

CHANGING LIVES
IMPROVING LIFE

ALMA AQUACULTURE RESEARCH STATION

University of Guelph, Office of Research

RESEARCH HIGHLIGHTS 2010 – 2016

Since 1993, 171 research projects have been conducted at the Alma Aquaculture Research Station. The primary areas of research interest include:

Breeding and genetics, culture methodology, engineering & system design, fish behaviour, fish health, fish welfare, growth physiology, nutrition, product development, reproduction and management, reproductive physiology, telemetry studies and waste management.

A summary of some of the current research follows:

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ARS 120 – Investigating the radiation bystander effect in fish: F1 generation.

In radiation biology, the accepted principle is that the effect of radiation is directly related to the dose which is received; i.e. an increase in the dose results in a directly proportional increase in the effect. However, at very low radiation doses, the effects begin to deviate from what would be predicted. This deviation is thought to be a result of the bystander effect. The bystander effect has been demonstrated in cultured cells and occurs when cells which have not been irradiated but are in proximity of a radiated cell begin to exhibit some or all of the effects of direct irradiation. However, the bystander effect has not been adequately investigated in whole animals. Since the cause of the bystander effect is thought to be a chemical signal, the effect may have particular importance in the aquatic environment since chemical transmission is easier through water than through air. As a result, fish may be a particularly important animal group in which to investigate this phenomenon. Therefore the aim of this investigation is to use very low (i.e. non-lethal) levels of X-radiation to investigate the bystander effect in rainbow trout.

The original study assessed whether the by-stander effect was trans-generational. To that effect, crosses were made using gametes from adult fish that had been either irradiated at different life stages or sham irradiated. Subsequent analysis of resultant fish from those crosses indicated that in specific crosses, F1 generation fish exhibited trans-generational radiation effects, and, more importantly, a detectable radiation bystander effect.

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The purpose of this project is to continue the study to determine if the trans-generational bystander effect is present in the F2 generation. The importance of this research relates to environmental protection when legislating the use of nuclear power, specifically exposure to low levels of radiation present in cooling water discharge or, more seriously, accidental radiation leakage from nuclear facilities.

Mothersill, C., R.W. Smith, R. Saroya, J. Denbeigh, B. Rowe, L. Banevicius, R. Timmins, R. Moccia and C. B. Seymour. 2010. Irradiation of rainbow trout at early stages results in legacy effects in adults. Int. J. Radiation Biol. 86 (10: 817-828.

Canadian Society of Zoologists, Scarborough, Toronto, Canada, 2009.
Oral presentation. Smith RW, Mothersill C, Saroya R, Moccia R, Seymour C. The effect of waterborne aluminum on the long-term legacy of radiation exposure of the early life history stages of rainbow trout (*Oncorhynchus mykiss*).

8th International Congress on the Biology of Fish, Portland, Oregon, USA, 2008.
Oral presentation. Smith RW, Mothersill CE, Moccia RD, Seymour CB. Legacy effects of direct exposure to X-rays and the X-ray induced bystander effect in rainbow trout (*Oncorhynchus mykiss*).

ARS 143 – Physical characteristics of fecal waste from rainbow trout.

The physical characteristics of feed and fecal waste products from trout aquaculture are important to the development of improved effluent treatment methods, and for the regulatory control of 'open' system technologies (e.g. cage farming), which is based in part, on the dispersal characteristics of wastes in the receiving ecosystem. The physical characteristics of most interest include the size distribution of particles and their settling characteristics. These characteristics provide the fundamentals for wastewater treatment in land-based aquaculture facilities (e.g. predicting pipe size, flow rates and gravitational clarifier size) and for the modelling of waste dispersion and the benthic footprint of cage-based aquaculture facilities.

In an earlier study, the physical characteristics of feed and fecal waste generated by rainbow trout fed three commercial diets were determined. (Moccia, Bevan and Reid 2007). The results from this study have been used by the Department of Fisheries and Oceans Canada to examine the applicability of "DEPOMOD" (Cromey, Nickell and Black 2002) in the management of rainbow trout cultured within cages in the Great Lakes, Ontario. The results have also been used by Reid et al (2009) in their extensive review of the biophysical properties of salmonid feces.

In the proposed study, we aim to provide an expanded data set of the main physical characteristics of the feed and fecal waste produced by rainbow trout. The initial study was limited to a single size-class of rainbow trout (400 grams) and a single-size of feed (5mm pellets). Additionally, the original study used the principle commercial diets of the time (2006). Since 2006, there has been a substantial increase in the cost of fish meal and fish oil and a reduction in the cost of alternative vegetable oils resulting in increased opportunities for alternative feedstuffs in fish feed (Naylor et al. 2009). Our initial study showed differences in fecal waste between diets with similar raw ingredients, and it is expected that increased vegetable oil in rainbow trout diets will further affect the fecal physical characteristics.

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The proposed project intends to extend the data set to market sized fish (~1kg) and include diets that have partially substituted vegetable oil for fish oil in their formulation. The study will also develop a technique to determine the critical scouring velocity of settled feed and fecal wastes which are components required for further validation of DEPOMOD. The established methodology for the measurement of physical characteristics of feed and fecal waste from the earlier study (Moccia, Bevan and Reid 2007) will be used to permit a rapid collection of data.

The four diets used in this trial are currently being evaluated in a concurrent rainbow trout growth trial at the Alma Aquaculture Research Station (AUP 09R123). The physical characteristics of fecal manure from fish fed these diets is required by feed companies, fish farmers and legislative authorities to refine and develop environmentally sound management strategies for fish manure. The Department of Fisheries and Oceans Canada are evaluating the use of the marine-based mathematical model "DEPOMOD" for freshwater cage culture applications. The data obtained in this study will provide additional input for this model's validation and expand the data set required for developing other waste management models for freshwater aquaculture.

Cromey, C.J., T.D. Nickell, and K.D. Black (2002). DEPOMOD – modelling the deposition and biological effects of waste solids from marine cage farms. Aquaculture 214: 211-219.

Moccia, D., D.Bevan and G. Reid, 2007. Composition of feed and fecal waste from commercial farms in Ontario: Physical characterization and relationship to dispersion and depositional modelling. Report submitted to Ontario Sustainable Aquaculture Working group, Environment Canada, 14th July 2007 (21 pages).

Naylor, R.L., R.W. Hardy, D.P. Bureau, A. Chiu, M. Elliott, A. Farrell, I. Forster, D. M. Gatlin, R.J. Goldburg, K. Hua and P. Nicholas. Aquaculture in an era of finite resources. Proceedings of the National Academy of Science (PNAS) 106: 15103-15110.

Reid, G.K., M. Liutkus, S. Robinson, T. Chopin, T. Lander, T. Blair, J.A. Mullen, R.D. Moccia and F. Page. 2009. A review of the biophysical properties of salmonid feces: Implications for aquaculture waste dispersal models and integrated multi-trophic aquaculture. Aquaculture Research 40:257-273.

ARS 145 – Growth and maintenance of genetically important families of Nile tilapia.

Tilapia are a warm-water fish species that are widely cultured in Asia, Africa and South America. In North America, tilapia can be grown in warm-water recirculation water systems. The proposed project is focused on maintaining a valuable tilapia broodstock line that was developed by Northern Tilapia Inc. (now Sustainable Seafood Inc.) over the past 15 years.

The original facility for Northern Tilapia Inc. was located at Sir Sandford Fleming College, Lindsay, Ontario. This facility has been closed and a new facility is being sought. During this transition time, the Alma Aquaculture Research Station has the facilities and experience to maintain these valuable tilapia broodstock.

The broodstock consist of two pedigree lines, composed of reproductively mature fish and juveniles. The fish will be held in the dedicated quarantine/warm-water recirculation facility at the Alma Aquaculture Research Station.

The proposed project will ensure that a unique genetic line of tilapia is maintained. The genetic line has been developed over a 15 year period from founder fish that were originally collected from Egypt. Replacement of this line would be extremely difficult and represents many years of selective breeding. The industry partner is seeking a permanent relocation of the broodstock farm facility and the proposed project provides a temporary holding of the fish while a suitable location is developed.

ARS 147 – Evaluation of stress response in rainbow trout embryos at different developmental stages. F1 generation expression.

The research program explores the effects of early exposure to stress (via maternal exposures) on egg quality and on early development of the embryos produced from these eggs. The program will specifically examine the effects of stress hormones and environmental contaminants that are transferred from the female brood stock to eggs on the growth and development of embryos and early juveniles, and on the expression of growth-related and immune-related genes. Of particular interest is to determine whether very early exposures to stress factors permanently affect the growth phenotypes of the juveniles (and possibly the reproductive potential of the adults).

Stress response patterns have been studied in juvenile and adult salmonid fishes; however, few such studies have focused on the effects of stressors on embryo development, energy partitioning and growth in embryos. Stressors (including environmental factors) are likely to divert energy resources of the embryos from normal growth and development and thus adversely affect growth, and possibly other aspects of the animal's physiology; they might also exert epigenetic actions that result in altered adult phenotypes.

Some stressors, such as those associated with intensive aquaculture, particularly with regard to routine maintenance protocols, transfer of animals between tanks and between farms, hypoxia etc., result in elevated stress hormone levels in the oocytes, and therefore pose a potential risk to embryo development, particularly at key "windows of development" when growth related and immune system-related genes are expressed. Other stressors, such as ubiquitous environmental chemicals also pose potential hazards. Aquatic animals are generally impacted more than terrestrial animals because the chemical factors commonly find their way into aquatic ecosystems. The study will focus on two major groups (based on their mode of action on biological systems), namely xenoestrogens and chlorinated hydrocarbon compounds. In juvenile and adult salmonid fish, xenoestrogens stimulate the inappropriate synthesis of the yolk phospolipoprotein, vitellogen; chlorinated hydrocarbon compounds act as hepatic aryl hydrocarbon receptor (AhR)-initiating chemicals that stimulate the production of hepatic mixed function oxidase enzymes. In both situations, energy that would normally be invested in growth is redirected.

The study will provide us with:

- A better understanding of the effects of stressor imposed on the broodstock and then transferred to the embryo on early embryo development.
- A better understanding of the ability of the embryos and early juvenile stages to respond to stressors.
- Provide much needed information about the effects of intensive aquaculture practices on the growth performances of the offspring.

ARS 149 – Effect of different plant protein sources on growth, feed efficiency and flesh pigmentation of rainbow trout.

Issues of economical and environmental sustainability are forcing feed manufacturers to reduce fish meal level and rely on the use of feed ingredients of plant origin for the production of fish feeds. Corn gluten meal and soy protein concentrate are two plant protein ingredients that are increasingly used in the formulation of rainbow trout feeds. Studies have shown that feeds formulated with high levels of these two ingredients can support high growth and feed efficiency in rainbow trout. However, some studies have yielded more mitigated results. The current hypothesis is that some studies were carried out with suboptimal nutrient levels. Estimates of nutrient requirements of rainbow trout have recently been revised by a committee of experts and the findings of the committee can be found in the newly published "NRC (2011) Nutrient Requirements of Fish and Shrimp". Questions remain about the effect of these two protein sources on final product (flesh) quality, notably pigmentation of rainbow trout. The production of fillets which are attractive to consumers is a very important for the economical sustainability of rainbow trout culture operations. The goal of this project is to examine the effect of the level of corn gluten meal and soy protein concentrate on growth, feed efficiency and final product (flesh) quality of rainbow trout. One of the goals of this project is also to test if the essential amino acid requirements of rainbow trout suggested by the newly published "NRC (2011) Nutrient Requirements of Fish and Shrimp" are adequate for commercial feed formulations.

The research projects carried out under this project will help scientists and feed manufacturers develop highly nutritive diet formulae that result in healthy, fast growing and disease resistant rainbow trout with good final product (flesh) quality.

ARS 150 – The effects of bisphenol A (BPA) on reproduction, growth development and stress response in rainbow trout.

Bisphenol A (BPA) has been measured in the Grand River, and the muscle of fish inhabiting this water body. While the accumulation of this chemical in the fetus leads to multi-generational effects in mammals, we know very little about long-term effects of BPA exposure in fish. Here we are proposing to test the multi-generational effects associated with BPA accumulation in fish eggs. The rationale behind this paradigm is that contaminants such as BPA, which accumulate in tissues, are transferred to the eggs from the mother. This may have hugs implications in developmental programming events. Here we are asking the question whether BPA accumulation in eggs of rainbow trout, mimicking maternal transfer, can lead to phenotypes compromised growth and stress responses in the F1 generation. A multi-tiered approach comparing genes in trout phenotype along with changes in genome and metabolic pathways (termed “OMICs” in this proposal) in the F1 generation will be undertaken. Such “OMICs” responses will be compared with other physiological measures, including changes in hormone levels and their action, in response to growth and stress, as indicators of altered fish performance. Collectively, the results will allow us to develop novel risk assessment tools that will increase our capacity for predicting population-level damage. The knowledge and understanding of generational effects induced by BPA accumulation in eggs, and the development of markers that will predict these effects, will be useful tools for Canadian government managers monitoring the aquatic environment, and for industry environmental toxicologists.

This study will provide insight into the mode of action of BPA. Moreover, candidate genes that are targets for BPA will be identified and will assist with the development of molecular markers during early life stages for predicting long-term effects, including reproductive success. The research conducted as part of this study could be used to assess the long-term impacts associated with maternal transfer of chemicals commonly found in Canadian fresh waters, such as those released from agriculture and urban runoff. The study will not only establish the phenotypic traits that are disrupted by chemical exposure during a critical period of development, but will also identify mechanisms that will result in long-term effects in fish and in their offspring, to better predict the impact that chemicals and numerous xenobiotics have on aquatic populations.

ARS 151 – The evaluation of submerged membrane filtration as an alternative to UV disinfection and the removal of *Flavobacterium psychrophilum* from recirculation aquaculture systems.

Rising environmental and social pressures to increase water conservation, waste discharge standards, and production biosecurity continues to raise the potential for recirculation technologies in aquaculture. Recirculation aquaculture systems (RAS) utilize combinations of wastewater disinfection treatments, e.g. UV and ozone, to reduce the pathogen load exposed to cultured fish. However, UV disinfection efficiency is limited by decreasing bulb intensity, high levels of wastewater turbidity, and UV tolerant pathogens. The variability of UV disinfection may make RAS vulnerable to increased pathogen loads and eventual disease outbreaks. *Flavobacterium psychrophilum*, the pathogenic agent for bacterial cold water disease (BCWD), is able to tolerate UV doses commonly used in aquaculture. Alternative disinfection systems are needed to reduce outbreaks of this pathogen in RAS in order to reduce mortalities and production losses associated with BCWD. In the past, RAS have routinely adapted municipal wastewater treatment technologies (e.g. UV) that have become affordable due to their recognized success. Today, membrane filtration continues to be recognized as a reliable and affordable wastewater treatment process used for clarification and disinfection purposes in numerous industrial applications. This study will evaluate membrane filtration as an alternative wastewater treatment system in RAS in comparison to UV. A membrane filtration system will treat fish wastewater in parallel with a UV reactor in a RAS for a period of 30 days. Its performance will be evaluated on the basis of membrane fouling rate and removal efficiencies of bacteria, suspended solids, and other wastes. Also, this study will determine if membrane filtration can achieve 3-log removal of *Flavobacterium psychrophilum* in a closed loop system. This evaluation will determine if membrane filtration can be an effective wastewater treatment process in improving water quality and biosecurity in RAS.

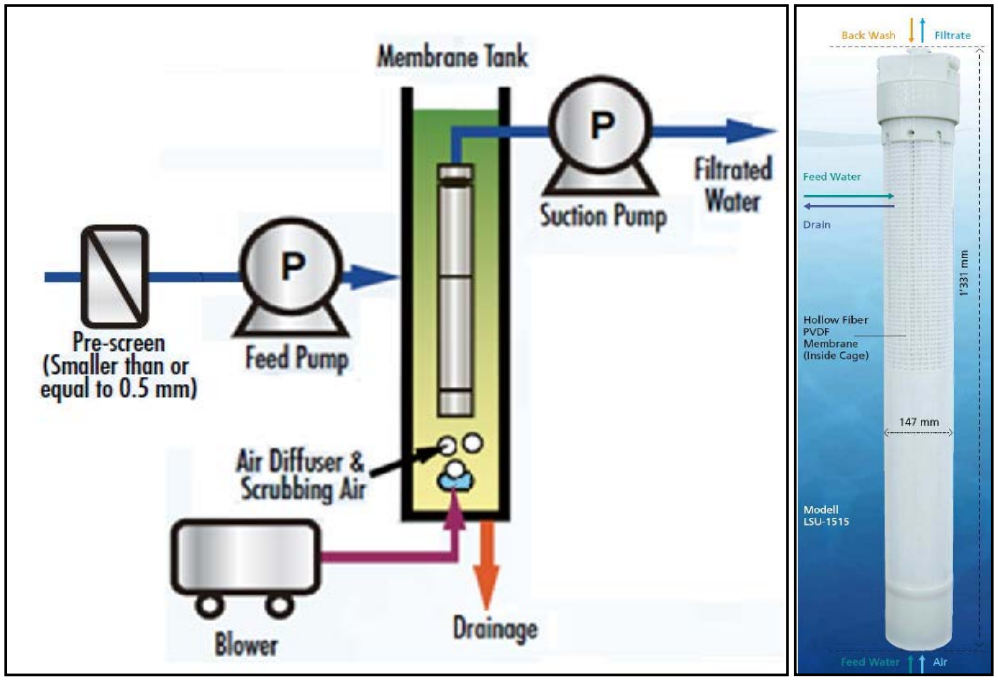

Figure 4. Submerged hollow-fibre ultrafiltration membrane filter and its configuration (courtesy of Toray Membrane USA, Inc.).

ARS 152 – Evaluation of ration reductions on the growth, feed conversion pigment retention and somatic indices of rainbow trout.

In aquaculture, feeding is crucial to viability and success. As a rule, fish farmers rely on feed manufacturers to provide well balanced diets for their operations. While the farmer generally has little input into the composition of the diet, he determines the ration that is offered the fish to promote good growth and minimal waste. Underfeeding results in poor growth and production, while overfeeding results in wastage and water quality deterioration. The ration size is normally calculated as a percentage of the biomass present and feeding charts are widely available for rainbow trout. However, it is difficult to predict with any accuracy the exact biomass of the fish to be fed. Furthermore, many physiological factors (size, reproductive condition, social stressors, nutritional requirements, gastro-intestinal evacuation, etc.) and environmental factors (oxygen availability, waste metabolite concentrations, temperature, photoperiod, water velocity, etc.) result in day-to-day variations in appetite and these variations are very difficult to predict. As a result, many trout farmers rely on feeding to near-satiation with modifications being made to allow for ambient environmental conditions to achieve optimal feeding rates (the rate that results in the best growth and feed conversion ratio). Feeding to near-satiation may not be be the best strategy utilized, if feed costs and environmental concerns are considered. The use of expensive trout diets would suggest greater financial returns are possible if reduced feeding rates are utilized to maximize the feed conversion rate even at the expense of growth rates.

The objectives of this study is to feed rainbow trout varying feeding rates from near-satiation to 67% of near-satiation to determine the effects of reduced daily ration on growth, condition factor, size variation, and feed conversion efficiencies, as well as such economically important processing traits as pigmentation, dress-out yield and fillet yield.

Feed can account for approximately 40–60% of a rainbow trout farm's operating costs depending upon the type and size of the farm and the feeding husbandry practices followed. Given this fact, significant cost savings could be realized if the farmer was able to reduce the daily feeding rate without compromising fish health, growth, size variation, pigmentation levels and carcass yield.

ARS 155 – Genetic studies of growth, maturation timing, spawn timing, and family relatedness in salmonid fishes.

This research addresses aspects of the influence of different genes on various phenotypic traits in salmonid fishes. These traits include growth, spawn timing, maturation timing, stress/disease resistance and growth performance. An understanding of the underlying genetic influence on these traits is of both basic and applied significance. The basic knowledge gained will increase our knowledge of where the genes influencing these traits are located in the salmonid genome. In addition, the fundamental knowledge gained from this research may also enhance the aquaculture of these species via the ability to select fish with desirable genes for the traits being studied. Aquaculture will grow in increasing importance in the future and may help to alleviate pressures on wild capture fisheries, many of which, are already greatly endangered. To facilitate these experiments fish from commercial broodstocks are selected and submitted to my lab for genetic analysis. These fish may be reared to maturity and periodically handled to measure growth and reproductive state. Either small gill tissue biopsies or adipose fin clips are taken from selected individuals that may be used in different experiments, if it is desired to maintain the fish for continued observation, or they are humanely euthanized at the end of an experimental time period. DNA is extracted from these small tissue samples to determine genetic variation in DNA marker association studies. Most procedures involve general anaesthesia of the fish. Through molecular genetic pedigree analysis we will be characterizing the genetic variability present in a commercial strain of rainbow trout (i.e., LYNDON strain), and use the information on growth rate performance in the progeny from several families derived from this strain to identify parents that possess 'superior' growth performance genes, and genes conferring high degrees of spawning time variability in females.

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The phenotypic manifestation of complex life-history traits such as the timing of first maturation in an animal's life, the time within a reproductive season when a female's eggs are ovulated, and the developmental trajectories in an animal's ontogeny is a complex interaction between the expression of specific genes controlling the onset of these specific traits, and modulation of these events through environmental interactions. Underlying the expression of all these important life-history developmental events is a requisite for the anabolic acquisition of energy resources to fuel subsequent developmental transitions. Growth rates per se, are known to be intricately coupled to the onset of early maturation rates and spawning times in fishes, and this research furthers our understanding of this process in a group of model research species, the salmonid fishes.

We are studying the arrangement (chromosomal location) and gene expression profiles of specific co-functioning gene families that prior research has indicated to be of importance in regulating the transitions of important life-history events in two model species of salmonid fishes (i.e. rainbow trout, *Oncorhynchus mykiss*; and Arctic charr, *Salvelinus alpinus*). Previous research from our lab has implicated chromosomal regions bearing the circadian timing genes (i.e. multiple *Clock* genes, *BMAL1*, multiple *Period* genes, *ROR* complex, and *RevErb* complex) as being important in influencing the life-history traits mentioned. In some instances, we have directly cloned and mapped genes within this complex to known haplotype blocks that differentially associate with progeny expressing alternate life-history phenotypes (e.g. early vs. late maturing; early vs. late spawning). In other instances we are using comparative genomic approaches with more completely characterized genomic species such as zebrafish and medaka, to infer the expected location of key candidate genes and we are now currently cloning and mapping these genes in our model species. Our second group of target genes involve those regulating myogenic development and to a lesser extent lipid metabolism, and as such, growth differentials within fishes (i.e. mTOR; AKT; myogenic factor (Myf and MRF family genes); IGF1, IGF2, GH1, GH2; Grf/PACAP; SIRT gene family; ID regulatory family; etc). Concordant with these studies is the investigation of many of the genes important in regulating the initial sex determination, and the final sexual differentiation and sexual maturation pathways (i.e. aromatase(Cyp19); 11β-hydroxylase; amh; Nr5A gene family; GDF9; BMP15; DAX; DMRT-related; etc.).

Knowledge gained from the research will further our understanding of the genes regulating spawning time, maturation rate, and growth in salmonid fishes, and will aid the Canadian aquaculture industry in identifying family lines possessing superior growth characteristics for the commercial industry. This will reduce environmental waste by through improved food conversion efficiencies in broodstock families, and reduce grow out times to harvest for production lots. Most of this research will focus on improvements to the main commercial egg-producing strain of rainbow trout in Ontario (i.e., LYNDON Fish Hatcheries, New Dundee, Ontario). The LYNDON strain of rainbow trout is likely the only rainbow trout strain in the world that has been selected to express an almost year-round egg production cycle (i.e., April-first week of March).

ARS 160 – Experimental infection trials with bacterial coldwater disease (Flavobacterium psychrophilium) in rainbow trout.

Bacterial coldwater disease (BCWD), caused by *Flavobacterium psychrophilum*, has a marked deleterious impact on the freshwater salmonid aquaculture in Canada. With mortality of some trout strains approaching 20-30% and associated heavy antimicrobial use, the costs of the disease are substantial and the risk of antimicrobial resistance is serious. In spite of the obvious need, there are no commercial vaccines available. Further, breeding programs are currently underway to improve the growth of rainbow trout, but it is imperative that any gains made via a family selection program aren't negated by increased mortality or other costs due to BCWD. For these reasons, development of effective management tools to reduce the deleterious impact of this disease are needed.
This project therefore has three major goals: 1) to evaluate cold-induced proteins as vaccine candidates, 2) to identify BCWD resistant and susceptible families of rainbow trout that can be used to understand the immunological basis for disease resistance and 3) to better characterize the humoral and cell-mediated immune responses stimulated by vaccination and by natural and experimental infection. The results of this project should help to deliver effective tools for the prevention of BCWD and provide high quality training for four doctoral candidates and several summer students.

ARS 163 – Aquaculture development and profitable commercialization of Arctic charr in Canada.

The expansion of the Canadian aquaculture industry resides in the ability to develop new species for culture. The Arctic charr (*Salvelinus alpinus*) has several characteristics that make it an attractive aquaculture species that can only be reared at more northerly latitudes. To be successful and gain an international competitive advantage, the Arctic charr industry needs to develop and manage strains that are uniquely suited to the Canadian environment. The production potential of commercial Arctic charr in Canada is greatly reduced by large variation in growth and early maturity resulting in low global output. Selective breeding of Arctic charr with desirable characteristics requires knowledge of relative family performance (e.g., growth, maturation schedule, etc.) combined with identification of chromosomal regions that control the traits of economic significance.
This research will meet those needs and (1) identify chromosomal regions for growth and age at maturation among multiple families of Arctic charr from different strains and (2) develop genetic evaluation models to compute estimated breeding values (EBVs) for these traits. These two sources of information will be used to develop a Total Merit Index (TMI) suitable for use in a marker assisted selection program. If successful, the results of this research will have applications to the commercial aquaculture industry in Ontario and across Canada.

ARS 164 – Development of cost-effective tilapia diets suited to the high demands of intensive recirculation facilities.

This project will help to increase the understanding of growth processes (pattern and cost nutrient deposition) of tilapia in order to generate appropriate models for utilization of nutrients, energy and feed. This project aims to: reduce waste outputs of these fish under a wide range of rearing environments; examine the suitability of common and novel ingredients in diets for tilapia; and examine issues related to quality of fish feed ingredient or their impact on performance of animal and final product (flesh) quality and healthfulness.
The objectives of this study are to: 1) Asses the nutritional requirements of tilapia; 2) Adapt and explore the potential usefulness of a novel bioenergetics model for tilapia; 3) Produce three experimental cost-effective feeds meeting the nutrient requirements of tilapia and the specific commercial requirements in Ontario and assess physical characteristics of the feeds; 4) Compare three experimental diets with three commercial feeds currently used with regards to growth, feed conversion ratio, fecal stability, pellet quality and cost. The anticipated impact of this study are: 1) Increasing the understanding on the nutritional requirements of tilapia 2) Development of cost effective formulations for tilapia 3) Develop the production of formulated diets for tilapia by Canadian feed manufacturers This will in turn, promote the production of well nourished, healthy tilapia for aquaculture purposes.

ARS 165 – Precision formulation of trout feeds with low fish meal levels.

This project will help to develop nutritive diet formulae for hatchery-reared fish intended for stocking or for aquaculture. To examine the suitability of novel high quality plant protein ingredients for their inclusion in formulated diets for fish. To examine issues related to quality of fish feed ingredient or their impacts on performance of animal and final product (flesh) quality and healthfulness. To develop a greater understanding of the growth processes (pattern and cost of nutrient deposition) in fish in order to develop accurate and practical nutrient, energy, feed and oxygen requirement and waste output models for these fish under a wide range of rearing environment. The results from this project will help scientists and feed manufacturers develop highly nutritive diet formulae. This will, in turn, promote the production of well nourished, healthy fish for stocking and aquaculture purposes.

ARS 168 – Muscle pigmentation of rainbow trout (*Oncorhyncus mykiss*) fed diets supplemented with different sources of astaxanthin.

This project will help to develop nutritive diet formulae for hatchery-reared fish intended for stocking or for aquaculture. To examine the suitability of novel high quality plant protein ingredients for their inclusion in formulated diets for fish. The novel ingredients include high protein sunflower meal, high protein canola meal, canola and soy protein concentrates and flaxseed meal. These ingredients are novel as they are of slightly higher nutritive value than conventional ingredients of similar origin. The ingredients are produced using simple technique aimed at concentrating the useful nutrients for salmonid fish (protein, amino acids, lipids) and decrease the level of indigestible components (indigestible carbohydrates, lignin, phytates, etc.) To examine issues related to quality of fish feed ingredient or their impacts on performance of animal and final product (flesh) quality and healthfulness. To develop a greater understanding of the growth processes (pattern and cost of nutrient deposition) in fish in order to develop accurate and practical nutrient, energy, feed and oxygen requirement and waste output models for these fish under a wide range of rearing environment. The results from this project will help scientists and feed manufacturers develop highly nutritive diet formulae. This will, in turn, promote the production of well nourished, healthy fish for stocking and aquaculture purposes.

ARS 169 – Evaluation of four commercial starter feeds for rainbow trout (*Oncorhyncus mykiss*) held under typical hatchery conditions.

Since the introduction of high-pressure moist extrusion technologies in the 1980's, modern dry and durable high-energy salmon and trout diets have been available to Ontario rainbow trout farmers. The diet of rainbow trout should meet the requirements for all essential nutrients, and much of the nutritional research to date has concentrated on the identification and utilization of those nutrients. More recent studies have investigated nutrient substitutions to develop more cost effective feeds and to reduce the solid and nutrient wastes into effluent waters. The result of this research has allowed fish feed manufacturers to develop and distribute rainbow trout diets that are highly effective in insuring both rapid growth and minimal waste.

The rapid proliferation of aquaculture over the past two decades has seen the growth of fish feed manufacturers on the global, national and local levels. Choice of manufacturer tends to be dictated by cost of feed and availability, rather than performance of the fish fed any particular brand of feed. Feed evaluations are usually presented by the manufacturer or by fish farmers. There are obvious problems with either of these sources. Manufacturers promote their feed with a bias and seldom provide data that supports their claims. Evaluations of fish feeds from fish farmers tend to be largely anecdotal. Furthermore, the effects of environmental conditions (water temperature, dissolved oxygen, fish densities, etc.), fish genetics and culture methodologies can have greater influences on the growth and mortality of fish than does nutrition. As these effects are seldom accounted for and vary greatly from farm to farm and year to year, data collected by farmers is generally considered ineffective in determining which brand of feed to use.

The Alma Aquaculture Research Station (AARS) of the University of Guelph is uniquely suited to evaluate rainbow trout diets. The purpose of this study was to grow rainbow trout (*Oncorhynchus mykiss*) fry from first feeding to 35 g using starter feeds purchased from four different feed manufacturers. The objective was to determine which feeds best promoted growth and survivability, and at what cost.

ARS 170 – Evaluating four commercially available rainbow trout diets on the growth and feed conversion of Ontario domestic rainbow trout (*Oncorhyncus mykiss*).

In aquaculture, feed can account for approximately 40-60% of a rainbow trout farm's operating costs depending upon the type and size of the farm and the feeding husbandry practices followed. Since the introduction of high-pressure moist extrusion technologies in the 1980's, modern dry and durable high-energy salmon and trout diets have been available to Ontario rainbow trout farmers. Choice of manufacturer is dictated by the cost, availability and performance of the fish. While unit cost and availability of the feed is easily determined by the farmer, the performance of the fish fed any particular brand of feed is more difficult to ascertain. Feed evaluations are usually offered by the manufacturer or by fish farmers. There are obvious problems with either of these sources. Manufacturers promote their feed with a bias and seldom provide the relevant data to support their claims. Evaluations of fish feeds from fish farmers tend to be largely anecdotal. Furthermore, the effects of environmental conditions (water temperature, dissolved oxygen, fish densities, etc.), fish genetics and culture methodologies can have greater influences on the growth and mortality of fish than does nutrition. As these effects are seldom accounted for and vary greatly from farm to farm and year to year, data collected by farmers is generally considered ineffective in determining which brand of feed to use. The Alma Aquaculture Research Station (AARS) of the University of Guelph is uniquely suited to evaluate rainbow trout diets. The purpose of this study is to grow rainbow trout (*Oncorhynchus mykiss*) from 450 g to market size of 1,200 g using four different commercially available grower feeds.

The objectives of this study is to feed rainbow trout four different commercially available grower feeds to determine their effects on growth, condition factor, size variation, and feed conversion efficiencies so that Ontario trout farmers can make a more informed choice with regards to feed selection for their fish.

ARS 171 – Effects of water alkalinity, pH, and dosing regimen on lake sturgeon sensitivity to the lampricide, 3-trifluoromethyl-4-nitrophenol (TFM).

The lampricide 3-trifluoromethyl-4-nitrophenol (TFM) selectively targets larval sea lampreys (*Petromyzon marinus*), which have a lower capacity to detoxify and eliminate TFM through its conversion to TFM-glucuronide than non-target fishes. Although non-target fish mortality is relatively uncommon, juvenile lake sturgeon (*Acipenser fulvescens*) are vulnerable to TFM-induced mortality, particularly when smaller than 10 cm. Moreover, sturgeon are unexpectedly more susceptible to TFM toxicity in waters of higher alkalinity, which contrasts with the decrease in TFM toxicity seen in sea lampreys and other fishes with increases in alkalinity. There is therefore a need to determine why lake sturgeon are more vulnerable to TFM in their early life stages, especially in waters with different alkalinities and pHs, and to better understand how they take-up and detoxify TFM. With such information, it may therefore be possible to develop alternate TFM treatment protocols that protect these fish from TFM toxicity, without compromising sea lamprey control efforts.

Table 1. Research Projects Conducted at the Alma Aquaculture Research Station 2010 – 2016.

AARS #	Researcher(s)	Research Title	Fish Species	Start	Finish
ARS120	Dr. Richard Smith, Dr. Carmel Mothersill, Dr. Colin Seymour & Prof. Richard Moccia Dept. Biology, McMaster University and Dept. Animal and Poultry Sciences, Ontario Agriculture College	Investigating the radiation bystander effect in fish	**Rainbow Trout**	09/2008	11/2013
ARS143	Prof. Richard Moccia/ David Bevan Dept. Animal Poultry Science, Ontario Agriculture College	Physical characteristics of fecal waste from rainbow trout.	**Rainbow Trout**	02/2010	04/2010
ARS144	Dr. John Leatherland/ Mao Li Dept. Biomedical Sciences, Ontario Veterinary College	Evaluating the effectiveness of an artificial extender (Acti-Fish) in retaining egg quality and hormone/chemical delivery efficiency.	**Rainbow Trout**	09/2010	03/2011
ARS145	Gary Chapman Sustainable Seafood Inc. Bond Head, Ontario	Growth and maintenance of genetically important families of Nile tilapia.	**Nile Tilapia**	06/2010	04/2014
ARS146	Dr. M. Vijayan/ Oana Birceanu Dept. of Biology University of Waterloo	Effect of estrogenic compounds and dose response to bisphenol A on gene expression in early embryogenesis using microarray analysis: F1 generation expression.	**Rainbow Trout**	09/2010	10/2011
ARS147	Dr. John Leatherland/ Mao Li Dept. Biomedical Sciences Ontario Veterinary College	Evaluation of stress response in rainbow trout embryos at different developmental stages. F1 generation expression.	**Rainbow Trout**	08/2010	12/2010
ARS148	Dr. Roy Danzmann Integrative Biology College of Biological Sciences	Genetic studies of growth, maturation timing, spawn timing, and family relatedness in salmonid fishes: Lyndon male evaluation.	**Rainbow Trout**	11/2010	06/2014

AARS #	Researcher(s)	Research Title	Fish Species	Start	Finish
ARS149	Dr. Dominique Bureau/ Martin Mills Inc. Dept. Animal Poultry Science Ontario Agriculture College	Effect of different plant protein sources on growth, feed efficiency and flesh pigmentation of rainbow trout.	**Rainbow Trout**	06/2011	12/2011
ARS150	Dr. M. Vijayan/ Oana Birceanu Dept. of Biology University of Waterloo	The effects of bisphenol A (BPA) on reproduction, growth, development and stress response in rainbow trout.	**Rainbow Trout**	11/2011	01/2012
ARS151	Prof. Richard Moccia/ David Huyben Dept. Animal Poultry Science Ontario Agriculture College	The evaluation of submerged membrane filtration as an alternative to UV disinfection and the removal of *Flavobacterium psychrophilum* from recirculation aquaculture systems.	**Nile Tilapia**	11/2011	12/2011
ARS152	Prof. Richard Moccia/ Martin Mills Inc. Dept. Animal Poultry Science Ontario Agriculture College	Evaluation of ration reductions on the growth, feed conversion, pigment retention and somatic indices of rainbow trout.	**Rainbow Trout**	02/2012	10/2012
ARS153	Prof. Richard Moccia/ Dr. Janusz Pawlisyn Dept. Animal Poultry Science Ontario Agriculture College, and University of Waterloo	Determination of geosmin GSM) and 2-methylisoborneol (MIB) concentrations in rainbow trout by *in-vivo* sampling using solid phase microextraction (SPME).	**Rainbow Trout**	04/12	05/2012
ARS154	Dr. John Leatherland/Mao Li Dept. Biomedical Sciences, Ontario Veterinary College	Evaluating last stage of maternal stress effects on gravid ovulation; maternal stress hormones and xenobiotics on embryogenesis of rainbow trout (ER and GR interaction on embryogenesis.	**Rainbow Trout**	08/2012	03/2013
ARS155	Dr. Roy Danzmann Integrative Biology College of Biological Sciences	Molecular pedigree analysis for the establishment of an elite rainbow trout broodstock.	**Rainbow Trout**	09/2012	09/2014
ARS156	Dr. John Leatherland/Mao Li Dept. Biomedical Sciences, Ontario Veterinary College	Evaluating circulating cortisol variations of gravid fish during reproduction season of rainbow trout.	**Rainbow Trout**	05/2012	04/2012

AARS #	Researcher(s)	Research Title	Fish Species	Start	Finish
ARS157	Dr. John Leatherland/ Jackie Ferris. Dept. Biomedical Sciences, Ontario Veterinary College	A microarray analysis of the effects of bisphenol A on gene and protein expression in bovine and trout early embryogenesis and bovine trophoblast cell culture.	**Rainbow Trout**	10/2012	12/2012
ARS158	Dr. John Lumsden/ Elena Contador Fish Pathology Lab Pathobiology Ontario Veterinary College	Diagnosis and pathogenesis of chlamydia-like organism in trout.	**Rainbow Trout**	08/2012	08/2013
ARS159	Dr. Brian Dixon/ Terin Robinson Dept. of Biology University of Waterloo	An immunogenetic assessment of variation in Arctic charr (*Salvelinus alpinus*).	**Arctic Charr**	10/2012	02/2013
ARS160	Dr. John Lumsden Fish Pathology Lab Pathobiology Ontario Veterinary College	Experimental infection trials with bacterial coldwater disease (*Flavobacterium psychrophilium*) in rainbow trout.	**Rainbow Trout**	11/2012	04/2014
ARS160b	Dr. John Lumsden Fish Pathology Lab Pathobiology Ontario Veterinary College	Experimental infection trials with bacterial coldwater disease (*Flavobacterium psychrophilium*) in rainbow trout.	**Rainbow Trout**	09/2013	08/2014
ARS160c	Dr. John Lumsden Fish Pathology Lab Pathobiology Ontario Veterinary College	Experimental infection trials with bacterial coldwater disease (*Flavobacterium psychrophilium*) in rainbow trout.	**Rainbow Trout**	09/2014	06/2015
ARS160d	Dr. John Lumsden Fish Pathology Lab Pathobiology Ontario Veterinary College	Experimental infection trials with bacterial coldwater disease (*Flavobacterium psychrophilium*) in rainbow trout.	**Rainbow Trout**	09/2015	-
ARS161	Dr. Roy Danzmann Integrative Biology College of Biological Sciences	Aquaculture development and profitable commercialization of Arctic charr in Canada.	**Rainbow Trout**	10/2013	06/2015
ARS163	Dr. Moira Ferguson Integrative Biology College of Biological Sciences	Aquaculture development and profitable commercialization of Arctic charr in Canada – Labrador Strain.	**Arctic Charr**	10/2013	-
ARS163b	Dr. Moira Ferguson Integrative Biology College of Biological Sciences	Aquaculture development and profitable commercialization of Arctic charr in Canada – Nauyak Lake Strain.	**Arctic Charr**	20/2014	02/2015

AARS #	Researcher(s)	Research Title	Fish Species	Start	Finish
ARS163c	Dr. Moira Ferguson Integrative Biology College of Biological Sciences	Aquaculture development and profitable commercialization of Arctic charr in Canada – Nauyak Lake Strain.	**Arctic Charr**	05/2015	-
ARS164	Dr. Dominique Bureau Dept. Animal Poultry Science Ontario Agriculture College	Development of cost-effective tilapia diets suited to the high demands of intensive recirculation facilities.	**Nile Tilapia**	11/2013	04/2014
ARS165	Dr. Dominique Bureau Dept. Animal Poultry Science Ontario Agriculture College	Precision formulation of trout feeds with low fish meal levels.	**Rainbow Trout**	06/2014	11/2014
ARS166	AARS Office of Research	Evaluation of commercial rainbow trout starter feed with regards to growth rate, mortality rate and gastro-intestinal pathologies.	**Rainbow Trout**	04/2014	06/2014
ARS167	Prof. Richard Moccia Dept. Animal Poultry Science Ontario Agricultural College	Effects of increasing density on the growth and production of Arctic charr fingerlings.	**Arctic Charr**	-	-
ARS168	Dr. Dominique Bureau Dept. Animal Poultry Science Ontario Agriculture College	Muscle pigmentation of rainbow trout (*Oncorhyncus mykiss*) fed diets supplemented with different sources of astaxanthin	**Rainbow Trout**	12/2014	03/2015
ARS169	AARS Office of Research	Evaluation of four commercial starter feeds for rainbow trout (*Oncorhyncus mykiss*) held under typical commercial hatchery conditions.	**Rainbow Trout**	11/2014	06/2015
ARS170	Prof. Richard Moccia/ Martin Mills Inc. Dept. Animal Bioscience Ontario Agriculture College	Evaluating four commercially available rainbow trout diets on the growth and feed conversion of Ontario domestic rainbow trout (*Oncorhyncus mykiss*).	**Rainbow Trout**	03/2016	-
ARS171	Prof. Richard Moccia/ Dept. Animal Bioscience Ontario Agriculture College, Dr. Mike Wilke Dept. Biology, Wilfred Laurier University	Effects of water alkalinity, pH, and dosing regimen on lake sturgeon sensitivity to the lampricide, 3-trifluoromethyl-4-nitrophenol (TFM).	**Lake Sturgeon**	05/2016	-