ECONOMIC EFFICIENCY IN FISHERIES AND
AQUACULTURE

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Abstract

Paul Molyneaux, author of "The Doryman's Reflection: A Fisherman's Life," and "Swimming in Circles: Aquaculture and the End of the Wild," describes a real life re-evaluation of efficiency in fisheries and aquaculture that begins on a very organic level, with the author as a worker looking to make the best use of his time and energy. His innate understanding of the principles of ecological economics followed by exposure to the discipline’s advancing theories leads to a revelation regarding the backwards logic of fisheries and aquaculture policy thus far, and the decline in real seafood production. Along with many others, Molyneaux looks to ecological economics to create a new paradigm for sustainable fisheries.

Article

In October of 2003, Hurricane Juan drove 30-foot high waves into the sea wall guarding Halifax, Nova Scotia, and 80 mile an hour winds toppled giant old oaks across the city’s flooded streets. As the storm raged, Peter Tyedmers, an ecological economist at Halifax’s Dalhousie University, explained the theory of dissipating structures to me, via a tenuous telephone connection. “As you increase order in a subsystem, it comes at a higher cost to the over-arching system. You see more rapid entropy,” said Tyedmers, an expert on energy efficiencies in fisheries and aquaculture. “Higher levels of order are possible, but for shorter duration.”

I had long experienced the cycle of dissipating structures, in one fisheries melt down after another. But when I started out, as a teenager pounding the docks of various East Coast ports in 1976, an infectious optimism masked all concerns about sustainability. The United States had just declared the 200-mile limit, establishing sovereignty over 3 million square miles of ocean — an area roughly equivalent to the landmass of the lower 48 states — and Congress poured millions of dollars into modernizing the fleet. Fishermen did not see themselves increasing the order of a subsystem; they expected to feed the world with the unlimited bounty of the sea.

Efficiency, according to the policy makers, amounted to catching more fish faster. In the late 70s, newly launched stern trawlers, all more than 80 feet long and built of steel, headed to sea equipped with the latest electronic technology. Sonar’s for finding
fish, and loran assisted track plotters enabled the boats to tow their nets through the schools repeatedly, with lethal accuracy. New diesels, with increased horsepower enabled the boats to tow larger nets, and like many others I gravitated toward the new technology without questioning its efficiency — until the bill arrived.

All the new toys had to be paid for with fish. Rising landings flooded the market and prices dropped, requiring fishermen to further increase landings in order to make the same amount of money. Competition drove the most progressive fishermen to invest in more sophisticated technology: global positioning systems connected to computerized track plotters replaced the old Lorans, and digital sonar displays showed fish more clearly. Every advance led to increased landings and as soon as everyone in the fleet adopted the technology, they required those increased landings just to maintain the status quo.

I experienced an awakening of sorts one bright summer day in 1984, aboard the 90-foot long trawler, Atlantic Harvester, out of Rockland, Maine. On a ten-day trip in the Gulf of Maine, out near the Canadian boundary, we caught thousands of pounds of hake, much of it too small for our market. Tow after tow we sorted out the bigger fish and shoveled the small ones over the side, dead. Looking up from my work I saw the bodies of juvenile hake, their bellies to the sun, bladders distended from their mouths, floating all around the boat and out toward the horizon for quite a distance. An airplane, bright red against the blue sky and sea, flew past low enough that when I looked up I saw the insignia of the Canadian Coast Guard. A helmeted crewman leaned out an opening in the fuselage and looked down at the scene. Years later I met a former pilot of one of those planes and he told me about seeing fishing boats surrounded by dead bycatch.

“Maybe you saw us,” I said.

“Who knows, there were so many,” he replied.

Standing on deck of the Atlantic Mariner in 1984 I started to do the math. The hired captain had to produce something to pay for the trip, loading the boat with small hake at 15 cents a pound, we spent at least the first seven or eight days of our ten days at sea, working to cover expenses. In the meantime we killed and discarded as many fish as we caught. But we believed we had no choice; we had to pay for the trip and make a profit anyway we could. We had to maintain our economic sustainability. The sea dotted with dead fish represented an expense, an externality that we would internalize a few years later in the form of empty nets.

I made only one trip on the Atlantic Mariner; working more than a week just to pay the fuel bill of an overcapitalized fishing boat may have made sense to some fisheries economists, but it seemed a waste of my time. I went back to the boat I’d worked on the summer before, the Irene Alton. Her owner, Bernard Raynes, had built the 57-foot wooden boat in his backyard. She carried the minimum in technology: an old paper recorder depth sounder, a loran and a vhf radio. Raynes carried in his head all that he needed to catch fish. He had inherited the accumulated wisdom of 11 generations of his
ancestors, all fishing folks in the Gulf of Maine. An image of the seafloor and a map of the currents, formed over the years through the combined observations of those preceding generations, became part of Raynes’s own mental landscape. Working with his father and grandfather from the time he could hold an oar, Raynes had learned, as much as anyone can, the ways of fish and how they moved in the sea and seasons. “You have to learn to think like a fish,” he once told me.

Figure 1. Basil Burns working on the ribs of the Irene Alton, designed in 1940 by Alton Raynes and built in Bernard Raynes’s backyard in Owls Head, Maine, 1975.

Figure 2. The 57-foot long Irene Alton rigged for fish dragging. As a time when new steel boats entered the fishery off the northeast U.S. at a rate of one every four days Raynes launched an anachronism. His boat is still fishing, while the 80-foot plus, heavily subsidized fleet has vanished from the nearby Rockland waterfront.

Raynes’s boat required basic maintenance, most of which he accomplished with the help of his crew. The work cost him time, not money and acted as a bonding exercise
for all of us. We laughed a lot on the summer days we spent scraping and painting, and paid close attention as Raynes taught us how to splice new shrouds and stays, and build nets. When groundfish landing crashed in the late 80’s and the 1990’s his self-sufficiency paid off.

He continued to fish long after the big fish draggers had all disappeared from the Rockland waterfront, one way or another. The owner of the Atlantic Mariner, Lee Riley, a man I never met, re-rigged her as a purse seiner for herring fishing. The O’Hara fleet, half a dozen 90-foot steel boats — all built with government subsidies — left for Alaska, where stocks remained healthy enough to support their wasteful mode of fishing.

The Irene Alton, with her low fixed and operating costs, survived and in 2006 the 30-year-old boat continued to fish. Unfortunately the infrastructure that enabled her to take on ice and offload fish vanished. She survived due to her efficiency, only to become functionally obsolete due to the breakdown of the supporting infrastructure.

I left Bernard in the late 80’s, and moved to an isolated stretch of the coast of Maine, where I began an experiment in efficiency.

Like Raynes, I built my own boat, but lacking his history and confidence in what the stocks could support, I built a 5 meter dory, a lovely little craft that I rowed along the open shore searching in the intertidal zone for periwinkles, “wrinkles,” and later, sea urchins.

From 1988 to 1991 I had the wrinkles all to myself. On spring tides I could earn $120 in six hours. The rest of the time I worked in my garden, cut wood, and read. Wendell Berry’s book of essays, “The Unsettling of America,” and Masunobu Fukuoka’s, “One Straw Revolution,” awakened me to definitions of efficiency that made more sense to me than what I had seen in industrial fisheries. Both writers advocated more human effort and less purchased inputs in food production. I learned that a human working by hand in a garden gets about 10 calories back for every one invested. Petroleum driven machines reverse the ratio: for every ten calories invested, with a tractor or roto-tiller, the garden returns one. I assumed that by rowing I would get the same sort of calorie for calorie return ratio in my fishing as I did in my garden. Following Raynes’s example I kept my fishing expenses low by relying more on my senses and accumulated knowledge than on technology.

One afternoon as I rowed past a new fiberglass lobster boat anchored in the harbor, the captain hollered over, “Why don’t you put a motor on that thing?” I dug my oars in and stopped, then pulled quietly into an eddy next to his boat.

“I want my money in my pocket,” I told him. “A motor costs $1000 for something decent; then I have to register my boat; there’s another 20 bucks every year; plus gas

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1 She was later rigged over as a pair trawler, and renamed the Starbound. She sank in 2001 after being rammed by a Russian freighter.
all that. Adds up to a lot of goddamn wrinkles, and what’s it going to save me? A two mile row with the tide in my favor.”

More than a decade later I read a book by an eco-economist named Kozo Mayumi, in which he explained what I instinctively knew: that there were two types of efficiency. One measured work accomplished in relation to energy used, the other looked at production in terms of speed. As an example Mayumi noted that cars had an ideal economical speed in terms of gas consumption and distance covered, but most people used more gas than necessary in order to get to their destinations faster. “Such drivers prefer efficiency in terms of speed of the car to efficiency in terms of gas consumption,” wrote Mayumi.

Indeed as declining fisheries forced more fishermen to turn to wrinkle picking, they arrived with outboard motors, which needed to be paid for with wrinkles. The new entrants to wrinkle picking thought less about efficiency or sustainability than I did. They took the small with the big, they took every wrinkle they could find, and before long the wrinkles had all been picked, the bulk of the money gone to the Honda outboard dealer, and the local gas station. I did not need the terminology of ecological economics to understand the direction shortsighted harvesters were taking me: bigger engines would not replace the periwinkles.

As the U.S. economy boomed in the 1990s, wealthy newcomers bought up the shore where I worked, cluttering the scenic coast with their architectural nightmares. I complained: “The value of the land is what it can produce, year after year and land around here does not produce much. But these folks decide it’s worth a million dollars and acre, and raise my taxes so I have to take more wrinkles, and there are none left anyway.”

To increase my earnings I entered the lucrative sea urchin fishery. At fisheries meetings where we gathered to discuss the conservation and management of our sea urchin resource, most fishermen still seemed enchanted with the myth of infinite abundance. The chorus of harvester calling for the right to make as much money as they could as fast as they could, drowned out the handful of urchin divers arguing for a sustainable future. There is no tomorrow in an open access fishery; the discount rate must be close to 100 percent, so the short-term interests consistently won the regulatory battles. Urchin landings fell from 40 million pounds in 1993 to 3.4 million in 2005 and for all intents we lost the fishery.

Sea urchins represented the last opportunity to create a thoughtful management regime in a fishery I could participate in; after the stocks collapsed I quit working on the water. In 2000 I became a full time journalist, a chronicler of fisheries.

The stories became depressingly repetitive, but probably the best example of misguided development occurred in the herring fishery. In July 1999 at a meeting in Stonington, Maine, outraged herring fishermen demanded protection from a fleet of technologically advance mid-water trawlers catching thousands of tons of herring within
sight of shore. One fisherman complained about these 100-foot plus 3,000 Horsepower boats coming from distant ports to took the herring that belonged to the local people. I recognized him as the captain of a boat that had traveled 100 miles and dumped 3 urchin divers into an area right outside the harbor where my neighbor and I had been urchin diving from a dory. “Yeah I know what you mean,” I told him, expressing my sympathy for his argument. The mid-water trawler fleet consisted of single boats, and pairs of boats that towed quarter-mile wide nets between them, and regularly landed as much as 200,000 pounds of herring in a half hour tow. Between 1994 and 1999, roughly 25 such boats had entered the New England herring fishery; some had come from the west coast, where they had been regulated out of the hake fishery, others, such as the *Atlantic Mariner*, had been rigged over from purse seiners.

Regulators called the new boats, some capable of landing a million pounds of herring twice a week, “efficient,” but the mid-water boats cost upwards of $2 million to build, and used more fuel per ton of fish landed than any other sector of the fishery; they seemed simply more “effective” than “efficient.” Or as Mayumi would say, they opted for the efficiency of speed rather than energy efficiency.

By 2003 the mid-water boats landed 70 percent of the herring off the coast of Maine, and increasing evidence indicated that the landings came at a cost beyond just their fuel. The boats ravaged the ecosystem; predators such as right whales and tuna, both of which often rely on herring for 90 percent of their diet when feeding in the Gulf of Maine, abandoned areas where the mid-water boats had been. Often the herring in the nets did not meet market needs, and thousands of tons of fish were discarded dead.

![Figure 3. Photo of Mid-water trawler Jean McCausland. The Jean McCausland, one of several mid-water trawlers investigated in 2004 for landing thousands of pounds of juvenile haddock as bycatch.](image-url)
Figure 4. The Rockland based herring trawler *Sunlight*, was fined $50,000 for landing an estimated 27,000 pounds of baby haddock.

Anxious to protect the resource they depended on, the Stonington fishermen argued that standards in the U.S. Sustainable Fisheries Act of 1996 called for protecting communities. The big boat owners contended that they too were a community: a community of mid-water trawlers.

“You know how if you keep cutting the distance in half between you and the wall you can do that forever and never reach the wall?” a friend commented. “That’s what I hate about fisheries policy; it’s like they’ve fired a bullet at my head, but they just keep cutting the distance in half so it’s never going to get there.” When regulators officially recognized the mid-water trawlers as a “community,” many in Stonington felt the same way.

While the mid-water trawler fishery grew, use of herring weirs, fish traps, declined. The weirs that once lined the coast of New England from Cape Anne to Canada were based on Neolithic technology and provided the maximum level of energy efficiency the herring fishery had ever known.

In 2002 Maine had one weir fisherman left: Maynard Morrison, of Perry, Maine. In July of that year I accompanied him and his crew as they tended two wiers in the estuary of the St. Croix River.

Morrison motored out from shore, running along the fine mesh net hung from a line of stakes, whole tree trunks driven into the muddy bottom. The fence, as they called it, lead from shore out into a circular array of stakes, also hung with fine mesh twine. When schools of herring and mackerel struck the fence, they headed out to deeper water
and swam into the weir. "They can find their way in, but they can't seem to find their way out," said Morrison.

The boat entered the weir, and Morrison flipped the switch on his miniature fish finder. The crew, Morrison’s neighbor Peter McPhail and his daughter Vanessa, watched his expression as he looked at the screen. Morrison shook his head. "Mackerel," he said. They all looked away toward the next weir, but when they got there it was the same story.

The mood resembled a party where the guests of honor had failed to arrive; feeling embarrassed people gradually left. Along the Perry shore loose groups of blackened stakes reached out of the water like bony fingers, marking the many abandoned weirs.

From a mooring Morrison and the crew picked up a small skiff piled high with a seine net, and an empty dory, and towed the boats into the weir. Slowly McPhail paid out the long net, as Morrison maneuvered it around the inside of the weir.

Once they circled the school of mackerel, McPhail and his daughter pulled quickly on the line that closed the bottom of the net. Morrison joined them at the side of the dory and together they began to drag the twine back aboard until the water next to their skiff boiled with mackerel.

While Maynard held the seine, the McPhail's drove a dip net into the splashing mass and scooped fish aboard the dory. They measured their catch by the hogshead — 17 1/2 bushels — a volume measure left over from the days when scales were a novelty. They loaded less than a hogshead.

"We used to have a lot of fun back in the 60s," said Morrison, "running fish to Eastport. There were canneries all around here and Canada back then. Now, even if we get fish we have a hard time to sell'm." Morrison kept his operation going by selling mackerel at premium prices, for zoo food, and lobster bait. "If it wasn't for the fresh market we got, it would've been over years ago," he said.

Morrison noted that the multi-million dollar herring industry still existed, it had simply moved. "When the trawlers came that was the beginning of the end. They catch’m [the herring] offshore and sell to Connors or Stinson," he said, referring to the two automated canneries that replaced the hundreds that once dotted the shores of Maine and New Brunswick, Canada. The modernized canneries were tallied on the national accounts as “economic growth,” but in reality they amounted to a downsizing and re-alignment of the industry, with most of the product going to the bait and aquaculture markets.
Figure 5. In August 1999, Harry Bishop, looked over the last meager catch of herring he ever took from this weir off the shore of Perry, Maine. The weir has since been abandoned.

In the 60’s, most lobstermen used cuttings from the many sardine canneries for bait; using the herring heads and tails as bait represented a way to reclaim some value from what would otherwise be wasted. But as people’s appetites changed and the canneries disappeared the lobster industry came to rely on whole, food grade herring for bait. In 2005 Maine lobstermen dumped an estimated 73,000 tons of high protein fish into the coastal waters in order to land 20,000 tons of lobster, which in turn yielded 4,000 tons of edible meat. Given that herring yield over 60 percent edible meat, the herring to lobster conversion ratio is more than 10 to 1. The value ratio however, eight cents a pound for the edible meat of a herring, versus $20 a pound for the edible meat of a lobster, makes clear why the waters off Maine abound with traps baited with herring.

Figure 6. September 2002, The Double Eagle, unloads whole fresh herring at a lobster wharf on the Island of Vinalhaven, Maine, where the fish will be sold as bait. A venerable sardine carrier built in the 1930’s, the Double Eagle used to carry fish to local packing plants.
The growing aquaculture industry also provided an increasingly strong demand for forage fish. Herring, mackerel, menhaden, and other small North Atlantic fish, such as blue whiting and sand lance, as well as anchoveta, and various types of sardines from South America and elsewhere in the world, are reduced to fishmeal and oil and used in aquaculture feeds. As yet no other source has been found for the Omega 3 fatty acids needed to grow fish. Fishmeal and oil comprise as much as 50 percent of the food formulas used in salmon farming, and by 2010 the aquaculture industry is expected to use 57 percent of the available fish meal and 98 percent of the available fish oil in the world.2

Aquaculture promoters, at the United Nations Food and Agriculture Organization (FAO) and elsewhere, expected the industry to augment seafood production in the face of a global stagnation in seafood landings. But some of the fastest growth occurred in shrimp and carnivorous fish farming, leading to a net decline in protein coming from the sea.

Nonetheless, the FAO produced a graph that totaled wild catch, aquaculture, and all reduction fisheries, to show a rise in global seafood production. But half the products from reduction fisheries go into various forms of aquaculture as feed, and if the FAO eliminated that double counting the graph would reveal a decline in and overall seafood production. What that chart shows is aquaculture’s conversion of low value food to high value food, destined for developed countries.

2 Barlow and Pike.
Figures 7 and 8. These FAO graphs show a rising level of fish coming out of the ocean, but over 16 million tons goes back into the ocean as fish feed. If this tonnage were deducted from the graphs, it would show an increasing inverse relationship between rising carnivorous fish and shrimp aquaculture and net production from the sea.

Aquaculture proponents contend, however, that since farmed fish have a wet weight to wet weight feed conversion ratio of 4 to 1, and wild fish have a feed conversion ratio of 10 to one, farmed fish are actually the more efficient users of feed.

Peter Tyedmers, speaking at an Aquaculture Task Force meeting in Woods Hole, Massachusetts in 2005, projected a statement to that effect onto an overhead screen. “I find this fallacy everywhere,” he said. “This particular quote is from the [Canadian] Department of Fisheries and Oceans literature on salmon farming.”

Tyedmers pointed out that the comparison ignored an important factor: the nature of the food being consumed by wild and farmed fish. “Not all fish food is created equal,” he said.

According to Tyedmers data, the fishmeal and oil that made up 50 percent of the feed consumed by farmed salmon at all stages of growth came from reduction fisheries that included species which would have eaten the small salmon in the wild. This turning the food chain upside down, feeding one species with fish from a higher trophic level expanded the ecological footprint of carnivorous fish farming exponentially. In addition, there are the energy costs inherent in catching the fish, processing them into meal and oil, transporting the oil to feed mills and storing and transporting the feed.

On the other hand, Tyedmers noted that the wild fish feed primarily on plankton for most of their lives. “Up until the time of harvest, this is a completely solar driven food production system,” he said of the wild.
In much of the world however that system has been wrecked. The most productive areas of the world’s oceans: the estuaries, nearshore waters and intertidal zones critical to at least seventy percent of commercially important fish species, have been ravaged. In the U.S, the National Oceanic Atmospheric Administration (NOAA) sampled 28 percent of the nation’s 99,000 square miles of estuaries and found 44 percent of them “impaired.” Salmon farming and other forms of aquaculture, some of them useful, represented a way to capitalize what remained of nearshore ecosystem function without the cost of cleaning up the environment.

I suggested to Ted Ames, a recent McArthur Grant recipient active in restoring the productivity of wild fisheries, that using aquaculture to maintain economic growth on the ocean was like paying off one’s mortgage with a credit card. “You just up the interest rate and put off the day of reckoning,” I said.

“That might be how an economist would express it,” said Ames. “But as a fisherman I’d say that fish farms and mid-water trawling are driving nails into the coffin of coastal ecology.”

Aquaculture proponents argue that it is natural to learn to farm the sea, comparing it to the progression that took place on land beginning 10,000 years ago. When you think about how we are going to feed the world in the future, it’s not going to be from hunter/gathering,” said Jason Clay of the World Wildlife Fund, expressing an opinion held by many. Some types of aquaculture, such as mollusk, seaweed and vegetarian finfish farming, seem to work well, but when it comes to producing shrimp and carnivorous finfish the natural system appears to be much more efficient.

“But we need the whole ecosystem,” said Ames. “Not just pieces of it.” He believes that every time habitat is damaged and species wiped out it creates an opening for invasive species. Invasive species come in many varieties, such as the green crab that now devours young sea urchins in Maine. By some definitions farmed salmon represent an invasive species that competes with wild stocks of carnivorous fish thousands of miles away by utilizing as feed the forage fish those wild stocks depend on.
More could be said about the plight of fisheries and aquaculture, and it is, by a growing number of voices on a variety of fronts, but my final point is this: that fisheries development following the neo-classical economic model aimed exclusively at economic efficiency that created a few winners and many losers, consistently failed. Many forms of aquaculture, following the same logic, are failing and taking ecosystems with them.

Economy of scale seafood production systems geared for the global economy offers slim hope for food security. Predicated on assumptions regarding energy availability, as well as market, climate, resource, and social stability, they ignore and exacerbate the degradation of all these systems. Specialists focused on narrow issues arrive at solutions that, outside their context, cause more problems than they solve.

Problem solving in a vacuum is sort of like developing a fishing strategy that assumes the seas will always be calm, but seas change rapidly, and are seldom calm. In order to achieve sustainability in seafood production the industry must shift into the ecological economics paradigm: actively measuring energy use, as well as ecological and social impacts, and using these measures to determine the course of development.

Ames advocated protecting what remained of wild production systems, and salvaging them where possible. But this requires a level of thinking that goes way beyond linear problem solving. Aquaculture using advanced technology may play a role in restoring food producing ecosystems, but problem solving in the global age must take place within multiple contexts, meeting a set of criteria that constantly changes on a variety of levels — a bit like playing chess in a matrix. Solutions must run a gauntlet of shifting parameters in order to be viable. Fishermen provide an example of the kind of thinking necessary to function in a world of shifting parameters where the only
assumption that holds is that things will change, sometimes very fast, and what one needs
is a well built vessel and a crew that can handle problems quickly; these in turn are often
the product of traditions and cultural history being conveyed through generations.

Management that fosters human rather than industrial development, and promotes
complex strategies adopted by people like Bernard Raynes, could build natural and social
capital. According to Harold Coward, editor of the book, Just Fish: Ethics and Canadian
Marine Fisheries, published by ISER books in 2000, the solutions to managing fisheries
sustainably have existed for thousands of years within the ethical codes of the world's
religions and spiritual traditions. In the past, people preserved the productive qualities of
the environment by leaving areas fallow and periodically forgiving debt so that resources
were redistributed and people were not driven to overexploitation. Herman Daly drew
similar conclusions in his book, Beyond Growth, noting that the guidelines for
safeguarding resources and establishing intra and inter-generational equity are well
established in spiritual traditions, though the cultures that embodied those traditions have
largely vanished.

Without a cultural anchor, many fishermen and fish farmers seem to have been
sucked into the vortex of dissipating structures and consequent diminishing options.
Managers refer to them as the winners, though they are actually survivors, clinging to the
illusion of growth created by consolidation. After almost 40 years of rapidly collapsing
fisheries, ecosystems and communities — a vivid demonstration that finite resources
impose limits on economic growth — a powerful minority of consolidated fishing
interests still resists the idea of conservation.

“We have to get rid of the old mentality,” as Ted Ames succinctly put it. But after
more than thirty years of watching the havoc wrought by the “efficiency of speed”
mentality that Ames referred to, optimism seems almost pathological. Genuine hope
however lies in working to replace the old paradigm with an ecological economy.