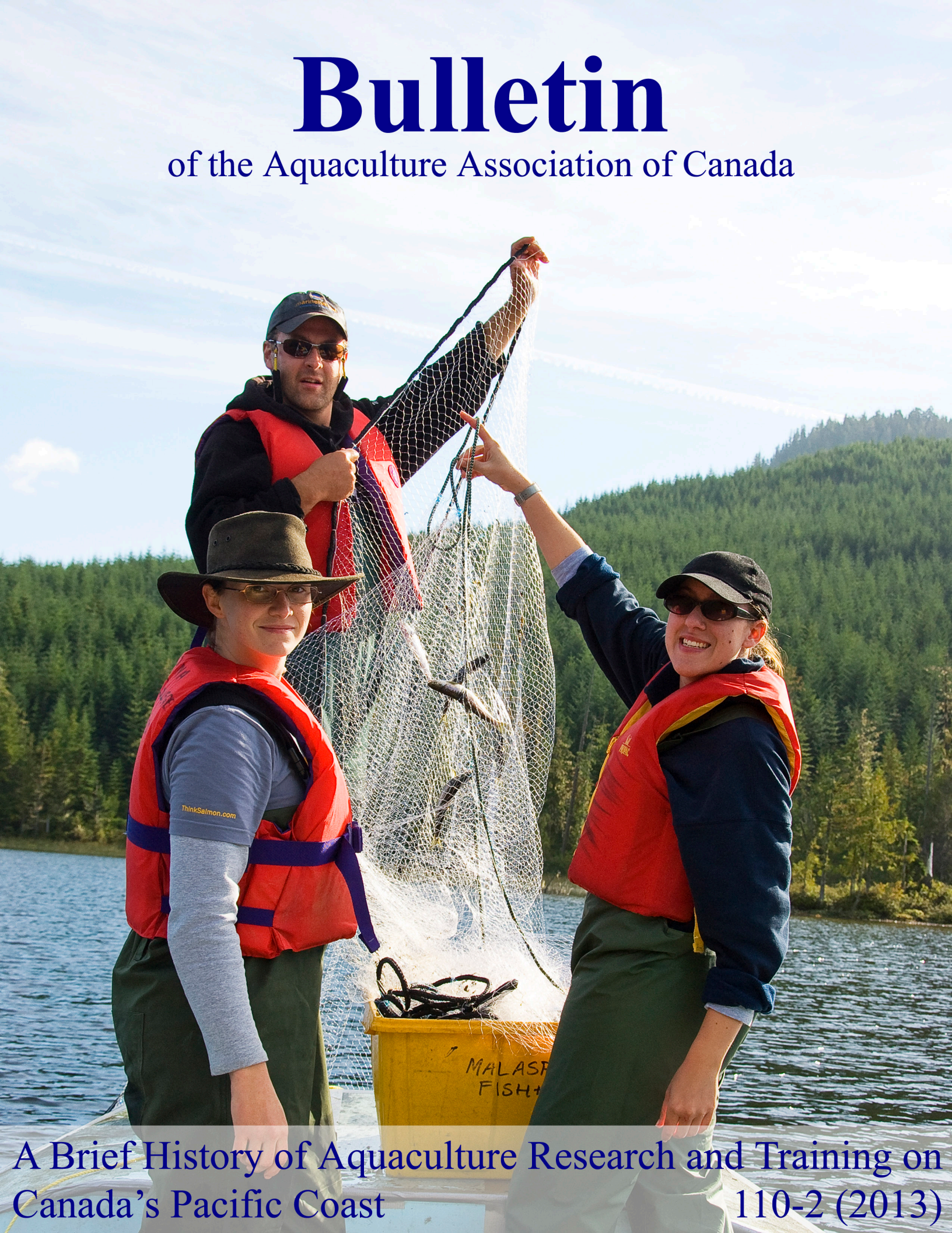
Bulletin

of the Aquaculture Association of Canada



A Brief History of Aquaculture Research and Training on Canada's Pacific Coast

110-2 (2013)

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Cover:
Students from Vancouver Island University's Fisheries and Aquaculture Program learning field techniques at Klaklakama Lake, BC. Photo: Bill Pennell.

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A Brief History of Aquaculture Research and Training on Canada's Pacific Coast

Introduction from the President

This issue of the Bulletin details the formative years and ongoing development of aquaculture research and training on the Pacific Coast of Canada. These articles are a testament to the ingenuity and perseverance of pioneering researchers and educators. From salmon to sablefish, and oysters to scallops, cultured seafood is a major economic driver for coastal regions of British Columbia and has developed continuously despite immense technical and political challenges. This is largely due to the successful collaborations by academia, industry, government, independent researchers and first nations, many of which are highlighted in this issue. Perhaps one of the most telling aspects of the expertise and dedication from this region is the ongoing research and commitment to fostering sustainable aquaculture in developing regions around the world. We are very fortunate to have such dedicated and enthusiast aquaculture professionals. The AAC is proud to highlight their achievements and I encourage you to read the enclosed articles.

Céline Audet

President of the Aquaculture Association of Canada

Mot de la Présidente

Ce numéro du Bulletin présente les développements en recherche et formation en aquaculture réalisés sur la côte ouest du Canada. Ces articles se veulent un éloge à l'ingéniosité et la persévérance des pionniers du domaine. Du saumon à la morue charbonnière et de l'huître aux pétoncles, la production de produits marins est une importance force économique sur la côte ouest et s'est continuellement développée et diversifiée en dépit de défis importants tant sur le plan technique que politique. Les collaborations fructueuses entre chercheurs universitaires, gouvernementaux, indépendants et les premières nations sont en grande partie responsable de ce succès et ce numéro en illustre quelques unes. La recherche et l'implication dans le développement d'une aquaculture durable dans les pays en voie de développement font écho aux compétences des acteurs de cette région et nous sommes chanceux de pouvoir compter sur l'enthousiasme et l'implication de ces professionnels de l'aquaculture. L'AAC est fière de pouvoir illustrer leurs réalisations et je vous invite à lire les articles qui font partie de ce numéro.

Céline Audet

Présidente, Association aquacole du Canada

Aquaculture Research and Development on the Pacific Coast

C Clarke and W Pennell

Craig Clarke

Bill Pennell

The Pacific Biological Station (PBS) was established in 1908 and is the principal centre for fisheries research conducted by the Department of Fisheries and Oceans (DFO) on the Pacific Coast. Aquatic facilities are supplied with ambient temperature, chilled and heated salt water and fresh water lines. A netpen complex is located in Departure Bay adjacent to the station.

Shellfish

The original species selected for aquaculture in British Columbia (BC) was the Pacific oyster (*Crassostrea gigas*) which was imported from Japan. It is now the most widely cultivated oyster in the world, having been transplanted to many countries in the northern and southern hemispheres. Prior to introduction of the Pacific oyster, the native Olympic oyster, *Ostrea lurida*, was subject to a small fishery which expanded significantly during the first three decades of the 20th century. Relatively little actual culture was done with this species in BC, although European culture methods were applied to it in Puget Sound, Washington, USA. In BC, efforts were made to better understand the biology of *O. lurida* with intent to preserve the oyster beds and sustain the fishery; however the species was essentially fished out by the late 1930s[(1)] Today the Olympic oyster is still widespread, and abundant along the west coast of Vancouver Island; around the Strait of Georgia its abundance is generally low except for a few moderately dense populations; it is, however, abundant in the Gorge Waterway in Victoria Harbour.[(2)] In addition to overfishing, pulp mill pollution in the 1940s – 1960s has been blamed for its decline or failure to rebound.

Pacific Biological Station and adjacent experimental fish farm in 2012 (Photo: C. Clarke)

The Pacific oyster was brought into Washington State in 1902, initially as a source of fresh oysters for luxury ships crossing the Pacific as well as serving a fresh oyster market in western cities, and later as a possible replacement for the native Olympic oyster. Attempts to bring the Eastern oyster, *Crassostrea virginica*, to the west coast of the United States and to BC were only moderately successful because it suffered very high mortalities. By contrast *C gigas* survived and grew well on the west coast and could be imported as seed. In 1914 Pacific oyster seed was brought into BC from Japan via Washington State. These introductions may have been preceded by unrecorded shipments from Japan by private citizens. By the 1920's large shipments were coming into BC from Washington State and experimental farms were forming in Boundary Bay and Ladysmith Harbour. The new industry developed based on intertidal culture and spread to other areas, such as Baynes Sound. Products included fresh shucked oysters, single oysters, canned and smoked oysters, and canned oyster stew.

Ward Griffioen at the PBS experimental fish farm in 1976 (Photo: R. Brett)

Initial research on the culture of the Pacific oyster was done by Dr Roy Elsey at PBS. He was followed by his student Dan Quayle. After Elsey moved to BC Packers, Quayle joined the staff at PBS in 1938; he left in 1941 to serve in the Air Force. After obtaining his PhD in 1948, he then worked for the BC Department of Fisheries before returning to PBS in 1958.

During warm years (most likely *El Niño* events), oysters on farms spawned and spread via planktonic drift to many parts of southern BC. In 1949 juvenile oysters were found on commercially harvested adult oysters and these were traced back to Pendrell Sound on East Redonda Island. Dan Quayle undertook studies in Pendrell Sound that led to its becoming an important seed source for BC, eventually eliminating the need to import seed from Japan.[3] By the 1960s the intertidal culture of oysters was well established in the Strait of Georgia, and in the 1970s growers began to experiment with raft and long line culture using technology developed by Quayle.[4]At the same time hatchery seed was being produced in the United States and in one location in BC, and the half shell market was increased. Over the sixty years since the discovery of a seed source in Pendrell Sound, the shellfish aquaculture industry expanded to a value of $32.5 million. [5]

Drs Trevor Evelyn, Gordon Bell and Bill Kennedy dip vaccinating smolts at PBS in 1976 (Photo: R. Brett)

It should be noted that most of the shellfish species currently grown commercially in BC are exotics including Pacific oyster, Manila clam *(Venerupis philippinarum*), Japanese scallop (*Patinopecten yessoensis)*, blue mussel (*Mytilus edulis*) and Mediterranean mussel (*Mytilus galloprovincialis*) Recent introductions have been done carefully through quarantine hatchery procedures, but the early shipments of Pacific oyster seed from Japan accidentally carried at least 17 additional species that have integrated themselves into BC coastal ecosystems.[3]

The techniques for growing the Japanese scallop were developed by Dr Neil Bourne and Dr Ian Whyte at PBS beginning in 1981 with funding jointly from DFO and the BC Ministry of Agriculture and Fisheries.[6] Island Scallops Ltd. was established in 1989; it built up a large hatchery in Qualicum Beach for producing shellfish seed and currently holds more than 500 hectares of scallop farm tenures. In 2002 following Neil Bourne's retirement, Dr Chris Pearce was hired to conduct research on shellfish aquaculture at PBS; he has worked primarily with alternative species such as geoduck clam (*Panopea generosa*), basket cockle (*Clinocardium nuttallii*), purple sea urchin, (*Strongylocentrotus purpuratus*), California sea cucumber (*Parastichopus californicus*), and signal crayfish (*Pacifastacus leniusculus*). Development work was done by the private sector with candidate species such as the spot prawn (*Pandalus platyceros*) and the pinto abalone (*Haliotis kamtschatkana*) but it did not result in commercial production.

New facilities at Vancouver Island University (VIU) in the Centre for Shellfish Research (CSR) and the Deep Bay Marine Field Station (DBMFS) have also begun research programs on novel species of invertebrates for culture. Dr Helen Gurney-Smith and her colleagues at the CSR have developed techniques for the culture of the basket cockle in collaboration with Chris Pearce and she is presently working on gene expression in mussels related to stress in collaboration with Dr Stewart Johnson at PBS.

Dr Sarah Dudas at the CSR, a recently appointed Canada Research Chair, will work on environmental aspects of shellfish culture. Her research will take place predominantly in Baynes Sound. She is the first researcher in BC to focus entirely on this important topic, although researchers at PBS and in other BC universities have worked on individual projects in this area. Brian Kingzett and collaborators at DBMFS are currently working on techniques for the spawning and hatchery production of the California sea cucumber.

Considering the diversity of the current industry, international demand for seafood products, and the vastness of the highly productive BC coast, it is surprising that the shellfish aquaculture industry has not grown more rapidly and to a greater extent. There have been several studies suggesting that the industry should have grown to 100 million dollars by now and considering that salmon farming is now valued at approximately 500 million dollars per year with a much shorter history, the question is a fair one. The current industry, dominated by Pacific oyster and Manila clam farming, is characterized by many small operations (companies earning less than $50,000 annually) with a very small number of larger companies. The small companies are largely undercapitalized and find it difficult to take advantage of modern technology or attain the benefits of scale.

Despite the excellent and fundamental work by Elsey, Quayle, and Bourne at PBS in years past and the important work now being done there by Pearce, research support for invertebrate aquaculture in BC has been limited by comparison with that for salmon. Salmon aquaculture had the benefit of an extensive biological knowledge generated to support fisheries management and public hatchery operations. Dr Chris Pearce at PBS is the sole research scientist for shellfish aquaculture supported by DFO on the west coast, and the new VIU facilities are in the early stages of development. Many sources of research funding for aquaculture have either disappeared or diminished (e.g., the Aquaculture Collaborative Research and Development Program, and the British Columbia Aquaculture Research and Development Committee Aquaculture and Environment Fund). Compared to industries of many other countries (e.g., Japan, China) the BC shellfish industry appears to be lagging, developing far more slowly than its potential would predict. Limited government research support, lack of capitalization within the industry, and failure to attain critical mass seem to be important factors.

"Other challenges facing the industry include changes in climate. It is possible that changes in water temperature, pH and wind patterns could be increasingly disruptive to an industry already undercapitalized."

Other challenges facing the industry include changes in climate. It is possible that changes in water temperature, pH and wind patterns could be increasingly disruptive to an industry already undercapitalized. Ocean acidification could easily become the greatest challenge to all molluscan production, both wild and farmed, within the next two decades. In summer along the west coast, water that is acidic and low in dissolved oxygen from water as deep as 200-300 metres upwells onto the continental shelf and into the ocean surface layer. Over the past few years hatchery failures (oysters, clams, scallops) in Oregon, Washington and BC has been attributed to sea water of low pH. Although research on this topic is just beginning, it may be that deep, offshore waters have been upwelled at more than usual levels to coastal zones and hence into hatchery intakes. Their increased appearance inshore may be related to changes in coastal upwelling driven by atmospheric circulation. Whatever the cause, waters of low pH have been noted in many west coast hatcheries and very little oyster or clam seed was available from the usual hatchery sources in the summer of 2012. [(7)]

The outlook is not entirely negative however. The larger BC companies are developing new culture technologies and new products, and there is increased interest in investment in the BC industry from off-shore, especially from western Pacific Rim countries. The new species that have been developed for culture are showing promise and several are well beyond proof of concept (e.g. mussels, scallops, geoducks) and are expanding. Despite funding limitations, DFO has a creditable research program underway and VIU's new research centres are building their staff and programs. The shellfish industry provides valuable jobs in

coastal areas where employment is generally in short supply, and First Nations throughout the BC coast have shown a strong interest in shellfish aquaculture.

Finfish

Dr Bill Kennedy initiated research on sablefish or black cod (*Anoplopoma fimbria*) at PBS in the mid 1960s, showing that captured juveniles adapted readily to confinement and grew well.[8] His program was discontinued once it was realized that it is not possible to secure a reliable supply of captured wild juveniles for stocking of farms. In 1985, research on sablefish was restarted; Dr Ed Donaldson at the West Vancouver Lab (now the Centre for Aquaculture and Environment Research, CAER) produced a methodology for induced spawning of captive broodstock, Dr Don Alderdice developed techniques for egg incubation and Sandy McFarlane studied larval rearing at PBS. The research was interrupted due to lack of funding but Dr Craig Clarke led a renewed program in 1996 in collaboration with industry.[9] The first cultured juvenile sablefish were produced at PBS and Island Scallops Ltd. in 1998.[10,11] Juveniles from a hatchery built by Sablefin Hatcheries (now Sablefish Canada) on Saltspring Island in 2003 are sent to netpen sites for grow out to market size. By 2010, 579 tonnes of farmed sablefish were produced annually with a farm gate value of $6.7 million. [5]

Beginning in 1985, a research program was carried out by the Fisheries and Aquaculture Program at VIU to spawn the white sturgeon (*Acipenser transmontanus)*. The work started in collaboration with scientists at the University of California at Davis, using broodstock collected from the Sacramento River. The program achieved the first successful spawning of sturgeon collected from the Fraser River in 1991. VIU provided eggs and fry to Target Marine Farms Ltd. in Sechelt in 2000, 2001 and 2004. Target Marine Farms now produces sturgeon meat and harvested its first 300 kg of caviar from a recirculating aquaculture system in 2011. Also in 2011, the inaugural year for the International Centre for Sturgeon Research at VIU, 15,000 sturgeon juveniles were provided to Taste of BC Aquafarms Inc. in Nanaimo which is starting up.

Salmon: early years

Although there was no formal research program on salmon aquaculture at PBS in the 1960s, Dr Roly Brett led a number of fundamental studies of energetics and growth of juvenile salmon which culminated in trials demonstrating that sockeye (*Oncorhynchus nerka*) and pink salmon (*O. gorbuscha*) held in 6-ft tanks could be reared to pan size in 280 days.[12,13]

In 1970, Brett and several scientists at PBS together with Dr David Groves at the University of Victoria were planning for the expansion of aquaculture research. [14] They formed the company Aquafarm Consultants Ltd. with Roly Brett serving as president. [15] In 1972, Brett and Bill Kennedy left the company when they received approval for a salmon aquaculture program at PBS. Brett travelled to Norway to visit salmon and trout farms. Kennedy toured yellowtail (*Seriola quinqueradiata*) farms in Japan to learn about floating pen culture systems; a netpen facility was constructed in 1974 adjacent to PBS in Departure Bay and used to test the performance of various species of Pacific salmon under farming conditions.[16] Despite initial expectations that sockeye, pink and chum (O. *keta)* would be suitable, it was found that coho (*O. kisutch*) and chinook *(O. tshawytscha)* salmon had the best survival and growth.[17,18] Sockeye salmon had high mortality due to gill damage by siliceous spines of the diatom *Chaetoceros*

convolutus, an organism that Dr Gordon Bell (PBS) had previously implicated in mortality of lingcod (*Ophiodon elongatus*) held in live wells at Porlier Pass, south of Nanaimo.

The contemporary DFO hatchery program for Pacific salmon was established just before the start of commercial salmon farming, with construction of the hatcheries on the Big Qualicum River (1968), Capilano River (1971) and Quinsam River (1974). The Robertson Creek facility began as a spawning channel for pink salmon in 1960 and a pilot hatchery for chinook and coho salmon was started in 1972; it was later expanded to a major hatchery.

Chinook salmon from coastal rivers could be readily transferred to seawater with low mortality but only a limited supply of surplus eggs was available from DFO hatcheries in the Georgia Strait area in the early years; the chinook stock at Robertson Creek hatchery on the west coast of Vancouver Island was abundant, but concerns about introduction of infectious haematopoietic necrosis virus led DFO to prohibit egg transfers from Robertson Creek hatchery into Georgia Strait. (18)

Dr. Bill Kennedy with coho salmon at the PBS experimental fish farm in 1976 (Photo: M. Trim)

Coho salmon are robust and fast growing but normally not able to adapt to seawater until after a year of rearing. Early attempts by salmon farmers to accelerate smolting of coho salmon frequently resulted in high mortality or stunting of growth. Dr. Craig Clarke was hired by the Aquaculture Program at PBS in 1974 to work on this problem; he discovered that good quality underyearling coho smolts could be produced by a combination of photoperiod and temperature manipulation. (19,20)

The first private salmon farm license in BC was issued to Allan Meneely to operate Moccasin Valley MariFarms near Egmont in 1972. David Groves left the University of Victoria to form Apex Bio-Resources with John Stavrakov; several other investors joined later, including Union Carbide of Canada. Apex Bio-Resources reared coho and chinook salmon in hatcheries near Great Central Lake and Westholme, then transferred them to 6.5 m x 6.5 m netpens in Alberni Inlet. It expanded production through the late 1970s, but was placed into receivership early in 1982 when Union Carbide of Canada withdrew its half interest. After the receivership, Groves and his partners bought its hatchery at Westholme plus a small netpen site in Genoa Bay; they established Sea Spring Salmon Farm Ltd., which became a major supplier of Chinook salmon smolts to the industry. The Westholme hatchery is now operated by Creative Salmon Ltd.

Growth of the industry was slow for the first decade. Production of farmed salmon in 1981was only 180 tonnes; compared with 1,415 tonnes of Pacific oyster. Results were lower than expected, due to a lack of technology for rearing adult salmon. The initial optimism was based on the success of rearing juveniles but much of the technology for cultivation of adult salmon was yet to be developed.

Control of disease was a major focus in the early years. Dr. Trevor Evelyn had identified vibriosis as a cause of mortality in salmon reared in tanks at PBS and CAER before the experimental farm was established. He directed research to develop vaccines for vibriosis, as well as furunculosis during the early years of the experimental farm program [figure 5 near here]. Efforts to develop vaccines for bacterial kidney disease were unsuccessful so the focus became control of horizontal and vertical transmission of the disease. Dr Bob Kabata at PBS helped scientists at the National Marine Fisheries Service in Seattle identify the

myxosporean parasite *Kudoa thyrsites* in cage-reared Atlantic salmon (*Salmo salar*) in Washington State in the mid 1980s. Although *Kudoa* was not a problem in farmed Pacific salmon, it caused significant economic losses to the industry once it starting rearing Atlantic salmon. The problem was not harm to the fish but rather a post-mortem myoliquefaction, or 'soft-flesh' syndrome after harvest which made it non-saleable. Kabata had previously found that the same species of *Kudoa* is a cause of poor flesh quality in processed Pacific hake, *Merluccius productus*. The life cycle of the parasite is not known, so it is not yet understood how salmon acquire the infection; Marine Harvest Canada and the BC Center for Aquatic Health Sciences are conducting a 3-year study to shed some light on this.

Dr. Gordon Bell and John Slind at Slind's farm in Sechelt Inlet in 1983 (Photo: C. Clarke)

The strategy of the early farms was to harvest salmon at portion size (250-350 g) as was the practice in freshwater trout farms. However, development work in Norway and Scotland had shown that Atlantic salmon could be reared to adult size in netpens and this example prompted BC salmon farmers to extend the rearing cycle. Coho salmon were less suitable for harvest of adults because they mature after one sea winter, and must be harvested before the onset of sexual maturation. Chinook salmon were more amenable to harvest of a larger product, although many males mature after one sea-winter. In order to overcome this limitation, Dr Ed Donaldson led a program at CAER to develop technology for production of all-female stocks of chinook and transferred it to industry. [(21)]

Dr. David Higgs directed the fish nutrition program at CAER with a focus on development of practical dry diets, and reducing the use of costly fish meals by substitution with suitable protein meals. The nutrition program was placed under the direction of Dr. Ian Forster after Higgs retired. Dr. Bob Devlin directs a molecular genetics program at CAER which has developed sensitive molecular diagnostic assays for genetic sex (Y-probes), stress and pollution markers as well as markers for several parasites of wild and farmed salmon. Devlin also produces transgenic salmonids and evaluates their response to different environmental factors to assess potential risks associated with this technology if it were put to commercial use.

Dr. Roly Brett on a herring barge in Pender Harbour in 1981 (Photo: H. Kreiberg)

Coincident with the growth of the salmon farming industry, funding for relevant research in the Pacific region was shrinking. In large measure this was due to the absence of a clear national mandate for aquaculture, so that other programs took precedence. A large salmonid enhancement program (SEP) was approved in 1977 with a budget of $150 million. By 1983, SEP facilities released 10.9 million coho and 22.7 million chinook salmon juveniles. The nascent salmon farming industry was dependent on surplus coho and chinook salmon eggs from SEP hatcheries so it benefited from greater availability of eggs as hatchery production grew. However, government funding for salmon farming research at PBS declined following the arrival of SEP.[(22)] In addition, staff and resources were drawn away from salmon farming research at PBS when Roly Brett initiated a multi-year program on impounding mature herring in 1980 at the request of the director.[(23)]

Salmon: expansion and consolidation of the industry

In a review prepared for the 1983 National Aquaculture Conference in Saint Andrews, Roly Brett characterized salmon farming in BC as "essentially a cottage industry."[(22)] This was soon to change, as an influx of money and expertise from Norway and the UK led to a rapid expansion of the industry. Norway had conducted similar research efforts since the late 1960's with large-scale government support in research, hatchery production of smolts, selection

programs, and marketing. In the mid 1980s, Oddvin Vedø, an economic development officer for the Sunshine Coast Regional District, undertook to bring this technology to BC. Familiar with the rapidly growing Norwegian industry, he organized a tour in Norway for a score of BC politicians, managers, business people, and researchers who returned astounded by the Norwegian salmon farming industry which by then had created large markets in Europe.

Thus began the BC salmon farming gold rush with a rapid expansion from ten operating netpen sites in 1984 to 113 by 1987 [(24)] These new farms were established in the eastern Strait of Georgia and along the west coast of Vancouver Island. They used Norwegian technology including steel cages (15 metres on a side) capable of withstanding somewhat higher wave and current levels, and they reared fish to larger sizes. Each farm typically had 24 such cages capable of producing 100 tonnes of 2-kg fish in two years of rearing. A few companies had built large hatcheries and had developed several grow-out sites; two of these formed public companies listed on the Vancouver Stock exchange. Chinook salmon overtook coho as the species of choice, and the industry requested permission to import Atlantic salmon.

The first batch of 10,000 Atlantic salmon eggs from a hatchery in Scotland was imported to a quarantine facility at PBS in 1985; industry was authorized to import another 120,000 eggs to its own quarantine facilities that year. By 2009, more than 29 million Atlantic salmon eggs had been authorized for importation from Scotland, Washington State, Ireland, New Brunswick and Iceland. [(25)]

DFO acquiesced to industry requests for introduction of Atlantic salmon from certified sources knowing that the risk of escaped Atlantic salmon in BC waters was already present. Washington State had issued permits for farms rearing Atlantic salmon in the Strait of Juan de Fuca and the San Juan Islands in the early 1980s. Furthermore, between 1951 and 1991 Washington State agencies made 27 releases of 76,000 smolts of Atlantic salmon of various sizes into the Puget Sound basin in attempts to introduce it there. [(26)] Earlier deliberate attempts to introduce Atlantic salmon into BC had failed; between 1905 and 1935, more than 13 million Atlantic salmon eggs, alevins or fry were transplanted into many sites on Vancouver Island and the BC mainland. [(27)]

Unfortunately despite new technology and high enthusiasm, most of these new farms suffered the same ills as their pioneering forbears; this was exacerbated by site locations in waters too warm and too prone to harmful algae blooms. Bankruptcies followed and larger companies began their emergence buying the failed companies and their assets. By the early 1990s all involved realized that most sites in the Strait of Georgia were poor for salmon farming, and the industry was given permission to move north of Discovery Passage into the Discovery Islands and the Broughton Archipelago. Some farms on the west coast of Vancouver Island remained. The industry continued to coalesce into a smaller number of larger companies, a process that was to continue to today's very small number of large corporate firms. Technology and research continued to advance: vaccines were developed, large and better cages were designed, nutrition was improved, Atlantic salmon supplanted Pacific salmon, and smolts were produced at different times of the year. Today survival from smolt to harvest is often 95%, food conversion ratio at about 1:1.1, and fish are grown to weights of ca 5-6 kg. The farms are generally large often producing 600,000-800,000 fish per cycle which has been reduced to about 18 months. The value of farmed salmon in BC

"Unfortunately despite new technology and high enthusiasm, most of these new farms suffered the same ills as their pioneering forbears"

exceeds that of the commercial salmon fishery; for 2010 the respective wholesale values were $559.9 and $237.8 million. [5]

There have been several approaches to land-based or closed-containment alternatives to netpens for salmon farming in BC. The first was a system of land based 750 m^3 concrete tanks started by Hagensborg Marine Farms just south of Nanaimo in 1989. The farm used supplemental oxygen to reduce the requirement for pumped seawater but ceased operation in 1992 following a mechanical malfunction. Unique Sea Foods Ltd. purchased the site and used part of it for production of algae while leasing space to other companies for shellfish and sablefish hatcheries. Future SEA Technologies designed a floating bag controlled environment fish rearing unit which was evaluated in collaboration with Henrik Kreiberg at the PBS experimental fish farm. [28] Marine Harvest evaluated a 6-module array of Future SEA bags at a site on Saltspring Island as part of the green economy initiative by the Province of BC following the salmon aquaculture review. Future SEA declared bankruptcy in 2010 because it did not sell enough systems to offset its development costs. Another project approved under the green economy initiative was a pilot by Agrimarine Industries Inc. using some leased tanks at the former Hagensborg site; Agrimarine successfully marketed chinook and coho salmon but found that pumping costs were too high despite the use of supplemental oxygen. Agrimarine together with the Middle Bay Sustainable Aquaculture Institute is now developing a demonstration farm near Campbell River with floating rigid tanks that it says will reduce energy demand by 90% compared with a land-based facility. The first tank installed in 2011 was removed this year for modification; another two tanks being constructed in the USA and one in China are scheduled to be installed at the Middle Bay farm later this year. The ‘Namgis First Nation is constructing the first module of a commercial-scale recirculating aquaculture system (RAS) near Port McNeill; it plans to start rearing Atlantic salmon next year. A DFO-sponsored theoretical analysis of ten rearing technologies in 2010 concluded that only two, net-pens and RAS had the potential for positive financial returns. [29]

“This would be a brilliant success story were it not for a sea of controversy that began in the mid-1980s”

Salmon: social license

This would be a brilliant success story were it not for a sea of controversy that began in the mid-1980s. Upland owners on the sunshine coast objected to the encroachment of salmon farms on their viewscapes. Fishermen opposed what they considered an economic threat to their way of life and livelihood. Public alarm about escapes of salmon and large-scale mortality due to plankton blooms and disease caught the attention of environmental groups who mounted a media campaign that continues to this day. The issue has polarized coastal communities, politics and academia. Young and Matthews characterized it as “one of the most bitter and stubborn face-offs over industrial development ever witnessed in Canada.”[30]

Both sides of the debate have used science to validate positions for or against salmon farming. This has developed to such an extent that controversy has influenced research priorities, particularly for the sea lice issue. The dispute about whether sea lice from salmon farms present a risk to wild salmon populations has created a situation in which scientists were pitted against other scientists far beyond the usual constructive scientific debate. Despite large-scale expenditures on research over several years by DFO, universities and environmental groups, the controversy has continued. In an attempt to seek constructive solutions, the federal and BC governments set up the Salmon Aquaculture Forum in 2003; it was chaired by the Hon. John Fraser, a former federal Minister of Fisheries and

had a budget of $5 million. One of the recommendations in the forum's final report issued in 2009 was to adopt an ecosystem-based approach to managing salmon farms in the Broughton Archipelago as a pilot. [31] The report concluded that there was no scientific consensus concerning the impact of sea lice on wild salmon populations; however it made recommendations for managing sea lice on salmon farms as a precautionary measure. Subsequently, a coordinated area management plan has been developed with physiologically-based thresholds for sea lice infection. [32] A recent analysis of salmon farm sea lice data and wild salmon population data concluded that pink salmon populations were not influenced by prevalence of sea lice. [33]

The controversy over salmon farming has been intense in part because more than environmental issues are at stake. There are important socio-economic matters such as benefits to local and regional coastal communities and First Nations. Young and Matthews also point out that aquaculture is controversial simply because it is a latecomer. VIU is now addressing some of these concerns in its Aquatic Foods Initiative located in its Institute for Coastal Research, exploring the pathways to social license for what in BC is a very new approach to aquatic food production.

Education at BC Aquaculture Research Facilities

Over the three decades that the Fisheries and Aquaculture program at VIU has been in existence, hundreds of students have taken practicums at the Pacific Biological Station (PBS) in Nanaimo. Many other VIU students in this and related programs have done directed studies with PBS scientists or had summer jobs there. Many dozens of these former students now work at PBS as technicians and biologists. PBS has also hosted graduate students from other universities and been the key to the creation of many valuable research careers in BC and across Canada. In many ways PBS is as much an educational institution as a research centre.

The above four VIU research centres host more than 100 VIU students each year on a variety of practicums, independent studies, field trips and work placements. Graduate students from other universities do their research in these facilities, and there are a growing number of postdoctoral fellows studying here.

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Duane Barker

Dan Fox

Fisheries & Aquaculture Training at Vancouver Island University, Nanaimo, BC: *a small college program that has emphasized making things work.*

D Barker and D Fox

Building 380, home of the Fisheries & Aquaculture Department, rests atop the western campus of Vancouver Island University (VIU, formerly Malaspina University-College) in Nanaimo, overlooking the Nanaimo estuary and Strait of Georgia; bordered by the glacier-capped coastal mountain range of BC. Building 380 is one of the smallest on the VIU campus, yet has a fascinating history of literally 'blood sweat and tears' and, has been the focal point of training for key personnel of aquaculture, fisheries and environmental sectors in BC for decades. Its location on campus is very fitting, overlooking an array of landscapes and habitats. In much the same manner as a lighthouse disperses a broad navigational beam, the Fisheries & Aquaculture students have dispersed into a vast array of careers.

Humble beginnings

Nanaimo, known as the Harbour City, is ideally located next to the ocean, mountains, estuaries, streams, rivers and lakes; all of which are utilized in the training programs at VIU. The Fisheries & Aquaculture program began in 1979 under the guidance of internationally-recognized Dr. David Lane, soon joined by Dr. Bill Pennell and Ms. Eunice Lam in 1980. At that time, building 380 was a small 40' x 20' wood-frame building complete with one faculty office, a simple rearing area (*i.e.* plastic barrels) for fish and algae, a tool shop and tiny storage closet. In its infancy (or perhaps its industrial phase), small classes of 10-15 students exemplified perseverance, diligence and passion for BC's aquatic resources. "We didn't have much, but we made things work" recalls 1983 graduate and recently retired Department member, Frank Dalziel. Frank affectionately retells a tale of how a class BBQ turned into something much more "…we were told to be here on a Saturday for an orientation BBQ, but wear work clothes, oddly." During their orientation BBQ, Frank and his classmates built an addition to the existing trout and sturgeon hatchery, including plumbing. The hatchery facility started as two 6' diameter tanks for white sturgeon and rainbow trout broodstock and; several smaller 40 L tanks for juvenile rearing. Frank Dalziel noted that at one point they also used "…a bunch of sinks that someone borrowed from somewhere and outfitted with stand-pipes. The trout didn't mind."

"We didn't have much, but we made things work."

As the program expanded with more students, three more concrete tanks were built from brick and mortar outside the hatchery. Soon, more space was needed to expand so the staff took over husbandry duties of a "solar hatchery", which became the warm water hatchery used for breeding and rearing tropical aquarium fishes. Frank recalls, "Shortly thereafter, we were allowed to import sturgeon, so we took over another small greenhouse on campus which became the sturgeon hatchery."

In the late 1980s, current faculty member and then recent Fisheries and Aquaculture graduate, Gord Edmondson was added to the Department; beginning his passionate dedication to the culture of white sturgeon, which remains evident

today. Gord's endless construction, plumbing and fish husbandry talents were essential to upgrading and maintaining the facility. Located near VIU, but off-campus, is the Chase River Hatchery, a small Fisheries & Aquaculture student-operated wild coho salmon enhancement facility. The Chase River Hatchery was built in the mid-80's, funded by the Department of Fisheries and Ocean's Public Involvement Program and a labour grant from what is now Human Resources Development Canada. The first coho salmon release from that facility was in 1987. "The program was basically a lot of blood, sweat and likely tears," says Frank Dalziel. "Students were very involved, not because they had to be but because they wanted to be. In the process, many fine graduates walked out the doors with life training that extended far beyond the curriculum that was offered in the classroom; they knew how to make things work."

Fine products

Fine graduates indeed. Since its initial graduating class of 1981, over 500 students have completed the program. Most graduates from those early years are now leaders, decision-makers and key stakeholders in the aquaculture, fisheries and environmental sectors of BC. On Vancouver Island alone, alumni are employed at the University of Victoria, The Freshwater Fisheries Society of BC, the BC Conservation Foundation, The BC Ministry of Environment (Fish & Wildlife Branch), Fisheries and Oceans Canada, Bamfield Marine Sciences Centre, Marine Harvest Canada, Mainstream Canada and numerous environmental consulting firms. In addition, four former graduates, one from the mid-1980s, are currently key personnel in the Fisheries & Aquaculture Department at VIU.

"The program was basically a lot of blood, sweat and likely tears..."

New growth equals more success

As the program continued to expand through the 1980s, it quickly became obvious that the existing facilities were space-limited. In the spring of 1991, about 15 minutes after classes ended, bulldozers arrived and flattened almost everything that had been built by the students and new construction began. The end result was the current Building 380 which houses all classrooms, labs and faculty offices. New growth also included a diverse array of new facilities including cool and warm water hatcheries, a saltwater recirculation system and a fish health laboratory. These new facilities coincided with a new B.Sc. in Fisheries & Aquaculture program in 1991 in addition to the existing 2-year technical diploma, which has since been completed by over 60 students.

Part of the ongoing success of the VIU Fisheries & Aquaculture program is that it boasts a strong practical training component. Unique to this program are courses that target specific ecological and environmental topics that provide a balanced mix of aquaculture (e.g., *Trout Culture, Fish Health, Aquaculture Engineering - Hydraulics, Larval Rearing & Invertebrate Culture, Warm Water Fish Culture, Aquatic Plant Ecology & Culture*) and fisheries assessment (e.g., *Biology of Fishes, Life History and Management of Salmonids, Fisheries Field Techniques, Invertebrate Zoology, Fisheries Management, Coastal and Estuarine Ecosystems*). In addition to the diverse assortment of in-class and laboratory courses, there are several hands-on outside the classroom courses. For example, the students complete a field practicum course every semester. Regarded as a junior apprenticeship, the practicum course enables students to spend one day per week gaining key work experience at either provincial or private fish hatcheries, laboratories, private fish or shellfish farms, or non-governmental organizations (NGOs). This quality training is only possible because of the close working relationships between the Department and such groups. Another practical training

course, Projects in Fish Husbandry, links students with faculty as they engage in some aspect of applied training and research for one afternoon per week. Some of the specific training acquired during this course includes:

- Domesticated rainbow trout hatchery operation
- Wild coho salmon hatchery operation
- Sturgeon hatchery operation
- Microalgae culture
- Fish health assessment techniques
- Marine invertebrate rearing
- Tropical aquarium fish rearing
- Recirculation technology
- Aquaponics system operations

Research opportunities

Several Fisheries & Aquaculture faculty at VIU regularly engage in externally funded (e.g., Natural Sciences and Engineering Research Council, Aquaculture Collaborative Research and Development Program) research programs. These research activities provide unique 'beyond the classroom' training opportunities for students via summer employment and senior undergraduate research projects. The undergraduate research projects are full credit year-long projects where students develop, complete and report on their research. Currently, there is no graduate program in fisheries and aquaculture at VIU, so some faculty regularly supervise graduate students registered at larger institutions such as the University of BC, Simon Fraser University and the University of Victoria. These graduate students conduct their research at VIU, but do their coursework at their registered institution.

Some of the recent research activities which involve undergraduate students, graduate students and post doctoral fellows include:

- Detection of bacteria and viruses from sea lice.
- Evaluation of sea lice as a vector of pathogenic bacteria among salmon.
- Histopathology of salmon parasitized by sea lice.
- Molecular and cellular responses of salmon to sea lice infections.
- Evaluation of oral immunostimulants for rainbow trout.
- Assessment of selective gear to reduce by-catch in the spot prawn fishery.
- Invertebrate larval settlement strategies near shellfish farms.
- Invasive species fouling shellfish farms.
- Genomic analysis of farmed mussels.

Industry & community linkages

The success of the VIU graduates combined with the recognition of the VIU Fisheries & Aquaculture Program has resulted in many industry leaders and private donors establishing scholarship endowments to reward outstanding Fisheries & Aquaculture students. Since 2008, scholarships have been distributed to over 40 students in the program, totaling over $60,000. In 2011, $19,300 was awarded to 18 students. Some of the higher value awards include: Frank Bernard Award (max. $3900), the Underwater Harvesters Association Research Society Award ($2500), Cultured Crustacean Award ($2000), Marine Harvest Canada Scholarship ($1500), ECO Dynamic Solutions Inc. Achievement Award ($1300),

the Eunice Lam Award ($1000), Nicholas Plecas Aquaculture Scholarship ($1000), the Pieter de Reuver Foundation Shellfish Research Scholarship ($1000) and the William E. Ricker Memorial Scholarship ($1000).

Community service is yet another avenue of training for VIU Fisheries & Aquaculture students. Every year, staff and students engage in several community involvement activities. Some examples include an educational display at *The River Never Sleeps Festival* at Rosewall Hatchery and the Nanaimo River Hatchery Open House every summer. Every July, the Department hosts a two day session for Vancouver Island University's *Grandkids University* in which children and their grandparents tour the hatchery, then participate in lessons on marine invertebrate diversity, aquatic and terrestrial macroinvertebrate diversity, and fish morphology/Gyotaku fish printing. The staff and students also host numerous tours of our hatchery facilities throughout the year. The tours are very popular for student groups, summer camps, and VIU Public Relations. Several reoccurring visiting groups include Bowen Explorer's Nanaimo Day Camp, Nanaimo Youth Services, Adventures in Leadership Nanaimo and Nanaimo Aboriginal Day Camp. During 2010, over 1600 individuals toured through the hatchery at a total of 115 tour-hours.

Now and the future

The program benefits from linkages with the Centre for Shellfish Research (CSR) and its newly opened Deep Bay Marine Field Station, plus the recently constructed, $4.6 million International Centre for Sturgeon Studies (ICSS). The CSR serves as the west coast centre of shellfish research excellence and with the new ICSS, VIU will be poised to be a prominent leader in sturgeon research excellence. Further assets of the program include strong linkages with the Pacific Biological Station and the Tofino Ecolodge & Botanical Gardens.

Today, the students at building 380 are different from those who literally built the program in its beginnings. Today's students are guided by a computer-technological age; however, the enthusiasm for the program is still vibrant and new technology is assisting the growth of the program (e.g., new course in Stream Habitat Assessment and Rehabilitation started in 2012). The applied research and training aspects of the program, combined with the active, outdoor lifestyle of BC add to its appeal. Building 380 continues to produce quality graduates that spread into diverse environmental sectors and help build the future of BC's aquatic resources.

Please visit http://www.viu.ca/fisheries/ for more information.

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Helen Gurney-Smith

Koren Bear

The Centre for Shellfish Research at Vancouver Island University

H Gurney-Smith and K Bear

The Centre for Shellfish Research (CSR) offers undergraduate and graduate research training opportunities, which range from practicum and work-opportunity placements to honours and graduate projects. Students have undertaken final year honours projects, research targeting new potential aquaculture species, including cockles and spiny scallops, and the influence of shellfish broodstock selection strategies on the genetic diversity of aquaculture populations. Throughout the research projects conducted at the CSR, we have been fortunate to have the involvement from practicum and work-opportunity students from the Fisheries and Aquaculture Department, who have received hatchery and laboratory training as well as conducting field sampling at the Deep Bay Marine Field Station aquaculture lease sites. In addition students have been involved in many phases of new species development and genomics as NSERC Undergraduate Student Research Assistants (USRAs). International graduate students have also spent training periods at the CSR, and we welcome motivated individuals with a passion for shellfish aquaculture and the environment.

First Nations Training Programs at the Centre for Shellfish Research

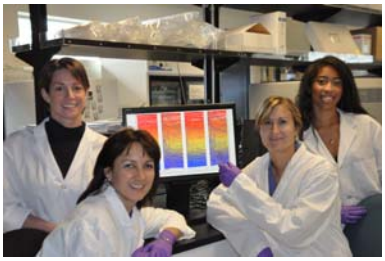
In the last decade there has been tremendous interest from First Nation groups pursuing involvement in the shellfish aquaculture industry. Many First Nation communities already participate in province's wild fishery, and with so many living coastally it is seen as a natural progression to have their members move from harvesting shellfish to farming of shellfish. The industry is seen as both environmentally sustainable and culturally appropriate given their rich history in cultivating clam gardens along BC's coastline. With the shellfish aquaculture industry worth $30 million wholesale annually, it also has the opportunity to be a lucrative investment, providing both employment and community revenue. With this in mind, the CSR has focused on being leader in providing training to First Nation clients and coastal communities. In 2006, the CSR launched its' Coastal Communities Shellfish Aquaculture Training (CCSAT) program. Through this program individuals can obtain one of four aquaculture non-credit certificates by taking a combination of 16 shellfish courses. There are certificates designed to provide education and skills for entry level work, as well as supervisory and management levels.

In 2011, as part of new scallop aquaculture initiative in northern BC, CSR staff travelled to Prince Rupert to deliver a customized training program to employees from four northern First Nation communities. Once established, these farms could be some of the largest in the province. Students were trained in numerous aspects including farm development and planning, scallop biology, production planning, record keeping, environmental monitoring and knot tying.

This year, through a Canada-British Columbia Labour Market Agreement, the CSR is delivering three 6-week Shellfish Aquaculture Technician Programs. The intent of these programs is to prepare individuals with multiple barriers to

"The program was outstanding! It gave us the knowledge and insight into the finer points of shellfish farming in BC. We look forward to more training!" Gladys Gus, Tseshaht First Nation

education, with the skills and knowledge necessary to gain entry level employment in the shellfish industry, but also to give them a broad spectrum of skills that are transferable to other industries such as marine transport, fishing or resource management fields. It kicks off with a one-week foundation course that provides life skills as well as some upgrading in literacy and numeracy. The rest of the program provides an introduction to basic shellfish biology, culturing employed to grow different species, farm siting and planning, marine biotoxins, shellfish pathogens, harvesting and processing, regulatory requirements for operating a shellfish farm and worker health and safety. "Because this program combines shellfish aquaculture skill development along with 'essential skills' training as defined by Human Resource Canada, it provides an opportunity for individuals to gain entry to an industry they may not have considered otherwise. It can also serve as a stepping to prepare students for further education," says Don Tillapaugh, Director, CSR. Aside from receiving a quality education, an additional benefit to students has been the free tuition and books, which has made education accessible to students who might not have been able to attend school. Because of this training program, students will have an opportunity to expand their knowledge of the industry and will hopefully have the confidence to apply for a job in the industry.



To find out more about us please visit our website at www.viu.ca/csr

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Craig Stephen

Training at the Centre for Coastal Health

C Stephen

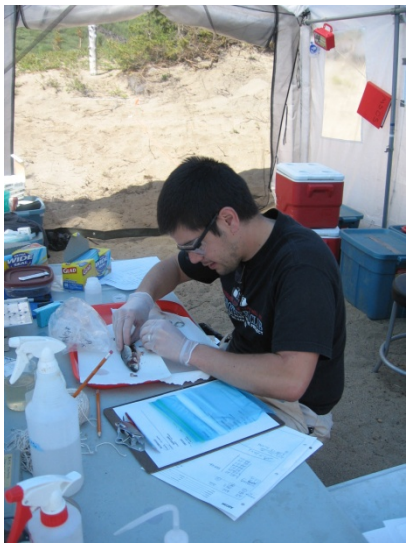
The Centre for Coastal Health (CCH) was established in 1996 in Nanaimo, British Columbia as a non-profit organization dedicated to examining the interactions of human, animal and environmental health. The founding members of the CCH recognized that comparatively little attention was being paid to the health and well-being of coastal communities and coastal species, despite the fact that much of the world's population and biodiversity live in coastal zones or in association with the marine environment. They also recognized that little work was being done to think about health issues in a socio-ecological perspective; a perspective that tries to link and integrate the physical, social and biomedical sciences to find ways to promote and protect health as well as to prevent and combat disease. The CCH has been trying to deal with these deficits through applied research, risk assessment, policy assessment and education. In addition to this population health work, the CCH has provided diagnostic and health management advice to public aquaria and universities. At all times, we seek to link our training with our ongoing activities to link training to the resolution of real-world, real-time issues.

"Integrating human, animal and environmental health since 1996"

Training opportunities at the CCH reflect the nature of work we do in population health, risk assessment and policy. Trainees are given a chance to be incorporated into the ongoing CCH activities and be part of a unique population health practice. The CCH is the only population health unit dealing with aquaculture health management, research and policy in British Columbia. Its expertise in ecosystem approaches to health is unique in the aquatic health world. By drawing on additional work in terrestrial animal health and public health, the CCH has skills in interdisciplinary and participatory research that are valuable for dealing with health issues in the aquaculture world. The CCH defines health not simply as the absence of infectious diseases, but rather as the capacity for populations to access their needs for daily living, adapt to or cope with stress and changes, and be able to meet expectations. We infuse this perspective in our training and educational activities.

CCH staff have been involved in a diversity of aquaculture issues. For example, Dr. Craig Stephen has been part of many local, national and international reviews of the impacts of salmon aquaculture, most recently by providing a technical report to the Cohen Commission into the Decline of Sockeye Salmon in the Fraser River. The CCH helped to develop many key health initiatives in the BC salmon farming industry including the fish health management plans, and the disease surveillance auditing program. CCH staff has served on an expert group from the World Animal Health Organization (OIE) on invasive animal species to local fish health committees. More recently, the CCH has been involved in issues of food security and sustainability associated with aquaculture, both in Canada and abroad. An example is our exploration of aquaculture as a means for rural poverty reduction in Sri Lanka. This project supports the training of 4 post-doctoral fellows, 1 PhD, 3 Masters students and affiliated technical trainees and it is a good example of how we strive to link education, research and knowledge-to-action. Trainees working on this project must not only worry about the biological factors affecting sustainable food production through shrimp farming, ornamental fish farming and culture-based fisheries, but also need to learn about how social networks affect knowledge and how research can be turned into management

practices. They learn this through a combination of classroom work, field experience and mentored support from CCH staff and collaborators.



Education and training takes on many faces at the CCH. Core CCH staff hold academic positions in the Faculty of Veterinary Medicine (University of Calgary) and School of Population and Public Health (University of British Columbia). This allows us to bring CCH experiences into undergraduate and graduate level classrooms. The CCH often hosts undergraduate veterinary students on externships and provides summer research positions for students in biology, fisheries, aquaculture and veterinary medicine. We also provide opportunities for public health trainees through practicum and rotation placements, While not all trainees work on aquaculture or marine issues, having this mix of students allows us to introduce aquatic health issues to all of the students, raising the general awareness of each trainees about this field as well as helping to create a learning environment that fosters cross and multi-disciplinary approaches.

Summer students and externships

Summer student placements have helped us to look at topics such as the development of a teaching aid for multi-criteria decision analysis to be used to assess international development opportunities for aquaculture; the risk of using 'doctor fish' in spas; and small-scale trials of antiparasitic drug use for aquarium species. A summer intern from the University of Colorado spent 4 months at the CCH developing new skills in aquatic animal health policy review. This veterinary student was interested in the concept of sustainable food development. He reviewed fish health literature and legislation in British Columbia to examine its consistency with goals for sustainable food production. He supplemented his desk-work with site visits and interviews with government officials, farmers and NGO representatives. The outcome of this training experience was a new perspective for this student on means to promote and protect health while encouraging sustainable food production as well as an introduction to system-based management of aquaculture. This project, like many of our training opportunities, resulted in a report for the student to add to his CV, in this case, a peer-reviewed paper in the journal Ecohealth.

Graduate student training

The Centre has hosted and supported graduate students, most often in the field of epidemiology. These students have worked on a number of disease outbreaks in BC salmon farms including investigations of infectious hematopoeitc necrosis and Kudoa. Graduate students have also examined farmer decisions for antibiotic use and implementation of biosecurity in prawn farms; the prevalence of antibiotic residues in prawn products and their relation to farm drug use; and policy for sustainable ornamental aquaculture. One doctoral student from Italy secured Canada-Europe exchange funding to come to the CCH for a year of intensive training in risk assessment. This student recognized the need to take his pathology findings and be able to use them in a risk assessment and decision support if he hoped to effect health outcomes beyond individual cases. He was integrated into the CCH work to give him practical experience in population health and risk assessment. After that initial experience, he was made a team-researcher on a review of diagnostic data and surveillance being used to assess the risk of translocating aquatic pathogens due to a major international water diversion. This required the student to gather diverse diagnostic data, critically review their biases and limits of surveillance methods and interpret the biological meaning of the

results. Most importantly, this student gained new skills in risk communication as the report he helped to prepare to the International Joint Commission required him to translate his scientific understanding in a manner acceptable to scientific peer reviewers while at the same time accessible to a lay audience. This project was a great example of the teaching philosophy of the CCH which is to integrate students into ongoing projects to promote learning-by-doing.

Post-doctoral fellows and post-professional training

The collaborative multi-disciplinary approach used at the CCH can be challenging for more junior trainees. Therefore we try to focus our more integrative and systems-based training opportunities for more advanced trainees, like post-doctoral fellows. Post-doctoral training opportunities have recently focused on the role of aquaculture in development and food security, with an emphasis on how extension programs can better use existing farmer networks. One example is a current project which is focussed on a systematic review of the evidence for positive impacts of aquaculture on development. This project is scoping the English-language literature to compare and contrast aquaculture projects internationally that have positively or negatively affected human development outcomes in order to find common features of success or failure. Another post-doctoral trainee is examining the role of mobile phones and SMS messaging to supplement farmer extension programs in the theme of shrimp health disease prevention. That project requires intense field work abroad that is supported using web-based communication tools by CCH researchers. People have also gained mid-career training experiences at the CCH through secondments, sabbatical and professional leaves to work within our group for an extended period of time. In one case, a senior scientist from the Public Health Agency of Canada spent 6 weeks at the CCH learning about ecohealth, using aquaculture as an example.

Professional continuing education

In addition to our university affiliate training, the CCH offers professional continuing education and some public education. Previous workshops on risk assessment and epidemiology have been offered to fish health professionals in BC, the US Pacific Northwest and to organizations such as the Great Lakes Fishery Commission. These short courses provide intense training focussed on specific aspects of population health tailored to the specific audience. The CCH provide the very first training in Sri Lanka on fish health where veterinarians and fisheries biologists came to the same course at the same time. After the tsunami of 2004, there was a tremendous loss of capacity in Sri Lanka as well as remarkable impacts on the fishery. Government saw a need to replace the income and protein from fishing with new opportunities in aquaculture. However, at that time, few people had received basic training in fish health and there was no existing mechanism for linking the diagnostic capabilities of the veterinary community with the knowledge of aquaculture in the industry and biology community. This workshop was part of a large capacity building project in Sri Lanka headed by the CCH which provided a neutral venue to bring together diverse expertise and individuals together to not only gain technical knowledge and skills, but also to develop new professional networks for ongoing learning and support. Out of this workshop arose 4 new graduate student projects that linked fish health professionals in veterinary science, biology and industry. Their results have in turned been integrated into local best management plans and reflect the CCH goal of mobilizing academic training outcomes to professional continuing education and community learning opportunities.

Training opportunities at the CCH are unique. Located on the campus of Vancouver Island University, the CCH provides close access to public and private aquaculture, public aquaria and a "natural laboratory' to look at ecohealth approaches to marine species conservation. Our training focus emphasizes applied research and practice for future professionals who will need to think about the health of marine and aquatic species, wild or farmed, within a socio-ecological content. Rather than focusing on developing specific technical skills, our training aims to encourage critical thinking that can be applied to problems in aquatic food systems and conservation settings. Our strong linkages to academia provide for experienced teachers while at the same time, our "practice" strongly roots training experiences in real-world settings.

Please visit http://centreforcoastalhealth.ca for more information.

Author

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Stephen Cross

Mark Flaherty

The University of Victoria Coastal Aquaculture Research and Training (CART) Network

SF Cross and M Flaherty

Located on southern Vancouver Island, the University of Victoria (UVic) is a research-intensive institution and the second oldest public university in British Columbia. Consistently ranked among the highest research universities both nationally and internationally (e.g., Times Higher Education World University Rankings), UVic supports an academic population comprised of over 18,000 undergraduates, 3,500 graduate students, and 6,500 faculty and staff.

With a strong academic focus on ocean systems and coastal resource issues, the University of Victoria is well equipped and staffed for addressing the multi-disciplinary nature of coastal aquaculture systems.

History of the CART-Network

Research on topics related to both the social and physical science aspects of coastal aquaculture development has been ongoing at UVic since the mid nineties. The research program has had a strong international component that continues to this day. Graduate students from Canada, Thailand, India and Brazil participated in a variety of research and development projects funded by the Canadian International Development Agency (CIDA), Social Science and Humanities Research Council of Canada (SSHRC), the Rockefeller Brothers Fund, and the Shastri Indo-Canadian Institute. In 2000 Dr. Flaherty invited Dr. Stephen Cross, as an industry partner, to participate in a project that was being funded by the Canadian International Development Agency through its University Partnerships in Cooperation and Development (UPCD) program. The 6-year project entitled *Building Capacity to Manage Aquaculture in Thailand* focused on developing local expertise in aquaculture site evaluation, planning and monitoring, and was carried out in conjunction with the Department of Aquatic Sciences at Burapha University.

The collaboration of Drs. Flaherty and Cross on the CIDA project soon lead to the development of other initiatives. In 2006, Dr. Cross was awarded a 5-year BC Innovation Award (BC Science Council) for his ongoing research program in Integrated Multi-Trophic Aquaculture system development, and he joined the Department of Geography, with this funding, as an Associate Professor (Limited Term). This funding has since been extended and supplemented with industry contributions in support of a wide variety of directed research programs.

The Coastal Aquaculture Research and Training (CART) Network was founded by Drs. Cross and Flaherty in 2008 who currently co-direct and manage this new and growing University of Victoria initiative. With combined aquaculture experience of >45 years, our management team provides an effective combination of Marine and Social Sciences expertise, with one (Dr. Cross) focused on the technical (production-related) and environmental management aspects of aquaculture while the other (Dr. Flaherty) specializing in human (coastal community, First Nation) and governance aspects. A unique aspect of our

management partnership is that we remain active within the industry, providing very strong technical expertise and a direct link to the sector - ensuring an effective and meaningful exchange of ideas, direction and practical problem-solving capacity.

Currently, the UVic CART-Network supports regional, national and international projects, and is engaged in temperate as well as tropical latitude aquaculture initiatives. Our goal is to focus on our strengths as an experienced and recognized research institution, and to build a unique Canadian west coast aquaculture program that capitalizes on this capacity – providing research and graduate-level training in all disciplines associated with this global aquatic agri-food sector.

University of Victoria Social Sciences and Mathematics Building - administrative offices for the CART- Network

CART program structure

The multi-disciplinary nature of coastal aquaculture necessitates the involvement of researchers from a variety of faculties and academic departments. Although administered from the Geography Department, the CART-Network draws on colleagues (and their applicable expertise) from across campus on a project-by-project basis, and thus represents an *intra*-institutional network of research scientists and educators. Rather than comprise a fixed facility that attempts to house all of the resources required to address the complex issues of the aquaculture industry sector, the CART-Network is, in essence, a *virtual institution* yet one that encompasses specialties from every research contingency associated with this industry – for example, Marine Biology/Ecology, Microbiology/Biochemistry, Oceanography (School of Earth and Ocean Sciences), Chemistry, Physics, Geography, Economics, Engineering, Mathematics/Statistics, Business, Education, Aboriginal Studies, and Law.

In addition to the *intra*-institutional nature of CART, our operational Network also extends beyond the campus to include collaborative partnerships with other researchers and institutions. This *inter*-institutional network facilitates the development and implementation projects of regional, national, and international significance. The CART *inter*-institutional aquaculture research network includes faculty collaboration, graduate student exchanges, and course sharing. Exposure to aquaculture operations and issues, in a global context, represents an important aspect of our graduate experiential training objectives and is envisioned as a cornerstone for future program development.

Operationally, the University of Victoria CART Network is primarily a research-focused with projects developed to address industry issues or innovations. These projects are typically jointly supported by industry and government sources of funding, e.g., NSERC SSHRC, NRC (National Research Council), CIDA, etc. Graduate students (M.Sc., M.A., M.A/Sc., Ph.D.) and post- doctoral fellows are always integrated into these programs and projects to provide research training and degree opportunities across the disciplines listed above.

Undergraduate students visiting a salmon farm site in coastal British Columbia.

To ensure that our new students have a basic understanding of the aquaculture industry, from an industry, governance and environmental non-governmental organization (eNGO) perspective, an upper level undergraduate course has been developed through CART to provide this valuable overview prior to initiating a graduate research program. Currently focused on the Canadian west coast, students in this course are introduced to the aquaculture industry of British Columbia, reviewing the history, culture species, production methods (hatchery

through seafood processing), technological innovations, economics, marketing, environmental impacts/management, social (including First Nations) issues, and the regulatory framework for the aquaculture industry. A 1-week field excursion provides an experiential learning opportunity with visits to industry facilities representative of all components of cultured seafood production - fish and shellfish hatcheries, juvenile rearing and growout/production sites, harvesting vessels, processing plants, and R&D sites.

CART facilities

The *virtual* nature of the CART-Network eliminates the inherent need to construct and maintain dedicated infrastructure for its aquaculture research program. The primary benefit of this CART-Network approach is that each *intra*-institutional partner/department (e.g., Engineering, School of Earth & Ocean Sciences, Biology) will build, maintain, and upgrade their facilities to meet the specific needs of their research faculty and graduate student enrollment.

In addition to the various departmental resources (e.g., testing labs, analytical equipment, teaching venues, computing facilities) the University of Victoria also supports an independent Aquatic Facility on campus. This small re-circulation facility (freshwater and saltwater) was designed to work with other facilities on the UVic campus. The facility was built in 1987 and consists of laboratories, aquatic animal holding facilities, and a water treatment building. Both outdoor and indoor research areas are available depending on what environment needs to be created for testing. Water exchange rate, temperature, salinity, and light can be accurately controlled among the various tank configurations, allowing flexibility in experimental design. Adjacent photographs show a bank of outdoor experimental tanks (upper) and indoor experimental hydroponics system (lower).

The Aquatic Facility is maintained by a number of full-time technicians, and is used extensively by CART-Network researchers in a variety of husbandry-related aquaculture initiatives.

Temperate CART-Network initiatives

CART-Network researchers from across campus are routinely engaged in collaborative aquaculture research in temperate (coastal British Columbia) waters. Working with local industry sectors – finfish, shellfish, aquatic plants – these projects typically address issues with new species (life cycle, husbandry, siting/operating issues), increasing operational efficiencies (system design, innovations, materials use), societal issues (First Nations, Coastal Zone Management), and environmental fate and effects (governance). Examples of current initiatives include the following.

Canadian Integrated Multi-Trophic Aquaculture Network

A number of CART-Network researchers are currently involved in the NSERC/DFO Canadian Integrated Multi-Trophic Aquaculture (CIMTAN) Network. With a focus on the national program's west coast industry partner's farm site (Kyuquot SEAfoods Ltd. – SEA Vision Group), faculty and graduate students from Geography, Marine Ecology/Biology, Ocean Physics, Geography, and Engineering are engaged in a variety of projects that will explore the Ecological Design and System Engineering aspects for these relatively new multi-

species production approaches, as well as a number of Social (First Nation, governance) and Economic (business) considerations.

Engineering Initiatives

The department of mechanical engineering has a number of facilities and tools useful for aquaculture research. Ongoing projects in offshore wind, wave and tidal energy are developing tools such as combined hydrodynamic and wind simulations that can be used for aquaculture infrastructure design. Experimental facilities such as the PIV-equipped flume tank are being used to study hydrodynamic responses.

Energy system models are also being developed to accurately size and control renewable energy-based power systems to avoid diesel usage at remote sites, and a new project is currently underway to examine the potential for using kelp biomass for the production of bioethanol.

CART-Network collaborations for these initiatives include Biology, Geography, Microbiology, Economics, and Engineering.

Coastal Zone Management

The CART-Network, with researchers from Geography, Biology, Oceanography, Business, and Aboriginal Studies, is currently working on a project that will facilitate the integration of Traditional Ecological Knowledge of coastal First Nations, with a holistic, ecosystem based management framework for aquaculture siting and operating. Working with industry and at the Territorial level this project will outline a process that will provide individual First Nations with local decision-making capacity and options for development or management of aquaculture opportunities within their traditional territories.

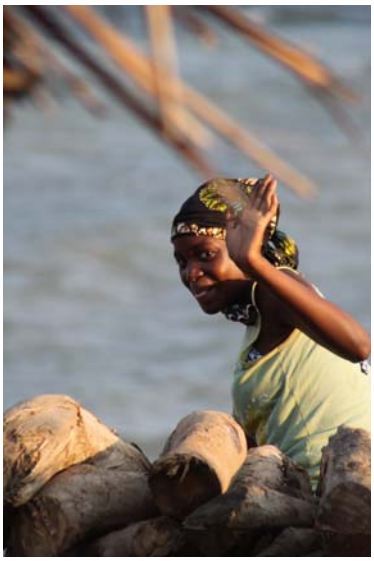
Roberta Stevenson, Executive Director of the BC Shellfish Growers Association with Kyuquot-Chechlesaht First Nation representative – *'working the beach'*.

Tropical CART-Network initiatives

CART-Network researchers also continue to work with colleagues in both developed and developing countries, to develop grant applications and produce regional aquaculture publications in support of government policy or industry operations. Our tropical initiatives are focused on Thailand, Vietnam, Bangladesh, India, Brazil, Central America, the Caribbean, and Mozambique.

The SOED Project

The CART Network and the University of Victoria Centre for Global Studies are currently co-directing the *Southern Oceans Education and Development Project (SOED)*. This 5-year project, which is funded by CIDA through its University Partnerships in Cooperation and Development (UPCD) program, is supporting Mozambique in achieving its national environmental and poverty reduction priorities for coastal communities. The Majority of SOED's work has been with the School of Marine and Coastal Sciences (ESCMC) a satellite campus of Universidade Eduardo Mondlane University, in the northern city of Quelimane. Alongside INAQUA, the Mozambican National Institute for Aquaculture Development, SOED has focused on improving the teaching capabilities of ESCMC so that its graduates can become leaders in the field of aquaculture.



New & Developing Opportunities

New CART-Network initiatives include collaborative research with: (i) the Environmental Research institute at the University of Belize, and the Toledo Institute for Development and Environment; (ii) World Fisheries Trust, examining *Food Security, Fish Farming and Aquaculture in the Bolivian Amazon* - funded by IDRC through its Food Security Initiative, and (iii) the United Nations Food and Agriculture Organization (UN-FAO) in developing spatial tools (GIS-based) in support of environmental management of aquaculture in Thailand.

Future of CART

The future of our CART Network will see new and dedicated on-campus aquatic research facilities, increased involvement of inter-departmental faculty, expansion of our national and international collaborative networks, and continued growth in our graduate student population. Although our focus will remain on research and higher-level (graduate program) training, our plans also include the integration of aquaculture modules among the applicable university departments, as well as the creation of additional 4th-year undergraduate courses specific to the needs of future aquaculture research.

Authors

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