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Maine Project Office
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Subject: File Number NAE-2017-01342 Presidential Permit for CMP's New England Clean Energy Corridor (NECEC) (PP-438)

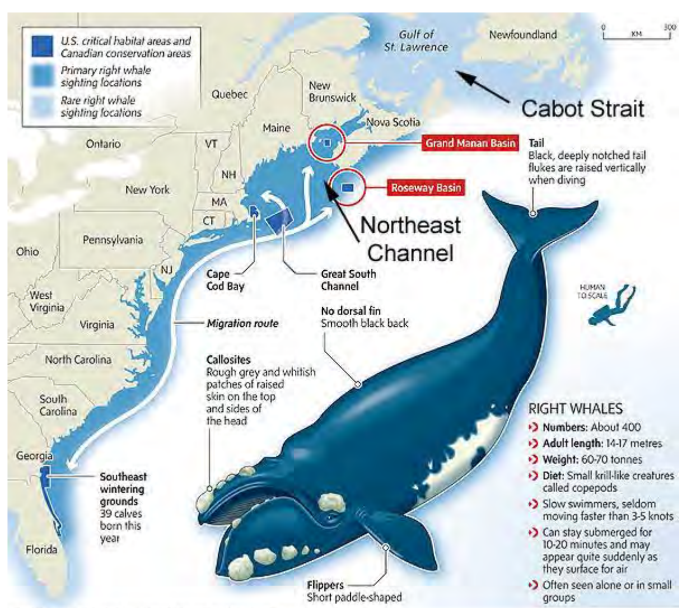
I am writing to ask the USACE to include in its Environmental Assessment (EA) on CMP's application for a Presidential Permit the impacts that long term storage of the spring runoff from Canadian rivers is having on the Gulf of Maine, which is Essential Fish Habitat (EFH) for the federally listed endangered Maine Atlantic salmon and North Atlantic right whale.

CMP has made the long term storage of the spring runoff part of its application when it submitted the attached HydroQuebec December 14, 2018 letter to Maine's PUC with the following statement: "Excess water not used to generate electricity is stored in large reservoirs for use in later periods. As the reservoirs become full, and storing water is no longer an option, water is spilled."

HydroQuebec's long term storage of spring run off into the Gulf of St. Lawrence is not clean energy if it has starved the Atlantic salmon and North Atlantic right whale to the point of depletion.

Before storage, the spring runoff flowing past Cabot Strait created a colossal freshwater wave of 4 month duration. This wave was the driving force behind strong upwelling currents pumping dissolved silicate and other essential nutrients of the deep seas waters up onto the Scotian Shelf and into the Gulf of Maine via the Northeast Channel.

Map 1



Map 2

“The growth rate of diatoms (silica-shelled phytoplankton) are determined by the supply of silicate” (Venugopalan Ittekkot et. Al. 2000) from the spring runoff and thermohaline currents.

“Diatom phytoplankton populations are the usual food for zooplankton and filter feeding fishes and contribute in a direct way to the large fishable populations in coastal zones.” (C.B. Officer at al 1980) The diatoms and copepods are essential to the survival of the Atlantic salmon smolt and the right whale while they are in the Gulf of Maine.

“The lack of silica can change aquatic ecosystems from those dominated by diatoms to non-diatom based aquatic ecosystems usually dominated by flagellates.” (E. Struyf 2009) (see “HydroQuebecs’s Dams have a Chokehold on the Gulf of Maine’s Marine Ecosystem” by S.M. Kasprzak, January 15, 2019)

Diatoms dominate spring blooms of phytoplankton in temperate waters and coastal upwelling regions of the North Atlantic. Copepods usually dominate the zooplankton along the Scotian Shelf and coastal waters of the Gulf of Maine.

The North Atlantic right whale feed upon the copepods from late spring until fall and releasing the waters of the spring runoff in the winter does not help the whales who have already migrated to their southern calving grounds.

I am asking USACE to expand its consultation request to the National Marine Fisheries Service to include the impacts of long term storage of the spring runoff on the North Atlantic right whale and the Atlantic salmon during its smolt migration in the Gulf of Maine.

The post-smolt feeding migration route across the Gulf of Maine, up along the south and eastern coasts of Nova Scotia, crossing the entrance to the Gulf of St. Lawrence, up and around Newfoundland then to the Labrador Sea represents Essential Fish Habitat (EFH) on which the Maine Atlantic salmon have also been starved by HydroQuebec’s reservoir hydroelectric facilities.

The applicant has called this a “clean energy corridor” but you have allowed CMP to narrowly define the scope of the project to not include the reservoir hydroelectric facilities generating the so called “clean energy”

Maine citizens are being prevented from challenging this so-called clean energy and I believe one of the purposes of the Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996, is to ensure that an evaluation of these EFHs for Atlantic salmon and right whale are part of your EA.

In less than 25 years, Atlantic Salmon became endangered.

The Atlantic salmon, cod et.al. fisheries of the Gulf of Maine are the beneficiaries of two critical Canadian spring runoff events. The first creates a huge freshwater wave traveling through the Gulf of St. Lawrence, out of the Cabot Strait and over the Scotian Shelf down to the mouth of the Northeast Channel and up into the Gulf of Maine. (See Map 3 on page 10)

This freshwater wave lowers salinity by 1 percent at Halifax, Nova Scotia, and its flow creates strong thermohaline (upwelling) currents which pump the nutrient enriched waters of the deep sea up onto the Scotian Shelf and into the Gulfs of Maine and St. Lawrence via the Northeast and Laurentian Channels.

These currents help to feed the Maine Atlantic salmon smolt during migration from Maine rivers into the Gulf of Maine and the post-smolt Maine Atlantic salmon on their feeding migration to Labrador Sea.

The second freshwater wave is at least two-fold larger than the first and comes from James and Hudson Bays and produces strong upwelling currents which pump the nutrient enriched deep sea waters up and into the Grand Banks of Newfoundland, Northeast Newfoundland Shelf, and Labrador Shelf. The 5 channels feeding the Labrador and Northeast Newfoundland Shelves are also shown on Map 3.

"A part of this fresh water continues along the coast of Nova Scotia – shown in Fig. 2b as a weak but noticeable drop in salinity in Halifax in January – reaching Georges Bank probably in the early spring. So, after being quickly transferred from the North and along the coast of Labrador during the summer, the fresh water affects the Grand Banks during the autumn, the Scotian Shelf during the winter and Georges Bank probably during the spring. The distance travelled by the fresh water wave during a period of 9 months is about 4000km. On the Scotian Shelf, therefore, there are two freshening cycles annually, a larger one in summer from the St. Lawrence and a smaller one in winter from the Canadian North. On Georges Bank, these fresh water waves should arrive in autumn and spring respectively." (Dr. Hans Neu 1982)

Post-smolt salmon migrate from Gulf of Maine in June, cross the entrance to Gulf of St. Lawrence and arrive at the southern end of Newfoundland by mid-August. "The post-smolts feed along the northeastern coast of Newfoundland and the southern half of Labrador for the balance of their first summer at sea…By mid to late October, the post-smolts have roughly doubled in size (12-14 inches) and they congregate in the Labrador Sea for their first winter in the Atlantic Ocean." (see attached pages 42-43 of Maine Atlantic Salmon by Ed Baum 1997)

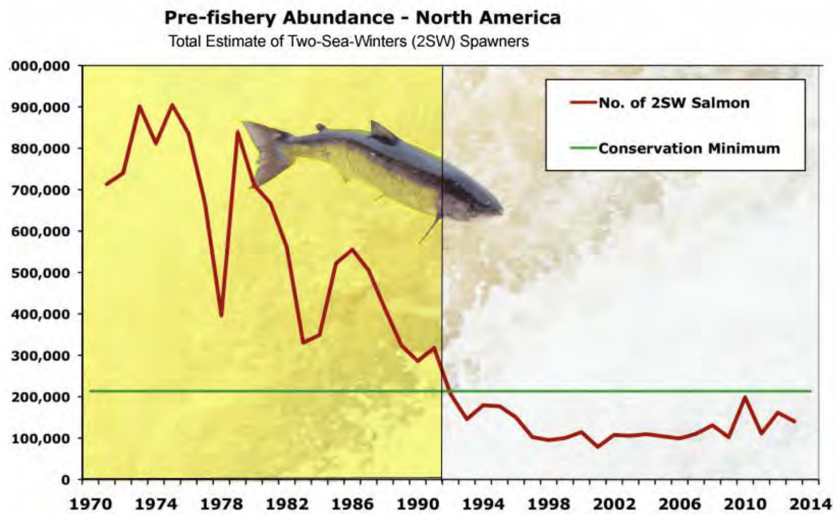
HydroQuebec has starved the Maine Atlantic salmon along its migratory route by witholding 50-70 percent of the historic and natural spring run off. It is not a coincidence that the abundance of both Maine Atlantic salmon and cod have declined to the point of depletion at the same time as shown on the following graphs on the next page.

The functions of the spring runoff are just as important to the survival of the Atlantic salmon and right whale as wetland functions.

There are three spring runoffs which impact the fisheries and ecosystem of the Gulf of Maine. It took milleniums for them to evolve and reach equilibrium within the natural water cycle. In less than 25 years, hydroelectric reservoir dams have destroyed this equilibrium and starved the fisheries and warmed the oceans.

The first runoff occurs between March and June on the six major rivers of Maine ("Reservoir Hydroelectric Dams -Silica Depletion - A Gulf of Maine Catastrophe" Kasprzak 11/28/18 submitted to DEP). The second and third runoffs are much larger and have been described above.

EIGHTY PERCENT DROP IN SALMON ABUNDANCE IN LESS THAN 25 YEARS



Pre-fishery Abundance (PFA) graph for North American 2SW salmon showing the total number needed to meet the total Minimum Conservation Limit in North American rivers in green (corrected for 11 months of natural mortality). The PFA numbers are those 11 months before they return to their home rivers in North America.

Source: Atlantic Salmon Federation 2015

From 1969 to 1993 (highlighted in yellow) HydroQuebec built 7 mega reservoir hydroelectric facilities which have starved the salmon, cod et.al. fisheries to the point of depletion.

THERE WAS A SUSTAINABLE MEDIAN (COD) CATCH FOR 100 YEARS OF 8,000 METRIC TONS IN THE GULF OF MAINE AND THE PRECIPITOUS DECLINE, WHICH BEGAN IN 1991, IS CONSISTENT WITH THE TIMING OF COD COLLAPSES IN THE GULF OF ST. LAWRENCE AND WESTERN ATLANTIC (see attached Fact Sheet Feb. 4, 2019)

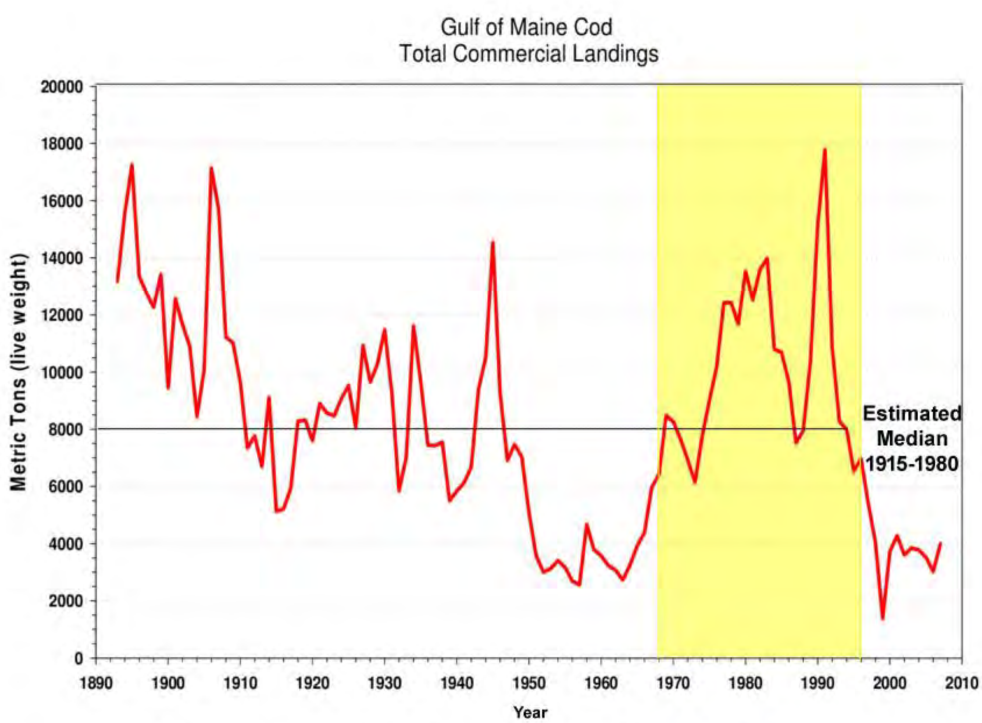


Figure 1.2 Total commercial landings (mt) of Atlantic cod from the Gulf of Maine stock, 1893-2007.

Elimination of Spring Runoff by HydroQuebec Has Weakened the Regional Thermohaline (Upwelling) Currents from Maine to Labrador

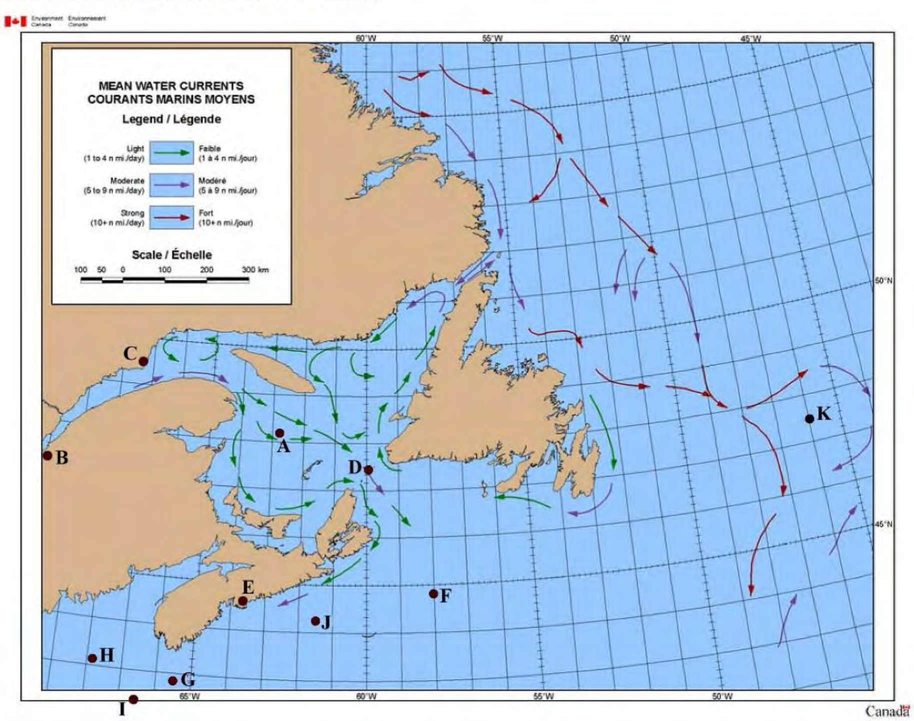
Before HydroQuebec built all of its hydroelectric dams, Dr. Hans Neu, a Canadian oceanographer, described the Gulf of St. Lawrence's spring runoff as creating a large freshwater wave flowing through the Gulf. Using 1960-1976 salinity data and estimated river discharges, Dr. Neu determined this freshwater wave was still a deluge of about 8,000 cubic meters/second when it arrived at Cabot Strait in the mouth of the Gulf of St. Lawrence during June.

This deluge of water was a natural pump feeding the Maine Atlantic salmon, North Atlantic right whale, herring, cod et.al. fisheries by constantly transporting large quantities of nutrient enriched deep sea water onto the Scotian Shelf and up the Northeast Channel into the Gulf of Maine.

"From here it can be traced to Halifax and even to Georges Bank at the entrance of the Gulf of Maine in the autumn" (see attached "Man-made Storage of Water Resources, a Liability to the Ocean Environment, Part 1 Dr. Neu 1982)

This freshwater wave lasts for over 4 months at Cabot Strait and it has reduced surface salinity by as much as 7 percent at Pte. Aux Orignaux; by 4 percent at Pte. Des Monts; by 3 percent at Cabot Strait, and 1 percent by Halifax, Nova Scotia. (see Fig.2 in Part 1, Dr. Neu 1982)

Surface Currents on East Coast of Canada



A. Gulf of St. Lawrence

B. Pte Aux Orignaux

C. Pte Des Monts

D. Cabot Strait

E. Halifax, Nova Scotia

F. Mouth of Laurentian Channel

G. Mouth of Northeast Channel

H. Gulf of Maine

I. Georges Bank

J. Scoatian Shelf

K. Flemish Cap

Source: Fisheries and Oceans Canada 2012

I repeat, CMP has admitted that the cold and nutrient enriched waters of the spring freshet (runoff) have been witheld and stored behind HydroQuebec's reservoir hydroelectric dams and "Excess water not used to generate electricity is stored in large reservoirs for use in later periods." (HydroQuebec 12/14/2018)

HydroQuebec’s standard operating procedure is to store at least 50 to 70 percent of the runoff, which has significantly weakened the currents shown on the above map. (See attached Fact Sheet “Man-Made Storage of Water Resources – A Liability to the Ocean Environment by S.M. Kasprzak revised March 28, 2019)

A flow of 8,000 cubic meters/second equals 282,000 cubic feet/second and a flow of this size would fill Moosehead Lake in just 7.5 days. During this 4 month period, the equivalency of 16 Moosehead Lakes flowed through the Cabot Strait, creating very strong upwelling currents.

According to Dr. Neu, this freshwater wave flowing through the Gulf of St. Lawrence created strong density thermohaline currents in the estuaries and coastal waters of the Gulf.

“This current was primarily the result of the difference in density between the freshwater of the runoff and the saline waters of the ocean.” And in its simplest form, “this arrangement forms a two layer flow system in which the surface layer flows outward and the deeper layer flows inward. The system acts like a large natural pump during the spring runoff which constantly transports large quantities of nutrient enriched deep ocean water on to the Continental Shelf (including Scotian Shelf, Kasprzak) and up into the embayments and estuaries (including the Gulf of Maine and St. Lawrence, Kasprzak).” (Part 1, Dr. Neu 1982)

The mouths of the Northeast Channel leading into the Gulf of Maine and the Laurentian Channel leading into the Gulf of the St. Lawrence are about 150 miles apart latitudely.

“…regulation was stepped up from an average of 4000 cubic meters/second to about 8,000 cubic meters/second with the implementation of the Manicouagan-Outardes-Bersimis hydro-power-complex. **I contend that this further reduction in the spring flow was probably the final straw in the decline of the fish stocks**.” (Part 1, Dr. Neu 1982) (emphasis added by me)

A colossal amount of spring runoff has been eliminated by HydroQuebec’s reservoir dams and has led to the starvation of the salmon, right whale et.al. fisheries in the Gulf of Maine and St. Lawrence while also warming the waters and climate. Both of these water bodies had a sustainable annual cod catch for approximately 100 years, and they dropped to the point of depletion, at the same time, around 1990. (see attached Fact Sheet “Hydro Dams Blamed for Decline in Fish Stocks” S. M. Kasprzak, February 4, 2019)

Atlantic salmon, a federally listed endangered species, has experienced a similar drop in population (see graph on page 14 of attached “The Problem is the Lack of Silica”, S.M.Kasprzak October 15, 2018”)

“Eighty percent of the annual input of dissolved silicate to the ocean is transported via our rivers and streams” (P Treguer et. Al. 1995) Silica encased diatom phytoplankton is at the bottom of the food chain and the cod and salmon are being starved to death.

The size of the deluge calculated above can be easily verified. The amount of water stored behind these reservoir facilities is 142 cubic kilometers at Manicouagan (aka Daniel Johnson Dam), 24.3 cubic kilometers at Outardes and 13.9 cubic kilometers at Bersimis.

This is a total of 180.2 cubic kilometers and the amount of water in Moosehead Lake is 5.19 cubic kilometers. These 3 hydroelectric facilities have stored the equivalence of 35 Moosehead Lakes and witheld 50 to 70 percent of the spring runoff.

The Department of Environmental Protection and the U.S. Army Corp of Engineers must include the Gulf of Maine and the Canadian rivers, which are in its watershed, (in their assessments) because there has never been an environmental study on the impact of long term storage of the spring runoff on Maine Atlantic salmon, cod or water quality by either Quebec or Maine.

The providence of Quebec and HydroQuebec have muzzled Canadian scientists for over 50 years. (complete newspaper articles are attached)

1. **<u>Science Abandoned, Scientists Muzzled</u>** Andrea Hill, Postmedia News in "The Leader Post" January 10, 2014 "The federal government 'really doesn't grasp what science is about' and could be unable to respond to adverse environmental changes because it has abandoned research into climate change and water pollution, say scientists interviewed for CBC's The Fifth Estate"

2. **<u>MPs panel to probe allegations fisheries scientists were silenced</u>** in Vancouver Sun, November 1, 1997 "Allegations in a published article by scientists allege they were muzzled and their work is tainted by politics"

3. **<u>James Bay seen as test on environment</u>** Star Phoenix January 8, 1976 "The man in charge of assessing the environmental impact of Quebec's massive James Bay hydroelectric project admitted Wednesday no one is sure just what its impact on the environment will be. 'We are using this project as an experience to see what will happen,' Alain Soucy said in an interview. 'We have about $100 million to spend over the next 3 years on remedial action, though.' The head of James Bay Energy Corporation's environmental department said that even if there were severe environmental problems caused by the project it would not be curtailed. 'We can't change the scale of the project or it will not work.' he explained."

4. **<u>Dams stop nature's ways on mighty rivers</u>** by Bruce Little in Calgary Herald February 25, 1974 "Protests over the environmental effects of huge power dam projects usually focus attention on what happens to the land above the dams that will be drowned in water. Hans Neu does not go along with that assessment. He is an expert in hydrology at the Bedford Institute of Oceanography here and he feels hydro power may be far dirtier than most people realize. Instead of looking upriver for the effects of a dam, Neu looks at the ocean into which the river waters eventually spill."

5. **<u>Research shows Canada's dams are salmon's doom</u>** by Dianne Murray in Windsor Star March 5, 1974 "Canadian oceanographer Hans Neu has shown we've already got the world's highest rate of blocked freshwater flow. For his trouble in trying to alert the federal government to his research, he was virtually run out of his job at the Bedford Institute"…."Also, biologist Wilfred Carter makes it sound like there's no relevant research, when in fact Canadian government scientists have been muzzled by their director general on this issue for some time."

6. **<u>Environment Studies Lacking</u>** in Ottawa Journal October 26, 1971 "Dr. J. S. Nelson, president of the Canadian Society of Environmental Biologists, says the Canadian government has not called for a single environmental study at the outset of any major development"….. "Hans Neu, an engineer-scientist with the Bedford Institute near here, said the environment is becoming another business…."a political football"…. "we have to take a closer look at the environment before we continue exploitation."

The NECEC project covers 2,644 acres and the HydroQuebec's reservoirs have flooded over ten million acres; including one million acres of wetlands, streams, ponds, rivers, and lakes?

This is the equivalent of clearcutting almost one half of Maine and these Canadian forests will never grow back again. The Canadian Boreal Forests represent a quarter of the world's remaining intact forests, they are the lungs of the land. The sequestration of carbon dioxide by these 10 million acres of trees has been lost forever!

The spring freshet is nature's design to provide as much silica and nutrient enriched water as it can just at the time it is needed most to feed the fisheries, silica-encased diatom phytoplankton, and zooplankton. And, HydroQuebec has eliminated it!

"Diatoms are at the bottom of the food chain and suck up nearly one quarter of the atmosphere's carbon dioxide….Size matters for the creatures that eat them and also for carbon sequestration, as large diatoms are more likely to sink when they die….If smaller size diatoms dominate, then carbon sequestration becomes less efficient, and there may be more carbon dioxide in the atmosphere, which would exacerbate global warming." (Litchman et. al. 2000)

"Worldwide, diatom numbers, like other beneficial phytoplankton, are disappearing by about 1 percent per year. In the Gulf of Maine, phytoplankton, including diatoms, have decreased by a factor of five in just 17 years. Diatoms require adequate dissolved sillicate to grow their heavy thick shells" (Bangor Daily New Editorial, Roger Wheeler, January 8, 2019, submitted to DEP)

The natural (unregulated) spring freshets typically last up to 4 months with river flows three to five times greater than fall and winter flows?

"To meet the demand of electricity during cold weather, dams and diversions have increased the winter flow on the La Grande River in Quebec by eight times (from 17,600 cubic feet per second to 141,000 cu.ft/sec.) and in order to store water for the following winter have eradicated the spring flood, flow reduced from 177,000 cu.ft./sec to 53,000 cu.ft./sec. (Excerpted from "Silence Rivers: The Ecology and Politics of Large Dams" by Patrick McCully)

The spring freshet (flood) on the La Grande River has been reduced 70 percent by HydroQuebec and the typical reduction on all its dams has been between 50 to 70 percent.

Many in the scientific community, particularly in the U.S., have remained silent over these high reductions in the spring runoff which exceed "a common universality, namely if spring runoff diversions cross 25 to 30 percent of its perennial norm then a coastal ecosystem's dynamic equilibrium will be irrevocably distorted." (Michael A. Rozengurt 2003)

"Among numerous coastal embayments, estuaries occupy special places whose immense influence on the adjacent marine environment and fisheries has been recognized by mankind since time immemorial. By definition, estuaries are intermediate, dynamic, and cumulative links with the river-delta (estuary)-sea ecosystems where continual variable confluence, interaction, and mixing between river and sea takes place….."
There is "….strong support to the statement that river runoff was, is and will continue to be the

ultimate, intrinsic guarantee of estuary-coastal systems survival. The pragmatic manifestation of this statement is based on the universality of the Laws of Thermodynamics, which govern the paths and control the runoff energy distribution and dissipation along the river course (fig.1). Note that the basic principles of river hydraulics and estuarine hydrodynamics are derivatives of the laws of conservation of mass and energy. The three major equations: (1) motion of water, (2) continuity of volumes of water exchanged between an estuary and sea, and (3) continuity of salt balance describe how these principles control the estuarine regime."

There is "ample evidence that the lesser the runoff, the greater is the salt intrusion, and higher the salinization of the estuary (fig.2). Simultaneously, the diminishing runoff adversely effects circulation, mixing and the entrainment phenomenon of runoff energy to repulse salt intrusion to maintain quasi-equilibrium dynamics of the estuarine ecosystems." (see attached, "Running on Empty: The Distortion of Coastal Ecosystems" by Michael A. Rozengurt, 1994)

"Little-known outside aquatic science, freshwater runoff is crucial to healthy fisheries. Dr. Michael A. Rozengurt and his colleagues have shown a real physical threshold for safely blocking runoff from fish: No more than 25 percent of this freshwater flow to the sea can be blocked before fisheries are doomed to an inevitable decline. In the U.S., the former Soviet Union and elsewhere, the story's the same." (Montreal, Winter Star, March 5, 1974 by Dianne Murray, coordinator Dam-Reservoir Working Group Ottawa)

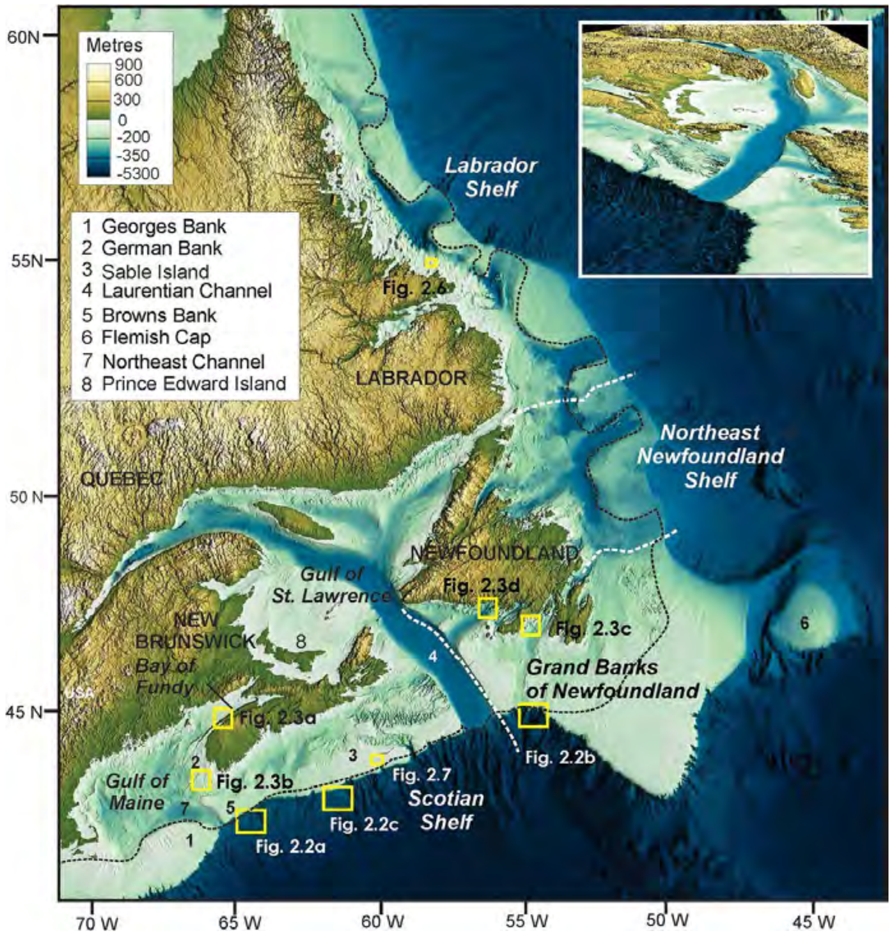
The spring freshets in the rivers of Quebec are so powerful that they eventually reach Maine's Georges Bank.

"On the Scotian Shelf, therefore, there are two freshening cycles annually, a larger one in summer and a smaller one in winter from Canadian North. On Maine's Georges Bank, these freshwater waves would arrive in autumn and spring respectively." (Dr. Hans Neu 1982)

HydroQuebec has eliminiated these fresh water waves, which were historically generated by the natural spring freshets.

The spring freshet was the lifeblood of coastal ecosystems and the discharge of its torrents into coastal waters would create temperature and density gradients, known as thermohaline currents, which would pump nutrient enriched deep sea water through deep channels up into the coastal waters and estuarties?

"Normally, the stronger the flooding the more kinematic's energy is available to regulate water and salt exchange between an estuary and coastal sea….Spring flooding used to serve as a physical barrier to repulse excessive saltwater intrusion into estuaries and deltas, and flush out natural or man-made contaminants. In other words, a natural spring inflow energy tended to maintain regime balance through outflows to seas as required by the first law of thermodynamics." (see attached "Agonizing Coastal Sea Ecosystems: Understanding the Cause; Placing the Blame!" M.A. Rozengurt 2003)



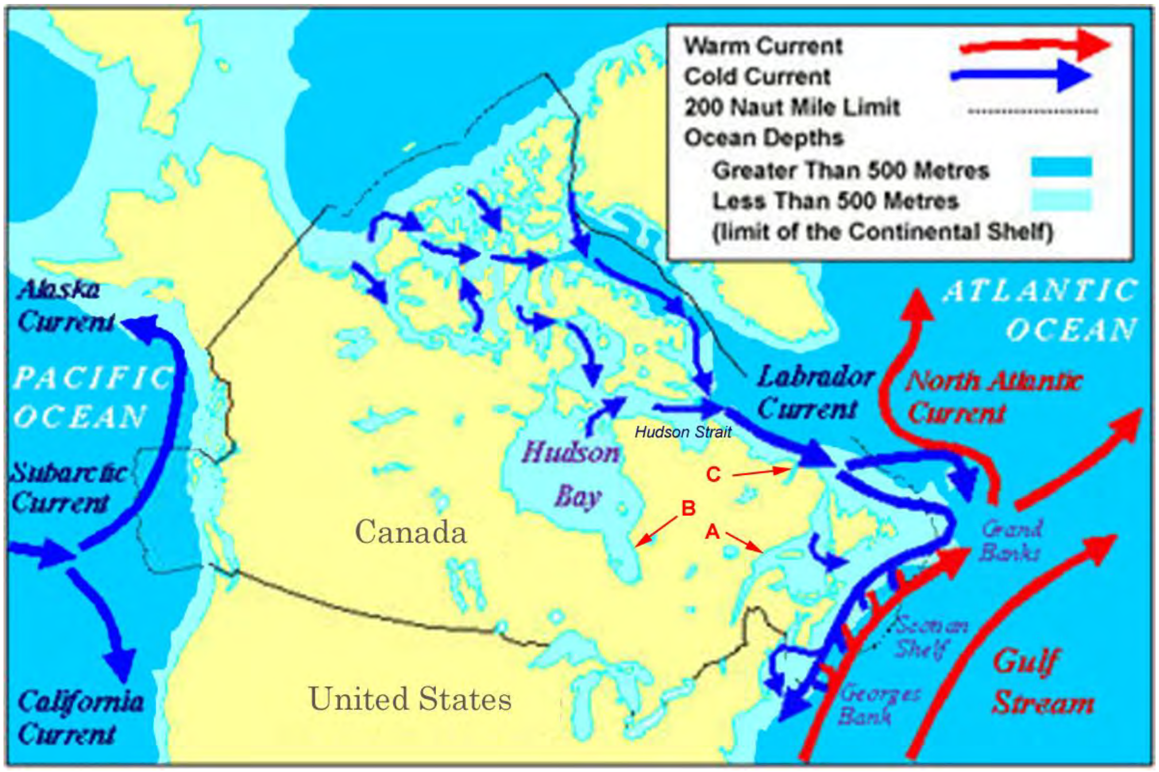
Map 3

Source: SHAW, TODD, LI, MOSHER & KOSTYLEV
Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography

HydroQuebec does not have an agenda to feed the ocean fisheries! So instead of letting all that energy of the spring freshet go to waste, their engineers have built larger reservoir dams, which are capable of holding the spring run-off of large drainage areas and storing it until winter, or for years.

The water volume of Moosehead Lake in Maine is 5.19 cubic kilometers and HydroQuebec built the following dams with a storage capacity equivalent to the amount of water in 80 Moosehead Lakes in the three watersheds listed below and labeled on Map 4.

A. Gulf of St. Lawrence Watershed		B. James Bay/Hudson Bay Watershed		C. Labrador Sea Watershed	
1956 Bersimis -1	13.9 km³	1979-81 Robert-Bourassa Generating Station	61.7km³	1971-74 Churchill Falls	32.64 km³
1969 Outardes-4	24.3 km³	1982-84 LaGrande -3 Generating Station	60.0km³		
1970 Daniel Johnson Dam	142.0 km³	1984-85 LaGrande-4	24.5 km³		
		1993 Brisay	53.8 km³		
	180.2 km³		200.0 km³		32.64km³

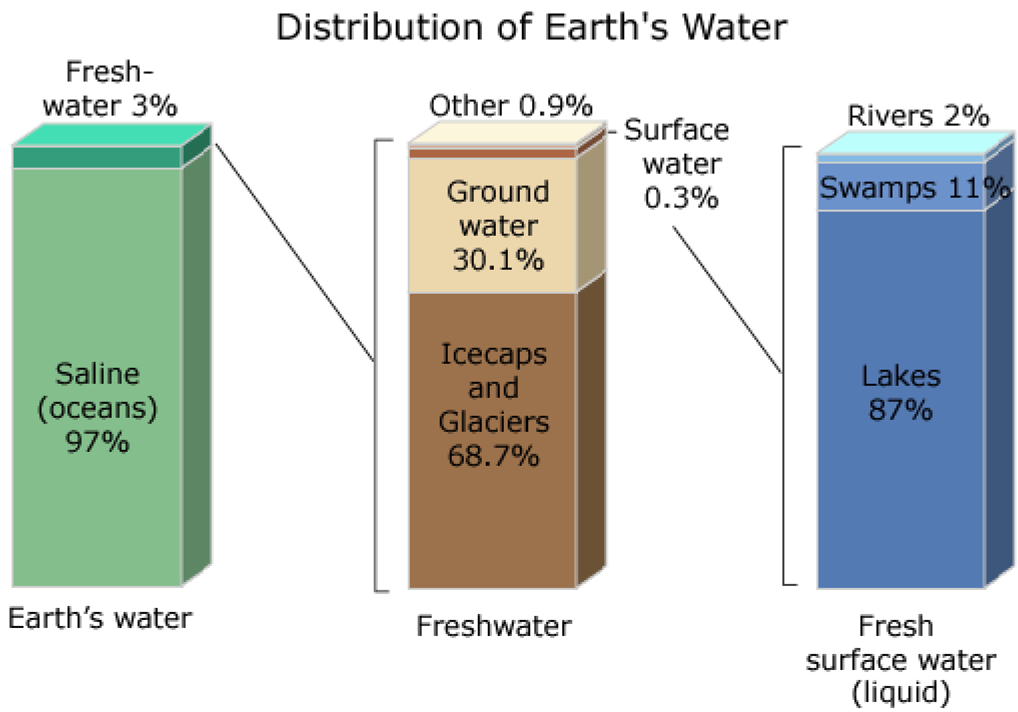


Map 4 Source: The Canadian Encyclopedia

This colossal storage of the water equivalency of 80 Moosehead Lakes is hard to envision. Moosehead Lake is the headwaters of the Kennebec River and the river is approximately 700 feet wide in Augusta. A simple analogy would be 80 Kennebec Rivers flowing together at this point would be 10 miles (56,000 feet) wide. All of this energy and nutrients of the spring freshet have been eliminated by HydroQuebec from Gulf of St. Lawrence and Northwest Atlantic.

Another way to envision the immensity of what HydroQuebec has done is to realize that the storage of 400 cubic kilometers of fresh water represents 20 percent of the water volume in all the rivers in the world.

Freshwater makes up only 3 percent of earth's water and rivers make up 0.006 percent of freshwater with a water volume of 2,120 kilometers.



Source: Gleick, P. H., 1996: Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.

One estimate of global fresh-water distribution

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of freshwater	Percent of total water
Lakes, swamps	24,600	102,500	0.29%	0.008%
Rivers	509	2,120	0.006%	0.0002%
Total global fresh water	8,404,000	35,030,000	100%	2.5%
Total global water	332,500,000	1,386,000,000	--	100%

Source: Gleick, P. H., 1996: Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.

In 1982, global warming was not a household word, but Dr. Neu warned "that both winter and summer temperatures of the surface layer will increase" because of the damming of the spring freshet.

According to the following, there was a boom in dam construction around the world:

"…dam construction began in 1900 and boomed from about 1950 with the use of concrete and inno-vation in excavation (Fig.1). Currently, ~70% of the world's rivers are intercepted by dams (Kummu and Varis 2007) and in China, >80,000 reservoirs were constructed by the end of 2008, among which were >5000 dams higher than 30 m. (http://www.chincold.org.cn). Dams are built to store water for various purposes. Acoompanied with the rapid increase of dam construction (from 1948 to 2010), the global active storage capacity of reservoirs grew from about 200 to >5000 km3, >70% of the total global reservoir capacity (7000-8000km 3); Vorosmarty 1997, Zhou et al. 2016).

Besides thermohaline currents in coastal waters, there is a thermohaline circulation in the world ocean and a major force in the strength of this circulation is the freshwater fluxes of the rivers in Quebec, Newfoundland Labrador (NL) and Gulf of St. Lawrence, including the Great Lakes.

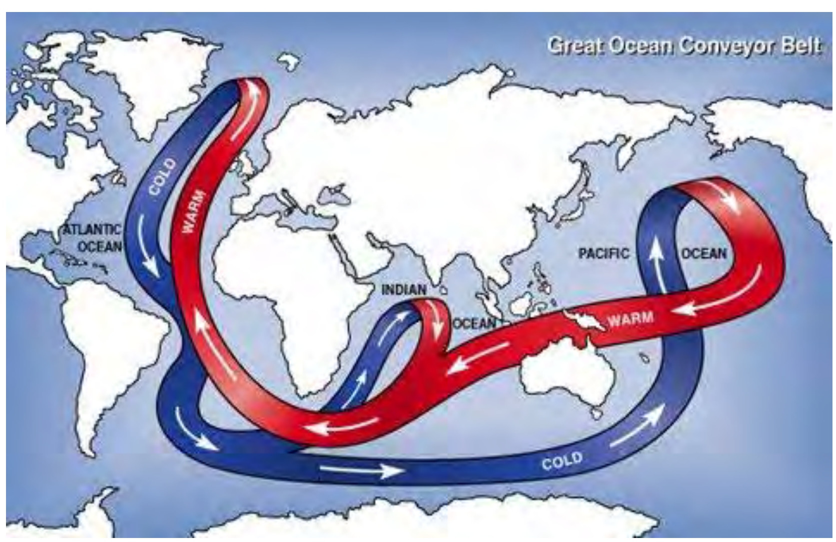
HydroQuebec has withheld the energy of the icy cold torrents of the spring freshet which was the major pump driving the thermohaline circulation.

This large scale ocean circulation is driven by global density gradients created by surface heat and freshwater fluxes, caused by differences in the salinity.

The biggest freshwater fluxes are the spring freshets in the northern latitudes. As you know, in a southern climate, there are no spring freshets.

Thermohaline circulation
(*thermo*=temperature, *haline*=salt

* Thermohaline circulation is the part of the ocean circulation which is driven by density differences. Seawater density depends on temperature and salinity. Differences arise from heating and cooling at the sea surface and the introduction of freshwater into the salty sea water. Heat sources at the ocean bottom play a minor role.



Source: Argonne National Laboratory

The strength of the thermohaline circulation has a large impact on the climate of the earth.

Instead of climate change, a good case can be made that the proliferation of reservoir hydroelectric facilities and flow regulation may be the driving factor in the starvation of the salmon and other fisheries and a major, if not the driving factor in the warming of the oceans and atmosphere, and especially the accelerated warming of the Gulf of Maine.

The three graphs on the last page tell the story. The elimination of the cold waters of the spring freshet has contributed to the northern waters warming faster than those in the southern hemisphere along with weaker thermohaline currents allowing warmer gulf stream waters to have a greater impact warming northern hemisphere waters.

<u>Conclusion</u>

It took milleniums for the natural water cycle to develop along with the critical spring runoff.

HydroQuebec dams have witheld 50 to 70 percent of the spring runoff to generate electricity in the winter.

The cumulative impact of such a huge reduction in the spring runoff has led to a sharp decline in early 1990's of the population of the now-endangered Maine Atlantic salmon, cod and many other fisheries to the point of depletion in the Gulfs of Maine and St. Lawrence and the northwest Atlantic.

If you reduced monthly precipitation by 50-70 percent from March through August, what would happen to wetland functions and carbon sequestration by our forests and pasturelands? Increasing monthly outflows from December through February in the north country does not undo the environmental damage of the preceding months to the fisheries or the biochemistry, acidity, and temperature of the ocean waters.

The advocates of hydroelectricity blame this damage on the burning of fossil fuels.

Since 1948, we have increased the amount of water stored world-wide behind dams by 30 times, from 200 to 6,000 cubic kilometers. Moosehead Lake in Maine contains 5.19 cubic kilometers of water.

Both the strength of the regional thermohaline currents and the worldwide thermohaline circulation is directly correlated to the strength of the spring runoff.

Inevitably, spring follows winter! Not anymore in the Gulf of Maine or its ecosystem, which includes the Gulf of St Lawrence, Labrador Current, James Bay, and Hudson Bay.

Thanks to HydroQuebec, the cold and nutrient enriched waters of the spring runoff have been captured and stored behind its reservoir hydroelectric dams and "Excess water not used to generate electricity is stored in large reservoirs for use in later periods." (HydroQuebec 2018)

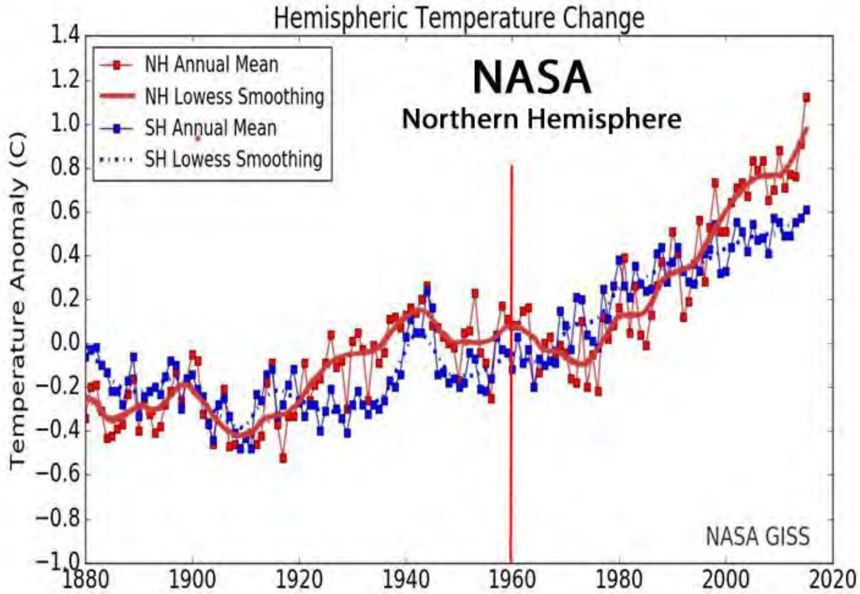
Since the oil embargo of the 1970's, we have been told that hydroelectricity is clean energy. (see attached, Proposed CMP NECEC Project is Not "Environmentally Clean" Energy by S. Kasprzak, submitted to DEP March 2019)

In sharing all of this scientific data, I hope it is no longer hard to conceptualize that large reservoir hydroelectric facilities are starving the Maine Atlantic salmon, cod, and other fisheries, polluting and warming the estuaries, coastal waters, and oceans of the world and subsequently the climate.

Sincerely,

Stephen Kasprzak

Stephen M. Kasprzak


Hemispheric Temperature Change
NH Annual Mean
NH Lowess Smoothing
SH Annual Mean
SH Lowess Smoothing
NASA
Northern Hemisphere
Temperature Anomaly (C)
NASA GISS
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
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−0.4
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1880
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1960
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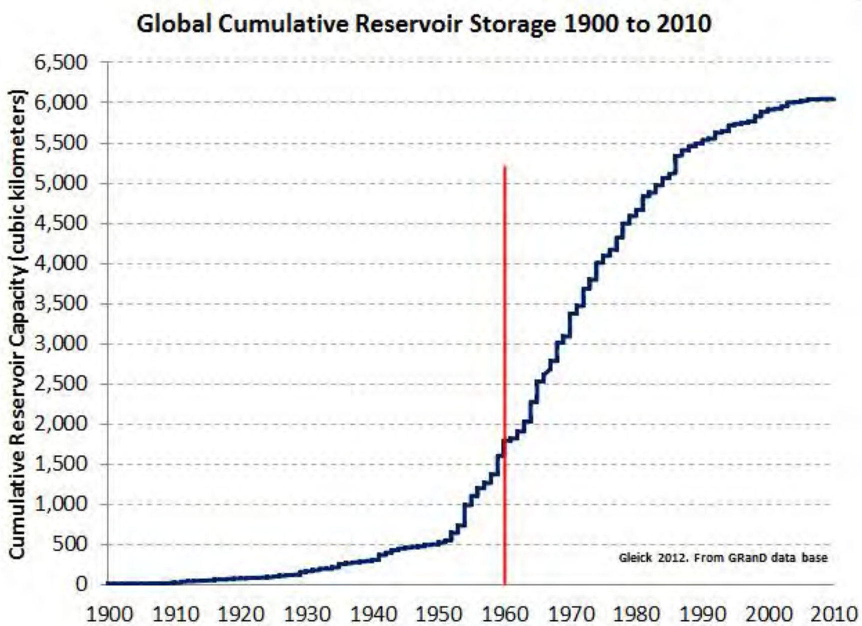
2000
2020


Global Cumulative Reservoir Storage 1900 to 2010
Cumulative Reservoir Capacity (cubic kilometers)
Gleick 2012. From GRanD data base
6,500
6,000
5,500
5,000
4,500
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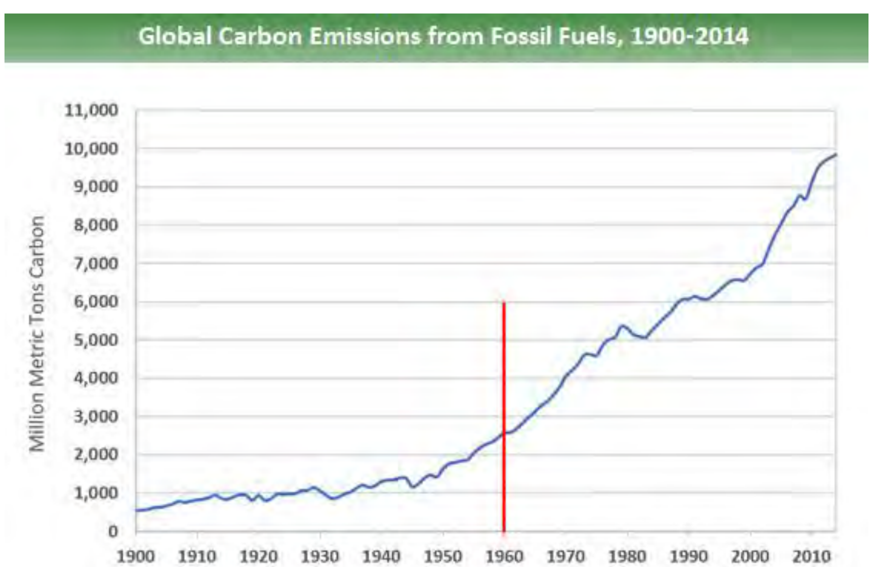
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010


Global Carbon Emissions from Fossil Fuels, 1900-2014
Million Metric Tons Carbon
11,000
10,000
9,000
8,000
7,000
6,000
5,000
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2,000
1,000
0
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

Hydro Québec

December 14, 2018

Thorn Dickinson
Vice President, Business Development
Iberdrola USA Management Corporation
52 Farm View Drive
New Gloucester, Maine 04260

Good Afternoon Thorn:

You have requested Hydro-Québec's assistance in responding to certain data requests pertaining to Hydro-Québec operations received in the CPCN proceeding for the New England Clean Energy Connect ("NECEC") project.

Below is information in response to questions 004-001 and 004-002.

004-001

Regarding the existing hydro-electric facilities that will provide electricity for NECEC, have those dams spilled water instead of generating electricity due to a lack of economic transmission in any of the years 2012-2017? If so,

a. Please provide a volume estimate per year of that spillage.

b. Please provide the reason(s) for that spillage.

Answer:

Yes, in 2017 Hydro-Québec spilled water due to a lack of economic transmission.

The quantity of spilled water in 2017 for this reason represents approximately 4.5 TWhs worth of energy. In the normal course of business, Hydro-Québec uses water to generate electricity. Excess water not used to generate electricity is stored in large reservoirs for use in later periods. As the reservoirs become full, and storing water is no longer an option, water is spilled.

In this category to date in 2018, Hydro-Québec has spilled approximately 10.4 TWhs worth of energy. Without additional transmission export capability, the quantity of spilled water in future years is expected to be comparable to the quantity of spilled water in 2018 under comparable market and operational conditions.

For the 2050 horizon, independent meteorological studies indicate that average flows in northern Québec are expected to increase by approximately 12%. This could lead to additional spilling[1].

---

[1] https://www.ouranos.ca/publication-scientifique/Synthesis_Summary.pdf

004-002

Does Hydro-Québec have an estimate of the maximum export capacity that existed at the end of 2017, without the existence of the NECEC line? (If that estimate is not available, but an estimate from a different year is, please provide that).

a. Please provide that estimate in aggregate or to the four export markets of Ontario, ISO New England, Maritimes, and New York ISO.

b. Please provide a discussion of factors that formed the basis of the estimate.

Answer:

Hydro-Québec's maximum export capability during 2017 is estimated at 34.4 TWh. Below is the breakdown of these exports to Hydro-Québec's primary external markets:

- Ontario: 4.6 TWh
- New England: 18.2 TWh
- Maritimes: 2.1 TWh
- New York: 7.9 TWh
- PJM/MISO/Other: 1.6 TWh

Many factors determine the maximum export capability for Hydro-Québec's hydropower system including the following:

- Water levels in individual Hydro-Québec reservoirs
- Specific transmission availability within Québec
- Specific generation availability
- Transmission availability to external markets
- Transmission congestion in external markets
- Wholesale market prices and demand in Hydro-Québec's export markets
- Operational constraints in Hydro-Québec's export markets

Please don't hesitate to contact me if you have any questions about this information.

Sincerely,

Simon Bergevin
Director, Energy Transactions
Hydro-Québec
75 Réne Levesque Blvd
Montreal, QC H2Z 1A4

and October (9%). The remaining 4% was equally distributed during September and January.

The length distribution of wild-origin two-year and three-year smolts from the Narraguagus River is illustrated in Figure 18a, while the weight to length relationship for these wild smolts is shown in Figure 18b. Two-year smolts (n = 3,078) measured during the period 1962–1966 ranged from 13 to 24 centimeters in length (5.0 to 9.4 inches), while three-year smolts (n = 791) were only slightly longer, ranging from 14 to 25 centimeters (5.5 to 10.0 inches) The average length of two-year smolts was 17.5 centimeters (6.9 inches), while three-year smolts were only an average of 1.1 centimeters longer at 18.6 centimeters (7.3 inches). During the 1960's Atlantic Salmon Commission personnel sampled nearly 500 wild, Narraguagus River smolts at the Beddington weir (mostly from miscellaneous moralities) to determine what the sex ratio of the smolt run was each year. Overall, the sex ratio was 35% males and 65% females, although there were annual differences noted (see Figure 19).

While the majority of Narraguagus River smolts were either two or three years old, small numbers of four and five-year-old smolts were also documented (Figure 20).

Post-smolts leaving the coast of Maine in June reach Cape Breton Island (N.S.) within 45-50 days. The salmon arrive in southern Newfoundland by mid-August, and a few make the journey to the mid-coast of Labrador in 90 days. Because of their larger size, post-kelts are able to migrate faster than smolts. Swimming between 15-25 miles per day, these Maine salmon are able to reach the south coast of Greenland in 120 days, and northern Greenland waters above the Arctic Circle in 160 days.

Marine Migrations

Webster's dictionary defines the word *migrate* as "to move from one region to another with the change of seasons, as many birds and some fishes." For Maine Atlantic salmon, migration is a two-way street of precise, directed, well-oriented movements between habitats for feeding and reproduction. The feeding migration from Maine to various areas in the North Atlantic allows the salmon to take advantage of distant abundant food sources. Conversely, the return migration to Maine allows the adult fish to spawn in the protected environment of its natal stream. Migration patterns in salmon are predictable; they are not random movements. Although affected by water temperatures, currents, and oceanographic (or stream and estuarial) features, these parameters do not guide the salmon during its migrations. The guidance methods used by salmon migrating at sea are thought to be of the map and compass, or orientation, variety; while the stream phase of migration may be appetite driven, or controlled by various physiological factors.

Theories of ocean migration revolve around the salmon's ability to use a combination of electromagnetic fields, polarized light, and various celestial phenomena such as the sun, moon, or stars. Riverine migrations, however, appear to be largely based upon olfactory cues, or the sense of "smell," as experienced primarily through the fishes' lateral line. There are two "odor" theories, one based upon the distinctive odor of the home stream and the other that is based upon pheromones. The distinctive odors that are thought to be imparted by the soils and vegetation in the drainage, possibly combined with odors added by human activities such as waste treatment facilities, pulp and paper mills, and so forth, may allow the fish to "home in" on the "scent" of its natal stream. The pheromone theory is essentially related to the scent of the fish's next-of-kin. Pheromones are hormonal substances secreted by living organisms that stimulate behavioral or physiological responses in other individuals of the same species. Thus, it is possible that adult salmon returning to their home stream are homing in on the scent of other salmon that are living in upstream areas.

The importance of olfaction for salmonid migration has been well documented in the scientific literature (Stabell 1981). Fish that have had their sense of olfaction destroyed have a much lower rate of survival and a much higher rate of straying. While olfaction is important, genetics is probably the number one factor that controls navigation in Atlantic salmon. That is why a Saco River salmon can embark upon a feeding migration to

West Greenland along with salmon from Canada and Europe, yet return to the Saco to spawn.

Tagging studies conducted in Maine since 1962 have taken *some* of the mystery out of where Maine salmon go during their oceanic migrations. During the past 35 years more than 4,100[6] Atlantic salmon tagged (with externally applied Carlin tags) in Maine have been recovered in the North Atlantic Ocean. Those tags were returned from Greenland (43%), from Canada (48%), and a small number (1%) was returned from coastal areas of the United States (mostly from coastal areas of Maine). Although about 8% of the tag returns could not be assigned to a specific location, most were taken in either Canada or Greenland (Table 7). The timing and distribution of these tag returns are extensively reported in Chapter 3 under the heading "Distant Water Commercial Fisheries."

Although tagged salmon have been released into seven rivers in Maine, the majority were released into the Penobscot River; therefore, the latitude and longitude of Bangor are usually used to calculate distances traveled by individual Maine salmon. The average number of days at large, distances traveled, and estimated migration rates for tagged Maine Atlantic salmon of various ages is presented in Table 8.

Based upon the tag return data and average rates of migration presented above, the oceanic migrations of most Maine Atlantic salmon may be summarized in the following manner (Figure 4):

> Leaving the coast of Maine in mid- to late-June, post-smolts move northeasterly across the Gulf of Maine and along the south and eastern coasts of Nova Scotia, reaching the Cape Breton Island (N.S.) area within 45 to 50 days. Crossing the entrance to the Gulf of St. Lawrence, the salmon arrive at the southern end of Newfoundland in 60 to 65 days (mid-August). The post-smolts feed along the northeastern coast of Newfoundland and the southern half of Labrador for the balance of their first summer at sea. While a few Maine salmon have made the journey to the mid-coast of Labrador in as little as 90 days, most take from 105 to 110 days to make the trip. By mid-to-late October the post-smolts have roughly doubled in size (30–36 centimeters; 12–14 inches) and they congregate in the Labrador Sea for their first winter in the Atlantic Ocean. The following year, sometime between April and June, depending upon environmental conditions, the one sea-winter salmon (as they are now called) have three choices: some will migrate in an easterly direction (to Newfoundland and Labrador), others will migrate in a northerly direction (to East and West Greenland), and still others will migrate in a southerly direction back to Maine. Those individuals migrating north or east will spend another summer feeding in Canadian or Greenlandic waters and will return to Maine as two sea-winter salmon the following year. Those that migrate south will return to Maine rivers to spawn as one sea-winter salmon or grilse in the current year. By August of the second summer at sea these salmon have grown to a length of about 56 to 62 centimeters (22 to 24 inches). The proportion of nonmaturing (i.e., those migrating to Newfoundland-Labrador and Greenland) and maturing (i.e., those returning to Maine to spawn as grilse) one sea-winter salmon varies from year to year. Generally speaking, fewer than 10% of any year class will mature as one sea-winter salmon, although some scientists have postulated that there is evidence of a trend toward a higher rate of maturity as one sea-winter salmon in the last decade. This may partially explain the noticeable decrease in two sea-winter salmon and a noticeable increase in one sea-winter salmon (grilse) in North American rivers in recent years.

The migration rates for Maine post-kelts (i.e., those salmon tagged as adults) are similar to those documented for smolts, except that large salmon migrate faster than small salmon. Swimming up to 26 miles per day (assuming straight line migration), the average Maine salmon reaches the mid coast of Labrador or the southern coast of Greenland in 120 days and northern Greenland waters above the Arctic Circle in 5 months.

While the majority of Maine salmon migrate along the eastern shore of Newfoundland, there is evidence that a small number occasionally migrate along the western shore and through the Strait of Belle Isle found between the provinces of Quebec and Newfoundland. Additionally, the recent recapture of two Maine-origin tagged salmon in the Faroe Islands shows that a few nonconformists rejected the original three choices presented to them after their first winter in the Labrador Sea. Perhaps they decided to follow their European "cousins" back to Europe?

On their return to home waters, Maine salmon migrate along the coasts of Nova Scotia and New Brunswick, following the prevailing ocean currents in the Gulf of Maine. This leads the adult salmon to somewhere between the southern and mid-coastal areas of Maine, where they appear to migrate "Downeast" in search of their home river, whether it is the Kennebec, the St. Croix, or any of the other salmon rivers of Maine.

6. The total to date is 4,143 tags from Maine-origin salmon.

Volume 13/Number 1/January 1982

Marine Pollution Bulletin, Vol. 13, No. 1, pp. 7-12, 1982
Printed in Great Britain

0025-326X/82/010007-06 $03.00/0
Pergamon Press Ltd.

VIEWPOINT

Viewpoint is a column which allows authors to express their own opinions about current events.

Man-Made Storage of Water Resources—A Liability to the Ocean Environment? Part I

HANS J. A. NEU

Mr. H. Neu is a Senior Research Scientist with the Canadian Department of Fisheries and Oceans at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia. A specialist for 27 years in estuarine and coastal hydrodynamics, he has studied the physical oceanography of the major waterways across Canada as well as on the continental shelf and in the north-west Atlantic.

A primary reason for estuaries, embayments and continental shelves being among the most fertile and productive regions on earth is the supply of fresh water from land run-off which, on entering the ocean, induces mixing and the entrainment of nutrient-rich deep water into the surface layer. For temperate regions such as Canada, the natural fresh water supply varies sharply with season – being low during the winter when precipitation and run-off is stored as snow and ice, and very large during spring and early summer when the winter storage melts. Nearshore biological processes and adjacent ocean activities are attuned to this massive influx of fresh water – this is the time when reproduction and early growth occur. To modify this natural seasonal run-off for human convenience is to interfere with the hydrological cycle and with the physical and biological balance of the coastal region. Artificially storing the spring and summer run-off to generate power the following winter must have a significant impact on the ocean environment and on the climate of the maritime region.

Introduction

As demonstrated by western society in the last hundred years, the material quality of life improves with the availability of natural resources and with cheap and abundant energy. Today's energy crisis, which arises from the curtailment of the energy supply, threatens this rate of improvement. It is therefore understandable that the prime concern of industrial planners is to develop reliable energy sources. In Canada, hydro-power plays an important role in this concept.

The utilization of power from water is as old as human civilization. In fact, the invention of the water wheel was a key step in reaching our present level of technology. Initially, effects on the environment were minimal but by the turn of the century, when technology was able to modify entire river systems, the consequences became perceptible. The major impact, however, started after the second world war when huge storage lakes were built for power development capable of holding the run-off of large drainage areas and storing it over entire seasons, years, and even longer. Today, these schemes are changing the hydrology not only of regions but of entire continents.

For rivers, this conflict has been somewhat recognized and reported upon (Atton, 1975; Dickson, 1975; Duthie & Ostrofsky, 1975; Efford, 1975; Geen, 1974; Ruggles & Watt, 1975; Townsend, 1975), but with a few exceptions (Asvall, 1976; Skreslet, 1973 a, b, 1976) it is generally assumed that when the river water meets the ocean it is quickly dispersed with little or no impact. However, this is not the case. Fresh water is a major factor in providing nutrients to coastal waters and continental shelves such as the Grand Banks of Newfoundland, and in producing a moderation of the climate.

It should be realized that the prime concern of this paper is not the development of power but the modification of the run-off, particularly its seasonal cycle. As will be demonstrated, this regulation represents a severe interference with the basic concept and balance of activities in the ocean.

Seasonal Variation of Fresh Water

In northern latitudes, winter precipitation in the form of snow remains stored until the following spring. During this period, biological activities slow down and become dormant with little or no need for nutrients. With the onset of spring, the snow melts, creating large river flows particularly during the early part of the season. At the same time the annual growth cycle begins and the nutrients required to support the renewed activities are provided on the land by the fresh water directly, and in the ocean indirectly by increasing the entrainment of nutrient-rich deep ocean water into the surface layer.

A typical monthly run-off hydrograph of a snow-fed river is given in Fig. 1. It shows the Manicouagan River discharge with a maximum in May which is 30–40 times

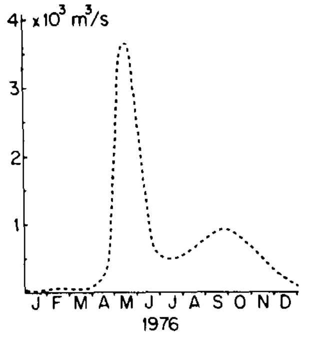

Fig. 1 Natural run-off to the Manicouagan River at Manic 5 power station.

larger than during the winter months. The seaward progress of the fresh water totals of the St. Lawrence and its tributaries, including the Manicouagan, is shown in Fig. 2a. These totals contain fresh water from melting surface ice which has formed in the system during the winter months. The estimated contribution at Cabot Strait is on the average about 4000 $m^3 s^{-1}$ and at its peak probably 6000 $m^3 s^{-1}$. The bulk of the spring freshet passes quickly through the estuary in May, then slows over the Magdalen Shoal in the southwestern Gulf in summer, and arrives at Cabot Strait by the beginning of August. From here it can be traced to Halifax and even to Georges Bank at the entrance to the Gulf of Maine in the autumn.

Similarly, although much larger in magnitude, one can consider the fresh water run-off from Hudson Bay and the Canadian North. Here, even more so than in the St. Lawrence, the winter run-off contribution is small but during the summer large quantities of fresh water are released which affect the surface layer of the coastal waters to a depth of 30–90 m. The peak of the fresh water arrives in July at Cape Chidley near the entrance to Hudson Strait with a discharge of about 300 000 $m^3 s^{-1}$ or about 30 times the flow of the St. Lawrence at Montreal – and in September between Newfoundland and Flemish Cap with a discharge of below 200 000 $m^3 s^{-1}$. This reduction in discharge is produced by a decline in speed over the Grand Banks region which lasts until the end of the year. A part of this fresh water continues along the coast of Nova Scotia – shown in Fig. 2b as a weak but noticeable drop in salinity at Halifax in January – reaching Georges Bank probably in the early spring. So, after being quickly transferred from the North and along the coast of Labrador during the summer, the fresh water affects the Grand Banks during the autumn, the Scotian Shelf during the winter and Georges Bank probably during the spring. The distance travelled by the fresh water wave during a period of 9 months is about 4000 km. On the Scotian Shelf, therefore, there are two freshening cycles annually, a

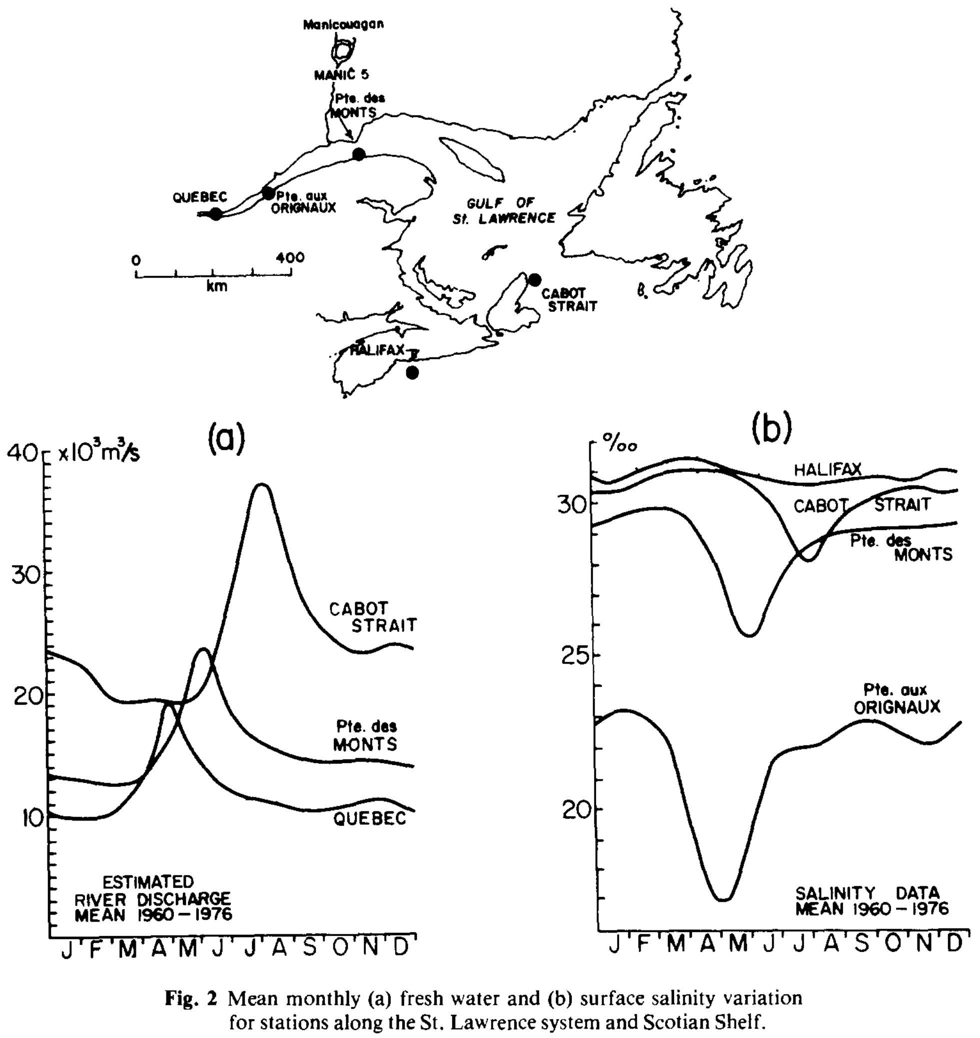

Fig. 2 Mean monthly (a) fresh water and (b) surface salinity variation for stations along the St. Lawrence system and Scotian Shelf.

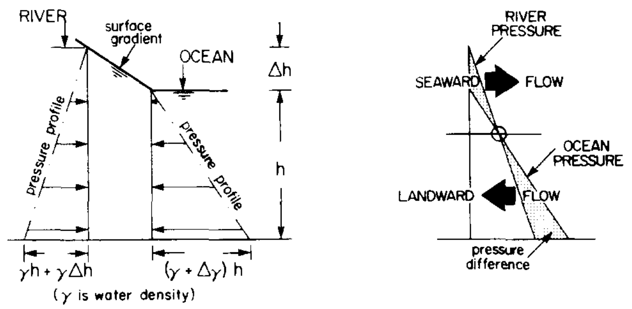

Fig. 3 Schematic diagram of pressure distributions for density currents.

larger one in summer from the St. Lawrence and a smaller one in winter from the Canadian North. On Georges Bank, these fresh water waves should arrive in autumn and spring respectively.

In assessing the man-made changes to water resources, it must be realized that the impact of river regulation on a physical property such as salinity declines the further north we go. The reason for this is that the fresh water deriving from melting sea ice increases relative to the land run-off. For instance, in the St. Lawrence estuary, the fresh water from sea ice is negligible; in the Gulf it increases to about one-fifth of the spring peak flow; in James Bay and southern Hudson Bay to between one-quarter and one-half and in Baffin Bay to between one-half and three-quarters of the spring and summer drainage. Thus, the further north, the smaller becomes the influence of the river run-off.

Obviously, the provision of large quantities of fresh water in spring and summer and the subsequent sweeping of the coastal region and continental shelf by this water are features of the Canadian North and the Canadian Atlantic region. It appears that this seasonal fresh-water movement is in tune with the relatively short reproduction cycle and growing season of the area. It is interesting to note that the two regions receiving major seasonal fresh water sources, the Grand Banks and Georges Bank, are ranked among the greatest fishing grounds in the world.

Fresh–Salt Water Interplay and its Seasonal Variation

The most outstanding feature in the encounter between fresh water and salt water is the formation of a current which oceanographers refer to as haline circulation and engineers as density current. The energy system which generates this motion is in principle the same as that which generates the winds in the atmosphere. While the winds are the result of inequalities in barometric pressure caused by non-uniform heating of the atmosphere under solar radiation, the density current in coastal waters and estuaries is primarily the result of the difference in density between the fresh water of the run-off and the salt water of the ocean.

There are basically two force components which generate this motion. First, fresh water entering the ocean raises the height of the water surface above the height of the ocean and establishes a horizontal pressure gradient. Water flows along this gradient resulting in a seaward flow of the surface water. The pressure gradient and thus the surface flows are maintained by the continuous input of river water. Second, sea water is more dense than river water and since pressure at depth depends on the water density times the water column height, there is a certain depth where the pressure from the low-density river water will be equal to the pressure from the denser sea water. As shown schematically in Fig. 3, below this depth the pressure difference is landward directed and above this point it is seaward directed. This arrangement imposes a two-layer flow system in which, as far as an estuary is concerned, the surface layer flows outward and the deeper layer flows inward. The major manifestation of this principle and the mixing involved is demonstrated by the large variation in salinity and temperature throughout an estuary.

Figure 4 shows salinity profiles at various locations along the St. Lawrence system to the Scotian Shelf. These profiles are in pairs to compare directly the two extreme seasons of winter and summer. The change in surface salinity along the system is also shown in Fig. 2b. As can be seen, the fresh water affects primarily the upper layer, consisting of a mixed layer, about 25 m thick, and a transition layer, about 50 m thick, in which the salinity increases from that of the mixed layer to that of the deeper layer. The water of the deeper layer is ocean water which originates off the continental shelf. It must be realized that this deep water enters the system and penetrates more than 1000 km upstream without any significant contact with the fresh water of the system.

The upper layer is deflected by the Coriolis force toward the right, thus forming (in cross-section) a triangular-shaped layer with the thicker side along the Gaspé Peninsula and the coast of Cape Breton. Evidently, the variation in salinity during spring and summer (Figs 2a, 2b and 4) is a function of the fresh water supply and is confined to the upper layer. The rate of change decreases toward the sea but can still be noticed on the Scotian Shelf.

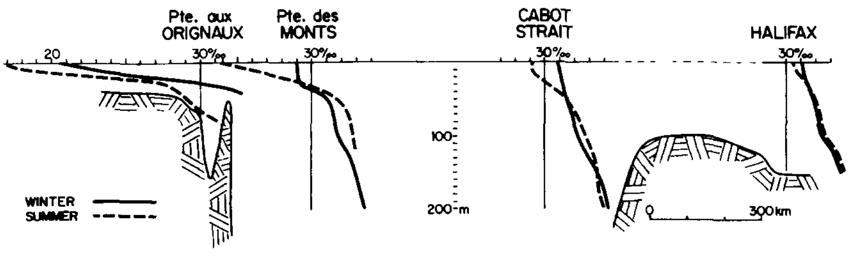

Fig. 4 Mean vertical salinity profiles along the St. Lawrence and Scotian Shelf for minimum (winter) and maximum (spring and summer) run-off.

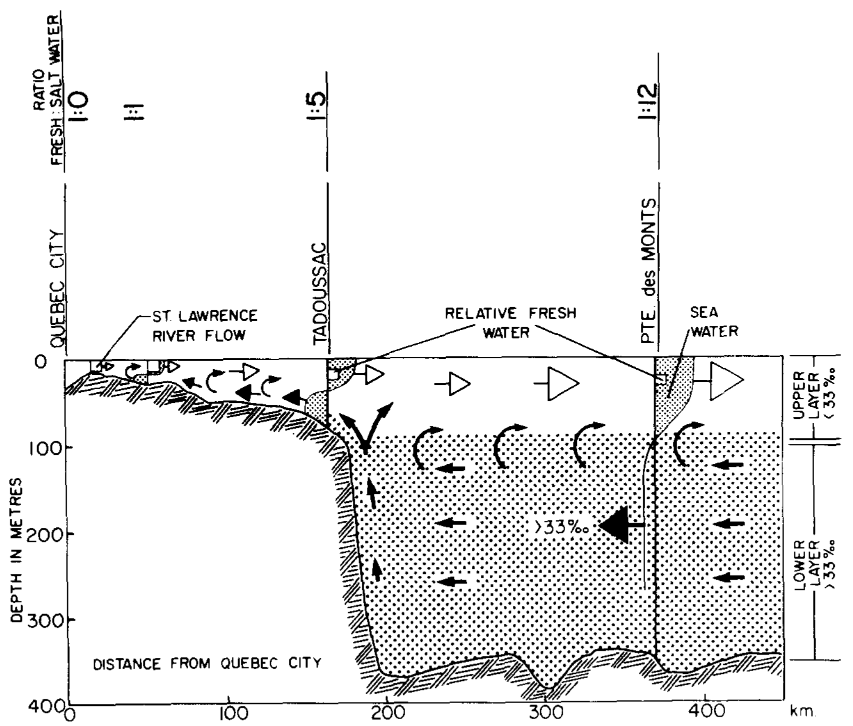

Fig. 5 Schematic presentation of density current in the St. Lawrence Estuary.

The waters off the coast of Labrador, and on the Grand Banks display the same behaviour.

The transport involved in the density current of an estuary can be demonstrated by the continuity principle. As shown in the schematic presentation for the St. Lawrence system in Fig. 5, the seaward directed upper layer contains the fresh water discharge of the river plus the salt water entrained from the landward directed deeper layer, the net flow of salt through the system being zero.

Between Ile d'Orleans and Ile aux Coudres, the average salinity of the upper and deeper layers are 11‰ and 22‰ respectively. Mixing equal volumes of river water (S = 0‰) and saltier water (S = 22‰) results in a salinity of 11‰ for the mixture; therefore, to one unit volume of river water was added the same amount of saltier water at this point. This ratio quickly increases seaward. Taking 33‰ as the reference salinity for sea water, these ratios are 1:5 at Tadoussac and 1:12 at Pointe des Monts, while further seaward they increase to about 1:25 at Cabot Strait, and even more along the coast of Nova Scotia where also fresh water from sources in the Canadian North is present. Obiously, the two-layer current system acts like a large natural pump which constantly transports large quantities of deep ocean water onto the continental shelf and then into the embayments and estuaries. The amount of ocean water required to maintain the level of salinity on the shelves of Atlantic Canada, the embayments and inland seas such as the Bay of Fundy, the Gulf of St. Lawrence and Hudson Bay included, varies from about 2 Sverdrup to more than 7 Sv (1 Sv = 1 million $m^3 s^{-1}$), depending on the season of the year and the salinity limits chosen.

Just as for the winds in the atmosphere, the magnitude of the current is proportional to the pressure difference. Hence in times where more fresh water enters the ocean, the longitudinal gradient seaward increases and with it the strength of the current system. From this it follows that in estuaries the density current varies with the seasonal run-off, being at a minimum during the low discharges in winter and at its peak during the large discharges in spring and summer. In coastal waters which are some distance away from the fresh water source (i.e. the Grand Banks, the Scotian Shelf and Georges Bank) there can be delays of from several months to almost a year before the freshwater peak arrives.

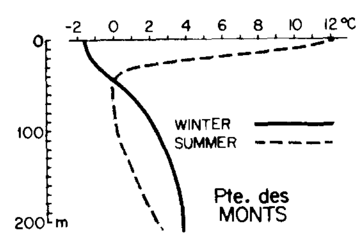

Fig. 6 Vertical temperature profile at Pointe des Monts in winter and summer.

Concerning the temperature of the water, similar variations occur but in this case not exclusively due to fresh water but to seasonal warming and cooling also. As shown in Fig. 6, the upper layer warms during the summer and cools during the winter. This trend is reversed in the deeper layer where during the summer an intermediate colder layer forms as a residue of preceding winter cooling, and is sandwiched between two warmer layers. This 'cold water' layer is characteristic of most of the coastal waters in the western North Atlantic. Although temperature, particularly during warming in spring, plays an important role in the biological activities of the upper layer, it has less influence on the density of the water, and hence on the motion and mixing, than the fresh water of the river.

There are other factors which also play a role in this large-scale circulation, especially the wind and the tide. They greatly affect the intensity of mixing in a particular section of the system; however, the haline circulation and its transport as a whole would prevail in their absence.

Principle of Regulation

In higher latitudes during the winter, river run-off is at a minimum while power demand is at its maximum. This is shown in Fig. 7, where an average hydrograph and the seasonal power demand of a city in northern regions are plotted. As can be seen, water supply and power demand are out of phase by nearly half a year.

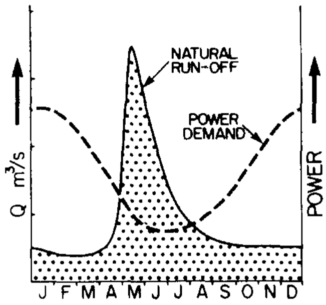

Fig. 7 Typical hydrograph and seasonal power demand.

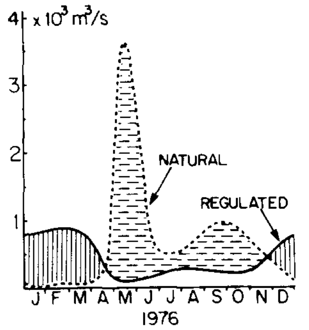

Fig. 8 Natural and regulated discharge of the Manicouagan River at Manic 5 power station.

Developers of electrical energy view this as an inconvenience of nature; thus they reverse the natural run-off cycle by storing the spring and summer flow in artificial lakes to be released during the winter. An example is shown in Fig. 8 for the Manicouagan River at Manic 5 power station.

The ultimate limit of seasonal regulation is achieved when spring and summer flows are completely stopped and the entire annual run-off is released during the winter months. Obviously, such a hydrograph is unrelated to and in outright conflict with natural conditions. Run-off is transferred from the biologically active to the biologically inactive period of the year. This is analogous to stopping the rain during the growing season and irrigating during the winter, when no growth occurs. Even if there were no scientific proof available to verify the danger of such modification, logic alone would show that seasonal regulation ignores the natural consequences of fresh water discharge.

Effect of Regulation on Physics and Dynamics of the Ocean

Reducing the flow of fresh water during spring and summer and increasing it during the winter changes the seasonal composition of the water in the surface layer and the seasonal strength of the density current.

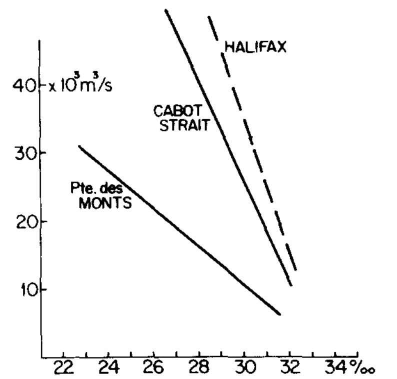

Fig. 9 Run-off versus surface salinity in the St. Lawrence and on the Scotian Shelf.

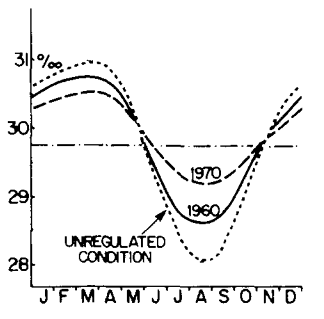

Fig. 10 Seasonal surface salinity variation on the west side of Cabot Strait prior to regulation and in the sixties and seventies.

In Fig. 9, the salinity variation of the surface layer versus fresh water discharge is given for the St. Lawrence and the Scotian Shelf. As can be seen, a reduction of the spring flow of 10 000 $m^3 s^{-1}$ increases the salinity at Pointe des Monts by 4‰, at Cabot Strait by 1.8‰, and near Halifax by 0.9‰. From this relationship, estimates were made of the seasonal variations which occurred at the south side of Cabot Strait for two periods of time, i.e. before regulation commenced and in the seventies. The results are given in Fig. 10. The solid line is the monthly salinity based on the 10 years mean from 1955 to 1964, referred to as the 1960 condition. At this stage, the spring flow was reduced by about 4000 $m^3 s^{-1}$. From the data of Fig. 9 mean monthly salinities were derived for the period prior to regulation, that is for natural conditions, and for the 1970 period when regulation in spring was increased to an average of 8000 $m^3 s^{-1}$. It can readily be seen that drastic modifications have been made to the salinity of the surface layer and that much of the cyclic variation has disappeared by 1970. The remaining seasonal difference will probably be gone with the development of the rivers along the north shore of the Gulf of St. Lawrence, which is already planned and will be implemented soon. As this trend continues, the cyclic variation will be reversed, the surface salinity becoming saltier in spring and summer, and fresher in the winter. This represents a fundamental change in the seasonal salinity patterns of the coastal region and continental shelf.

Concerning the temperature of the water, there will also be changes but since this property is non-conservative, it is difficult to predict the full effect. There is a definite possibility that both winter and summer temperatures of the surface layer will increase; in winter due to an increase in upwelling of deeper warmer water, and in summer due to slower surface currents which will allow the surface layer to absorb more heat during its passage through the system. It can be assumed therefore that fresh water regulation modifies the climate of the coastal region to be more continental-like in the summer and more maritime-like in the winter.

The greatest consequences will arise, probably, from changes imposed on the density current. This current determines the transport of deeper water from the ocean onto the shelf and from there into the embayments and estuaries. Reducing the flow of fresh water during the spring and summer decreases the strength of the density current to the point where, if taken far enough, it could be stopped altogether, while increasing the fresh water during the winter increases the current. Except where nutrients are produced locally, their rate of supply is directly related to the volume of salt water which carries them. A reduction in the transport of this water therefore decreases the influx of nutrients – the natural food supply – during the biologically active season of the year. An increase of supply during the winter does not compensate for these losses since primary and secondary production does not occur during this period, and the nutrients will return to the ocean body without being utilized.

Taking the St. Lawrence as an example, where today more than 8000 $m^3 s^{-1}$ (approximately one-quarter to one-third of the peak discharge) is held back in spring (Fig. 11), the seasonal inflow of ocean water into the Gulf must already be significantly modified. The reduction of the amount of water and with it the quantity of nutrients entering the system during the biologically active season must be in the order of 20–30% of its initial supply. According to El-Sabh (1975), the inflow into the Gulf through Cabot Strait is, at its peak in August, between 600 000 and 700 000 $m^3 s^{-1}$. Before regulation was implemented it probably was closer to a million cubic metres per second with all the extra nutrients that volume implies.

Beyond any doubt, similar reductions in the shoreward transport of sea water and nutrients have occurred at other places during the summer, such as in Hamilton Inlet below

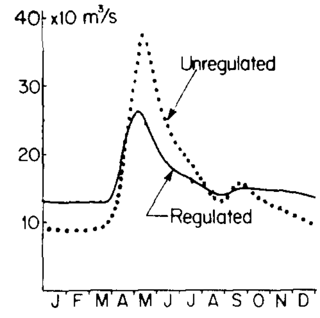

Fig. 11 Regulated and unregulated flow of the St. Lawrence at Pointe des Monts for 1976.

the Churchill Falls power development in Labrador, and will now occur in James Bay after the first power scheme there is in operation.

This article will be continued in the next issue of the Bulletin. In the second part, the effect on marine biology will be discussed and related to major schemes in Canada and Russia, the two countries where hydrological control on a continental scale is already contemplated. Their largest freshwater resources will be reviewed relative to the global hydrology, and alternative solutions to offset some of the negative effects will be suggested.

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MAN-MADE STORAGE OF WATER RESOURCES - A LIABILITY TO THE OCEAN ENVIRONMENT

The above title was also the title of a January 1982 Report by Dr. Hans Neu, a Senior Research Scientist at Bedford Institute of Oceanography in Dartmouth, Nova Scotia. Dr. Neu predicted that the huge storage lakes being built for power development would starve the fisheries (see my Fact Sheet "Hydro-Dams Blamed for Decline in Fish Stocks", Kasprzak, February 4, 2019) and weaken the seasonal strength of the density (thermohaline) current thereby warming the waters. The following excerpts were written by Dr. Neu in his 1982 Report:

> *"The most outstanding feature in the encounter between fresh water and salt water is the formation of a current which oceanographers refer to as haline circulation and engineers as density current".* (Today, this is called a thermohaline current) and *"Obviously, the two-layer current system acts like a large natural pump which constantly transports large quantities of deep ocean water onto the continental shelf and then into the embayments and estuaries."*

Historically, before reservoir dams, both the natural flowing rivers and the upwelling of large quantities of deep ocean water transported dissolved silica and other essential nutrients to the coastal waters and were the major source of nutrients to the estuaries.

> *"Just as for the winds in the atmosphere, the magnitude of the current is proportional to the pressure difference. Hence in times where more fresh water enters the ocean, the longitudinal gradient seaward increases and with it the strength of the current system. From this it follows that in estuaries the density current varies with the seasonal run-off, being at a minimum during the low discharges in winter and at its peak during the large discharges in spring and summer. In coastal waters which are some distance away from the fresh water source (i.e. the Grand Banks, the Scotian Shelf and Georges Bank) there can be delays of from several month to almost a year before the freshwater peak arrives."*

THE DRIVING FORCE WEAKENING THE THERMOHALINE CURRENT, AND THEREBY WARMING THE WATERS IN GULF OF ST. LAWRENCE, GULF OF MAINE, HUDSON STRAIT AND LABRADOR CURRENT HAS BEEN THE PROLIFERATION OF RESERVOIR DAMS BY HYDRO-QUEBEC.

The dams have created huge storage lakes capable of holding the run-off of large drainage areas and storing it over entire seasons, years and even longer. The water volume in Moosehead Lake in Maine is 5.19 km³ and Hydro Quebec built the equivalent of 80 Moosehead Lakes in the three watersheds listed below and 67 of them were built between 1969-1985, which is an average of almost 4 per year.

Gulf of St. Lawrence Watershed		James Bay/Hudson Bay Watershed		Labrador Sea Watershed	
1956 Bersimis -1	13.9 km³	1979-81 Robert-Bourassa Generating Station	61.7km³	1971-74 Churchill Falls	32.64 km³
1969 Outardes-4	24.3 km³	1982-84 LaGrande -3 Generating Station	60.0km³		
1970 Daniel Johnson Dam	142.0 km³	1984-85 LaGrande-4	24.5 km³		
		1993 Brisay	53.8 km³		
	180.2 km³		200.0 km³		32.64km³

Fact Sheet by Stephen M. Kasprzak
February 11, 2019 Revised March 28, 2019

NATURAL RIVER FLOW VERSUS REGULATED FLOW

Dr. Neu wrote the following in his 1982 Report:

> *"In higher latitudes during the winter, river run-off is at a minimum while power demand is at its maximum. This is shown in Fig. 7, where an average hydrograph and the seasonal power demand of a city in northern regions are plotted. As can be seen, water supply and power demand are out of phase by nearly half a year."*

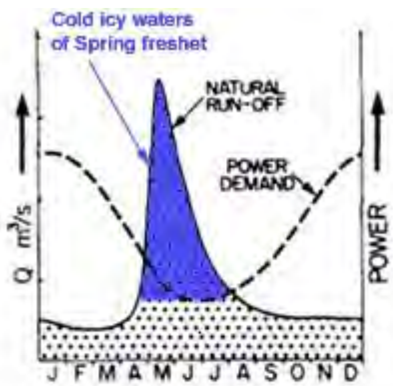


Fig. 7 Typical hydrograph and seasonal power demand.

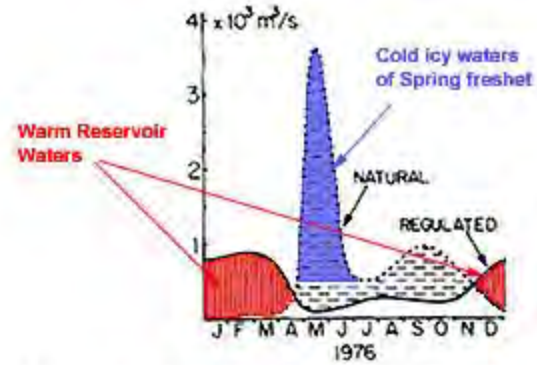


Fig. 8 Natural and regulated discharge of the Manicouagan River at Manic 5 power station.

> *"Developers of electrical energy view this as an inconvenience of nature; thus they reverse the natural run-off cycle by storing the spring and summer flow in artificial lakes to be released during the winter. An example is shown in Fig. 8 for the Manicouagan River at Manic 5 power station.*
>
> *Run-off is transferred from the biologically active to the biologically inactive period of the year. This is analogous to stopping the rain during the growing season and irrigating during the winter, when no growth occurs.*
>
> *Although temperature, particularly during warming in spring, plays an important role in the biological activities of the upper layer, it has less influence on the density of the water, and hence on the motion and mixing, than the fresh water of the river."*

Dr. Neu made the following observations and prediction, which again, have turned out to be true with the passage of time:

> *"Reducing the flow of fresh water during spring and summer and increasing it during the winter changes the seasonal composition of the water in the surface layer and the seasonal strength of the density current.*
>
> *As this trend continues, the cyclic variation will be reversed, the surface salinity becoming saltier in spring and summer, and fresher in the winter. This represents a fundamental change in the seasonal salinity patterns of the coastal region and continental shelf.*
>
> *There is a definite possibility that both winter and summer temperatures of the surface layer will increase; in winter due to an increase in upwelling of deeper warmer water, and in summer due to slower surface currents which will allow the surface layer to absorb more heat during its passage through the system. It can be assumed therefore that fresh water regulation modifies the climate of the coastal region to be more continental-like in the summer and more maritime-like in the winter."*

HYDRO DAMS BLAMED FOR DECLINE IN FISH STOCKS

I believe the driving force in the collapse of cod fisheries in the early 1990's in the Gulf of Maine, Gulf of St. Lawrence and Grand Banks of Newfoundland has been the proliferation of huge reservoir hydroelectric facilities by Hydro-Quebec on the rivers throughout the ecosystem of these three water bodies. The Daniel Johnson Dam discharges into the St. Lawrence Estuary and is the fourth largest in the world. It stores 142.0 cubic kilometers (km^3) of water, which is equivalent to 27 Moosehead Lakes. There were other large reservoirs built (see page 4) storing the water equivalency of an additional 63 Moosehead Lakes.

Dr. Hans Neu, a Senior Research Scientist at Bedford Institute of Oceanography, Dartmouth, Nova Scotia warned Hydro-Quebec, in a February 9, 1977 article in The *Sherbrooke Record*, that the proliferation of its reservoir hydroelectric facilities might be the cause of in the 1970's decline of fish stocks in Gulf of St. Lawrence, as shown in the below graph, and not overfishing.

In a 1982 report, "Man-Made Storage of Water Resources - A Liability to the Ocean Environment.? Part I and Part II," he made the following observations and prediction:

> "*Life as we know it in our coastal waters and its level of productivity has evolved over thousands of years in response to these seasonal variations. Changing this pattern by reducing the flow of fresh water during the biologically active season of the year, or even reversing the cyclic flow altogether, represents a fundamental modification of a natural system. Such a modification must have far reaching consequences on the life and reproduction cycle in the marine environment of the region affected."*

and he made the following prediction in regards to Gulf of St. Lawrence

> *"The next big decline (in fisheries stock) probably will be in the early or mid-eighties*" and "*will be worse, since regulation will have increased further in the meantime."*

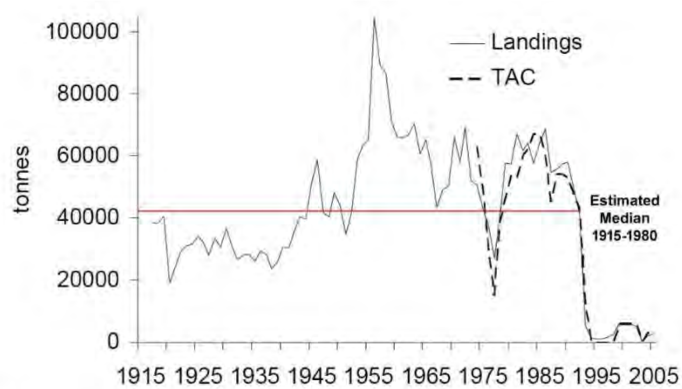


Figure 2: Landings and TAC (t) for the southern Gulf of St. Lawrence cod stock.
Source: Canadian Science Advisory Secretariat Science Advisory 2006/014

The above graph supports his prediction, and please note the following:

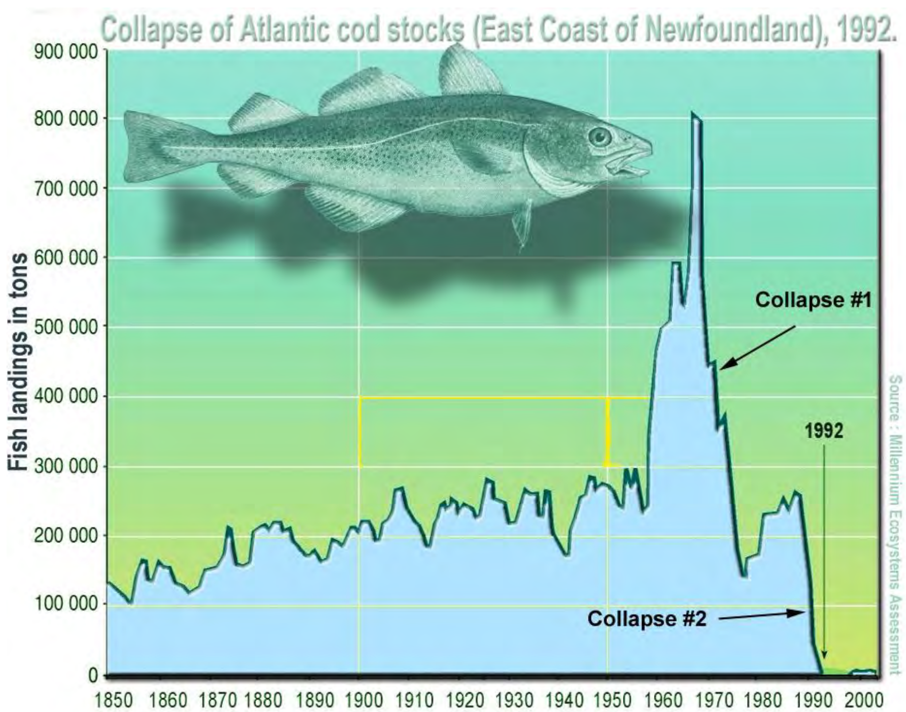
1. Dr. Neu predicted in 1982 that the next big decline after the 1975 decline would be worse because the Daniel Johnson Dam was coming on line. The decline was not only worse, but it has lasted 25 years and appears to be irreversible.
2. There was a sustainable median catch of 42,000 tonnes for the previous 80 years.

He also predicted a decline in the fishing stock off the Grand Banks of Newfoundland:

> *"Even if we cannot yet measure the effects with certainty in our own marine environment,* (Gulf of St. Lawrence SMK) *similar changes must already have happened to the coastal waters of Atlantic Canada and the effect must increase as regulation of our rivers continues. Of particular concern is the increased development of hydro-power-under construction or in the design stage – in Labrador, Ungava Bay, James Bay and Hudson Bay, which are bound to threaten the productivity of the Grand Banks of Newfoundland."*

The second collapse in the following graph supports this prediction. Shown below are two collapses of the Atlantic northwest cod fishery in the past fifty years. Both collapses have been analyzed as one and the cause blamed on overfishing and/or global warming by others

.



There is no doubt that overfishing caused the spike in cod landings during the 1960's and the first collapse in the 1970's is the consequence of overfishing. However, the second and more lasting collapse occurred in the 1989-1991 period. The driving force of this decline has been man-made storage behind the reservoir dams.

From 1850 through the late 1980's there was a sustainable median catch of 200,000 tons per year followed by what appears to be an irreversible collapse, which has continued through 2018.

I believe the elimination of this 140 year sustainable cod catch of 200,000 tons is what Dr. Neu had in mind when he said the storage of these waters **"***MUST HAVE FAR REACHING CONSEQUENCES ON THE LIFE AND* ***REPRODUCTION CYCLE IN THE MARINE ENVIRONMENT OF THE REGION AFFECTED."***

The passage of time has documented that his predictions, based on earlier research, were correct.

THIS NEGATIVELY IMPACTED MARINE ENVIRONMENT ALSO INCLUDES THE GULF OF MAINE

I have written a more comprehensive analysis on other environmental impacts in my January 15, 2019 report, "Hydro-Quebec's Dams Have a Chokehold on the Gulf of Maine's Ecosystem," in which, I describe how these dams have starved the fisheries in downstream waters of nutrients and changed the thermohaline circulation, not only in the Gulf of St. Lawrence, but also in the Labrador Current. Subsequently, this has changed the thermohaline current in the Gulf of Maine as the St. Lawrence waters and Labrador Current mix together over the Scotia Shelf, which is offshore of Nova Scotia, and then flow into the Gulf of Maine.

The strength of the thermohaline current and thus the transport of deep nutrient enriched ocean water into the St. Lawrence Estuary, Grand Banks and Gulf of Maine depends on the amount of fresh water flowing into these water bodies. Reduced spring and summer outflows from these reservoir hydroelectric dams have created a chokehold on the delivery of the annual budget of dissolved silica and other nutrients via both the rivers and upwelling ocean waters. The cumulative impact of these stored waters have starved the fisheries to depletion.

Dr. Neu was quoted as follows in *The Sherbrooke Record*:

> "*In their natural state, rivers carry smaller flows during the winter when precipitation is frozen as snow, and sharply increased flows after the spring thaw. This coincides with the life cycle of marine organisms, increasing food supplies as they come out of their winter hibernation and decreasing supplies when winter returns.*
>
> *But hydro-electric dams tend to level out the cycles, storing much of the spring and summer runoff in the reservoirs until winter, when consumer demand for power is greater. This means that fresh-water nutrients reach the ocean in the winter, when the fish don't need them, and are lost into the barren depths beyond the continental shelf. In the spring and summer the nutrient supply fails to increase as rapidly as is needed."*

THERE WAS A SUSTAINABLE MEDIAN (COD) CATCH FOR 100 YEARS OF 8,000 METRIC TONS IN THE GULF OF MAINE AND THE PRECIPITOUS DECLINE, WHICH BEGAN IN 1991, IS CONSISTENT WITH THE TIMING OF COLLAPSES IN GULF OF ST. LAWRENCE AND WESTERN ATLANTIC.

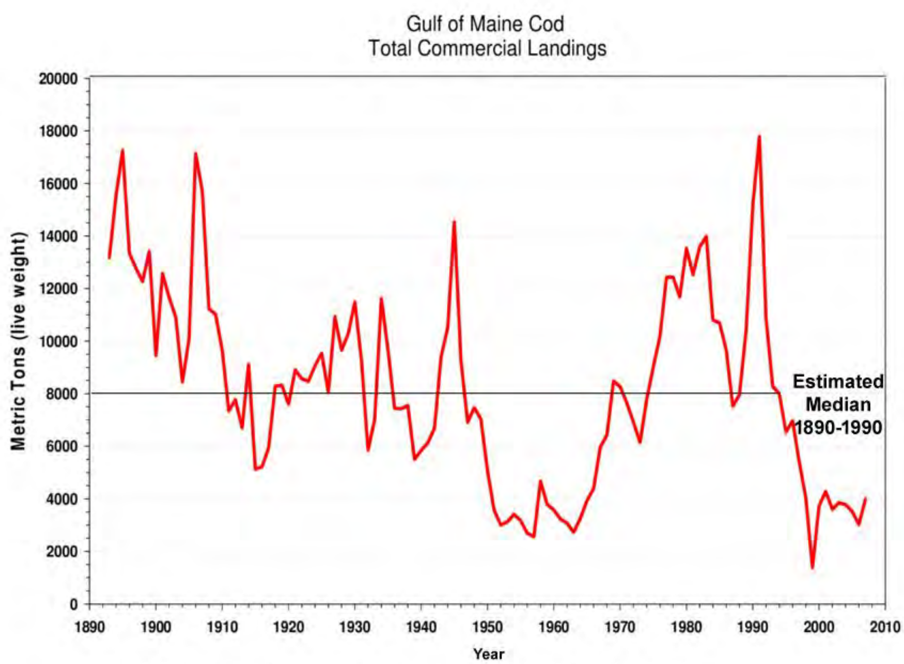
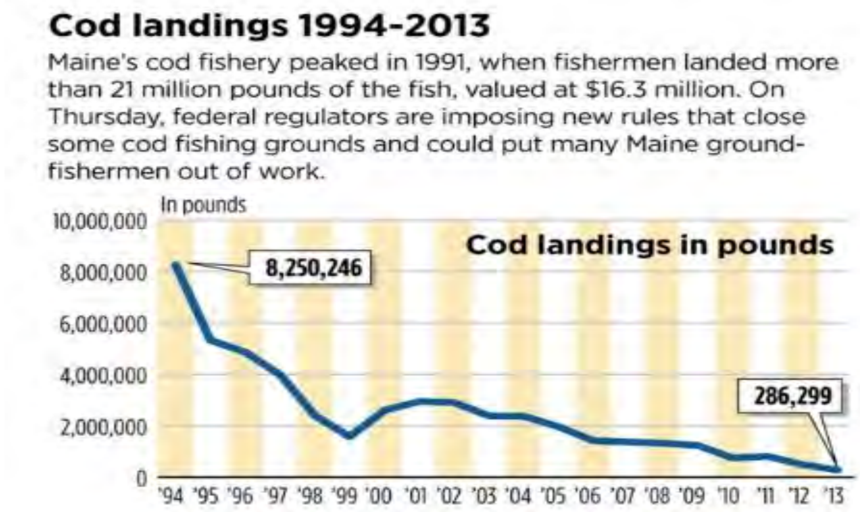


Figure 1.2 Total commercial landings (mt) of Atlantic cod from the Gulf of Maine stock, 1893-2007.

The public perception is that the depletion of the cod fishery has been caused by overfishing and/or global warming. The graph shown below by Michael Fisher of the Portland Press Herald does a great job of supporting this narrative, but fails to disclose there was a sustainable catch for the preceding 104 years, as shown in the graph on the preceding page.



THE DRIVING FORCE BEHIND THE DEPLETION OF THE COD FISHERY WAS CAUSED BY THE PROLIFERATION OF RESERVOIR HYDROELECTRIC DAMS BY HYDRO-QUEBEC

These dams created huge storage lakes built for power development and capable of holding the spring run-off of large drainage areas and storing it over entire seasons, years and even longer.

The water volume in Moosehead Lake in Maine is 5.19 cubic kilometers (km^3) and Hydro Quebec built the equivalent of 80 Moosehead Lakes in the three watersheds listed below.

Gulf of St. Lawrence Watershed		James Bay/Hudson Bay Watershed		Labrador Sea Watershed
1956 Bersimis -1	13.9 km^3	1979-81 Robert-Bourassa Generating Station	61.7km^3	1971-74 Churchill Falls 32.64 km^3
1969 Outardes-4	24.3 km^3	1982-84 LaGrande -3 Generating Station	60.0km^3	
1970 Daniel Johnson Dam	142.0 km^3	1984-85 LaGrande-4	24.5 km^3	
		1993 Brisay	53.8 km^3	
	180.2 km^3		200.0 km^3	32.64km^3

To put this in perspective, since the 1970's the review standards in Maine's Natural Resource Protection Act, which mandate submission of proof to minimize environmental impacts, would have prevented the building of even a small or large reservoir on any brook, stream, or river flowing into the Gulf of Maine.

RESERVOIR HYDROELECTRICITY GENERATED BY HYDRO-QUEBEC IS **NOT GREEN ENERGY. IF MAINE'S PUC & DEP** SAY **"**YES**"** TO **CMP'S PROPOSED** NEW ENGLAND CLEAN ENERGY CONNECT (NECEC), IT WOULD BE THE HEIGHT OF HYPOCRISY.

FACT SHEET BY STEPHEN M. KASPRZAK
FEBRUARY 4, 2019

THE PROBLEM IS THE LACK OF SILICA

Silica Shelled Diatom Phytoplankton

The Foundation of the Aquatic Food Web

Atlantic Cod

Atlantic Salmon

"Diatoms are at the bottom of the food chain and suck up nearly a quarter of the atmosphere's carbon dioxide . . . Size matters for the creatures that eat them and also for carbon sequestration, as large diatoms are more likely to sink when they die . . . If smaller size diatoms dominate, then carbon sequestration becomes less efficient, and there may be more carbon dioxide in the atmosphere, which would exacerbate global warming. " (Litchman et. Al. 2000).

Stephen M. Kasprzak
October 15, 2018

This Report is being written as a supplement to the editorial "*Reject CMP Power Line Because Hydro-Quebec Facilities Damage Ecosystem,"* which was published in the Portland Press Herald on October 9, 2018 (see Attachment 1). It also documents how Hydro-Quebec has significantly contributed to <u>the lack of silica</u> in northwest Atlantic and Gulf of Maine.

ABSTRACT

There is a commonly held belief that climate change is the driving force behind the decline in the population of cod, salmon, capelin and other fisheries in the Gulf of Maine and northwest Atlantic, as well as warming their waters.

There is another factor, namely, <u>the lack of silica</u>!

This Report documents how the lack of silica is the driving force in the decline of the fisheries and not overfishing. The following two quotes are consistent with my claim that the fisheries are being starved:

Research scientist with the Department of Fisheries and Oceans (DFO) Dr. Mariano Koen-Alonso says the sudden and sharp decline in cod stock is something being seen across the ecosystem.

"We've seen very important reductions in biomass of many species across the board," said Koen-Alonso. "We have to look at the big picture here, there are several factors and species involved."

"With reductions in the biomass of the cod's food sources such as shrimp and capelin, Koen-Alonso says the cause of the cod's decline appears to be more bottom-up than top-down. Bottom-up meaning that a lack of food and poor conditions are the driving force in the shrinking biomass, rather than predators or overfishing which are chief factors in a top-down cause of depletion.

Koen-Alonso says the signs show the capelin's declining numbers can also be traced to the food chain." (Northern Pen May 10, 2018).

and

"Atlantic ocean plant life, the phytoplankton, has been observed to be in tremendous decline. International science teams have measured more than 26% lost in the last 30 years. How bad is 26%? Remember when we destroy just 1 in 10 of any form of life we say that we have decimated that life. It's bad. Very bad. And the starvation and disappearance of Atlantic Cod stand as testimony to the collapse of the Atlantic Ocean pastures. Ocean pasture grass is plankton." (Russ 2014).

The building and management of Quebec Hydropower's reservoir hydroelectric facilities have reduced river discharge during spring freshet into Eastern Hudson Bay and Labrador Sea by forty to fifty percent and increased winter discharge by 300 percent.

"Eighty percent of the annual input of dissolved silicate to the ocean is transported via our rivers and streams." (Paul Treguer et. al. 1995). In our <u>northern</u> latitudes, the majority of this annual budget is delivered by the <u>roaring</u> waters of the spring freshet.

Less dissolved silicon, during spring months, is starving the silicon diatom phytoplankton blooms, which are the essential basis of marine food web.

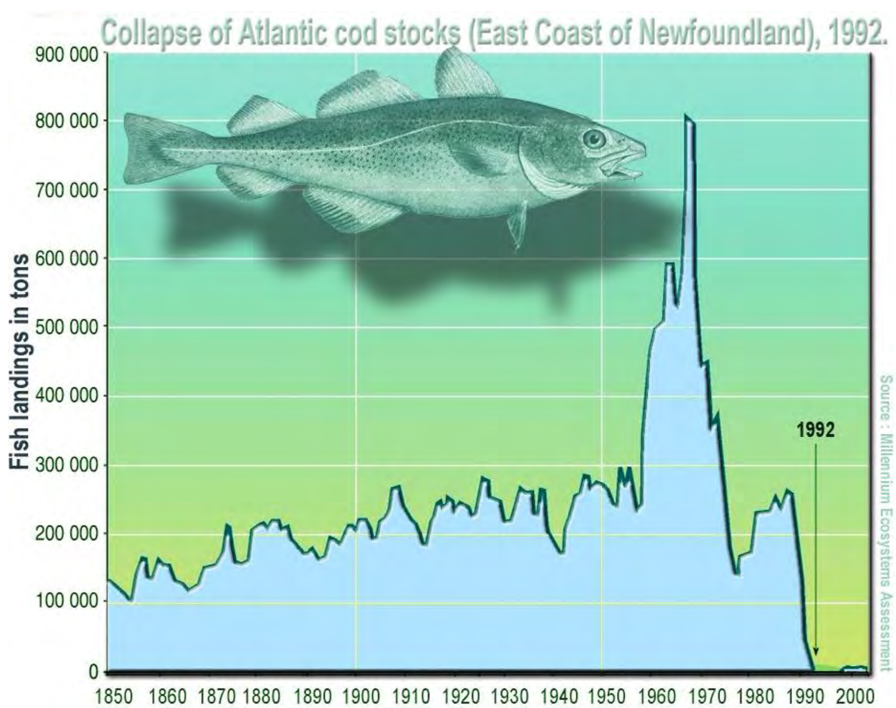
The advocates of hydroelectricity claim it is a power source that is clean and renewable because it uses the earth's annual water cycle to generate electricity.

They fail to mention that hydroelectric reservoir facilities have changed the seasonal pattern of annual natural water cycle by significantly reducing the spring run-off and summer outflows and using the captured waters to double and triple the winter outflows, due to high winter demand for electricity.

This is just the opposite to a typical unregulated river, which experiences low flows in winter when water is stored in the seasonal snowpack, then high flows during the snowmelt-driven freshet in spring and early summer.

STARVATION OF ATLANTIC NORTHWEST COD FISHERY

There have been two collapses of the Atlantic northwest cod fishery in the past fifty years, and they are illustrated in the graph below. Both collapses have been analyzed as one and the cause blamed on overfishing and global warming.



There is no doubt that overfishing caused the spike in cod landings during the 1960's and the subsequent decline in the 1970's.

However, the second and more lasting decline occurred in the 1989-1991 period. The major factor of this decline has been <u>the lack of silica</u> caused by the capture of the spring freshet in the reservoirs of hydroelectric facilities owned by Quebec Hydropower. These facilities have significantly reduced the transport of dissolved silica and other nutrients needed for healthy spring and summer diatom phytoplankton blooms in the northwest Atlantic and Gulf of Maine.

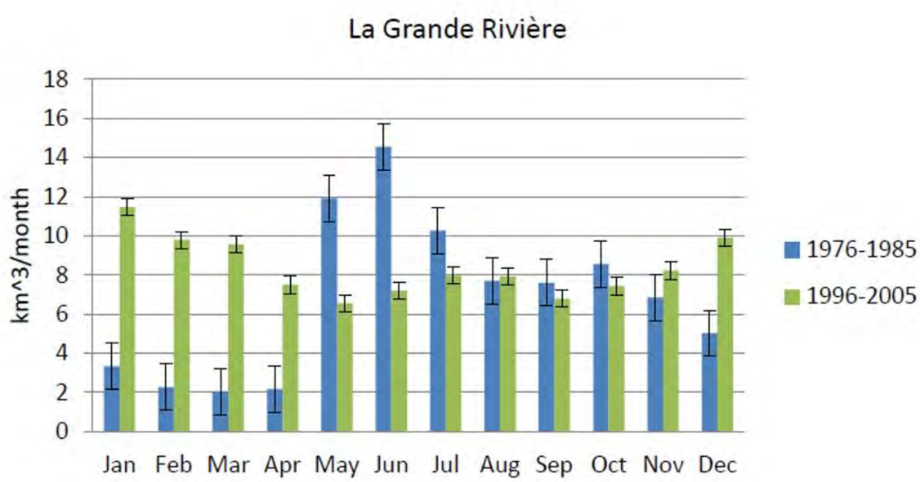
"The growth rate of diatoms (silica-shelled phytoplankton) are determined by the supply of silicate." (Venugopalan Ittekkot et. al. 2000).

"Diatom phytoplankton populations are the usual food for zooplankton and filter feeding fishes and contribute in a direct way to the large fishable populations in coastal zones." (C.B. Officer et. al. 1980).

***"The lack of silica can change aquatic ecosystems from those dominated by diatoms to non-diatom based aquatic ecosystems usually dominated by flagellates."*(**E. Struyf 2009).

QUEBEC HYDROPOWER HAS REDUCED SPRING FRESHET RIVER FLOWS BY 40 TO 50 PERCENT

A good example is the three LaGrande reservoir hydroelectric facilities, which have an annual capacity of 7,302 megawatt (MW). Two of the reservoir facilities went online in 1986 and the third in the early 1990's. The graph below illustrates how the dams have been used to capture the waters of the spring freshet which are then used to increase winter outflows by more than 300%.



Comparison of runoff by damming or diversion for the pre-1986 and post-1986 periods (Ray Roche 2007)

The following points should help put into perspective the scale of this facility:

1. Maine's annual hydroelectric generating capacity is 723 MW, compared to 7382 at LaGrande
2. The June outflow (1976-1985) of 14.5 cubic kilometers (KM^3)/month has been reduced to 7.0 KM^3./month (1996-2005). This reduction of 7.5 KM^3/month equals 102,129 cubic feet ($ft.^3$)/sec
3. The historic median flow in June on the Penobscot River at W. Enfield in Maine is 10,000 ft^3/sec
4. This June reduction in outflows from the LaGrande River into Hudson Bay would be analogous to eliminating 10 Penobscot Rivers flowing into the Gulf of Maine in June
5. The May reduction in outflows of 5.5KM^3/month would be analogous to eliminating 7 Penobscot Rivers flowing into the Gulf during May

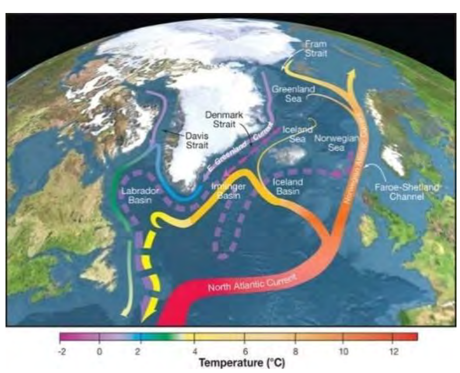
QUEBEC HYDROPOWER IS USING THE CAPTURED WATERS OF THE SPRING FRESHET TO INCREASE WINTER RIVER DISCHARGE THREE-FOLD

In a recent Canadian study of trends in river discharge from 1964-2013, the authors found: ***"that there has been a three-fold increase in river discharge during winter, when electric demand peaks, into the estuaries of Labrador Sea and Eastern Hudson Bay for the 2006-2013 period compared to 1964-1971 and a forty percent reduction in discharge during the summer."*** (*Recent Trends and Variability in River Discharges Across Northern Canada* Dery et. al. 2016).

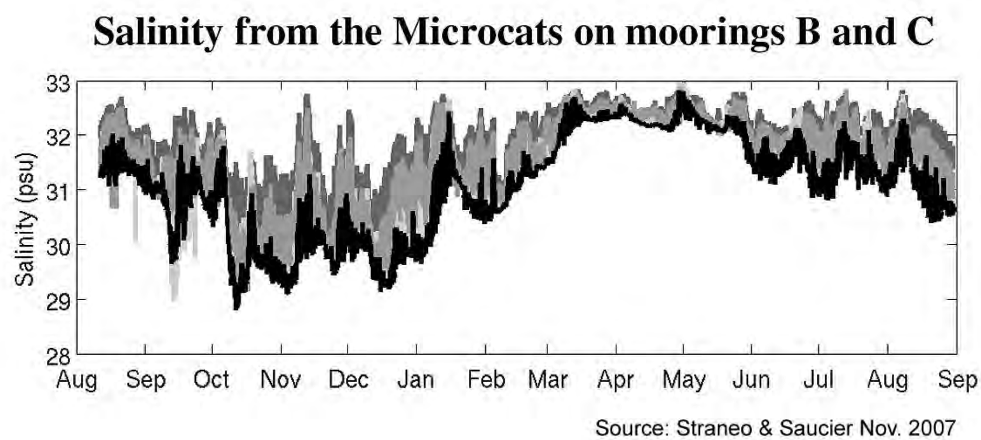
The earlier LaGrande Riverine Graph shows January-April outflows have been increased four-fold on average. Before reservoir hydroelectric facilities were built in Quebec and Newfoundland/Labrador (NL), the brooks, streams and rivers in these watersheds freely and naturally transported 80% of the annual budget of dissolved silica and other nutrients to the ocean.

The riverine spring freshet historically transported the majority of the annual load of silica and other nutrients into the Hudson Bay and eventually the Labrador Sea and Current via the Hudson Strait and then into the Gulf of Maine via the Labrador Current. These captured waters of the spring freshet are now being saved and historic summer generation reduced by forty percent in order to increase winter generation by threefold or more.

ATLANTIC MERIDIONAL OVERTURNING CIRCULATION



THE OUTFLOWS FROM THESE RESERVOIR DAMS ARE SO LARGE THAT SALINITY LEVELS IN HUDSON STRAIT ARE IMPACTED, AS SHOWN IN THE FOLLOWING GRAPH FROM A 2007 STUDY, THE OUTFLOW FROM HUDSON STRAIT AND ITS CONTRIBUTION TO THE LABRADOR CURRENT, BY STRANEO AND SAUCIER.



This graph shows the waters with the highest salinity flow past the moorings in the Hudson Strait during the mid-March through June period. Historically (pre-1970) this time period would have had the lowest salinity waters because of the high flows of the natural spring freshet flowing into Hudson Bay and then into Hudson Strait. This finding is another piece of evidence that these dams are starving the silica diatom phytoplankton of silica and other nutrients during the spring and summer.

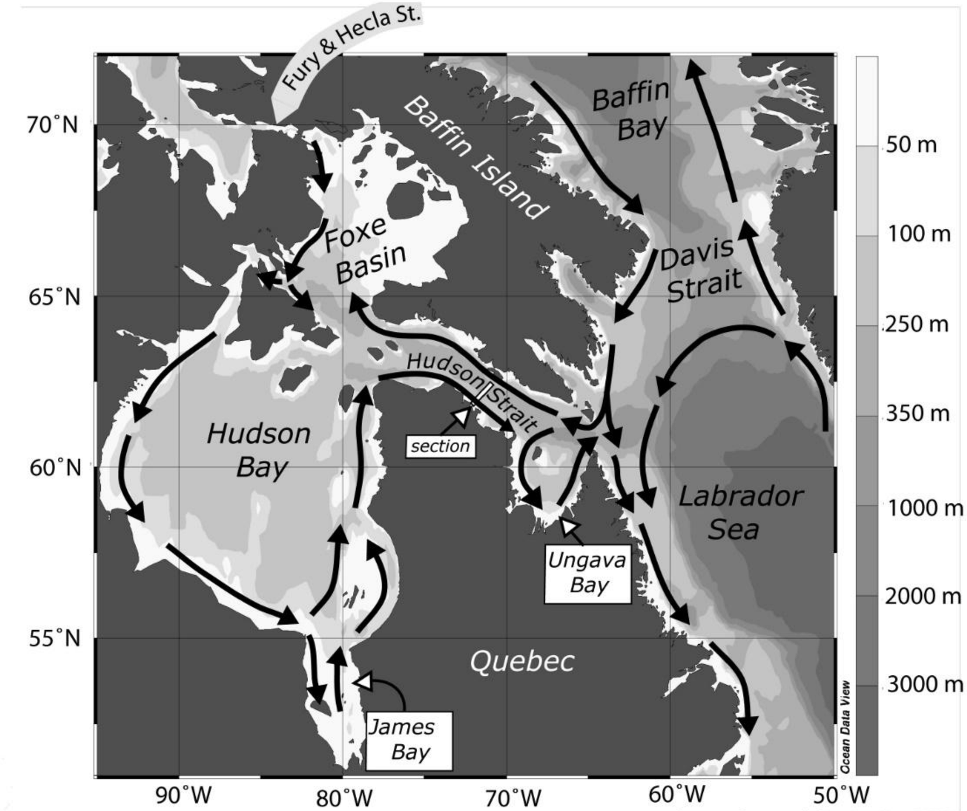
The threefold increase in winter discharge from the dams results in waters with the lowest salinity from mid-October through mid-January.

Straneo and Saucier wrote the following in their 2007 Report:

"Our results suggest that approximately 15% of the volume and 50% of the fresh water carried by the Labrador Current is due to Hudson Strait outflow. This is a striking new result, which suggests that we need to rethink the source waters for the Labrador Current and, in general, the fresh water pathways into the sub polar North Atlantic. They indicate that the role of Hudson Strait had been previously overlooked due to the absence of direct measurements from the Strait."

The surface area of water in Maine is only 4,537 square miles, compared to Quebec with 68,312 square miles and NL with 12,100 square miles. It is obvious that the Gulf of Maine is very dependent on the dissolved silica and nutrients transported by the rivers of these provinces during the spring freshet to fuel the Gulf's diatom phytoplankton blooms.

Hudson Bay System: bathymetry and schematic circulation



Source: Straneo & Saucier Nov. 2007

These blooms are the essential basis of the marine food web and their decline in both size and quantity are starving all the fisheries.

QUEBEC HYDROPOWER HAS SIGNIFICANTLY REDUCED SILICA AND NUTRIENT-ENRICHMENT ATTRIBUTED TO LAND BASED RUNOFF AND COASTAL UPWELLING IN HUDSON BAY AND LABRADOR SEA

"Most fisheries production world-wide is associated with three nutrient-enrichment processes: coastal upwelling, tidal mixing and land-based runoff, including major river outflow" (Caddy and Bakun, 1994).

"Many documented reductions in fisheries production have been attributed to river regulation, modifying natural variation in freshwater flow. Protecting natural flow regimes is likely to be an effective management strategy to maintain the production of estuarine and coastal fisheries" (Gillson, 2011).

Land based runoff has been significantly reduced as Quebec Hydropower manages it reservoir dams to capture the spring freshet and reduced summer outflows. Compounding this reduction in annual input of silica and other nutrients from land based runoff is the fact that nutrient enrichment from coastal upwelling is so limited in Hudson Bay.

The following was written in Bay Sys 2016 Mooring Program Cruise Report by Claire Hornby: *"The high riverine freshwater input in James Bay is causing a strong thermohaline stratification at the entrance to Hudson Bay,"*

and

"In Hudson Bay, a massive freshwater input by river runoff causes a strong stratification restricting upward nutrient flux into the surface layer and limiting phytoplankton production particularly in summer."

This is a double whammy negatively impacting the abundance of silica shelled diatom phytoplankton.

ABUNDANCE OF DIATOM PHYTIOPLANKTON HAS DECLINED

The results of a 2010 Study by Daniel Boyce using a 100-year data set concluded that the abundance of diatom phytoplankton had declined by 40% since 1950, and in a recent NASA study in "Global Biogeochemical Cycles," the authors have concluded the global diatom populations have declined by 1% per year from 1998 to 2012.

"Atlantic ocean plant life, the phytoplankton, has been observed to be in tremendous decline. International science teams have measured more than a 26% loss in the last 30 years. How bad is 26%? Remember when we destroy just 1 in 10 of any form of life we say that we have decimated that life. It's bad. Very bad. And the starvation and disappearance of Atlantic Cod stand as testimony to the collapse of the Atlantic Ocean pastures. Ocean pasture grass is plankton." (Russ 2014).

I offer the following analogy to help understand these spring blooms of the silicon diatom phytoplankton pastures and their dependence on the timely deliverance of this essential nutrient.

In the winter our lawns and fields are brown and barren. Spring heralds in more sunlight and the ground warms up. After the first rains deliver much needed nutrients to the lawns and fields, they seem to green up almost overnight. The farm animals begin grazing on the fresh and luscious grass, and the grasses begin transferring through photosynthesis carbon dioxide out of the atmosphere.

Out on the ocean, silica diatom phytoplankton are the pastures of the aquatic food web and one of earth's atmospheric thermostats for carbon levels. During late fall and through the winter these phytoplankton pastures are barren.

Spring heralds in more sunlight, and the oceans warm up. As the snow melts and rain falls on the landscape, the spring freshet begins to flow through our brooks and streams turning the rivers into a tumultuous roar.

These roaring waters are scrubbing silica, which is the second most common element, from the earth's crust.

Quebec Hydropower manages its reservoir hydroelectric generating facilities to capture the spring freshet. Spring discharges are now only 40% to 50% of historic (before reservoir damming) flows and silica diatoms are being starved of silica and other nutrients at this critical time of the growing season.

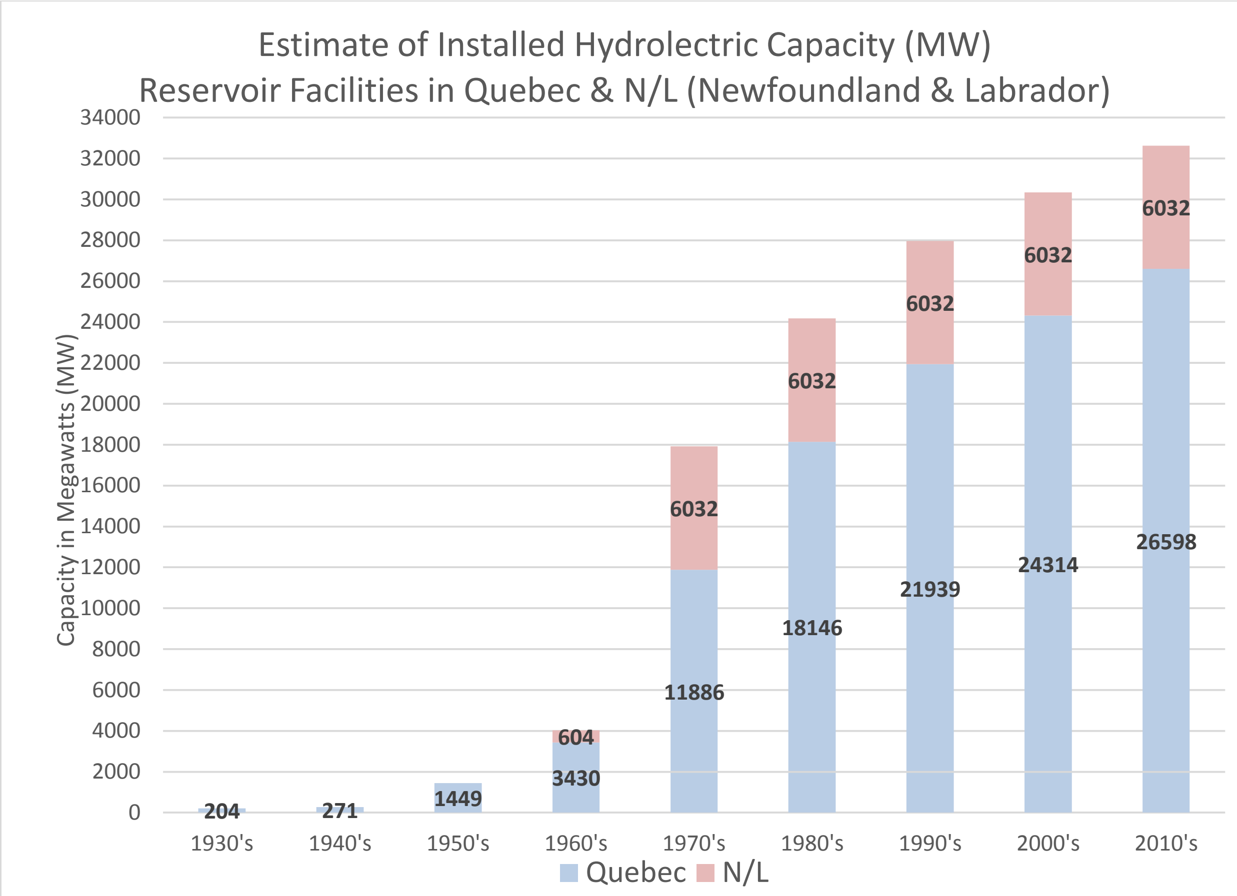
Starving the diatoms of silica means Quebec Hydropower's actions are starving the fisheries and maybe contributing to the increasing levels of carbon in our atmosphere.

Historically (thousands of years) if there was too much carbon in the atmosphere, then the atmosphere and oceans would warm up. This was followed by more evaporation and increased rainfall and snow, which resulted in roaring rivers transporting more silica to the oceans. This increased the size and abundance of silica diatom phytoplankton blooms, which provided more food for the fisheries and increased transference of carbon dioxide to the oceans. This, in turn, cooled off the atmosphere and oceans.

THE PROLIFERATION OF RESERVOIR HYDROELECTRIC FACILITIES OVER THE LAST FIFTY YEARS HAS PRODUCED A <u>LACK OF SILICA</u> WHICH HAS NEGATIVELY IMPACTED THE ABUNDANCE OF DIATOM PHYTOPLANKTON AND STARVED THE FISHERIES AND MAY BE CONTRIBUTING TO CLIMATE CHANGE

Quebec Hydropower not only built huge reservoir hydroelectric facilities throughout Quebec, but also built the 5,428 (MW) Churchill Falls Generating Station in Newfoundland and Labrador (NL).

The graph below illustrates how the annual capacity in MW's from Quebec Hydropower's reservoir hydroelectric facilities increased by 450 percent from 4,034 MW in the 1960's to 17,918 in the 1970's. and by another 200% in the 2010's to 32,630 MW.



Earlier I used an analogy to show how the reduction in May and June outflows from the LaGrande facilities is equivalent to eliminating 7 Penobscot Rivers flowing into the Gulf of Maine during May and 10 Penobscots flowing into the Gulf in June.

The LaGrande facilities have 3 reservoir facilities and one Run of the River, and their total annual capacity is 8,738 MW.

The graph above shows a total annual capacity for reservoir facilities of 32,630 MW.

It would not be unreasonable to estimate that the reduced May and June outflows from these facilities would be the equivalent of eliminating 26 (7 Penobscots x 32,630 MW ÷ by 8,738 MW) Penobscot Rivers flowing into Gulf during May and 37 in June.

These estimates are conservative as I did not include, in the above graph, facilities in Manitoba and Ontario.

THE CUMULATIVE EFFECT OF FIFTY-PLUS YEARS OF REDUCED ANNUAL INPUT OF DISSOLVED SILICATE FROM ALL THESE DAMS IS DESTROYING BOTH THE FISHERIES AND ECOSYSTEM OF GULF OF MAINE

The following quotes from a scientific report, *Hydrological Alterations and Marine Biogeochemistry: A Silicate Issue?*, by Ittekkat et. al. (2000) describes some of the processes that are responsible for the decline we are seeing in the ecosystem and fisheries of Gulf of Maine and Northwest Atlantic.

"Freshwater and sediment inputs from rivers play a major role in sustaining estuarine and coastal ecosystems. Nutrients from rivers promote biological productivity in estuaries and coastal waters . . . and help to maintain ecosystems along the periphery of land masses."

"Most studies addressing the causes of eutrophication have concentrated on the elements nitrogen and phosphorus, mainly because both these nutrients are discharge by human activities. Silicate, however, also plays a crucial role in algal growth and species composition."

"The source, transport and sink characteristics of silicate, as they relate to change in the hydrology of rivers, are distinct from those of nitrogen and phosphorus. Large-scale hydrological alterations on land, such as river damming and river diversion, could cause reductions of silicate inputs to the sea (Humbug et al 1997). By contrast, although all nutrients (nitrogen, phosphorus and silicon) get trapped in reservoirs behind dams, nitrate and phosphate discharged from human activities downstream of the dam more than make up for what is trapped in reservoirs, for silicate, there is no such compensation. The resulting alteration in the nutrient mix reaching the sea could also exacerbate the effect of eutrophication—that is, silicate limitation in perturbed water bodies can set in much more rapidly than under pristine conditions, leading to changes in the composition of phytoplankton in coastal waters."

QUEBEC HYDROPOWER'S RESERVOIR FACILITIES AND OPERATIONS ARE INCONSISTENT WITH MAINE'S NATURAL RESOURCES PROTECTION ACT

The proliferation of large reservoir hydroelectric dams by Quebec Hydropower over the last 50 years never would have been allowed in Maine because the construction and management of these dams would have violated Section 401 of the Clean Waters Act and Maine's Natural Resources Protection Act.

To put this in perspective, Quebec Hydropower has 66 hydropower generating sites, and 38 are Run of River with a total capacity of 11,100 megawatts (MW), and 28 are reservoirs with a total capacity of 26,800 MW.

Maine's annual hydropower generating capacity is only 723 MW.

Quebec Hydropower's reservoir facilities have basically eliminated the spring freshet on these rivers by capturing and storing the spring run-off.

This would be an act of pollution on Maine's rivers under the Clean Waters Act, because the storage of these free-flowing cold waters has reduced by 40% to 50% the historic and natural delivery of the annual budget of dissolved silicate to the Gulf of Maine via the waters flowing through the Hudson Strait and the Labrador current.

In 2006, the Maine Department of Environmental Protection (MeDEP) and S. D. Warren argued before the U. S. Supreme Court over whether S. D. Warren was polluting the Presumpscot River and violating Section 401 of the Clean Water Act (CWA), because it was using too low a minimum flow during hot summer months.

MeDEP argued that dissolved oxygen levels were too low in the river downstream of the Eel Weir Dam and a higher flow was needed to provide more dissolved oxygen for aquatic life.

The Supreme Court agreed with MeDEP in a 9 to 0 decision, and Justice Souter wrote "***The decision interprets term "discharge" according to its "ordinary and natural meaning"*** and rejects efforts by S. D. Warren to have the Court read into CWA Section 401 any requirement that the regulated activity result in the ***"addition of a pollutant."***

In other words, holding back clean water laden with dissolved oxygen was polluting downstream water, which did not have enough dissolved oxygen to support the river's fisheries and aquatic life.

Furthermore, the construction of these reservoirs have not only flooded and eliminated the functions and values of hundreds of thousands of acres of wetlands, but have also captured the cold and free-flowing water of thousands of miles of brooks, streams and rivers in these reservoirs, along with the dissolved silica, which was being transported in the spring freshet by these once naturally free-flowing water bodies.

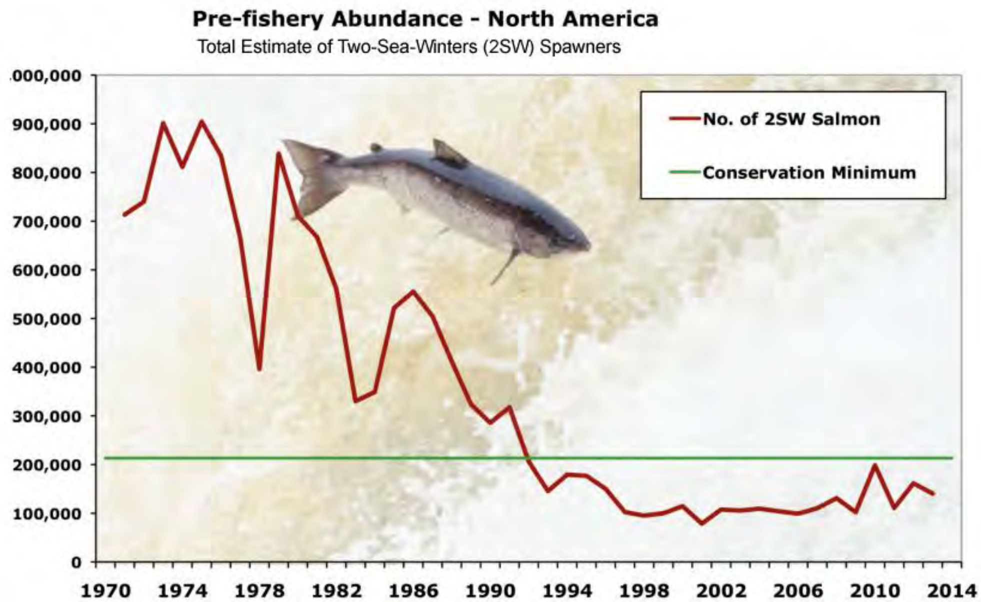
Quebec Hydropower's reduction of spring and summer outflows is polluting Hudson Bay, Labrador Sea and the Gulf of Maine by depriving the silica encased diatom phytoplankton population of its much needed dissolved silica during its growing season.

Diatoms are algae cells enclosed with cell walls made of silica, and their growth rate and size are determined by the availability of dissolved silica and the temperature of the water. In March, with more daylight hours, the diatom population increases its rate of photosynthesis enabling it to start dividing and multiplying into a healthy diatom bloom and the more silica, the bigger the diatoms and bloom.

These reservoirs prevent the cold natural waters of the spring freshet from reaching the coastal estuaries, and these retained waters are then exposed to "aging" as the water temperature quickly rises and changes in its biochemistry occur before being discharged from the dam.

The Gulf of Maine is one of the most important oxygen producing ocean "rain forests" in the world, and its diatom rich ecosystem is responsible for superior fisheries, ameliorating ocean acidification and regulating climate change. The cumulative effect and the proliferation of reservoir hydropower in its ecosystem are destroying it.

QUEBEC HYDROPOWER RESERVOIR FACILITIES ARE NOT ONLY STARVING THE SILICA DIATOM PHYTOPLANKTON POPULATION, BUT ALSO THE ATLANTIC SALMON FISHERY (SEE GRAPH BELOW)



Pre-fishery Abundance (PFA) graph for North American 2SW salmon showing the total number needed to meet the total Minimum Conservation Limit in North American rivers in green (corrected for 11 months of natural mortality). The PFA numbers are those 11 months before they return to their home rivers in North America.

Source: Atlantic Salmon Federation 2015

IT IS NO LONGER A QUESTION OF MAY!

There were early warning signals that the proliferation of these reservoir hydroelectric facilities may have a negative impact on the food chain in the northwest Atlantic and Gulf of Maine.

Sutcliffe et. El. (1983) hypothesized that reducing the spring freshet by hydroelectric regulation in the Hudson Bay area may affect northern cod populations along the Labrador coast.

The following was written in a 1998 Canadian study:

a. ***"Hydroelectric development on major rivers is seasonally altering the physical structure of the water column in coastal waters,"*** **and** ***"the implications of these hydro developments on the marine environment are not fully understood."*** **(Harding 1992)**
b. ***"Hydroelectric development has markedly reduced this spring run-off, and this may be enough to delay the phytoplankton bloom and thereby shorten an already brief growing season for larvae fishes and benthic invertebrates." (*****Morin et al. 1980)**

THE GULF OF MAINE AND CHINA SEA ARE WARMING AT AN ALARMING RATE, AND NOW THERE IS ANOTHER AREA

The countries who are the biggest producers of hydroelectricity are warming their nearby oceans**.** The Gulf of Maine and South China Sea are two areas in the global ocean, which are warming the fastest, and they are located next to the two largest producers of hydroelectricity in the world. Number one is China, and number two is Canada. Quebec Hydropower is Canada's largest producer, and it's warmer than natural discharge waters flow via the Labrador Current into the Gulf of Maine.

The third area is Barents Sea, and scientists say *"changes are so sudden and vast that in effect, it will soon be another limb of the Atlantic, rather than a characteristically icy Arctic Sea."* The Barents Sea is being impacted by Norway and Russia, which are the 5th and 6th largest producers of hydroelectricity in the world.

The water impounded by these large reservoirs is heated by the sun, and the discharged water from the impoundment is much warmer than the natural free flowing water upstream of the reservoirs. The temperature of the Gulf of Maine's waters is responding to the cumulative impact of more and more reservoir hydropower generation sites being built in the past fifty years. Since 1969, Quebec Hydro has built 22 reservoir hydropower dams, which is almost one every other year.

Since 1986, the area of the under ice plume from the LaGrande River has trebled and can extend 100 KM (62 miles) under the land fast ice of James Bay in the Hudson Bay (Roche 2017). Plumes of this magnitude, with warmer than natural flowing waters, could be contributing to thinner and weaker ice in the impacted area.

MORE CARBON IN THE AIR

The reduction in both the size and abundance of diatom phytoplankton blooms have contributed to the increased carbon in the air by significantly reducing the natural transference of carbon dioxide from the atmosphere to the ocean.

Mighty Diatom

(silica shelled phytoplankton)

The mighty diatoms are the microscopic plants that dominate all other ocean species in converting carbon dioxide to carbon and releasing oxygen.

"Diatoms are at the bottom of the food chain and suck up nearly a quarter of the atmosphere's carbon dioxide . . . Size matters for the creatures that eat them and also for carbon sequestration, as large diatoms are more likely to sink when they die . . . If smaller sized diatoms dominate, then carbon sequestration becomes less efficient and there may be more carbon dioxide in the atmosphere, which would exacerbate global warming" (Litchman et. al.2000).

Here in Maine, we criticize those that irresponsibly bring destruction to the world's oxygen producing forests, and yet we are fully complicit in policies that diminish the freshwater delivery of the critical necessary nutrients like silica to our own "ocean rain forests."

The proliferation of reservoir hydroelectric facilities on Quebec's major rivers has greatly altered the seasonal timing of silica-laden freshwater quantities delivered to Hudson Bay, Labrador Sea and eventually the Gulf of Maine. The diatom plankton ecosystems have not evolved to be starved of nutrients in the spring and summer and then fed nutrients under lower light and temperature conditions in late fall and winter. As a result, diatom population is adversely affected, and the rest of the food chain is starving and the percent of carbon dioxide in the atmosphere is increasing.

Quebec Hydropower's management is contrary to the good science found in the conclusion of a 2004 scientific report Lost to the Tide: the Importance of Freshwater Flow to Estuaries, by University of Rhode Island oceanographer Scott Nixon, et. al;

1. ***" Realization that fresh water serves an important ecological function in estuaries means that all engineering interventions in the flow of water to the coast should be looked at very carefully to see if diversions are really necessary and to see if releases from storage can be programmed to parallel the natural pattern as closely as possible."***
2. ***"It is important to understand that the freshwater that reaches the coast plays an important role in sustaining the productivity of estuarine ecosystems, which are also very important to people. Maintaining the flow of fresh water to the coast should be a consideration in fresh water management decisions."***

Mr. Jonathan Gilson wrote the following in a 2011 Report, in which, he referenced 217 Reports to support his conclusions:

"Episodic flood and drought events have pronounced impacts on fisheries production due to rapid change in physicochemical conditions modifying species richness and diversity. Many documented reductions in fisheries production have been attributed to river regulation modifying natural variation in freshwater flow. Protecting natural flow regimes is likely to be an effective management strategy to maintain the production of estuarine and coastal fisheries."

CONCLUSION

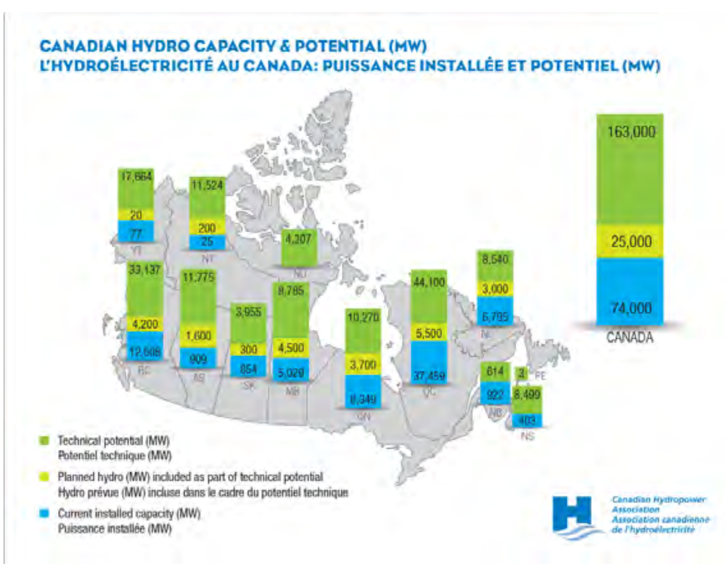
Let's put some of the above observations in layman's terms. It would be declared an extreme drought by meteorologists if total spring and summer precipitation was forty percent below normal. If it happened for fifty continuous years on land in the northern latitudes, the people would have starved to death. In the ocean waters of Newfoundland, Labrador and Maine, the fisheries are being starved to death.

For the past fifty years, a three-fold increase in river discharge of these warmer than normal reservoir waters (mid-thirty degree Fahrenheit) during the three months of winter represents a deluge of biblical proportion to the frozen seas. There are thousands of reservoir hydroelectric facilities throughout the northern latitudes operating in a similar manner.

The cumulative impact is predictable! Since the start of regular satellite observations in 1979, there has been an overall decline in Arctic sea ice in the past forty years. However, total sea ice in the Antarctic has increased by one percent per decade. Is this deluge of warmer than natural discharged waters a key factor in the decline of Arctic sea ice?

This Report has documented how the building and management by Quebec Hydropower of its reservoir hydroelectric facilities has captured the spring freshet and reduced the historic transport of dissolved silica. These actions are the driving force in the starvation of the fisheries and may be contributing to increase carbon levels in the atmosphere. Canada has ambitious plans to build many more reservoir facilities, which will only exacerbate the problem and may prove to be the tipping point.

MAP OF EXISTING AND FUTURE FACILITIES



Reject CMP Power Line Because Hydro-Quebec Facilities Damage Ecosystem

I am publicly writing to ask Maine's Department of Environmental Protection (MeDEP) to deny a permit for the 145-mile transmission corridor proposed by Avangrid-CMP to carry hydroelectricity generated by Quebec Hydropower from Canada to Massachusetts because Quebec Hydropower reservoir hydroelectric facilities are starving the fisheries in the Gulf of Maine and warming its waters.

In a recent 2016 Canadian study of trends in river discharge from 1964-2013, the authors found: that there has been a three-fold increase in river discharge during winter , when electric demand peaks, into the estuaries of Labrador Sea and Eastern Hudson Bay for the 2006-2013 period compared to 1964-1971 and a forty percent reduction in discharge during the summer. (*Recent Trends and Variability in River Discharges Across Northern Canada* Dery et. Al. 2016).

Let's put these findings in layman's terms. It would be declared an extreme drought by meteorologists if total spring and summer precipitation was forty percent below normal. If it happened for fifty continuous years on land in the northern latitudes, the people would have starved to death. In the ocean waters of Newfoundland, Labrador and Maine, the fisheries are being starved to death.

For the past fifty years, a three-fold increase in river discharge of these warm reservoir waters (mid-thirty degree Fahrenheit) during the three months of winter represents a deluge of biblical proportion to the frozen seas. There are thousands of reservoir hydroelectric facilities throughout the northern latitudes operating in a similar manner.

The cumulative impact is predictable! Since the start of regular satellite observations in 1979, there has been an overall decline in Arctic sea ice in the past forty years. However, total sea ice in the Antarctic has increased by one percent per decade. Is this deluge of warmer than natural discharged waters a key factor in the decline of Arctic sea ice?

The proliferation of large reservoir hydroelectric dams by Quebec Hydropower over the last 50 years never would have been allowed in Maine for the following reasons:

1. The construction and management of these dams would have violated Section 401 of the Clean Waters Act and Maine's Natural Resources Protection Act.
2. These dams are starving the fisheries of Hudson Bay, Labrador Sea and the Gulf of Maine, by reducing the transport of the annual budget of dissolved silicate during spring freshet to silicon diatom phytoplankton, which is the essential basis of the marine food web.

Attachment 1

Page 1

3. The reduction in diatom phytoplankton blooms have increased carbon in the air by significantly reducing the natural transference of carbon dioxide from the atmosphere to the ocean.
4. These reservoir dams are warming the waters of the Hudson Bay, Labrador Sea and the Gulf of Maine by capturing the spring freshet behind these dams and holding these waters to maximize hydropower generation during peak demand in the winter months.

If a permit is issued, it should be conditioned on Quebec Hydropower changing the management of their reservoir facilities to a Run of River mode, which uses the natural flow of the river. This would help restore large silicon diatom phytoplankton blooms to feed the fisheries and increase carbon dioxide transference from the atmosphere to the ocean. It should also help reduce the warming of the waters of Hudson Bay, Labrador Sea and the Gulf of Maine.

> *"Half of the Gulf of Maine's ecosystem lies in Canada, where much of the water feeding the Gulf and affecting its temperature comes from*," was written by Colin Woodward in 10/15/15 Maine Sunday Telegram article.
>
> Quebec Hydropower's reservoir facilities have eliminated the spring freshet on these rivers by capturing and storing run-off.

The proliferation of reservoir hydroelectric facilities on Quebec's major rivers has greatly altered the seasonal timing of silica-laden freshwater quantities delivered to Hudson Bay, Labrador Sea and eventually the Gulf of Maine. This would be an act of pollution on Maine's rivers under the Clean Waters Act.

The diatom plankton ecosystems have not evolved to be starved of nutrients in the spring and summer and then fed nutrients under lower light and temperature conditions in late fall and winter. As a result, diatom population is adversely affected, and the rest of the food chain is starving and the percent of carbon dioxide in the atmosphere is increasing.

It is time to recognize that there may be a key regional factor starving the fisheries and warming Hudson Bay, Labrador Sea and the Gulf of Maine. If the fisheries are starving in all these waters, then the obvious place to look is the food chain.

Stephen M. Kasprzak

Attachment 1
Page 2

Science abandoned, scientists muzzled

ANDREA HILL
POSTMEDIA NEWS

OTTAWA — The federal government "really doesn't grasp what science is about" and could be unable to respond to adverse environmental changes because it has abandoned research into climate change and water pollution, say scientists interviewed for CBC's The Fifth Estate.

"What we have done in Canada is turned off the radar. We are flying along in an airplane and we put curtains over the windshield of those pilots of that flight crew and we've turned off the instruments," former government scientist Peter Ross says in the episode Silence of the Labs, which airs Friday night.

"We don't know what is coming tomorrow, let alone next year, in terms of some of these potentially catastrophic incidents."

The scientists said Prime Minister Stephen Harper's government has cut funding of pure science and is instead spending on projects that benefit industry and commerce.

Meanwhile, scientists are being restricted from talking to media and all messaging goes through "a spin machine."

After years of not being allowed to talk to media, Ross's department was terminated last spring because its work was deemed no longer important.

"My ability to convey important findings to the general public, to the electorate, to the taxpayer, had been severely curtailed," said Ross, a marine mammal toxicologist who once gave frequent media interviews about contamination in Canadian waters, wildlife and among northern people.

In 2008, Postmedia News — then Canwest News Service — obtained internal government documents that outlined how Environment Canada was muzzling its scientists by requiring all media inquiries be sent to Ottawa, where communications specialists would help scientists develop approved messages.

"Just as we have 'one department, one website' we should have 'one department, one voice,'" an Environment Canada PowerPoint presentation reads.

Postmedia News has uncovered other examples of scientists being silenced.

Documents obtained under access-to-information law showed that fisheries scientist Kristi Miller was forbidden to speak to media in January 2011 after she published a landmark study about the decline in farmed salmon in the Fraser River. Similarly, ozone scientist David Tarasick was not given approval to talk to reporters about a study he published on an Arctic ozone hole in the fall of 2011.

Additionally, an Ottawa Citizen investigation in spring 2012

Additionally, an Ottawa Citizen investigation in spring 2012 showed U.S. government contributors to a study on snowfall pattern were happy to speak to reporters, while Canadian government scientists working on the same study could not talk. Instead, 11 government employees spent a day emailing back and forth to agree on "approved" lines that did not directly address the paper's questions.

"They're feeding the public a bunch of hogwash and I think most people would accept that you can't run a democracy and make it function on a public informed with B.S.," former government scientist David Schindler told the CBC.

Information commissioner Suzanne Legault confirmed in the spring she is investigating whether the government is breaching access-to-information law by restricting what its scientists can say.

The Leader Post. Jan 10, 2014

MPs panel to probe allegations fisheries scientists were silenced

A panel will question officials with the aim of preventing mismanagement blamed for the collapse of fish stocks.

CANADIAN PRESS

HALIFAX — A parliamentary committee has launched an investigation into policies and practices in the fisheries and oceans department after repeated allegations that scientists are muzzled and their work is tainted by politics.

The Commons fisheries com-

House of Commons without fear of retribution."

Baker's announcement came after months of controversy over leaked documents and a scientific journal article indicating fisheries science was moulded to suit a political agenda before stocks collapsed in 1992.

Between 37,000 and 41,000

Fisheries probe

The background: Allegations in a published article by scientists allege they were muzzled and their work is tainted by politics.

What's happening: The Commons fisheries committee has decided to

What's planned: Hear-

Vancouver Sun Nov 1, 1997

James Bay seen as test on environment

OTTAWA (CP) — The man in charge of assessing the environmental impact of Quebec's massive James Bay hydroelectric project admitted Wednesday no one is sure just what its impact on the environment will be.

"We are seeing this project as an experience to see what will happen," Alain Soucy said in an interview. "We have about $100 million to spend over the next three years on remedial action, though."

The head of the James Bay Energy Corporation's environment department said that even if there were severe environmental problems caused by the project it would not be curtailed.

"We can't change the scale of the project or it will not work," he explained.

Since the James Bay hydroelectric project was announced in 1971 environmentalists have been worried about its effects.

In 1973 engineer-scientist Hans Neu of the Bedford Institute in Halifax said the project may even affect the climate of the Maritimes.

contends that if the disease spreads to Canada it would jeopardize sales of semen from Canadian bulls to Australia, a major sheep producer. Semen sales to Australia earned Canada $2.5 million in 1974.

The cattlemen's association, representing most U.S. livestock producers, says the Canadian tests are a form of discriminatory trade practice.

Bill MacMillan, executive vice-president of the association, said in an interview he pressed the agriculture department to undertake random tests because he is convinced bluetongue, which can be spread by gnats, exists in Canada to the same extent as in the U.S.

He said the extensive testing done by Canada means a delay in delivery of about 60 days for some feeder cattle destined for export, making the trade uneconomical.

"I don't think the United States government should take the word of the Canadian government, considering all the problems we've had in the past," he added. He was referring to a restriction originally placed by Canada on U.S. cattle fattened with the growth hormone diethylstilbestrol (DES), potentially a cancer causing substance. Ottawa insisted that incoming U.S. cattle be certified free of the hormone.

Afterwards, Canada imposed import quotas on livestock and the U.S. retaliated with broader controls. The restrictions were lifted New Year's Eve

6 of 33

Star Phoenix Jan 8, 1976

Dams stop nature's ways on mighty rivers

By Bruce Little
(Southam News Services)

DARTHMOUTH, N.S. — Protests over the environmental effects of huge power dam developments usually focus attention on what happens to the land above the dams that will be drowned in water.

Apart from that, an energy-hungry world tends to see hydro projects as a source of power that is clean relative to nuclear reactors and oil-fired thermal generators.

Hans Neu does not go along with that assessment. He is an expert in hydrology at the Bedford Institute of Oceanography here and he feels hydro power may be far dirtier than most people realize.

Instead of looking upriver for the effects of a dam, Neu looks at the ocean into which the river waters eventually spill.

In his view, well-dammed rivers like the Manicouagan in Quebec, have given man the power to alter drastically the alter the entire ecosystem and the Atlantic coast.

His theories start with the hydrological cycle in which ocean waters evaporate, rise into the atmosphere and return to earth again inland in the form of rain that feeds the lakes with water.

In a southern climate, the process is continuous. But in the north, nature comes almost to a halt in the winter and doesn't need the water. Nature's solution is to store the water in the form of snow.

As a result, the flow of water from rivers to the sea falls off in the winter. In the spring, at the beginning of what he calls Canada's "very short but very strong biological activity season", the water is released.

It is nature's design to provide as much water as it can just at the time it is needed most. Before dams were built, water flows from the St. Lawrence, into which the Manicouagan drains, rose to an immense peak in the spring, more than three times the level of winter.

This is where the other half of Neu's theory comes in.

As the fresh water of the St. Lawrence tumbles into the Gulf, it acts as a pump on salt water, drawing in salt water from the sea through deep gorges and pulling it up to mix with the new water on top.

This churning of the deep-running salt water brings to the surface the nutrients from near the ocean floor which fish and other forms of life need for food.

PROVIDED FOOD

The relationship of the two systems meant that the strongest flows of water, coming as they did in the spring, helped bring near the surface abundant quantities of food and nutrients.

But the daming of rivers has changed that neat interaction.

Instead of letting all that power-producing water in the spring go to waste, engineers have built huge storage lakes behind the dams that can hold the water until the following winter. Then it can be released to create power when the normal river flows would be small.

The result of these storage lakes is a flattening of the wide swings in the flow of rivers. And that means more nutrients in the Gulf are brought up in the winter, when they are needed least, while fewer nutrients are supplied in the spring and summer, when they are needed most.

Manicougan River dams cut the flow of the St. Lawrence River by as much as one-third in the spring, according to Neu's research, and he is worried that it could produce a stagnant Gulf.

Coming events

Announcements appearing in the Coming Events column are charged $2.35 for the first 25 words or less and 40¢ for each additional five words or portion thereof.

★ ★ ★

NO Shangri-La Bingo at the German Canadian Club on Monday, Feb. 25. T0796U

★ ★ ★

PLAN to attend the North Hill Eagles No 3473 Marathon Bingo March 9th at

Bingo every Tuesday 7:45 p.m. CLPH Hall, 425 - 4th Ave. N.E.

★ ★ ★

Montgomery Bingo 3583 - 16 Ave. N.W. every Wed. 7:45 p.m. $10 and $15 games, 4 jackpots and bonanza game.

Announcements

5 Births

McGINLEY — Patrick and Margaret (Daly) are happy to announce the arrival of Pauline Margaret on February 5. U9720J

WUDRICH — Emil and Valerie are pleased to announce their first arrival on February 4th, a daughter Tanya Lee, 8 lbs. 11 oz. Many thanks to Dr. McQuilty and Dr. G. Brown and staff at Foothills Hospital. U[illegible]

CALGARY HERALD Feb 25, 1974

Research shows Canada's dams are salmon's doom

You otherwise excellent front-page articles ("Outlook bleak for wild salmon, scientist fears" and "Threatened species take centre stage," June 9) missed several crucial causes of salmon and sturgeon declines. Also, biologist Wilfred Carter makes it sound like there's no relevant research, when in fact Canadian government scientists have been muzzled by their director general on this issue for some time. Plenty of research is already public, though.

Scientists in Russia and the U.S. have shown much of the fault for collapsed sturgeon stocks in the Caspian Sea and elsewhere belongs to blocked migration routes and destroyed spawning and nursery sites caused by water "development" schemes.

Dams and power stations do more than block migrating salmon; they:

1. kill smolts (baby salmon) coming through power-plant turbines on their way to the sea from spawning grounds;

2. destroy spawning grounds and habitat through diversion flooding and drainage;

3. cause migrating fish to get "the bends" from nitrogen bubbles whipped up by power station turbines;

4. kill fish by increasing the temperature of the rivers;

5. destroy coastal nursery habitat by depriving these areas of the freshwater flows from inland — flows that provide oxygen and nutrients, that clean pollution, and that keep the delicate salt balance right for developing salmon at the coasts.

Little-known outside aquatic science, freshwater runoff is crucial to healthy fisheries. Dr. Michael A. Rozengurt and his colleagues have shown a real physical threshold for safely blocking runoff from fish: No more than 25 per cent of this freshwater flow to the sea can be blocked before fisheries are doomed to an inevitable decline. In the U.S., the former Soviet Union and elsewhere, the story's the same. Canadian oceanographer Hans Neu has shown we've already got the world's highest rate of blocked freshwater flow. For his trouble in trying to alert the federal government to this research he was virtually run out of his job at the Bedford Institute.

Wilfred Carter is wrong: There is lots of research from Canada, from the U.S., from all over — we don't need too much more. In point of fact, Canada has some of the best, if unsung, scientists working on this issue.

Hydrologist Bob Newbury is helping restore Scottish salmon stocks in Scotland. He believes that dams are a relic of the past and have outlived their usefulness. State-of-the-art river management in the U.S. and Australia is seeing the decommission of dams to save fisheries. Yet Canada drags its feet.

Our federal and provincial governments court disaster by reopening the Atlantic salmon fishery while promoting more dams on the lower Churchill River. Dam that river, cut more flow, reopen the fishery, and we doom the whole salmon fishery to oblivion.

There are alternatives. Conservation and renewable-energy technology investment will provide jobs. A continued moratorium on our salmon runs for the near future, and legislation to protect and guarantee 75 per cent freshwater flow to each river and basin will protect our stocks.

We can learn from the mistakes and knowledge of other countries. If governments and utilities just listen and act, we won't have to say goodbye to our salmon and all that they support.

Dianne Murray, co-ordinator
Dam-Reservoir Working Group
Ottawa

Letters to the Editor

WINDSOR STAR MAR 5, 1974

Environment Studies Lacking

HALIFAX (CP) — Dr. J. S. Nelson, president of the Canadian Society of Environmental Biologists, says the Canadian government has not called for a single environment study at the outset of any major development.

Dr. Nelson suggests biologists should be involved in studies for major developments just like engineers.

He told a conference of the Canadian committee on freshwater fisheries research that his organization proposes to become the environmental conscience for Canada.

"We're upset that anyone can claim to be an ecologist and hire themselves out. We see all sorts of incompetent studies done."

Hans Neu, an engineer-scientist with the Bedford Institute near here, said the environment is becoming another business . . . "a political football."

He told a symposium of about 60 scientists from across Canada that "we have to take a closer look at the environment before we continue exploitation."

Mr. Neu said control of nature has been exerted in the Gulf of St. Lawrence by the growing number of hydroelectric power dams.

By holding back the natural springtime flow of river water, he said, the mixture of fresh and salt water in the gulf was altered. Nutrients were reduced, the water temperature, marine life and climate changed.

Spring run-off in the gulf was vital but that the runoff now was largely regulated for power purposes.

He called on the scientists to find ways of determining the total cost to the environment of massive engineering projects.

"I place a lot of these responsibilities on your doorstep . . . to advise government agencies what shall be done to cause the least damage."

Golda Meir's Paris Trip Labelled Ill-Timed

PARIS (Reuter) — A decision by Israeli Premier Golda Meir to attend the Socialist International congress here is a loose organization of Democratic Labor and Socialist parties whose avowed aim is to unify the policies and aernment to Mrs. Meir's decision as vice-president of the Socialist International to visit here Jan. 13 and 14, but La

Ottawa Journal Oct 26, 1971

RUNNING ON EMPTY: THE DISTORTION OF COASTAL ECOSYSTEMS

Michael A. Rozengurt
County Sanitation Districts of Orange County, California

Abstract

Among numerous coastal embayments estuaries occupy special places whose immense influence on the adjacent marine environment and fisheries has been recognized by mankind since time immemorial. By definition, **estuaries are intermediate, dynamic, and cumulative links within the river-delta (estuary)-sea ecosystems where continual variable confluence, interaction, and mixing between river and sea takes place.** These processes result in development of four, specific zones of mixed water masses. In accord with the Venice International classification of 1958, they are typified by a strictly defined range of salinity, and other chemicals, and biological characteristics. As is known, the average salinity concentration of 5 g/L is a natural barrier for strictly estuarine species at early stages of their development within the avant-delta zone, the latter confined by 0.1 to 0.5 g/L salinity from the deltaic side.

These and other natural combinations of regime characteristics, developed under an umbrella of unimpaired runoff, have provided for the unique diversity and highest biological productivity of organisms directly or indirectly through food webs related to estuarine systems. But when the impoundment of watersheds has become fully operational, the river-coastal continuum has been mortally wounded, and fisheries have started to fade away since that time (Rozengurt, 1971, 74, et al., 1985).

For over the past two decades, the public perception has been that discharges treated wastewater into estuarine-marine environment was the major cause of their progressive impoverishment. Although some pollutants might have had measurable, progressive effects on the health and reproduction of living resources, the lack of sound scientific information on the more serious effect of the river impoundment on coastal systems has led many to mistakenly believe that more treatment or even "distilled" or "zero" discharges will restore the fishery. As a result, about $200- out of $541 billion were expended over the last two-three decades on pollution control to supposedly remedy the obvious depletion of fish and shellfish stocks. Despite this enormous cost and drastic improvement of treatment processes and the implementation of stringent water quality and fishery regulations (Clean Water and Magnuson Acts), the despoliation of coastal resources and economic losses has continued to persist.

It appears that the systemic depletion of river runoff over the same decades by numerous dams, water storage and the network of water conveyance facilities have had many times higher direct impacts on the aggravation of the regime and biota of the ecosystems in question than effluents (Rozengurt and Haydock 1981, 1993, 94). Ironically, in the Southern California Bight, the submerged ocean outfalls discharging at a distance of three to seven miles from the shore, at a depth of 60 meters are the closest to being a fresh water source, as over 150 rivers and streams of the Bight's watershed have ceased to exist due to impoundment. As a result of the latter, sport fishery has been rendered insignificant, kelp bed have declined, and over hundreds of miles of beaches have experienced inexorable erosion. This combined with other examples of ecological

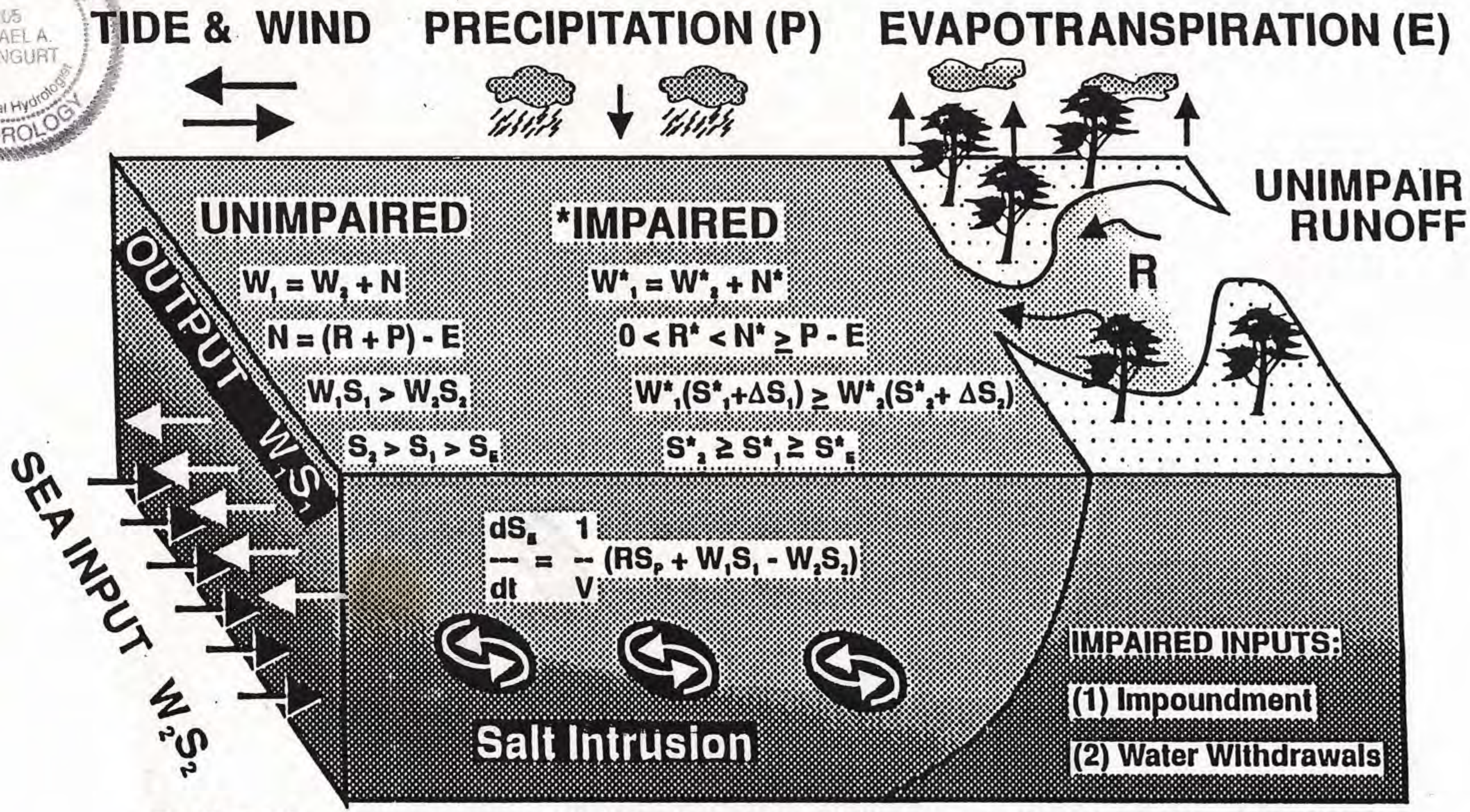
deprivation of the Nation's coastal embayments (Columbia River Estuary, San Francisco Bay, Colorado River Estuary, Gulf of Mexico, Chesapeake Bay, etc.) provide strong support to the statement that river runoff was, is and will continue to be the ultimate, intrinsic guarantee of estuary-coastal systems survival. The pragmatic manifestation of this statement is based on the universality of the Laws of Thermodynamics, which govern the paths and control the runoff energy distribution and dissipation along the river course (Fig. 1). Note that the basic principles of river hydraulics and estuarine hydrodynamics are derivatives of the laws of conservation of mass and energy. The three major equations: (1) motion of water, (2) continuity of volumes of water exchanged between an estuary and sea, and (3) continuity of salt balance describe how these principles control the estuarine regime. Their solutions together with the results of a statistical analysis of stochastic, seasonal and perennial behavior of unimpaired runoff characteristics provides ample evidence that the lesser the runoff, the greater is the salt intrusion, and higher the salinization of an estuary (Fig. 2).

Simultaneously, the diminishing runoff adversely effects circulation, mixing and the entrainment phenomenon of runoff energy to repulse salt intrusion to maintain quasi-equilibrium dynamics of the estuarine ecosystems. The failure to recognize these and other universal regime features of coastal embayments by watershed development have contributed to: (1) alarming depletion of runoff to 60 to 90% of normal spring or annual values (note that the author had found that unimpaired intra-annual and perennial runoff fluctuations rarely exceed more then plus/minus 25 to 30% of their norms, Rozengurt 1971, 74, 85); (2) deprivation of the entire Central, South Atlantic and Western Pacific coastal zones from thousands of millions of acre-feet freshwater; (3) the current remnants of "regulated" flow, spring in particular, correspond to atypical chronic drought conditions regardless of wetness of the year (a seldom measured phenomenon for a unimpaired regime), their volumes no longer capable of absorbing even natural pollutants, or maintain adequate environment for migration and spawning, and (4) loss of millions of tons of oxygen, organic and inorganic matter and sediments so vital to coastal ecosystem survival. Concurrently, deltas and coastal erosion, subsidence of levees, oxygen deficit, hypoxia, eutrophication and agricultural discharges laden with chemicals have further aggravated the precipitous decline of habitat. The curtailment of 90% of migration routes and spawning grounds by thousands of dams together with the conversion of deltas into plumbing conduit have inflicted the final mortal blow to the Nation's and world fishery. Accordingly, an escalating entropy has become a new, highly negative property of a formerly healthy and rich coastal ecosystems. Subsequently, the new surrogates have only one thing in common with their natural, lustrous past - the same geographic locations and names on the maps. The reason why many prognostic contemporary models have provided erroneous results may be attributed to their inability to integrate the cumulative role of environmental losses (discussed earlier) on coastal systems. Thereby rendering their results nothing more than whistles in the dark. Arguably, the Nation's estuary is in peril.

The dissection of rivers by dams has distorted interaction of coastal ecosystems and led to the formation of "impounded seas" on a global scale. All the above belies the statements claiming that it is possible to restore historical habitats of impounded coastal ecosystems (delta-estuary-coastal seas) despite the fact that their unnatural, broken river continuum has nothing in common with the history of their evolution should be considered as reductio ad absurdum.

Michael Rozengurt

Conceptual Model of Estuarine Water and Salt Balanc



R - Runoff

W_2, W^*_2 - Sea Inflow

W_1, W^*_1 - Estuarine Outflow

V - Estuarine Volume

N, N* - Fresh Water Balance

S_1, S^*_1, S_2, S^*_2 - Salinity Fluxes

S_E, S^*_E - Estuarine Weighted Average Salinities

Application of Laws of Thermodynamics to River-Delta-Estuary-Sea Ecosystems

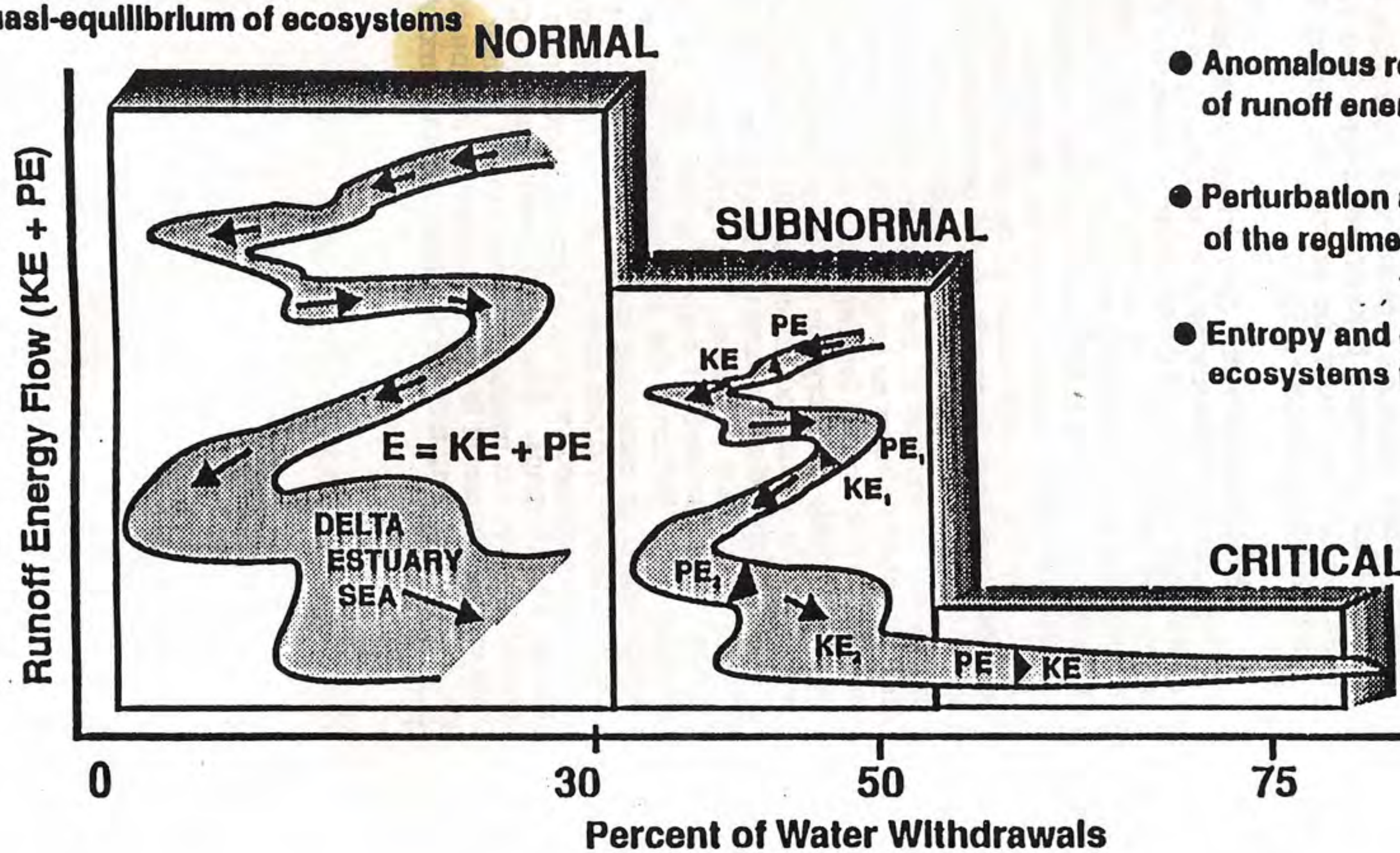
THE FIRST LAW ⟵ ENERGY CONSTANT ⟶ THE SECOND LAW

(Energy Is Conserved)

- Fluctuation runoff energy within natural range
- Energy dissipation at minimum; Entropy insignificant
- Excess of free energy maintains quasi-equilibrium of ecosystems

(Transformation of Energy Is Accompanied by Entropy)

- Runoff energy transformed by the impoundment and diversions
- Anomalous redirection (alteration) of runoff energy
- Perturbation and cumulative aggravation of the regime of ecosystems
- Entropy and despoliation of ecosystems tend to attain maximum



- Retardation of ecosystems
- Entropy maximum

Attachment 9

From:	Michael Rozengurt
To:	ngmplcs@pacbell.net; b.stickel@charter.net; Rogers, Pat@DeltaCouncil; Delta Plan Comments@Deltacouncil
Cc:	terry.macalauy@deltacouncil.ca.gov
Subject:	Fw: Agonizing Coastal Sea Ecosystems
Date:	Thursday, October 06, 2011 8:44:10 PM

Dear Coleagues,
Due to malfaction of my computef, I send again this publication.

Cordially,

M.Rozengurt

MEDCOAST 03, October 7-11,2003, Ravenna,Italy, vol. 2

Agonizing Coastal Sea Ecosystems: Understanding The Cause; placing the blame!

Michael A. Rozengurt, Ph.D., P.H., Senior Associate
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Abstract.

The dissection of rivers by dams has distorted interaction of coastal ecosystems and led to the formation of "impounded seas " on a global scale.

All the above belies the statements claiming that it is possible to restore historical habitats of impounded coastal ecosystems despite the fact that their unnatural, broken continuum has nothing in common with the history of their evolution should be considered as reductio ad absurdum.

Introduction. Consideration for river-estuaries-coastal sea management.

Coastal sea ecosystems used to be the world's most productive basins. They supported migration routes, spawning, nursery, and feeding grounds for a reach diversity of valuable fish and shellfish. Their properties and survival were based on four fundamental processes: 1) stochastic fluctuations of unimpaired runoff; 2) dynamic equilibrium of water and salt balance; 3) ecological continuity, and 4) biological tolerance. Their natural regime peculiarities sustained life in coastal embayment for millenniums, and concomitant enhancement of coastal seas. Spring runoff was the lifeblood of ecosystems. Normally the stronger the flooding the more kinematics' energy is available to regulate water and salt exchange between an estuary and coastal sea, or to enhance advection, horizontal and vertical mixing, and circulation of estuarine and marine waters as well as sea biochemical characteristics. Spring flooding used to serve as a physical barrier to repulse excessive saltwater intrusion into estuaries and deltas, and flash out natural or man-made contaminants. In other words, a natural spring inflow energy tended to maintain the regime balance through outflows to seas as required by the first law of thermodynamics (Fig.1). Suffice to say, that the powerful frictional drag could entrain up to 10 to 100 times volume of marine waters than that of flood itself. In this case, the enrichment of seas with thousand tons of oxygen, inorganic and organic matters took place. Riverine or estuarine plumes that participate in these processes can be seen between mixed and fully marine waters of many kilometers from river mouths or straits. Moreover, a part of the energy outflow transfer is linked to the dispersion into an unavailable form of energy as required by the second law. But most important was its ability to maintain essential equilibrium of food chain and vitality of numerous fresh and marine waters' organisms for millennia (Rozengurt, 1974).

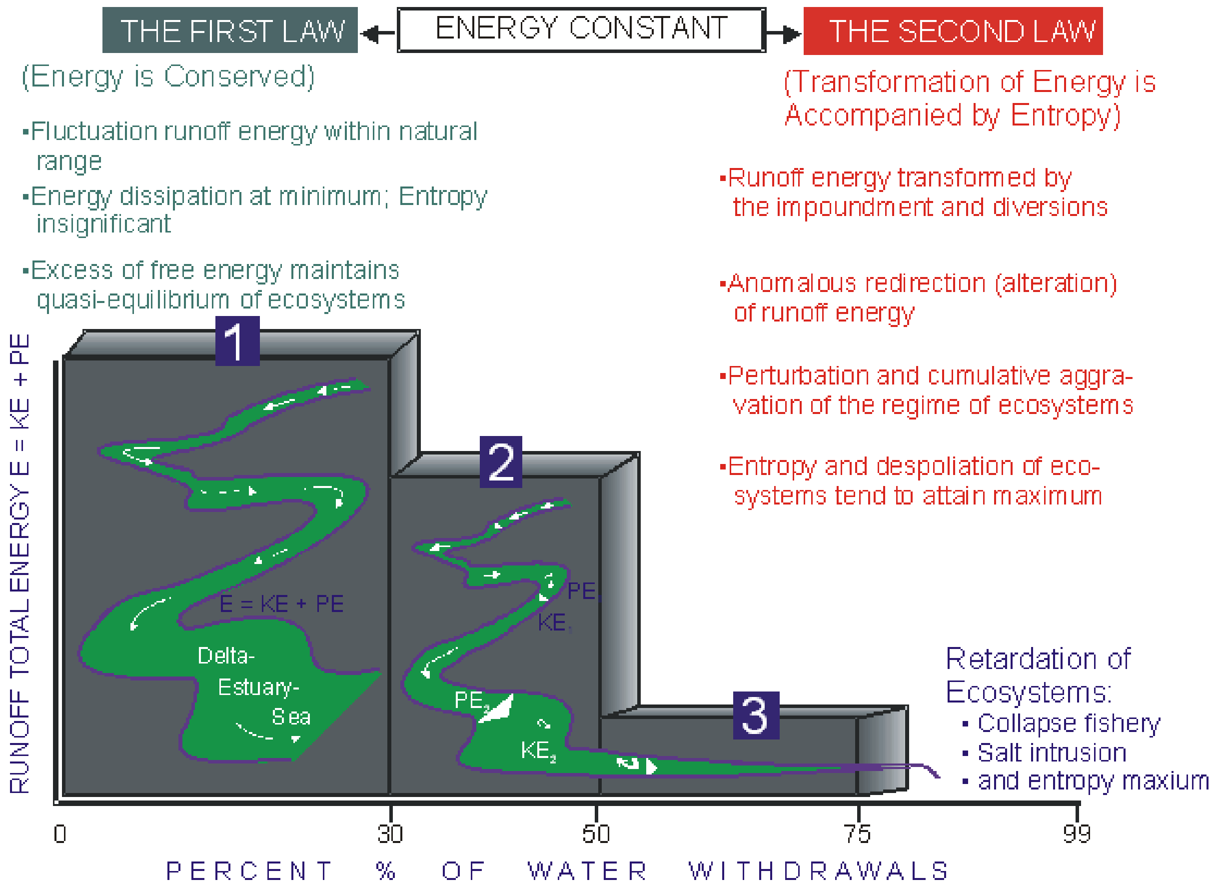


Figure 1. Application of Laws of Thermodynamics to River-Delta-Estuary-Sea Ecosystems

1- Normal, 2 - Subnormal, 3- Critical

KE- Kinetic Energy, PE- Potential Energy, ▷ Dams

However, when hundreds of major and numerous minor dams were built in 1950s – 1960s, then cumulative depletion of runoff to coastal seas became chronic features that inflicted mortal blows to some Mediterranean basins (Rozengurt, 1992; Zaitsev, 1998).

The Black Sea and its northwestern region (NWBS).

-

The sea biota (about 180 - 200 species of fish out of 2000 marine organisms) used to inhabit about 4.2% of its volume (V = 547,015 km^3), which encompassed life-sustaining surface layer between 0 to 150 meter depths. The rest of the Sea was anoxic for all living creatures because two layers of density discontinuity significantly restricted vertical mixing between surface and stagnant deep waters. Since time immemorial, excess of runoff + rainfall over surface evaporation used to be the principal ecological feature of the Sea whose environmental essence has been given by Nature' certain limitations on runoff's withdrawals. In other words, seasonal and perennial norms of rivers' discharges and their deviations have determined the ecological significance of the sea's three regions (Bol'shakov, 1970): 1. Northwestern, 2. Northeastern, and 3. Southeastern. In the 1930s the Soviet fishery fleet was able to harvest in these regions which experienced the manifestation of natural runoffs about 200,000 tons valuable fish; in addition, nearly 2,000,000 dolphins were able to catch thousands of tons of fish for food. The NWBS (V_{volume} = 1150 km^3) was the most dynamic and productive part of the Sea. The NWBS accommodated in average about 264 km^3 out of a total unimpaired runoff of 392 km^3. Among three major rivers (Danube, Dniester, and Dnieper) emptying into the region, the Danube was and is the greatest source of freshwater (R_{avr} = 198±6 km^3; R_{max} = 296 km^3 (1941); R_{min} = 125 km^3 (1921); at the same period (1910 - 1960) the Dnieper and Dniester rivers discharged in average of 54 km^3 and 10 km^3 per year, respectively (the rest provided by some minor rivers). Thus, the NWBS accommodated about 75% total river runoffs to theBlack Sea. Spring flooding (late March – June) amounted to 55% - 60% of annual runoffs (Rozengurt, 1974).

This phenomenon controlled advection and entrainment of 1450 ±70 km^3 of the NWBS outflow to the open sea, saturated with many hundred tons of oxygen (up to 9 mg/liter). This well-mixed cooler and denser brackish water masses sank into the underlying marine, slightly saltier but warmer water of lower density. This was not only enough to satisfy the shelf's oxygen demands, but also to dissolve poisonous hydrogen sulfide at of 200m to 500 m slope depths. The combined annual discharges were able to entrain substantial volumes of coastal brackish water (1180 ±100 km^3 marine inflow to the NWBS). Annually, about 2630 km^3 of seawater (2.3 times the volume of NWBS) was in renewal over a period of 6 to 7 months, alleviating stagnation. It is important to emphasize that density, temperature, and wind - driven circulation commanded the oxygen enrichment of thousands of cubic kilometers of subsurface seawater masses.

Note the Sea of Azov outflow through the Kerch Strait had enormously enhanced the oxygen and organic elements concentration of the eastern Black Sea that affected very positively its fishery. Hence, the foundation of their coexistent continually maintained the food chain, i.e. of 60% of total biomass of the entire Sea, including a rich fish diverse, namely: 121 marine and 34 freshwater species. Moreover, the NWBS used to be teeming not only with fish but also about 7 to 9 million tons of raw mass of edible mussels and oysters. At the same time, almost 15,000 km^2 NWBS bottom was covered with about 10 million tons of the unique sea weed (Phyllophora) which provided a food and cover for up to 70% of the commercial landing of valuable fish before the dams became operational.

However, since 1950s the major spring runoffs draining to the NWBS have been subjected to gradual increasing diversions: Danube 28% to 40%; Dniester 45% to 75%; and Dnieper 45% to 85% of runoffs, and their reservoirs now accommodate 44+ km^3, 4+ km^3 and 35 + km^3 water, respectively. Annual and spring water withdrawals from the Dnieper and Dniester have reduced to 20 km^3 and 4 km^3 –5 km^3, respectively. In the last few decades, the remnants of spring deviations of impaired runoff from unimpaired volumes reach up to 45% - 85% (instead ± 25 ± 30% natural deviations for unimpaired runoffs). This implies that the current annual and especially spring regulated runoff correspond to dry or critical dry years of what otherwise would have been average runoff for the Dnieper and Dniester estuaries under pristine conditions. Note that natural chronic dry events of these kind are rare and particular stressful, they are usually typified by a very low probability of occurrence (1 to 3 times per 25 to 45 years of subnormal wetness).

For example, the Dniester spring (April through June) average outflow (1.5km^3) to the estuary reduced to75% of its spring norm, and annual regulated runoff (4.5 km^3) constitutes of about 45% of its norm (10.2 km^3). Moreover, the frequency of occurrence of dry, critical dry or drought-like conditions (particularly in spring) have increased up 3 to 6 fold in comparison with the same period under unimpaired conditions. Such persistent dewatering led to a gradual impoverishment fish in coastal sea ecosystems. This stagnation places the NWBS in grave peril (Rozengurt, 1991; Zaitsev, 1998). The truncated flooding cannot force vertical and horizontal mixing (entrainment) or turnover of marine waters much time as it was before water withdrawals. Note that between 1955 and 2002 the NWBS was deprived of about 2280 km^3 of freshwater, including 25% to 35% of Danube runoff (800 km^3 - 840 km^3), presumably diverted by the Central European countries. These cumulative losses exceed that of the NWBS volume, not counting the Sea of Azov spring runoff' losses.

Fresh water perennial deficit to the Dnieper and Dniester estuaries exceed 330 and 130 times their volumes, respectively, or nearly half the volume of the NWBS; runoff depletion triggered the measurable increase salinity intrusion into estuaries and deltas. Diversions make impossible for a current exhausted spring runoffs to provide mixing and life-giving substances, or to move down toward deep waters of the NWBS slope (200m - 300m). This hampered oxygen renewal and increased detention times, which, in turn, triggered the rise of hydrogen sulfide concentration even in the layers of 50 to 100 meters. The hypoxic water masses moved up to the lower boundaries of photic zones and caused mass mortality of shelf biota (over 15,000 km^2 bottom is now stagnant and anoxic). This triggered the disintegration of the Phyllophora, millions of tons benthos organisms and demersal fish. In practice, this development has menaced the entire Black Sea. It is conceded that under conditions of runoff deficit, the introduced agricultural nutrients to coastal water have been an overriding factor in eutrophication of the NWBS shelf. Chronic seasonal blooms may substantially degenerate even the remnants of marine habitats. Under such conditions virtually all attempts to slow down the degradation of lower rivers, estuaries, and coastal sea by pollution control or artificial fish-breeding hatcheries have failed to work. Furthermore, the summer releases of water from the dams accelerated development of discontinuity layer that appears to have isolated underlying water masses at depths of 8-40 meters. This resulted in nearly complete cessation of deoxygenating in 60% - 70% of the NWBS deep and bottom layers (since the late 1970s over 20,000 km^2 has been contaminated with hydrogen sulfide). In addition, detention time (known as Dynamic Index of renewal of the water body) increase from 11 to 150 days for Dniester and Dnieper estuaries, and from 180 to 360 days for the NWBS. Consequently, nutrients from agricultural fields have more time to be the major catalysts of catastrophic eutrophication over 29,000 km^2 of the NWBS surface (about 40%). The thick, fleshy mats of micro-algae in the summer has reached several kilograms per cubic meter and exceeded several thousand times of normal algae concentration. What used to be the granary of the entire basin is now seized by hypoxia.

. The niche formally ccupied by shellfish, red algae and fishes has been filled (1973-1987) by hundreds of million tons of jellyfish of the class Aurelia and Rhizostoma. But in 1989-1990, their abundance was suppressed by another jellyfish-like species (Gucu, 2002) Mnemiopsis leidyi (a ctenophore) reaching about 800 million tons that significantly depleted food resources for fish on the account for over 90% of total zooplankton biomass of the Black Sea. Scientists linked the catastrophic development of the ctenophore to the lack of natural predators (fish), which first appeared to be the victims of poor management of quantity and quality of inland water resources. It is important to point out that the invasion medusae lagged by water withdrawals10 to 15 years before interrupting the existing dynamic equilibrium. Finally, the Black Sea shifted toward a new equilibrium in which historical coexistence of major elements of the food chain and its consumers have been eliminated.

***The Decline of the Sea of Azov*.**

The Azov basin was once the richest sources of food resources whose volumes per square kilometer exceeded many times over other known productive seas and estuaries. According to some reports, the annual commercial catch in the 1930s reached 300,000 tons, including 136,000 to 167,000 tons of valuable fish: such as beluga, sturgeon, sevruga, herring, walleye, bream, and roach. Such yield was related to the unimpaired runoffs of the Don (in the north) andKuban (in the southeast) rivers (Brofman and Hlebnikov, 1985; Simonov, 1985). The Don and Kuban rivers runoff constitutes 95% of historical norm (R= 41- 43 km^3). The remaining 5% is confined to the irregular flow of numerous minor streams. The Sea of Azov (V=320 km^3) is an exceptional by shallow (maximum of 14 meters) transitional ecosystem typified by brackish water masses. Characteristics of water masses vary greatly in space and, attributed to substantial runoff variations, and rather essential, year-round salt and water exchange with the Black Sea through the Kerch strait. Naturally, the Crimean Peninsula partially divides the Black Sea into two highly productive estuarine areas: Northwestern and Northeastern. The latter includes the Sea of Azov and the vast adjacent shelf of the Black Sea.

In the Sea of Azov as in the NWBS before construction of dams started in the 1950s, the combined spring flooding, whose duration used to be equal to 30 to 45 days, provided for low salinity (10.6 ‰) of about 0.8 area of the Sea where anadromous and semi-anadromous fish could thrive. The flood carried out substantial amounts of nutrients and oxygen and maintained exceptional conditions for migration and spawning. The Sea of Azov fauna comprises 114 species of fish that include (similar to the Black and Caspian seas) members of freshwater and Atlantic-Mediterranean complexes. But only 16 out of 114 fish species inhabiting the sea are considered to be commercially valuable, including some semi-anadromous and anadromous forms. In the Sea of Azov the 1930s commercial fish catch was equaled 80 kg/hectare and or 6 to 25 times higher than the corresponding harvest in the Caspian and Black seas in the same period. However, the impoundment of rivers: Don (1952); Kuban (1948,1974) and Phedorovsky water diversion network (1967), modified the stochastic-periodic nature of runoffs to a deterministic, i.e. to the detriment of the marine environment.

The Tsimlyanskaya Dam eliminated 100% of spawning Don River' ground of the giant Russian sturgeon beluga, 80% for a lesser sturgeon, and 50% for herring and sevruga. The Krasnodarskaya Dam (Kuban River) blocked all spawning grounds of sevruga, shemaya, vimba, and other valuable fish. Consequently, the annual catch of valuable fish amounted to a fraction of the pre-project years. The vast network of artificial reservoirs and ponds of 5,500 km^2 catches 40 to 60% of historic spring flow and over 30 to 50% of an annual norm; therefore, the combined regulated runoff to the Sea varies between 20- 28 km^3 or less per year. These volumes constitute 49% to 68% of the deviations of the annual norm, for a regulated runoff up to –32% to -51%. This frequency of occurrence of subnormal and dry years exceeds by several times their natural probabilities had no impoundment taken place. As a result, cumulative spring losses reached around 750 km^3. This is more than 2.3 the volume of the Sea of Azov. Subsequently, such runoff depletion facilitated the Black Sea's intrusion into the Sea of Azov through the Kerch Strait. Correspondingly, salinity of the sea has increased from 9-9.5 g/L to 14 g/L and up to 16 g/L in the southern part of Sea after only 15 years. Note that this increase was exacerbated by exceptionally subnormal total runoff in 1967 – 1977, whose volume equaled 25 km^3 per year in average.

This runoff deprivation, coupled with increase volume of point and non-point discharges, led to the rise of chloride, magnesium, sulfate, and other unnatural chemical elements attributed to agricultural drainage and industrial discharges. This, in turn, triggered increases in the frequency of occurrence of hypoxia from 4 m depth to maximum 14m over 60% of the Sea. The lack of oxygen spelled out a mass mortality of fish and shellfish almost annually during the last two decades. The climax of this event has taken place in the late spring and summer-early autumn when the dense blooms of algae occur. Such seasonal outbreaks are unprecedented in their severity, frequency and spatial scope and put the sea environment in peril. The short-lived million tons of algae die and sink to the bottom, where upon decaying they consume the already depleted oxygen. As a result, the bottom water is contaminated by lethal hydrogen sulfide. Today, the insignificant Don and Cuban inflow cannot carry away point or non-point wastes or repel salt intrusion from the sea. In addition, it cannot provide the ranges of nutrients, and other dissolved constituents necessary for the sustaining of normal conditions of fresh or brackish water fish, eggs, larvae and fry. Consequently a precipitous decline of recruitment in stock and commercial fishery stocks occurred.

By the end of 1970s over 150 marine species from the Black Sea invaded the Sea of Azov. At first, the most aggressive among them were the two mussels: <u>Mutilator</u> and <u>Mystiques</u> move recently a massive die-offs of these mussels occurred. Finally, there has been an ominous foray of jellyfish (Aurelia and Rhizostoma) into the Sea of Azov and this invasion lagged nearly two decades after the beginning of the impoundment. It is sad, but ironic, that a former Soviet water policy management has brought the Sea of Azov to the edge of ecological and piscatorial disaster in less than 20 years, while Nature carefully experimented over 2 million years to create this richest of seas. Undoubtedly, for the Azov-Black basin water future is clearly bleak.

The Nile delta -coastal ecosystem.

The annual yield from two major sources of water - White and Blue Nile varied from 46 km^3 to 150 km^3 (Shanin, 1985; Rozengrt, 1992) and the average over periods at Aswan ranged from 84 km^3 (1900-1958) to 93 km^3 (1870-1920), at these periods, the annual and monthly runoff deviations at Aswan gauge were predominantly in the range of ± 25%. But only 35km^3 to 50 km^3 could reach the Delta-coastal Mediterranean, with the rest used by agriculture. Runoff used to provide in average 125 million tons of fine sediment, which were carried into the Delta and the eastern Mediterranean Sea. This load and its organic and inorganic substances have formed over millennia an enormously fertile arable land, wetlands, marshes, lagoons, beaches, and exclusive ecological conditions in the eastern Mediterranean ecosystem (200km in length of the Delta shoreline). The total landings of pelagic and demersal fish from the Nile estuarine-coastal area were equal to about 120,000 tons, while the prawn fishery yielded up to 12,000 tons. But now, after completion the Aswan High Dam, the Nile runoff is about 4 to 10 km^3 per year; its supports only fish yield in the range of 600 to 4,000 tones and several hundred tones of prawn. Delta water quality and supply at the edge of collapse.

The Aswan High Dam, as opposed to the six previously built dams, is the only structure capable of holding the Nile flood and providing over year storage was finally completed in 1964 and reached its operating volume 121.3 km^3 of stored water (or up to 95% of runoff in a drought). The extensive water withdrawals (up to 55 km^3) during June through September have completely eliminated annual and intra-annual runoff fluctuations. The rest was lost due to evapotranspiration (the evaporation from the Aswan reservoir is about 14 km^3 per year) and irrigation (about 85%). The impoundment of the Nile has reduced the historical annual norm of 35 km^3/year (1913 - 1963) in and out of the Delta to 5% to 17% of its norm. But even these remnants of flow have been heavily polluted by the returning agricultural discharges from a dense deltaic irrigation network.

Since 1965, the cumulative losses of evaporation have reached around 400 - 450 km^3 (nearly three times the volume of the dam, or 1.4 times of the Sea of Azov), plus about 1,000 km^3 of water withdrawn from runoff. These losses have a negative effect on the hydraulics processes of delta and the coastal zone. The following years, a gradual aggravation of the deltaic-coastal area has exceeded the known scale of long-term trends of natural processes (transgression and regression of sea level, climatic and sediment transport fluctuations) that molded and controlled the deltaic morphometric and morphological features in the course of its evolution over 35,000 years. The cessation of Nile runoff was accompanied by annual accumulation behind the dam of up 60 to 180 million tons of fine sand, silt and clay. For example, in 1964 – 1965, the Dam deprived its downstream delta and coastal perimeter of about 140-160 tons of fine sand, silt and clay. This jeopardized the capacity of the reservoir and, at the same time, evoked downstream scouring of the river bed because of intra-annual abnormal water releases from the hydropower plant and related modification of runoff velocity.

Over the last four decades the cumulative losses of runoff and silt spelled out the end of mighty and famous Nile plume, and facilitated erosion. The Delta 200 km seaside perimeter and the Nile deltaic perimeter have retreated toward the south of 125 to 175 meters per year (Halim, 1991). In reality, the inner Delta area has been transformed into a plumbing system superimposed by endless irrigation network, pumping stations, or barrages. The lack of runoff to flush out the salt from the delta, especially out of its northeastern part, partially isolated by the Suez Canal, has resulted in the transformation of this water body into a hypersaline lake and salt- pan. Moreover, the geomorphologic equilibrium between the delta and coastal zone has all but vanished. Besides, the Nile Delta-coastal ecosystem has lost a million tons of natural organic matter (silt and nutrients down to 10 to 20% of their perennial norms, respectively) that led to a ten-fold decline in the rich catch of the eastern Mediterranean sardines and prawns.

Something to think about.

Its appear a to be a common universality, namely if spring runoff diversions will cross limit of 25%- 30% of its perennial norm than a coastal ecosystems' dynamic equilibrium will be irrevocably distorted. All other perceived ills: pollution; over fishing; and, yes, even global warming, are secondary in importance to fundamental change brought by dewatering our global rivers. The ominous trends of the aggravation of hydrophysical and biochemical properties of coastal ecosystems have been exacerbated by (1) negligent recognition of the runoff limitations for diversions and their cumulative effects on coastal seas; (2) erroneous application of methods of a stochastic hydrology to combine database of unimpaired and impaired (deterministic) runoffs that make water development incompatible with living resources' survival, and (3) the lack of application of universal postulates of the First and Second Laws of Thermodynamics to evaluate the scales of ecological tolerance of ecosystems to excessive desiccation of watersheds by dams in concert with water withdrawals beyond which entropy of coastal seas tends to reach a measurable maximum. These events for the last decades gradually fortified eutrophication, oxygen deficiency (hypoxia or anoxia), and deprivation or even mass mortality of vegetation and living resources. The scale of such degradation and impoverishment of food chains poses not only threat to the sustainability of resources of coastal seas, but also to ocean fishery the world over whose decline of catches coincided with despoliation of Pacific and Atlantic coastal ecosystems (Fig. 2).

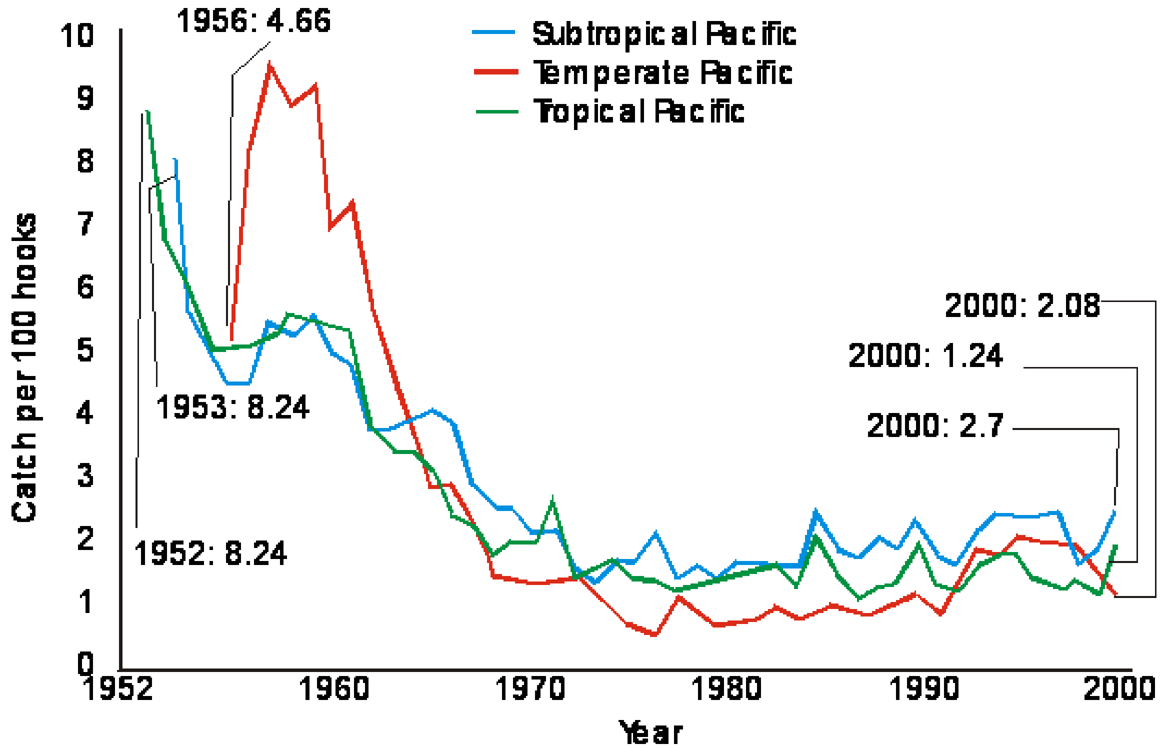
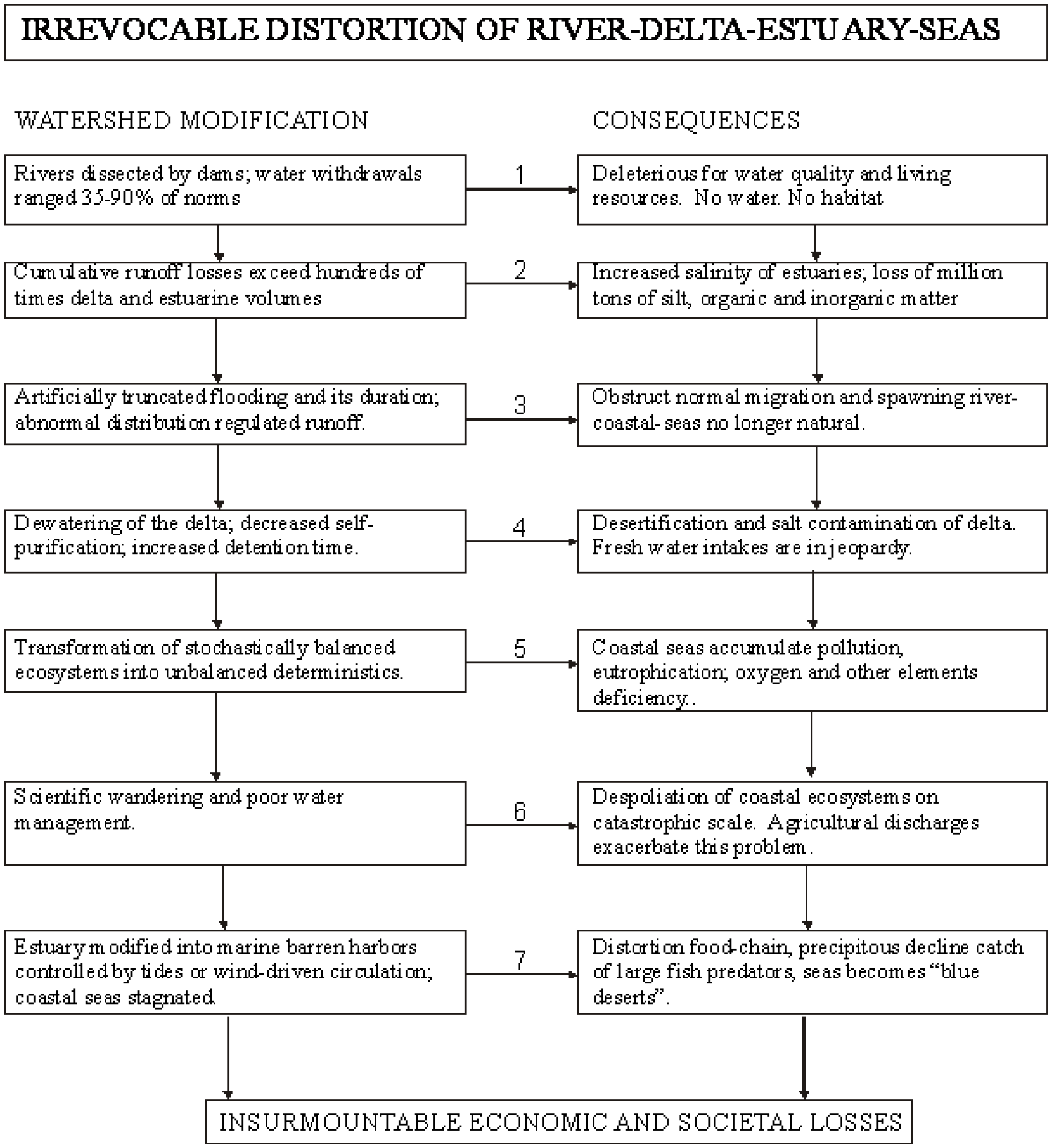


Figure 2. World wide large fish predator decline.
(Sources: Nature magazine; Ransom A. Myers and Boris Worm, Dalhousie University, Halifax, Nova Scotia; catch per 100 hooks, based on data from Japanese long-lining vessels)

Conclusion.

Coastal seas have experienced the effect of the "5**D**s" (**dams, diversions, dewatering, deforestation, and desertification**) with frightening similarity (Table 1) to the impoverishment of the northwestern Black Sea, Sea of Azov, Caspian Sea; Columbia River – coastal sea, the Delta- San Francisco Bay, Colorado River, Gulf of Mexico, Florida and the Nile River coastal ecosystems.

Table 1. Irrevocable distortion of coastal sea ecosystems



Acknowledgment. The author expresses gratitude to Dr. Irwin Haydock and Hai Nguyen for unfailing support in helping the preparation of this manuscript.

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