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January 10, 2006

Mr. Ed Friedman
Friends of Merrymeeting Bay
42 Stevens Road
Bowdoinham, ME 04008

Dear Mr. Friedman:

I have been a member of the faculty at the University of Maine since 1968, first in the Department of Zoology, then in the Department of Oceanography, and now in the School of Marine Sciences. My expertise is in the areas of the biology of migratory fishes and fisheries oceanography. I have had a special research interest in various aspects of eel biology since about 1970. I am a member of the Working Group on Eels of the International Council for the Exploration of the Sea, and I have participated in numerous national and international workshops and symposia on eel biology and management. I have published 42 research papers on eels of the Genus *Anguilla* in North America (*A. rostrata*), Europe (*A. anguilla*), and New Zealand (*A. dieffenbachia* and *A.australis*), plus a few additional papers on eels in other families. These papers have included, among others, aspects of the spawning of adult eels in relation of oceanographic features, the drift of larvae in the ocean, estuarine migration of glass eels (elvers), population attributes and sex ratios in rivers, homing movements and seaward migrations in estuaries, and movements in coastal seas. I have written one paper simulating the effects of multiple dams on reproductive potential of seaward-migrating adult eels in the Kennebec River, Maine. I am reasonably familiar with literature on downstream passage and mortality estimates of eels at hydropower projects. For your information, I have enclosed a C.V.

Dams adversely affect the upstream migration of glass eels, pigmented elvers, and juveniles. Upstream migrants congregate below dams, and even if some passage facilities are provided, the majority probably does not pass. For example, a large-scale commercial fishery for European glass eels in the Vilaine Estuary, France, is prosecuted by boats congregating and circling round and round, towing nets, just below the lowermost dam. The fate of those upstream-migrant eels not passing dams is unknown, but congregations probably lead to increased predation and competition for food. Dams have severely restricted access to growth habitat for yellow eels (sub-adults), contributing to an overall estimated restriction or complete blockage of >80% of American eel riverine habitat in the U.S. Furthermore, restriction of upstream passage may result in fewer females being produced within a drainage basin, because the proportion of females is generally greater in upper portions of rivers. Furthermore, the contribution of particular types of habitat to the sex determination, size of eels, and overall production is poorly understood.

Several general conclusions may be reached:

- The majority of upstream migrants probably do not pass dams, even when some passage structure is provided.
- Congregations below dams probably leads to increased mortality from predation or starvation.
- Dams have restricted access to large amounts of habitat, which once was inhabited by eels.
- Lower population density in restricted habitats alters sex ratios in ways not fully understood.

Dams adversely affect the downstream seaward migration of silver (adult) eels. The first effect is a delay of migration, with eels circling in the forebay and making multiple approaches to a dam. Few studies of this aspect have been done.

Mortality and injury when eels pass through turbines or over spillways is well documented for several species of *Anguilla*, including the American eel, the European eel, and two New Zealand species. Mortality rates from passage through Kaplan turbines ranged from 50-100% in 19 experiments with European eels of mean size 73 cm. In three other experiments, severe injury rates were 63-81% for eels of mean size 57 cm. Another study gave mortality rates of 15-50% depending on Kaplan blade angle. Yet another study, gave 6%, 10%, and 23% mortality in a large Kaplan turbine. In one study of a small Francis turbine, injury rate was 9%, 65%, and 100% depending on operating conditions.

For American eels, fewer studies have been conducted. Mortality rate of American eels was estimated at 26.5% in a propeller turbine (mean eel size 102 cm), and was estimated at 24% in a propeller turbine and 16% in a Francis turbine (mean eel size 88 cm), at two large installations on the St. Lawrence River, respectively. Another study reported only 9% mortality through a small Francis turbine.

Ten of twelve telemetered New Zealand eels that passed through Francis turbines were killed.

I simulated the impact of dams on the Kennebec River on the reproductive potential of silver female American eels in the Kennebec River basin. At the time (2001), the Kennebec has 22 hydro projects and about 73 water-control dams. Various upstream passage, downstream passage, sex ratio, eel-length structure, and mortality scenarios were simulated. Over the length classes combined, about 63% of the simulated eels produced survived to exit to sea at a mean survival rate of 90% at each hydro dam. Only 40% survived at 80% survival per hydro dam, and only 18% survived at 60% survival per hydro dam. The simulations did not take into account what basin-wide production might have been in the absence of hindrance of upstream migration.

Injury rates of eels initially surviving passage through turbines or over spillways have seldom been assessed. However, a number of sublethal effects may reduce ultimate reproductive success. Stunning, disorientation, physiological stress, and gas bladder, muscle, and skeletal injuries may lead to increased risk of mortality at subsequent dams or mortality to predators, or to reduced ability to migrate to the spawning area in the ocean.

Several general conclusions can be reached:

- Mortality rate through turbines is directly proportional to eel length, especially putting female eels at greater risk than males.
- Mortality rate is inversely proportional to turbine blade spacing (and probably directly proportional to blade speed).
- Mortality rate is heavily dependent on project operating conditions and river flow, suggesting that mortality rate is site and time specific.
- Mortality rates cumulate through multiple projects; even at a 75% survival rate, survival is <32% after passage through four turbines.
- Eels injured at one project are at greater risk of mortality at subsequent projects.
- Eels injured by turbine passage may be less able to perform an oceanic migration.
- Ultimate reduction in reproductive potential is underestimated because of the short-term nature of studies of turbine passage.

Design of effective downstream-passage facilities depends on the behavior of migrating eels. Contrary to conventional "wisdom," migrating silver eels are not bottom-dwelling fish. Telemetry studies in a European river, a New Zealand hydro reservoir, and by my group in the Penobscot Estuary and in coastal waters of the North Sea all demonstrated that eels swam or drifted downstream in the upper few meters of the water column. Vertical movements were common in some studies, but most of the travel occurred near the surface. Trawling in a large hydro reservoir on the St. Lawrence River yielded more migrant eels at intermediate depths, but also caught eels near the surface; sample size of captured eels was small.

When migrating New Zealand eels approached a dam near the surface, they made repeated dives to near bottom and back, apparently searching for downstream routes. In the forebay, already near a dam on the Connecticut River, eels spent most of their time close to the bottom, but they made frequent excursions to the surface.

Most studies of downstream migration reported that movement occurred primarily at night. Nocturnal migration is characteristic in rivers, reservoirs, and forebays. For passage purposes, the assumption of nocturnal migration is reasonable on a probability basis, but there are instances of substantial movement during daytime as well. Daytime migration has been reported in a river, an estuary, and coastal waters.

Seaward migration occurs in the autumn, but the actual timing of the run is quite variable intra- and inter-annually, depending upon meterological/hydrological conditions. Migration in rivers is pulsed, and tends to occur following rain events. Whether the trigger is atmospheric conditions, rainfall itself, or increase in water flow is uncertain. A recent study simulated the effect of inter- and intra-annual variability in timing of migration and of different project operating scenarios on mortality of eels at a hypothetical small hydro project. A turbine mortality rate of 25% was assumed, with the number of eels killed was proportional to the amount of water spilled (0% mortality) or passed through the turbines (25% mortality). Flow was apportioned between generation and spill. Mortality was reduced by about one-third to one-half, depending on spill, by suspending operations during a window typically encompassing dates with 25-75% cumulative passage of eels. Mortality was reduced by about two-thirds by combining that suspension with suspension during rain events outside that window.

For simplicity, I have not provided documentation of the literature upon which I have drawn in writing these comments. However, such documentation could be provided at a later date if necessary.

Sincerely,

James D. McCleave

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Professor

Encl. C.V.

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EDUCATIONAL EXPERIENCE

A.B.	Carleton College	1961
M.S.	Montana State University	1963
Ph.D.	Montana State University	1967

PROFESSIONAL EXPERIENCE

Assistant Director for Research, Maine Sea Grant College	2003-date
Professor of Marine Sciences, University of Maine	1996-date
Visiting Scientist, National Institute of Water and Atmospheric Research, Christchurch, New Zealand	2001-2002
Associate Director, School of Marine Sciences, University of Maine	1999-2001
Chair, Department of Oceanography, University of Maine	1994-1996
Professor of Oceanography, University of Maine	1990-1996
Cooperating Professor of Biological Sciences, University of Maine	1990-date
Mary Derrickson McCurdy Visiting Scholar, Duke University Marine Laboratory, North Carolina	1992-1993
Chair, Department of Oceanography, University of Maine	1990-1992
Chair, Department of Zoology, University of Maine	1987-1990
Professor of Zoology, University of Maine	1978-1990
Visiting Professor of Biology, McGill University, Montreal	1985-1986
Visiting Scientist, Fisheries Laboratory, Ministry of Agriculture, Fisheries and Food, Lowestoft, England	1978
Associate Professor of Zoology, University of Maine	1972-1978
Assistant Professor of Zoology, University of Maine	1968-1972
Assistant Professor of Biology, Western Illinois University	1967-1968

RESEARCH CRUISE EXPERIENCE (*Chief Scientist)

R.V. *Columbus Iselin*. Sargasso Sea.	4 weeks	1989*
Distribution of eels in fronts		
O.R.V. *Cape Florida*. Sargasso Sea.	3 weeks	1985*
Distribution of eel leptocephali	2 cruises, 3 weeks each	1983*
R.V. *Columbus Iselin*. Sargasso Sea.	2 cruises, 3 weeks each	1984*
Distribution of eel leptocephali	3 weeks	1981*
R.V. *Clione*. North Sea.	2 weeks	1980
Eel tracking	2 weeks	1979
	3 cruises, 2 weeks each	1978
A.R.A. *Islas Orcadas*. Scotia Sea, Antarctica	6 weeks	1976
Benthic fish and invertebrate ecology	7 weeks	1975
R.V. *Friedrich Heinke*. North Sea, Bay of Biscay	4 weeks	1974
Eel tracking, larval fish collection		

PROFESSIONAL SOCIETIES

American Fisheries Society
American Society of Ichthyologists and Herpetologists
Estuarine Research Federation
The Oceanography Society

PROFESSIONAL ACTIVITIES AND AWARDS

Member, Working Group on Atlantic Eels, International Council for the Exploration of the Sea	1990-date
Member, Marine Sciences Task Force, University of Maine	1995-1996
Project Director, National Science Foundation, Research Facilities Modernization Grant to Zoology/Oceanography	1991-1992
Associate Editor, Transactions of the American Fisheries Society	1985-1987
International Scientific Exchange Award, Natural Sciences and Engineering Research Council of Canada	1985-1986
Member, Board of Directors, Huntsman Marine Science Center	1983-1987
Leopold Schepp Foundation, Eppley Foundation for Research Postdoctoral Fellowships	1982-1984 1985-1986
Chairman of Organizing Committee and Editor, NATO Advanced Research Institute, Mechanisms of Migration in Fishes	1981-1983
Member, Anadromous and Catadromous Fish Committee, International Council for the Exploration of the Sea	1978-1985
University of Maine, Presidential Research Achievement Award	1979
Science Faculty Professional Development Award, National Science Foundation	1978
Project Director, Research Initiation and Support Grant to Migratory Fish Research Institute, National Science Foundation	1977-1981

PUBLICATIONS AND MANUSCRIPTS

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McCleave, J.D. 2003. Spawning areas of the Atlantic eels. Pages 141-155. *In* K. Aida, K. Tsukamoto and K. Yamauchi (editors). Eel biology. Springer, Tokyo.

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Barbin, G.P., S.J. Parker and J.D. McCleave. 1998. Olfactory clues play a critical role in the estuarine migration of silver-phase American eels. Env. Biol. Fish. 53:283-291.
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Fried, S.M., and J.D. McCleave. 1973. Occurrence of the shortnose sturgeon (*Acipenser brevirostrum*), an endangered species, in Montsweag Bay, Maine. J. Fish. Res. Board Can. 30: 563-564.
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