GENOMICS, FISHERIES & AQUACULTURE

MANAGING AND HARVESTING OUR WATER-BASED RESOURCES

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Aquatic species, including finfish, mollusks and crustaceans, make up a growing proportion of the world's food supply, reaching almost 17% of animal protein consumed globally in 2009 according to the United Nations. While wild capture fisheries have reached their peak and for certain species catches are in decline, aquaculture output is continually increasing, representing 40% of global fish production in 2010, up from 9% in 1980. In Canada, fisheries represent $2.5B in product value, with 1/3 of that coming from aquaculture, primarily salmon.

The growing importance of fish protein for feeding an expanding world population is putting increasing pressure on fisheries to assure sustainable supplies of wild and cultured fish while managing and minimizing the impacts on aquatic ecosystems. Genomics science provides tools for researchers to assist in this effort in a variety of ways, in particular:

monitoring, management and conservation of wild stocks

selective breeding of aquaculture species with desirable traits development of sustainable diets for cultured fish

development of vaccines for infectious diseases that threaten aquaculture

AQUACULTURE

World aquaculture production attained an all-time high in 2010, at 60 million tonnes (excluding aquatic plants and non-food products), with an estimated total value of US$119 billion representing over 500 different species and 190 producer countries.

While details differ depending on species and location, aquaculture producers face similar issues related to growth rates in culture, losses due to disease and pests and rising costs and diminishing supplies of predominantly fish-based feedstock. As in traditional livestock farming, these challenges are being addressed through a combination of improved processes and selective breeding of genetically improved broodstock.

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SELECTIVE BREEDING

By the end of 2012, complete genome sequences were available for very few aquatic species, including Atlantic cod, Pacific oyster and several "research" species like zebrafish and fugu (pufferfish). Major efforts are in progress to analyze genomes of essentially all commercially important species, including salmon, catfish, tilapia, and shrimp, to name just a few. This work is providing genomic tools, in the form of DNA Markers, that are enabling marker-assisted selective breeding programs for aquaculture broodstock to improve health and productivity.

Classical breeding has succeeded in bringing significant gains in growth and survival rates for many aquaculture species. Genomics research has identified DNA Markers for resistance to certain pathogens, including Infectious Pancreatic Necrosis virus (IPNv) in Atlantic salmon and Viral Haemorrhagic Septicaemia virus (VHSv) in rainbow trout, both associated with major losses in commercial aquaculture. These markers can be used to guide selective breeding of resistant broodstock.

In the case of halibut, genomics research has identified DNA markers that can be used to select faster growing fish, allowing producers to get their fish to market six months faster - a 20% reduction in the time to grow a fish to market size, with the associated reductions in resources and costs.

(In the case of Atlantic salmon, genetic modification with a Coho salmon growth hormone gene has produced a GMO salmon that grows to harvest size in 16 to 18 months, rather than the normal three years in culture; this AquAdvantage salmon has not yet been approved for sale).

FEED DEVELOPMENT

Finding the optimal diet for farmed fish can make the difference between healthy, fast growing fish, and those that fail to thrive. Genomics can play an important role in the research and development of feed formulas. For instance, salmon, trout and other carnivorous fish require some fish in their diet to flourish. But fish oil and fish meal have cost and sustainability issues. One plant-based alternative, *Camelina sativa*, is being explored as a partial replacement in feed. Researchers are looking at the impact of camelina on the genes of the fish, watching for changes in gene activity with the change in diet.

This research is in the early stages of indicating the precise amounts of camelina needed to create the best effects in the fish, which will help feed producers develop the optimal feed for performance and health, while using the least amount of resources.

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HEALTH MANAGEMENT

Genomics tools are also helping to manage the health of fish in aquaculture environments. They are used for accurate diagnosis of disease, including identifying the difference between lethal strains of illness and those that don't cause any damage. That information greatly informs the disease management process implemented by the fish producers, helping them determine when and if they need to introduce quarantine or treatment.

Genomics tools are also important in the development of vaccines that help to protect the fish. DNA sequencing of the pathogens can enable production of vaccines; this route has resulted in the first oral vaccine for IPNv. They can also help to tailor the vaccines to be more effective for particular families of fish.

TRACEABILITY

Genomics tools are helping producers of salmon and other aquaculture products address food safety and sustainability issues by using DNA markers to trace the product from the egg to the plate of the consumer. Producers and consumers of farmed fish can have confidence, knowing when, where and how it was produced and what process it followed along the way. This 'genetic fingerprint' of the fish can also help identify escaped farmed salmon, and track them back to their origins when they are found in the wild.

GENE REGULATION: UP-REGULATED/DOWN-REGULATED

The process of increasing or decreasing the expression of genes. In some circumstances it can also be thought of as a process of turning genes on and off. Gene regulation occurs in the cells of organisms during normal development and it can be activated to respond to changes to the environment.

MICROARRAY

A molecular tool used to examine the expression of thousands of genes simultaneously. It can help researchers understand which genes are associated with form and function of an organism.

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WILD STOCK MANAGEMENT

According to the United Nations, most of the world's wild fish stocks are either fully or over-exploited, and sustainable management practices are essential to avoid fisheries collapse as happened for Atlantic cod.

Genomics offers powerful new tools to monitor wild fish stocks for biodiversity, genetic origins and population health. It can provide critical information for regulation of the fisheries and, by providing traceability through DNA markers, genomics can protect consumers by helping to identify fish captured illegally or confirming that fish originated from sustainable fisheries. Better information from genomics can support better decisions and better policies to protect and preserve this natural resource.

SALMON

When wild Sockeye salmon migrate to the Fraser River in BC, it is natural for some of them not to finish their journey. Given the economic, cultural and environmental value of Sockeye to Canada, management of this wild species is important.

Recent research led to the identification of a gene associated with increased mortality in migrating salmon. A DNA test for the gene is now used by Fisheries and Oceans Canada to monitor wild salmon stocks as they migrate to the BC river system, and allows them to adjust harvest rates to ensure that enough sockeye reach their spawning grounds to maintain healthy salmon populations.

TROUT

In New Brunswick, river trout numbers are on the decline. Genomics can help ensure that appropriate restocking with disease-resistance and the appropriate balance of males and females can take place without undue ecological ramifications.

LOBSTER

Lobster is one of Canada's most lucrative food exports at over $800M annually. But relatively little is known about the genome of this tasty crustacean. Researchers are currently working closely with the lobster industry to find answers to some big questions. Like, how different are lobster families? What sparks their migration from region to region? What makes some families more resistant to disease than others? These findings will help us better monitor and manage our lobster populations, and ensure a healthy, sustainable, lobster industry while protecting the delicate ecological balance of our oceans and coastal regions.

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