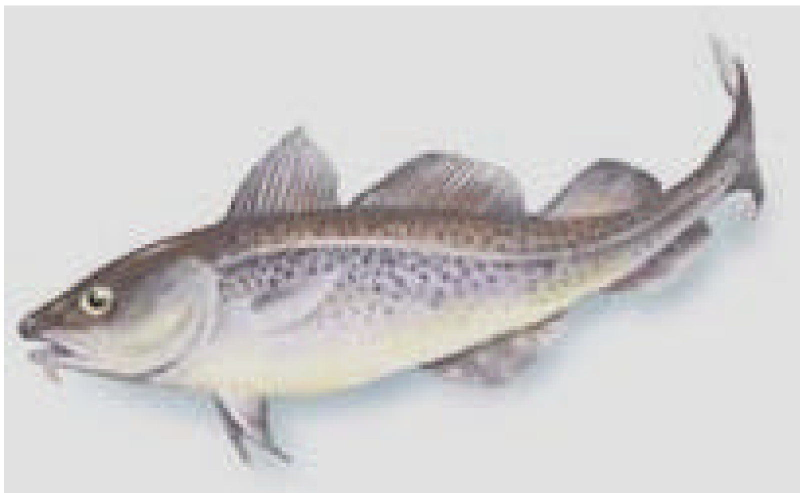
# From Hunting to Farming: Exploring the Development of Industrial Aquaculture in Newfoundland and Labrador from a Complex Systems Perspective



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## Abstract

This paper adopts a complex systems perspective to understand the development of industrial aquaculture in Newfoundland and Labrador. The first section explores the underlying industrial paradigm that has guided wild-stock management and aquaculture development in the province. Biophysical, sociopolitical, economic, and cultural-ethical systems are each examined and similarities between industrial aquaculture and the deleterious pattern of resource management applied to the Northern cod fishery are highlighted. The paper concludes by exploring alternatives to industrial aquaculture that emerge from a complex systems perspective.


## Introduction

When John Cabot arrived on the Grand Banks off the island of Newfoundland in 1497 he found cod (*Gadus morhua*) so plentiful that when his men threw baskets into the sea they filled faster with fish than with water. Five hundred years later on July 2, 1992 another *John*, the Canadian Fisheries Minister John Crosbie announced the closure of the Northern cod fishery. *Gadus morhua* had become "commercially extinct." It is from this historic context of massive regulatory failure, in Canadian fisheries management, that aquaculture development is now being promoted in Newfoundland and Labrador. As an alternative to the wild fishery, aquaculture is in the early stages of development in Newfoundland and Labrador. In 1997, the industry generated 5.1

million dollars, by producing 1,800 tones of product and employing just under 500 people (Department of Fisheries and Aquaculture, 1998a).[1] Aquaculture in the province has focussed on the production of single species—mussels, steelhead and Atlantic salmon (Government of Newfoundland and Labrador, 1999). Northern cod (*Gadus morhua*), the mainstay of the wild ground fishery prior to its collapse and closure in 1992, has also been captured and grown in sea pens, however this activity has not been economically viable due to problems with hatchery technology, low market prices, and legal restrictions on capturing brood stock and juvenile cod associated with the moratorium on the cod fishery (Calder, 1997).

Despite the relatively small numbers associated with present aquaculture activity in Newfoundland and Labrador, both the Federal and Provincial governments are aggressively promoting the industry, anticipating its exponential growth (Government of Canada, 1995; Government of Newfoundland and Labrador, 1998). Memorial University (through the Marine Institute and Ocean Sciences Centre) has been offering research opportunities, aquaculture education, and training courses since 1987—after the cod moratorium in 1993 the university significantly expanded its aquaculture programs. Funding for these

[1] These numbers are small when compared with other provinces. For example, in 1998 British Columbia was Canada's largest aquaculture producer with 48,331 tonnes, New Brunswick followed with 15,748 tonnes, PEI 14,532 tones, and Nova Scotia 4,066 tones (Canadian Aquaculture Industry Alliance, 2000).

programs has come from a specific aquaculture component built into the Canada/Newfoundland Agreement on Economic Renewal. The province has encouraged aquaculture development by conducting an aquaculture review, completing a study on conflict management in the industry, and creating a growth friendly legislative framework that includes an Aquaculture Act with favourable regulations (Government of Newfoundland and Labrador, 1999). In addition to specific Provincial actions, the Federal *Department of Fisheries and Oceans* has released a *Federal Aquaculture Development Strategy* that promises financial support for infrastructure and the creation of “a regulatory and policy framework conducive to industry development” (Federal Aquaculture Development Strategy, 1995:8). In 1998, the Federal government enhanced its’ support for the aquaculture industry by creating a new commissioner for *Aquaculture Development* thereby institutionalising Federal support for the industry (DFO, 1998b).

However, despite the enthusiastic promotion of aquaculture by Federal and Provincial governments their policy proposals bear a disturbing similarity to the policy frameworks that resulted in the collapse of the Northern cod stocks. In both the wild fisheries and aquaculture, a strong emphasis has been placed on technological and managerial improvements to achieve *maximum single species yields* in order to successfully compete in global seafood markets. This approach is succinctly illustrated in the Federal government's *Aquaculture Development Strategy*:

> To remain internationally competitive, Canadian producers must sustain the relentless pursuit of *technological* and *management* improvements that allow Canada to gain stature in world aquaculture. The capability to produce and market desired products at internationally competitive prices is paramount to sustained development (Federal Aquaculture Development Strategy, 1995:9 *emphasis added*).

By focussing on "technological and management improvements" within the economic *status quo* of boundless growth (without reference to social or ecological limits), aquaculture development couples ecosocial systems to the logic, time scale, and control of global capitalist markets and their corporate captains (Korten, 1995). In the wildstock fishery, this approach has relied on single species management using reductionist science, linear modelling, neo-classical economics, and command and control technocratic management in order to set Total Allowable Catch (TAC) limits that focus on controlling *how many* fish are caught, rather than how the fish are harvested (Finlayson, 1998 and Rogers, 1995)[2].

This industrial, reductionist, single species approach leaves critical system dynamics questions unexplored and has contributed to the overexploitation of many wildstocks in Canadian and international

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[2] In the context of industrial aquaculture, this policy approach focuses on maximizing how *many* fish are produced under the control of aquaculturalists rather than how they are grown, their quality, or the impact of fish farming on the sustainability of the larger social, economic, and ecological systems that they are embedded within and are dependent upon.

waters. It excludes from consideration the complex social, ecological, and technological contexts in which wildstock fishing and aquaculture take place. The approach assumes the ability to accurately predict fish stock abundance, by acting *as if* stocks were discrete commodities in space and time, unconnected to larger systems (Holling *et al.*, 1998). Technological improvements that directly effect catch-per-unit-effort (*how* the fish are found and harvested) are often overlooked, instead managerial activities focus on optimizing the *status quo*—stock assessments, the allocation of individual privatized quotas, and improvements in efficiency within existing management institutions (Berkes & Folke, 1998).

This wildstock fisheries management approach is being repeated in the policy proposals for the development and management of aquaculture in Newfoundland and Labrador. In Federal and Provincial policy documents aquaculture sites are treated *as if* they are discrete, disconnected objects (conceptualised as enclosed private property) amenable to privatized leasing arrangements. Technological and managerial interventions that directly effect *how fish are cultivated* (i.e.: the intensity of the farming activity, the wastes produced, the inputs used, the genetic make-up and species composition of the fish grown, the salaries and organizational abilities of employees, and other "internalized" business factors) are left to the discretion of individual aquaculture entrepreneurs who are to be guided primarily by market mechanisms. The Provincial and Federal governments' management structures focus on how many sites are to be licensed and where they will be located, rather than recognizing or seeking to understand the complex relationships that exist between activities which occur on aquaculture sites, and the larger systems within which they are embedded. This predominant way of framing aquaculture within Federal and Provincial policy documents significantly reduces the potential for encouraging alternatives that move beyond reductionist science, anthropocentric ethics, neo-classical economics, and political individualism that have produced unsustainable livelihoods in Canadian coastal zones.

David Bella (1997) has discussed the dynamics of this dominant institutionalised order as it applies to the salmon fishery on the West Coast of North America. Instead of proposing a static view of organizational *structures*, Bella (1997) argues that individuals are embedded within vast organizational *systems* that are complex, adapting, and nonlinear (CANL). The dynamics of these systems tend toward mutually reinforcing patterns of self-producing order that shape how the world is understood, and how crises (disorder) within management structures are perceived. The normal response to situations that challenge institutionalized order—such as the collapse of fisheries—is to seek ways to dampen the disorder rather than recognizing the challenge as a symptom of *profound failure* requiring fundamental reorganization around a new policy attractor (Bella, 1997).

> People are caught up within CANL [complex, adapting, non-linear] systems that shape their activities. Their perceptions of what is reasonable, possible, and proper gravitate toward a vast reinforcing attractor, and the world is being remade in its image (Bella, 1997:629).

The Federal Department of Fisheries and Oceans' *image* of endless technological and managerial improvements driving aquaculture development, into a globally competitive future serves as a powerful social attractor that continues to promote the very policy and administrative processes that led to the collapse of the wildstock cod fishery. The result of this market driven techno-managerial approach has been to produce what Buzz Holling (1995) has called the "pathology of resource management." The ability to manage for the maximum production of codfish led to overexploitation, vulnerable ecosystems, centralised technocratic organisational structures, and highly dependent coastal communities (Milich, 1999). Following this policy trajectory has meant that wild stock fisheries management in Canada has often resulted in iatrogenisis, paradoxically *producing what it is designed to prevent* (Bavington, 1998). Policy observers have noted that the apparent "success" of the Northern cod management regime prior to the collapse (measured by high levels of efficiency due to the expanding number of fish captured despite a declining annual catch-per-unit effort up-to-and-including the last year of the fishery) helped to *produce* the commercial extinction of *Gadus morhua* by encouraging unsustainable capitalization and technologically driven fishing effort until the highly "efficient" cod fishery was ultimately destroyed as a viable economic activity and way of life (Rogers, 1995). Holling *et al*. (1998) note, that this pattern of resource management pathology is common in fisheries management, where a frontier mentality of successive stock depletion continues to be observed.

The managed annihilation of the Northern cod fisheries (that has resulted in the reduction of stock abundance to 1% its historic level) leads one to pause, and call into question similar management strategies that aquaculture policies are presently promoting. If we are to learn from one of the world's largest resource management failures (the commercial extinction of *Gadus morhua*), the underlying reductionist philosophy behind market driven techno-managerial approaches to the cod fishery needs to be critically explored and new policy approaches that reach beyond reductionism must be developed. Complex systems theory and ecosystem approaches provide alternatives to reductionism and the pathology of resource management; they can be used to critique underlying assumptions contained in resource management science, economics, politics and philosophy. The approach being taken toward the development of aquaculture in Newfoundland and Labrador seems poised to repeat many of the mistakes of the past by focussing on the management of single target variables to achieve exponential industrial growth that is ultimately unsustainable for ecosystems and human communities. The predominant Canadian aquaculture policy approach is constructed upon a reductionist science of *parts*; a neo-classical economics focussed on profit maximization; and hierarchical forms of politics that are ultimately undemocratic. Assumptions about natural systems are made including the belief in certainty, linear causality, knowability, predictability, and control. In contrast to reductionism, complex systems theory and ecosystem approaches draw on an alternative view of natural and social systems flowing from post-normal science that focuses on ecosystem processes, ecological economics, and participatory forms of community-based politics (*Table I*). Under these new approaches non-linear dynamics, imperfect knowledge, limits to predictability and control, the recognition of self-organizing capacity, and the inevitability of surprise and uncertainty become the primary operating assumptions driving policy development and implementation. These new approaches have the potential to create policies that promote forms of environmental management that avoid producing what they are designed to prevent.

This paper sketches out a critique of industrial aquaculture from a complex systems perspective and proposes an alternative policy framework to guide Federal and Provincial aquaculture policies by exploring the biophysical, socioeconomic, and cultural-ethical systems that form the complex contexts within which aquaculture is practiced.

## Industrial Aquaculture: A Familiar Story that Repeats the Past

> We will domesticate the fish over time...knock them down to a more passive fish...And we'll have fish that will just swim around and graze like a cow...That's what we're all shooting for (B.C. Salmon Farmer *in* NFB, 1989:10-11).

The above quote from a British Columbian salmon farmer, succinctly describes the goal of industrial forms of aquaculture while illustrating the connections it shares with intensive feedlot beef production. Modern industrial aquaculture progresses by creating systems that domesticate wild species to produce maximum output while minimizing capital input. This is achieved through the use of genetically modified organisms (GMOs), enriched foods, intensive management (including fish health and nutrition), and the massive externalization of social and ecological costs. Aquaculture operations grow the most profitable species and attempts are made to harmonize harvest schedules with peek prices and market demand. Fish pens are conceptualized and managed to produce highly concentrated *closed systems* with management activities focused on maintaining the cage boundary to ensure profitability (i.e.: to prevent escapes and to avoid diseases from entering from the marine environment) (Figure I).

## System Attractors and Gradients

Industrial aquaculturalists are primarily concerned with optimizing processes that are occurring *within* their sea pens. In order to be successful they must maintain strong boundaries around their property, excluding or minimizing factors that negatively influence the health of their caged fish—such as disease vectors from the surrounding environment or invasions from predators. However, from a complex systems perspective, fish farms are dynamic, non-linear, *open systems* that operate far from equilibrium. They co-create, and are nested within, numerous systems of varying scales and types that self-organize around unstable attractors driven by exergy, material, and informational gradients (Kay *et al.*, 1999 and Regier and Kay, 1996).[3] The activities associated with numerous social, ecological, and economic *gradients* (operating far from equilibrium) create the conditions for both profitability and the potential for catastrophic, unpredictable changes and conflicts in the larger ecosocial system within which the fish farm is embedded. From this complex systems perspective, industrial aquaculture involves *high levels of uncertainty* and a strong tendency for the system to unpredictably flip from one set of multiply coupled *attractors* to another. The socioeconomic, political, and biophysical conditions that must be maintained to achieve successful industrial aquaculture create a highly unstable socioecological context that is susceptible to numerous catastrophic flips, gradual changes, and

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[3] The types of systems involved may include socio-economic and political systems, biophysical systems, and cultural-ethical systems which operate at a variety of scales from local to global. Exergy is defined by Kay *et al.* (1999:723) as high quality energy—the amount that is available to do work.

ongoing conflicts operating across numerous system types and scales (Figure II).

The proceeding sections will discuss some of the system interactions operating within the biophysical, socioeconomic/political, and cultural-ethical systems that comprise the environment of Newfoundland and Labrador aquaculturalists.

## Industrial Aquaculture: The Biophysical System

Ecologists are interested in the impact fish farms have on biophysical systems. Perspectives from ecological science differ from narrow economic understandings of aquaculture. The ecologist's perspective leads to questions about escapes (potential genetic and disease interactions with wild populations (Peterson,1999 and McKenna, 2000)); the impact of wastes on benthic[4] communities (which may lead to problems such as anoxia, and the production of hydrogen sulphide and methane (Davidson, 1999)); water quality concerns such as eutrophication (Folke & Kautsky, 1992); the potential for deleterious effects on marine mammals, birds and other species that are targeted as predators by aquaculturalists (Iwama *et al.* 1997); and the overall ecological footprint of the system (Folke *et al.*, 1998). *See Figure III.*

[4] The benthic environment associated with aquaculture sites represents the space located on the ocean floor that lies beneath fish cages. Benthic environments contain complex aggregations of marine flora and fauna.

### Concerns with Escapes

Fish from aquaculture sites escape from sea-cages that wear out or are torn by predators, storms and currents. The numbers of escaped fish can be large, leading to questions about possible genetic effects on wildstocks, disease transfers to wild populations, changes to ecosystem structure, and confounding effects on wild stock assessment, restoration and management.[5] There is a lack of empirical research that has been done on the effects of escapes on wild populations and their ecosystems, however past experiences with the introduction of exotics into terrestrial and marine ecosystems leads many to advocate for a precautionary approach (Westra, 1998). Ecological research into the population structure of Northern cod presents information that would lead one to be concerned about cod farming activities in Newfoundland. Smedbol and Wroblewski (2000) report multiple bay stock populations of cod which they hypothesize form a complex metapopulation (Figure IV). In a recent paper in the *Journal of Fish Biology* Ruzzante *et al.* (2000:431) reported DNA research findings that "provide evidence that Atlantic cod *Gadus morhua* inhabiting Gilbert Bay, Labrador are genetically distinguishable from offshore cod on the north-east Newfoundland shelf and from inshore cod in Trinity Bay, Newfoundland." These initial findings are *extremely* significant for policies aimed at aquaculture and wildstock fisheries management. Historically, wildstock cod populations have been managed *as if* they were one distinct population with little attention paid to distinct subpopulations—those associated with small scale inshore fisheries located in specific bays have received even less attention. With the recent scientific "discoveries" of bay stock populations (which have been asserted by inshore fishers since the early 80's) the need for altered policies influencing wildstock fisheries management and a precautionary approach to aquaculture are enhanced. As Ruzzante *et al.* note, "Harvesting strategies for northern cod should recognize the existence of genetic diversity between inshore and offshore components as well as among coastal components" (2000:431).

If escaped farmed cod (or other species) were to interbreed, out compete or spread diseases to the significantly reduced wild sub-populations of northern cod, the ability to restore wild-stocks and the prospect for sustainable fishing livelihoods could be placed in further jeopardy. In addition to genetic and disease concerns, escapees can confound wildstock fisheries management in other ways. Hansen *et al.* (1999) reported that 40% of the fish caught in the Faroes wild salmon fishery in 1990 were of farmed origin. They caution:

> When assessing salmon fisheries and wild salmon stocks, it is important to estimate the farmed and ranched component of the catch. If such fish are not accounted for, their presence will result in an overestimation of the catches of wild salmon and the size and status of the wild stock will be obscured (Hansen *et al.* 2000:205).

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[5] From 1987-1996 BC salmon farmers reported that an estimated 1,078,368 domesticated fish had escaped into the wild (Davidson, 1999).

Hansen *et al.* (2000) illustrate how aquaculture complexifies and increases the uncertainty associated with coastal zone policy and fisheries stock assessment and restoration by adding yet another variable that requires expansive data collection and accurate ecological modelling—to degrees of accuracy that are not currently possible to obtain (Gomes, 1993). Given our inability to sustainably manage wildstock populations that *do not* have these added complexities, it seems reasonable to argue that concerns around escapes should be taken seriously by policy makers (Hansen *et al.*, 2000).

### Concerns with Disease

The overcrowded, monocultured environment of fish cages and the use of exotics and genetically modified broodstocks create conditions amenable to the development and spread of disease to both farmed, and wild, populations of fish and other marine species. The highly stressful conditions under which fish are raised often leads to the use of pesticides, medicated feeds, and vaccines. While the use of medications, such as antibiotics, continues to decline with the development of vaccines (Conley, 1998), there are high levels of uncertainty surrounding the use of aquaculture therapeutics in relation to their effects on marine ecosystems and human health.

### Concerns with Wastes

Solid wastes that stream out of the bottom of fish cages, and dissolved wastes that are flushed into the surrounding water column, are produced by fish faeces and unconsumed feed. The feed pellets used in aquaculture require the compression of wild fish, agricultural products, and therapeutics that are collected and transported over vast terrestrial and marine areas. When fed to fish, these pellets generate “concentrated forms of waste which...are continuously dispersed into the surrounding ecosystem at a much higher rate than they are being assimilated” (Folke *et al.*, 1998:S65). The environmental impacts of intensive aquaculture development have been compared to untreated municipal sewage outlets and discharges from heavy industry (Folke & Kautsky, 1992:6). It is estimated that “to produce the fish pellets for cage farmed salmon, solar fixation by plankton from a sea surface area that is...40,000-50,000 times larger than the surface area of the cages themselves is required” (Folke & Kautsky, 1992:9). This expansive ecological footprint and concentration of energy, draws on a variety of ecosystems far away from the aquaculture site, including wild stocks (Figure V). Three to five pounds of wildstock fish are used to produce one pound of farmed salmon, similar inputs are required for other farmed species such as cod that are often fed species such as capelin which have been harvested from the wild (Roberts *et al.*, 1999 and Calder, 1997). The concentrated wastes that are produced by aquaculture sites can lead to eutrophication, algae blooms, oxygen depletion and the build up of hydrogen sulphide and methane, that can result in the contamination of benthic environments under fish farms and the pollution of surrounding water columns with deleterious effects on benthic organisms, wildstock fisheries, restoration, and aquaculture activities (Barg *et al.*, 1997 and Burd, 1997).[6] These deleterious consequences of aquaculture have already been observed in British Columbia, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and other marine environments world-wide (Calder, 1997).

### Concerns with Predator Control

Marine mammals and birds are attracted to large concentrations of caged fish. Aquaculturalists often shoot, poison, or harass these predators to avoid net damage and fish losses. During a recently completed aquaculture review process in British Columbia (1999) a salmon "farm manager reported that over the past four years...431 seals, 38 otters, 16 herons, 29 sea lions, an osprey and a porpoise had been killed" on his farm (Davidson, 1999:5). In addition to direct killing, aquacultural sites often employ acoustic deterrent devices (ADD's) that generate underwater noises to scare away predators. These devices

[6] Concerns have also been raised about the possibility for decreased microbial activity, and decomposition rates in benthic communities lying directly beneath aquaculture sites containing fish that have been treated with antibiotics (Burd, 1997).

become ineffective when predators such as seals lose their hearing or become acclimatized to the noise.

A recent study by Nordeide and Kjellsby recorded sounds from spawning cod concluding that “acoustic communication may be an important criterion by which females discriminate between males from different cod populations” (1999:326). Their study made no direct mention of ADD’s, however it illustrates how little we know about the potential effects of ADD’s on marine animal communication, migration patterns, mate selection, and other unknown behaviours and broader ecosystem functions.

There are high levels of uncertainty involved with each of the above concerns—they involve dynamic non-linear feedback loops and novel self-organizing processes located in coupled systems of different type, temporal and spatial scale. We have very little knowledge of these interactions and lack the ability to accurately predict how these various systems will respond to aquaculture related disturbance gradients created by the need for firm boundaries and high levels of economically profitable control. Adopting the precautionary principle as a central tenet in aquaculture policy would require the suspension of aquaculture development in Canada until many of the risks association with the farming of fish have been explored and publicly debated (especially the potential for deleterious effects on remaining cod stocks in Atlantic Canada and wild salmon stocks on the West coast). Keeping in mind

Canada's failed fisheries policy record, in the past, contemporary policy approaches should take the precautionary principle seriously, slowing down or halting fish farming development if necessary. As the Canadian environmental philosopher Laura Westra notes, there is bound to be alterations in natural systems due to industrial aquaculture, we should therefore error on the side of caution (Westra, 1998:88).

## Industrial Aquaculture: The Socioeconomic and Political System

> Aquaculture is the culture of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Culture implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. *Culture also implies individual or corporate ownership of the stock being cultivated* (Government of Canada, 1995:3 *emphasis added*).

The quote above, taken from Canada's *Aquaculture Development Strategy*, points to the socioeconomic and political implications involved with aquaculture development. "Culturing" requires the *enclosure* of marine organisms and their coastal environments, transferring ownership of marine species and spaces from the domain of the public "commons" into the hands of private interests. The enclosure of genomes and marine spaces that enables industrial aquaculture to be profitable, requires the restructuring of social, ecological, economic and political relations (Shiva, 1997). For example, the *Newfoundland Aquaculture Act* "provides the aquaculturist with property rights, through leases, to non-tidal and marine sites..." (Government of Newfoundland and Labrador, 1999). Changes in provincial legislation and co-management arrangements between the Federal *Department of Fisheries and Oceans* and the Provincial *Department of Fisheries and Aquaculture* create governance conditions necessary for the privatization of coastal property rights. International agreements and institutions such as the North American Free Trade Agreement and the World Trade Organization, enshrine intellectual property rights that enable the privatization and commodification of genetically modified organisms that are cultured on the enclosed coastal spaces of fish farms. Industrial aquaculture is nested within a number of enclosures that enable new opportunities for the commodification and privatization of coastal spaces and species that fall under the logic and control of global capital.[7]

In addition to legal and political restructuring, policy makers need to consider that the social identity of fishers is dramatically changed by the expanded logic of privatization, commodification, and enclosure that forms the *necessary* foundations for industrial aquacultural development. Following the logic of industrialization, a logic that promoted movement from a small scale inshore fishery to an intensive

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[7] These processes in the aquaculture industry are mimicked in calls for the full privatization of remaining wildstock species. Resource management failures are often explained as the result of tragedies of the commons (Hardin, 1968). This explanation casts common property as *the* problem, amenable to a host of privatisation solutions. For example, individual transferable quotas (ITQ's) are often proposed as *the* solution to over-fishing, with little understanding of the historical role communal property rights have played, and continue to play, in sustainable fisheries activity and with little evidence of the efficacy of privatisation solutions in Canada or abroad (Pinkerton, 1999).

offshore fishery in Newfoundland and Labrador, fishermen are told they must cease to convivially hunt for a living, and evolve into modern professionalized ranchers and farmers. This move is illustrated in an article from *The Economist*:

> In fact, [the ocean] is a resource that must be preserved and harvested. To enhance its uses, the water must become ever more like the land, with owners, laws and limits. Fishermen must behave more like ranchers than hunters (*The Economist*, 1998:4)

Newfoundland is particularly susceptible to this socioeconomic logic, as exemplified in the provincial decision to become the first in Canada to legally recognize and promote fishing as a profession—with governmentally administered qualifying standards, skills, and experience requirements (Government of Newfoundland, 1999). While seemingly disconnected from policies effecting fish farming, this general trend toward professionalization of fisheries workers is connected to a broader move toward a highly commodified coastal zone requiring increasingly comprehensive management, a smaller workforce, and higher levels of capitalization and integration into competitive global seafood markets, of which industrial aquaculture is the most recent expression. As increasing amounts of coastal spaces are shifted from multiple, largely self-organizing public uses, to single highly controlled private uses, rights to marine spaces and species become scarce, triggering conflicts that result from the expansion of centrally organized, comprehensive top-down management and planning practices as well as highly concentrated ownership patterns (Steinberg, 1999).

The socio-economic and political changes associated with aquaculture in Newfoundland have already led to significant conflicts in the coastal zone. Policy makers need to consider that many of these conflicts stem from practices of enclosure that are *required* for aquaculture operations to be established and expanded. These practices privatize and concentrate profits while simultaneously externalizing risks and broader social and ecological costs. The need to control the numerous conflicts associated with aquaculture led the Provincial government to commission a study on conflict management in the industry (Government of Nfld. and Labrador, 1999). The report documented numerous conflicts associated with:

- Navigational safety issues involving recreational boating and the inshore fisheries;
- Impaired access to the shoreline;
- Aesthetic concerns voiced by home and cabin owners;
- Environmental considerations in Green Bay and Bay D'Espoir;
- And the largest source of conflict—aquaculture's impact on access to *traditional fishing grounds*.

While not mentioned in the provincial report, researchers have observed that conflicts are also produced by the concentration of ownership that often follows enclosures associated with aquaculture development (Bailey *et al.*, 1996 *see Figure VI*). On the West coast of Canada, British Columbia's salmon farming industry has developed from 140 start-up operations to a concentrated group of 16 corporations with high levels of foreign ownership and corporate practices of vertical integration and contract farming (Conley, 1998). The business climate created by this concentrated ownership pattern means that individual aquaculturalists tend to capture only a small percentage of the overall value of their products (even though they absorb the majority of the economic risk) due to the fact that most cultivated species become "commodities with hypercompetition amongst producers that tends to drive [down] producer prices" (Lockwood, 1999:30). These socioeconomic outcomes illustrate that the economic systems associated with aquaculture (and the practices of privatization through coastal zone enclosure that underlie them) have import impacts on the distribution of benefits to human populations living in coastal zones as well as broader impacts on regional biophysical systems (Newkirk, 1997). They also illustrate the economic benefits that can be captured through enclosure, and the strong economic incentives for producers to externalize social and ecological costs in order to survive in highly competitive market situations. These dynamics must be recognised and *addressed* to achieve an ecologically and socially sustainable aquaculture policy.

In addition to more economically related concerns, the privatization of genetically engineered organisms adds additional complexity, conflict, and concerns to the socio-political system that effects aquaculture policy. Increasingly, organisms are engineered to fit the desired traits of dynamic global markets—producing a process which Donna Haraway has termed, "nature enterprized up" where natural systems, and the species that comprise them, increasingly become tied to the hyper-commodification pressures exerted by the shifting demands of global markets (Haraway, 1997) *See Figure VII.* Increasingly, large sections of the Canadian public are questioning the ethical legitimacy of genetically modified organisms and the ownership of genetic material (Shiva, 1997).

**Industrial Aquaculture: The Cultural-Ethical System**

Industrial aquaculture is embedded within a complex cultural and ethical system. The system draws on neo-classical economics; liberal democracy that emphasizes individual rights to private property; Newtonian reductionist science focussed on atomism and mechanism; and a thoroughly anthropocentric ethics focussed on narrowly defined human economic interests alone (Merchant, 1992). *See Figure VIII.* The underlying metaphor of industrial systems is the machine. Both natural and social systems are treated *as if* they were mechanical, amenable to a *normal science* focussed on parts, linear causation, and absolute control (Table I). Operating from this set of assumptions and intellectual models, the coastal zone is prepared for industrial aquaculture by being divided into parts that are conceptualized as being separate and static, amenable to commodification, privatization and managerial practices aimed at maximizing control over fish production, reproduction, marketing and consumption. In order to be successful, aquaculturalists must domesticate a number of elements from biophysical, socioeconomic, and political systems that require continuous, intensive management to maintain highly unstable energy, material, and informational flows across large gradient complexes.

This techno-managerial approach to aquacultural development illustrates a heightened level of arrogance, that seeks to engineer natural and cultural systems to fit them into the logic of capitalist economic growth and a cultural desire for predictability and control that has proven itself unsustainable with respect to numerous resources including the Northern cod. This industrial approach to farming fish follows the logic which guided the management and development of the Northern cod fishery which ended with the commercial extinction of the species in 1992.

Beginning *primarily* as a labour intensive, technologically primitive inshore fishery, cod fishing in Newfoundland and Labrador became rapidly industrialized throughout the 50’s, 60’s, 70’s, and 80’s producing factory freezer trawlers with the ability to accurately locate stocks of codfish offshore (Kurlansky, 1997). These factory freezer trawlers “vacuumed” portions of the ocean, high-grading and discarding massive amounts of by-catch before processing the targeted species at sea. These “ocean factories” represent the precursor to the modern fish farm with efficient resource location and capture, under human control. Modern industrial aquaculture extends human control into the reproduction and growing conditions of fish, completing the goal of total control over the targeted species. The result of this cultural-ethical system that guides industrial aquaculture policy is succinctly described by biologist Gary Meffe.

> The ultimate outcome of this techno-arrogance is the increasingly intensive and essentially perpetual management of a multitude of species in a world unfit for their natural existence (Meffe, 1992:354).

**The Next Step: Polyculture Aquaculture?**

In contrast to intensive industrial monocultures, polyculture fish farming seeks to apply ecological principles to close feedback loops by utilizing the wastes of one species as food for another. This biomimicry approach offers policy makers a more sustainable alternative to industrial aquaculture by encouraging farmers to fit their culturing techniques into the processes and functions of ecological systems (Benyus, 1997). Folke and Kautsky (1992) have proposed a polyculture system that would involve seaweed, mussels, and salmon. This hypothetical system seeks to close the input and output loops of an industrial fish farm through the application of ecological engineering principles.[8] The solid wastes produced by unconsummed feed, and fish faeces, serve as food for mussels that can be fed back to the fish. The high levels of dissolved phosphorus and nitrogen, produced by the wastes associated with fish faeces, are used as food by various forms of seaweed and plankton, some of which are consumed by mussels and the

[8] This approach shares similarities with industrial ecology that seeks to feed waste streams (produced in factories) back into the production process, with the ultimate goal of producing zero waste (Hawkins *et al*, 1999).

fish to complete a self-regulating cycle (Figure VIV).[9] By diversifying monocultured systems to include tropic levels that assimilate each others wastes, more *efficient production systems* are created (Brzeski and Newkirk, 1997).[10]

The bioengineering approach proposed by Folke and Kaustsky should not be seen as a sufficient solution to the complex policy issues surrounding aquaculture, even if it points policy makers in a potentially promising and ultimately more *ecologically* sustainable direction. Critics of Folke and Kaustsky point out that their proposal for a polycultured form of aquaculture attempts to piece together an ecosystem to serve human beings, moving the goal of human control to a higher and ultimately more complex and unpredictable level. By seeking to integrate wastes back into production, they shift out of the linear mechanistic paradigm which assumes unlimited inputs and endless sinks for wastes. However, these approaches rely on simplified understandings of marine ecology and have the potential to reinforce hubris and mechanistic thought, albeit with significantly more complicated arrangements. It is important that these new proposals are integrated into a larger

[9] Folke and Kautsky also discuss the possibility for land based run off (Nitrogen and Phosphorus) to be absorbed by plankton and seaweeds. However, in a more recent article, Troell, Kautsky and Folke (1999) emphasize the complexity and technical difficulties involved with operationalizing their proposed system.

[10] Brzeski and Newkirk (1997:66) explain integrated aquaculture systems in the following way: "Filter feeders remove the particulate suspending matter and deposit it on the sea bottom as faeces and pseudofaeces (biodeposition), seaweeds absorb dissolved nutrients (nitrogen and phosphorous), and detritus feeders (sea cucumbers and polychaetes) digest organic substances from the sediments."

*ecosystem approach* to policy that takes account of connections between the aquaculture system, and the larger ecosocial systems in which they are nested.

Wolfgang Sachs has explored the limitations of bioengineering forms of systems theory:

> Looking at nature in terms of self-regulating systems…implies either the intention to gauge nature's overload capacity or the aim of adjusting her feedback mechanisms through human intervention. Both strategies amount to completing Bacon's vision of dominating nature, albeit with the added pretension of manipulating her revenge. In this way, ecosystem technology turns…against ecology as worldview. A movement which bode farewell to modernity ends up welcoming her, in new guise, through the backdoor (Sachs 1993:32).

The environmental philosopher Laura Westra concurs with Sachs by noting that the underlying ethic of polycultured systems does not necessarily address larger moral questions surrounding what is "good" or what ought to be done.

> Such ethics may propose 'management' goals of ecosystem health, but they accept both management and manipulation as acceptable everywhere, under specific circumstances. At best, these theories question the 'how,' not the more basic 'why,' of any management goal. In other words, once manipulation and alteration is viewed as *prima facie* acceptable (in contrast with the principle of integrity), it becomes notoriously hard to draw the line on a continuum, and a special case needs to be made to explain why *this* particular kind of manipulation may need to be restricted (Westra, 1998:93).

The more radical critiques by Westra and Sachs allow policy makers to realize *some of what is left out* of the polyculture fish farming proposals and they reinforce the necessary complexity, conflict, and uncertainty associated with all forms of aquaculture. For example, no mention is made in polyculture to the role of economic enclosure and the social justice conflicts they produce; the lack of knowledge we have of marine ecosystems; nor the moral and practical concerns surrounding the use of genetically modified organisms. To address these concerns, and a host of others, policy makers must acknowledge discussions of the *good* as well as the factual and explore decision making processes that are democratic, inclusive, and participatory.

Postnormal science (PNS), advocated by Funtowich and Ravetz (1993), provides a model for policy makers to begin to address the above concerns. Postnormal science applies when facts are uncertain, values are in dispute, stakes are high, and a decision must be made. An extended peer community and extended facts are needed to allow for all who are interested in the issue to participate (Funtowich and Ravetz, 1993). Postnormal science does not seek to eliminate uncertainty to achieve predictability and control, it recognizes that some level of uncertainty is inevitable in complex situations. This recognition means that activities such as aquaculture and wildstock fisheries management must be recognized as being inherently *political* and *contingent* (Funtowich and Ravetz, 1993) *See Table I.* The failure to recognize the post-normal nature of interconnected resource, social, and ecological problems has resulted in the pathologies and iatrogenic effects discussed earlier.

Ecosystem approaches pull together insights from postnormal science, participatory forms of politics, environmental ethics and ecological economics to offer an alternative perspective on the role of humans in the ecosocial systems within which they are embedded. Ecosystem approaches begin with the recognition of human embeddedness within complex self-organizing ecosocial systems. Ecosystem approaches emphasize the *limits* of our ability to control a dynamic and highly connected system of which humans are only *one* member, and therefore offer the potential to shift the overall human-nature relationship from management to partnership (Merchant, 1998). The goal of human activities comes to be seen as the enhancement of the capacity for systems to self-organize, rather than exerting external managerial controls (Hollick, 1993). This involves shifting human behaviour away from optimization and control toward an ability to learn from, and cope with, change and complexity. As Tim Allen (1992:115) notes,

> The long term survival (or extinction) of any particular group of humans …is…more related to its ability to cope with uncertainty and change, and to generate responses, than to the optimality of its precise behaviour at a given time.

Adopting an ecosystem approach has an effect on how policy makers perceive industrial aquaculture. The approach points toward an emphasis on precaution and the recognition of complex system dynamics and their limits. A list of characteristics that flow out of an ecosystem approach to aquaculture have been outlined by Costa-Pierce and Peters (1994 *quoted in* Westra, 1998). They identify twelve factors that address many of the concerns raised above and serve as an initial set of sign posts for policy makers interested in sustainable aquaculture (Their recommendations with my additions appear in Table II).

Alternatives to industrial aquaculture in the Western world are only now beginning to emerge. When proposing policy alternatives it is important to remember that our understanding of the complex ecosocial systems of the North Atlantic is extremely constrained and will remain so into the foreseeable future.[11] The proposals by Folke and Kautsky (1992) and Costa-Pierce and Peters (1994 *quoted in* Westra, 1998) represent the beginning of a journey from crass mechanism and deleterious control oriented management toward ecosystem approaches embedded in democratic partnership ethics.

This paper has attempted to outline some of the impacts which the current promotion of industrial aquaculture is having on ecosocial systems, and some of the ideas that are in the literature for how policy makers might proceed in an alternative manner—focussing on insights from complex systems approaches that highlight complexity, conflict, uncertainty, non-linear dynamics, and nested self-organizing systems. These alternatives emerge from a conceptual framework that includes Postnormal Science, Participatory Democracy, Partnership Ethics, and

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[11] A recent paper by Steele and Schumacher (2000) explores what the ecosystem structure of the North Atlantic might have looked like before intensive fishing. These studies emphasise how little we know about marine ecosystem dynamics and the knowledge that must be gained before we can have an understanding of the wildstock fisheries collapse, let alone current alternations to the linked ecosocial systems of the North Atlantic!

Ecological Economics. (see Figure X). They emphasizes the fact that we are part of nature and not separate from it and must therefore learn to integrate our activities with the land and sea (Benyus, 1997).

**Toward a Conclusion...**

When John Cabot arrived off the coast of Newfoundland in 1497 he found codfish so plentiful they could be caught merely by dipping a basket into the Atlantic. In 1993, this abundant cod fishery had been reduced to 1% of its historic levels resulting in the commercial extinction of the species and a fishery moratorium affecting 30,000 Canadian livelihoods (Millich, 1999 and McGuire, 1997). Out of this climate of crisis, industrial aquaculture is developing within Newfoundland and Labrador. While still in its early stages of development, industry proponents claim that Newfoundland and Labrador aquaculture can produce fish in cages so plentiful that Newfoundlanders will replace hunting with farming—managing the (re)production of fish in "baskets" as opposed to casting them into an unpredictable sea. This paper has attempted to show why this promise is false, serving as a barrier to the implementation of sustainable livelihoods and ecosystem approaches in the province. As Grzybowski and Slocombe (1988:475) note:

> He who thinks that he is managing the evolution of a complex system is likely only managing the microscopic fluctuations, the incremental changes—optimizing the details and neglecting to anticipate possible qualitative changes. Then comes the surprise: a staggering realization that the old order no longer works.

Newfoundland and Labrador experienced the largest, most devastating "surprise" in the history of Canadian resource management. The commercial extinction of the cod and the ensuing ecosocial crisis should be taken as a learning experience compelling policy makers to change their predominant conceptual frameworks and fundamental assumptions. Rather than seeking (once again) to embark on a project aimed at domesticating the complex ecosocial systems of the province in order to chase after an all-too-familiar destructive form of prosperity, I suggest policy makers view the collapse of the cod fishery as an opportunity to learn from the past, accepting human ignorance and failure while continuing to struggle toward policy approaches that enhance understanding and the possibility for sustainable livelihoods (Lichatowich *et al.*, 1999). This will require giving up the God-like embattled attempt to *control* the North Atlantic and the species co-evolved to live there, in favour of seeking ways to recognize human embeddedness in natural systems and learn new ways to "integrate with local ecology instead of considering the surrounding waters as external and a source of threats" (Newkirk, 1997:69).

Table I. (Prepared from information in Funtowicz and Ravetz, 1993 and Merchant, 1998/6/2)

| | Normal Science | Post-Normal Science |
|---|---|---|
| **Central Metaphor** | Mechanistic (Clock)—Descartes, Newton, Bacon... | Holistic, Open, Complex Systems (Ecosystem) Prigogine, Koestler, Boulding... |
| **Goal** | Control of natural world | Cope with uncertainty |
| **Core organization** | Dualism, Separation and Hierarchy (Pyramid) | Wholeness, Interconnection and Heterarchy (Networks) |
| **Facts and Values** | Facts and Values Separate | Facts and Values linked, can not be separated |
| **Values** | Presupposed, fixed | Made explicit and open for debate |
| **Assumptions** | Predictability, control, one universal Truth | Unpredictability, incomplete control, plurality of legitimate perspectives |
| **Model of Scientific Argument** | Formalized Deduction—Popperian, falsification of hypothesis. Kuhn—Puzzle Solving | Interactive dialogue, confrontation of multiple hypothesis and realities (Lakatos) and PNS (Funtowicz and Ravetz) |
| **Knowledge** | Universal—context free, ahistorical (Homogeneity) | Context Dependent, historical (Particularity, difference, heterogeneity) |
| **Emphasis is placed on:** | Parts, atomistic | Processes, holistic |
| **Summing:** | Linear, whole is equal to sum of the individual parts | Non-linear, the whole is greater than the sum of the parts. Causes become effects in complex nested feedback systems. Emergent properties are recognized. |
| **Society** | Sum of individual rational agents who have submitted themselves to rule by the sovereign (Hobbes) | Synergy, the combined actions of separate parts may produce an effect greater than the sum of individual effects. Local and small scale decision making. |
| **Change:** | Linear, predictable (Predictions) | Non-linear, chaotic, unpredictable (Scenarios) |
| **Participants** | Experts, Specialists, Disciplinary (Domination of all other ways of knowing by Normal Science) | Extended Peer Community, Generalists, Inter/transdisciplinary (Co-operative, partnerships with other ways of knowing, including Local Knowledge) |
| **Certainty/ Uncertainty** | Certainty in knowledge and value neutrality. | Radical uncertainty and ignorance that is value laden. |
| **Data** | Emphasis on quantity and using/applying knowledge (Hard Facts, Soft Values) | Emphasis on quality and making ignorance useable (Hard Values, Soft Facts) |
| **Problem Formation** | Problems set and solutions evaluated by experts | Problems set and solutions evaluated by the criteria of broader democratic communities |
| **Systems:** | Hard, mechanical, closed, determined | Soft, organic, open, Sym/Autopoetic, emergent |
| **Underlying Politics** | Authoritarian: Narrow participation and emphasis on expertise | Democratic: Open to diverse ways of knowing and extensive participation |

Table II

**Ecological Aquaculture:**
(Adapted from Costa-Pierce and Peters (1994) *in* Westra, 1998:88)

1 Preserves forms and functions of natural ecosystems;
2. Derives most of its energy from renewables (solar, wind, water biomass);
3. Is a net protein producer, relying on waste animal or plant-based protein for feeds;
4. Does not produce nutrient or chemical pollution;
5. Develops a systems approach to nutrient recycling and regeneration;
6. Plans for ecosystem rehabilitation and enhancement;
7. Is integrated with agriculture;
8. Does not use chemicals or antibiotics;
9. Uses native or resident species (not Genetically Modified Organisms);
10. Is integrated with local communities to maximize job creation and equity;
11. Helps to develop an enhanced fisheries;
12. Encourages participatory forms of decision making;
13. Recognizes ignorance and limits to our understanding applying the precautionary principle and adaptive management techniques;
14. Shares information by partnering with other coastal communities;
15. Recognizes the importance of human and non-human rights and values.

Figure I. Industrial Aquaculture

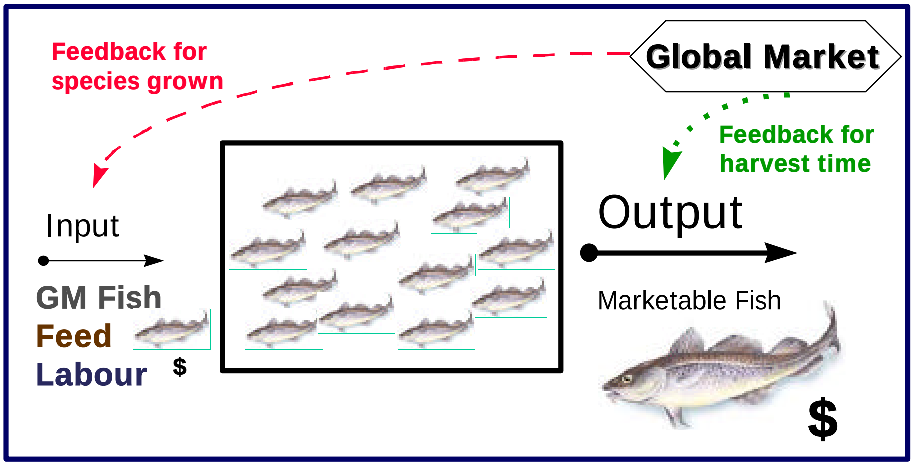
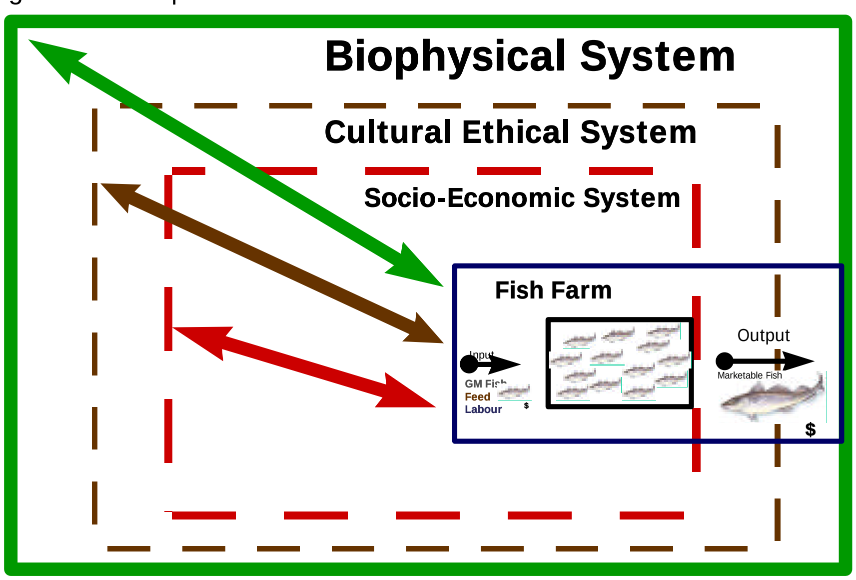



Figure II. Multiple Gradients and Attractors




**Coloured arrows represent dynamic feedback gradients involving highly complex and unpredictable self-organizing phenomena "pushing" and "pulling" toward numerous coupled attractors across multiple system types and scales. This diagram attempts to convey the nested, dynamic and highly complex context in which aquaculture activities occur.**

Figure III. Industrial Aquaculture: Biophysical System

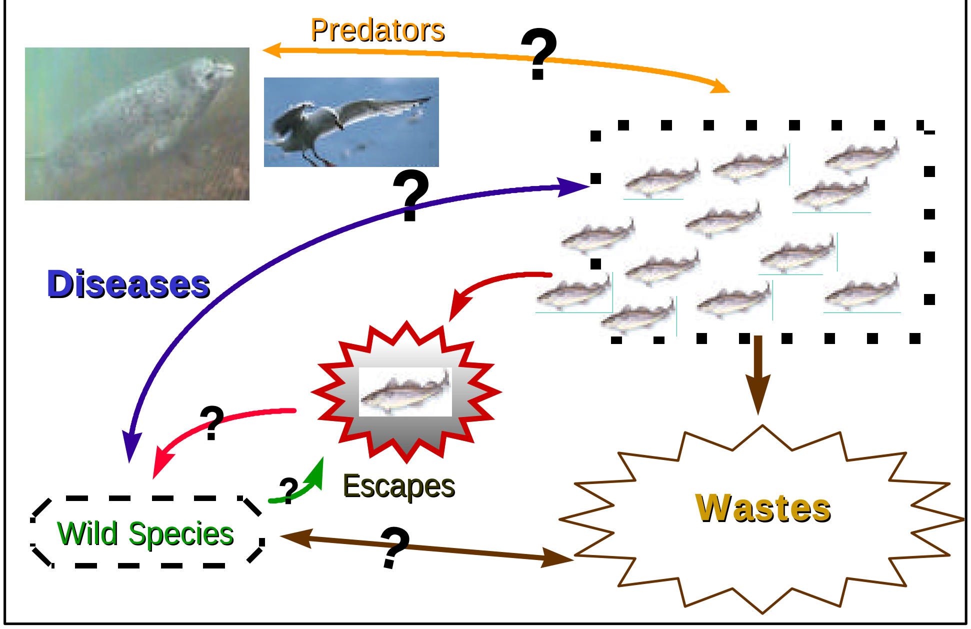



Figure IV. Hypothesized Northern Cod Sub-Populations. (Smedbol and Wroblewski, 2000)

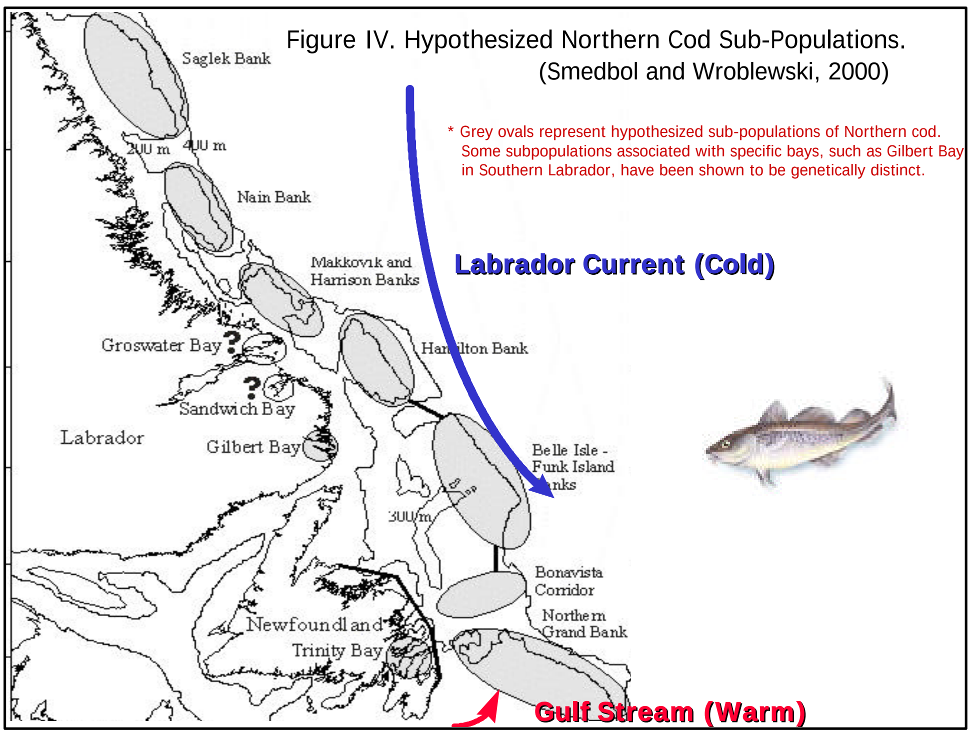


Figure V. Feed System

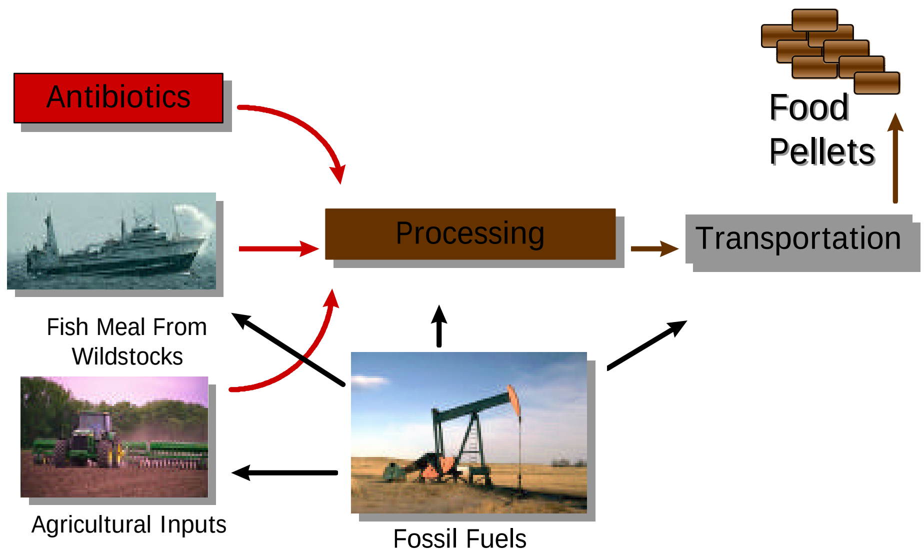



Figure VI. Socio-Economic-Political System: Enclosure

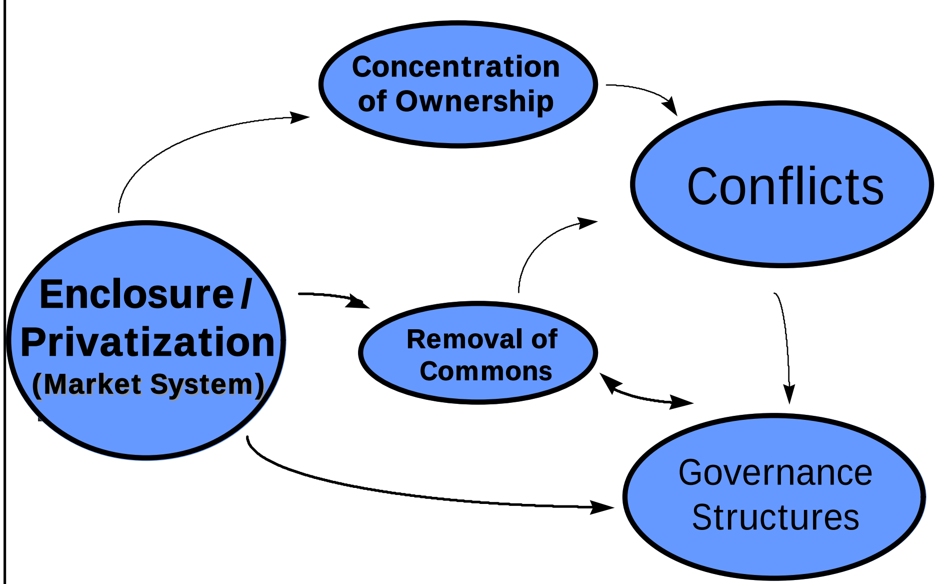


Figure VII. “Nature Enterprised Up”--Donna Haraway, 1997

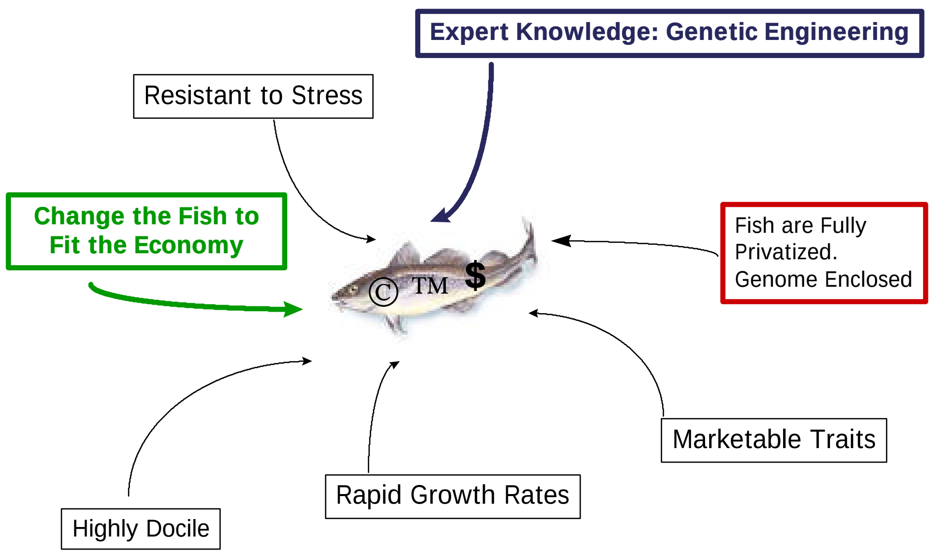



Figure VIII. Economic, Ethical, Scientific & Political Systems Underlying Industrial Aquaculture

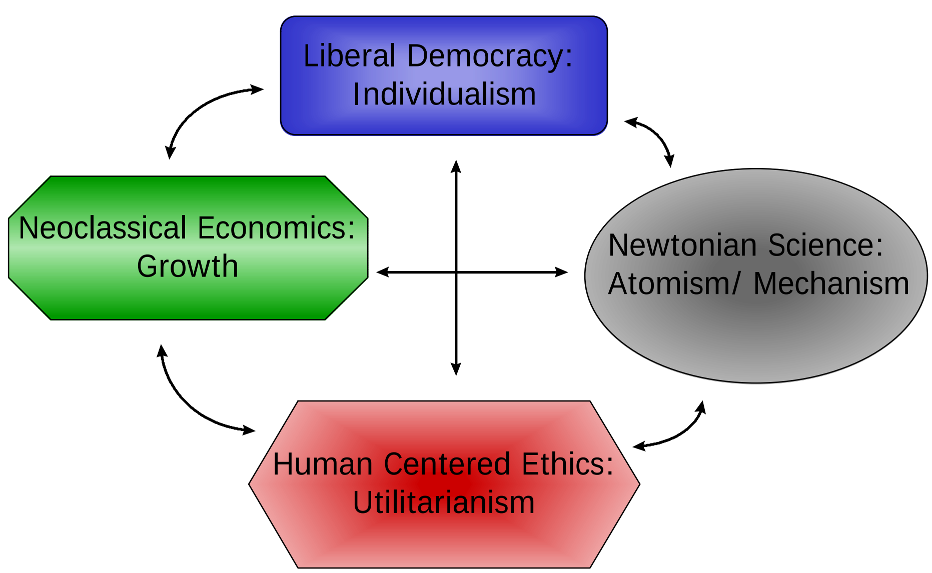


Figure **IX**. Poly-Culture Aquaculture

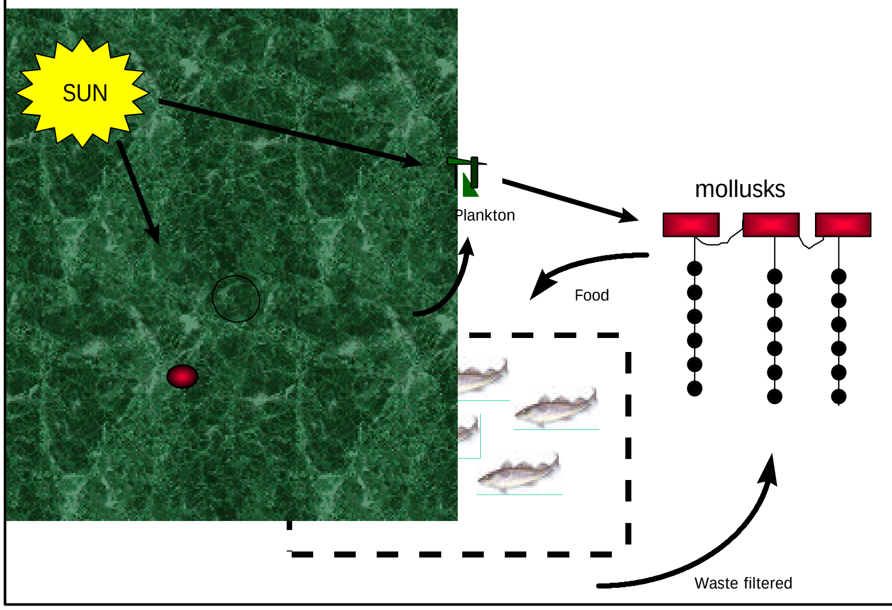
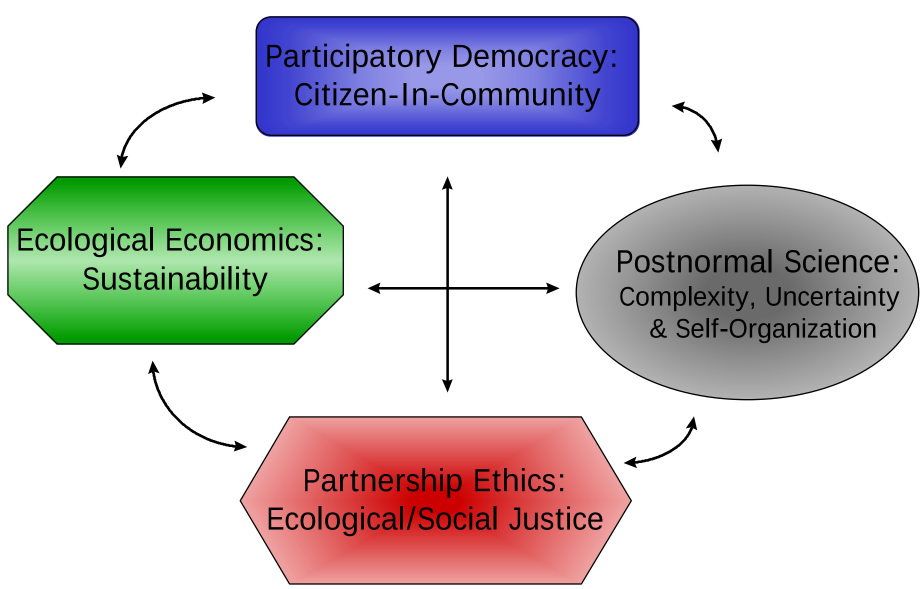



Figure X. Economic, Ethical,Scientific & Political Systems Underlying Ecological Aquaculture



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