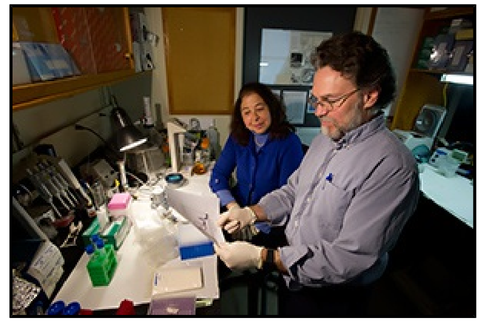
Genetic variation may explain PCB-resistance in Atlantic killifish

By Sara Mishamandani

Changes in a receptor protein may explain how killifish developed a genetic resistance to polychlorinated biphenyls (PCBs) in New Bedford Harbor, Mass., according to a new study
(http://www.ncbi.nlm.nih.gov/pubmed/24422594)
published in the journal BMC Evolutionary Biology. New Bedford Harbor, one of the largest U.S. Environmental Protection Agency (EPA) Superfund cleanup sites, is heavily contaminated with PCBs and heavy metals.



"Even though the specific molecular changes that are found in PCB-resistant killifish are different, AHR2 seems to be one of the genes - possibly the major gene - that is responsible for the resistance," said Hahn. Hahn, right, examines data with WHOI biologist Diana Franks, left, a co-author on the paper. (Photo courtesy of Tom Kleindinst, Woods Hole Oceanographic Institution)

Despite the substantial pollution, Atlantic killifish, a small fish common to estuaries, are thriving in the toxic conditions. Researchers at the Woods Hole Oceanographic Institution, led by Boston University Superfund Research Program (SRP) grantee Mark Hahn, Ph.D.,
(http://www.whoi.edu/profile/mhahn/)
are collaborating with investigators at the EPA, Boston University School of Public Health, and University of North Carolina at Charlotte to understand how killifish have been able to adapt to live in the highly contaminated environment.

Investigating genetic variation in killifish

The researchers examined diversity in three specific loci, or genes, related to the aryl hydrocarbon receptor (AHR), in killifish from seven different locations, including extremely polluted estuaries and reference estuaries with low levels of PCBs.

Atlantic killifish, only about three inches long, live their whole lives in the same area and do not migrate south for the winter. In New Bedford Harbor, they burrow into PCB-contaminated sediment for the winter. (Photo courtesy of Evan D'Alessandro, University of Miami)

Among all populations, investigators identified 98 single nucleotide polymorphisms (SNPs), or genetic variations, within the three AHR-related loci. However, they did not find significantly different genetic diversity at contaminated sites compared to reference sites.

However, when they looked specifically at the New Bedford Harbor killifish population, they found significant genetic differences from populations at two nearby reference sites. The data also revealed changes in specific nucleotides in AHR1 and AHR2, and specific AHR2 SNPs associated with the PCB resistance.

According to the authors, the results revealed that AHRs, especially AHR2, may be recurring targets for selection during local adaptation of fish to contaminants, although the specific molecular changes may vary among independently adapting populations or species. Other genes, not yet identified, may also have a role in the adaptation.

"It's a fascinating example of how human activities can drive evolution," said Hahn. "The ability to adapt to changing conditions is going to become even more important as humans impact the environment, whether it's from ocean acidification, or increasing temperatures, or other types of global changes that are occurring."

The AHR2 pathway

Normally, when fish are exposed to toxicants, the body increases production of enzymes to break down the harmful chemicals, a process controlled by the AHR2 protein. However, some PCBs cannot be broken down this way, and continue to stimulate the AHR2 pathway. This continued stimulus leads to a disruption of cellular functions, such as the control of cell growth and differentiation.

"These killifish have managed to shut down the AHR2 pathway," said Hahn. "It's an example of how some populations are able to adapt to changes in their environment - a snapshot of evolution at work."

A companion paper
(http://www.ncbi.nlm.nih.gov/pubmed/24422627)

by EPA collaborators, also published in BMC Evolutional Biology, examined SNPs from 42 genes associated with AHR-related pathways. The authors identified AHR2 as a gene under selection in resistant populations, and suggested that AHR2 plays an important role in the adaptive response to extreme contamination of PCBs and other compounds with similar structures.

"Obviously, the fact that they are resistant to PCBs allows them to survive in this really polluted environment, but what will happen once the harbor gets cleaned up?" asked Hahn. "There could be costs that make it no longer adaptive for these fish to live there."

Citation: Reitzel AM, Karchner SI, Franks DG, Evans BR, Nacci D, Champlin D, Vieira VM, Hahn ME.
(http://www.ncbi.nlm.nih.gov/pubmed/24422594)
Genetic variation at aryl hydrocarbon receptor (AHR) loci in populations of Atlantic killifish (Fundulus heteroclitus) inhabiting polluted and reference habitats. BMC Evol Biol 14(1):6.

Citation: Proestou DA, Flight P, Champlin D, Nacci D.
(http://www.ncbi.nlm.nih.gov/pubmed/24422627)
Targeted approach to identify genetic loci associated with evolved dioxin tolerance in Atlantic Killifish (Fundulus heteroclitus). BMC Evol Biol 14(1):7.

(Sara Mishamandani is a research and communication specialist for MDB Inc., a contractor for the NIEHS Superfund Research Program and Division of Extramural Research and Training.)
