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ENVIR. APPEALS BOARD

BEFORE THE ENVIRONMENTAL APPEALS BOARD
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

In re: Dominion Energy Brayton Point, LLC (formerly USGen. New England, Inc.) Brayton Point Station	)
NPDES Permit No. MA 0003654	)

EXHIBITS TO

PETITION FOR REVIEW OF NOVEMBER 30, 2006 DETERMINATION ON REMAND ISSUED BY REGION 1 IN RELATION TO NPDES PERMIT FOR BRAYTON POINT STATION

AND

MOTION TO SUPPLEMENT THE ADMINISTRATIVE RECORD

SUBMITTED ON BEHALF OF DOMINION ENERGY BRAYTON POINT, LLC

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TECHNICAL REVIEW OF:
U.S. EPA REGION 1 DETERMINATION ON REMAND FROM THE EPA ENVIRONMENTAL APPEALS BOARD BRAYTON POINT STATION, NPDES PERMIT NO. MA0003654

January 2007

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1.0 INTRODUCTION

The Region 1 office of the United States Environmental Protection Agency (EPA) reissued a National Pollutant Discharge Elimination System (NPDES) Permit (No. MA0003654) to the Brayton Point Station power plant on October 6, 2003. This Permit was appealed to the Environmental Appeals Board (EAB) by then owner and operator, USGen New England (USGenNE), a subsidiary of PG&E Corporation. Brayton Point Station was subsequently acquired by Dominion Energy Brayton Point who has continued to pursue the Permit appeal. On February 1, 2006, the EAB remanded the Permit back to Region 1 based on this appeal (*In re Dominion Energy Brayton Point, L.L.C. (Formerly USGen New England, Inc.) Brayton Point Station, NPDES Appeal No. 03-12 (EAB, Feb. 1, 2006))* (*Remand Order*). The *Remand Order* reopened the Permit proceeding so that Region 1 could address four "major holdings." On November 30, 2006, Region 1 addressed the remanded issues in *U.S. EPA Region 1 Determination on Remand from the EPA Environmental Appeals Board Brayton Point Station, NPDES Permit No. MA0003654* (*Determination on Remand*, AR 4065).

HDR|LMS (formerly Lawler, Matusky and Skelly Engineers, LLP [LMS]) is knowledgeable regarding Brayton Point Station §316(a) and (b) issues, having prepared the May 2001 Partial §316(a) and (b) Demonstration, the November 2001 Final §316(a) and (b) Demonstration (AR 555), the LMS Response to MA00003654 Determinations Document, as well as a number of technical documents relating to the Brayton Point Station Permit appeal and other environmental analyses. Accordingly, HDR|LMS is particularly qualified to provide comment on Region 1's *Determination on Remand* with regard to the two remand issues related to biological analyses relied on and put forth by the Region in its development of the Brayton Point Station NPDES Permit:

> **Remand Issue # 1 "production foregone re-analysis"** - The EAB directed Region 1 to place the "production foregone re-analysis" performed by one of the Region's consultants (Stratus Consulting Inc.) in the administrative record "Because the Region evaluated and relied on this document in developing the Final Permit".
>
> **Remand Issue # 2 - "selection of five days as the frequency for temperature exceedance"** - The EAB directed Region 1 to "either supplement the record with its

rationale" or "modify this value" with regard to the five-day criterion utilized in its determination of thermal effluent conditions in Brayton Point Station's Permit.

This report provides HDR|LMS' comments on the information Region 1 has provided in the *Determination on Remand* in support of these remanded issues (Sections 2.0 and 3.0, respectively). Other biological assumptions and analyses referenced by Region 1 in the document are also addressed (Section 4.0). HDR|LMS' review of the *Determination on Remand* is also provided in tabular format in a separate report title *Summary of Biological Errors in: U.S. EPA Region 1 Determination on Remand from the EPA Environmental Appeals Board Brayton Point Station, NPDES Permit No. MA0003654.*

2.0 REMAND ISSUE #1 – PRODUCTION FOREGONE RE-ANALYSIS

EPA (Region 1 and Office of Water, respectively) provided estimates of pounds of production foregone for Brayton Point Station in the MA0003654 Determinations Document (AR 192) and the Brayton Point Station Case Study in the proposed 316(b) rule for existing facilities (AR 3361). HDR|LMS performed a detailed review of the production foregone calculations reported by EPA through correspondence with EPA and attempted to reproduce EPA's results (AR 3263, Vol. II, p. II-8 to I-19; Englert, 2002). HDR|LMS concluded that EPA made two major errors in its calculations of production foregone. The errors resulted in inflated estimates for 14 of the 16 fish species analyzed. In several cases, EPA's estimates were hundreds of times higher than the correct values. The errors in EPA's analysis were also discussed in comments on the proposed 316(b) rule submitted to EPA on August 7, 2002 (AR 3305).

In its Response to Comments (AR 3346), Region 1 stated that its original production foregone estimates "were corrected for the Final Permit analysis" but then did not provide the corrected values. In Exhibit X of the appendices to Region 1's Response to Comments, Region 1's consultant, Stratus Consulting Inc., stated that "EPA acknowledges that some of the values employed were invalid because of various incorrect biological assumptions and/or clerical errors, and a re-analysis was conducted incorporating the changes (see attached)." However, the attachment purportedly showing the corrected production foregone estimates was not provided.

Region 1 states on page 2 of the *Determination on Remand* that "the referenced material was inadvertently left out of the administrative record" and on page 5 that "Region 1 has now placed a new copy of the complete document, including previously missing attachments, in the administrative record as AR 4020."

AR 4020 is, in fact, the same memorandum from Stratus Consulting Inc. to Phil Colarusso EPA – New England, labeled as Exhibit X in Region 1's *Response to Comments* with the addition of certain text and three tables labeled "Commercial Fishing Losses and Benefits at Brayton Point", "Percentage of Total Impacts Occurring to the Commercial and Recreation Fisheries and Commercial Value per Pound for Species Impinged and Entrained at North Atlantic Facilities" and "Recreational Fishing Losses at Brayton Point". However, *none of these tables contain estimates, or corrected estimates, of production foregone.*

It is important that Region 1 provide the corrected production foregone numbers and not the resulting pounds lost to the fishery because Region 1 used its uncorrected production foregone estimates in arguing that Brayton Point Station is having an adverse impact on Mount Hope Bay. For example, on page 7-126 of the Determinations Document Region 1 states "well over 54 million pounds of…nekton production is foregone due to entrainment and impingement" with the Enhanced Multi-mode scenario while in its Response to Comments (AR 3346 Comment IV.47, p. IV-69), Region 1 stated it "estimated that the loss of non-commercial fish would be more than 54 million pounds per year". However, when corrected for the errors Region 1 acknowledges it made, this value is reduced by a factor of nearly 300, so that 54,000,000 pounds becomes 185,000 pounds (AR 3263, Vol. II, Tab 11, pp. II-19). The EAB on page 154 of its *Remand Order* reports the original, uncorrected overestimates of production foregone calculated by Stratus Consulting Inc., which Region 1 acknowledges were incorrect.[1]

The "attachment" provided in AR 4020 does not fulfill EAB's expectation (from page 12 of the *Remand Order*) that "[t]he missing 're-analysis' details the production foregone calculations

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[1] On page 154 of the *Remand Order*, the EAB stated that "The Region also found that the annual total production foregone for BPS under different operating scenarios was wide-ranging: from about 122 million pounds under the 1993 permit, to about 83 million pounds under the current operating conditions, to about 55 million pounds for Petitioner's proposed approach."

performed by Stratus Consulting Inc. in response to comments pointing out several errors in the initial calculations." The attachment neither details the production forgone calculations nor does it provide the corrected estimates of production foregone.

3.0 REMAND ISSUE #2 – SELECTION OF FIVE DAYS AS THE FREQUENCY FOR TEMPERATURE EXCEEDANCE

Region 1 based its determination of summer discharge limits for Brayton Point Station on the following four criteria applied to young-of-the-year (YOY) winter flounder (Determinations Document, AR 192):

1. Maximum areal impact – 10% of the Bay
2. Critical temperature – 24°C
3. Frequency of critical temperature exceedance – five days
4. Reasonable worst case year temperatures – 1999

Region 1 described its thermal discharge analysis on page 15 of the *Determination on Remand* as "summer discharge limits were designed to ensure that no more than 10% of the bay exceeds 24°C for five or more days per summer month" (footnote reference omitted). This description fails to acknowledge criterion number four, which is important because it represents another layer of conservatism in that 1999 represents the 95th percentile of warm years – or the warmest year out of 20 – and thus is not representative of Mount Hope Bay in a typical year.[2]

While the only criterion of the four thermal discharge criteria remanded by the EAB is the "Selection of the Critical Temperature Exceedance Threshold of Five Days" (page 21 of the *Determination on Remand*; Criterion 3 from above), in the *Determination on Remand* Region 1 revisits the "Maximum Areal Impact – 10% of the Bay" (page 15; Criterion 1 from above) and "Selection of Critical Temperature – 24°C" (page 18; Criterion 2 from above) criteria and in some cases supplements the administrative record in an effort to bolster support for its position.

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[2] When one looks at how much of Mount Hope Bay would reach 24C during a normal (mean) summer such as was experienced in 1997, it is a much smaller area than during the 1999 worst-case summer. The proportion of the Bay affected for more than five days with Brayton Point Station discharging 28 tBTUs per year drops from 62% in 1999 to only 6.5% in 1997.

This section summarizes methodological and factual errors associated with Region 1's justification of the thermal discharge analysis and its criterion as they relate to the information provided in the *Determination on Remand.*

3.1 Characterization of the Condition of the BIP in Mount Hope Bay

Throughout the discussion of its thermal criteria, Region 1 references the condition of Mount Hope Bay fish populations (the BIP) as support for its conservative approach in selecting thermal criteria for Brayton Point Station. On page 12 of the *Determination on Remand* Region 1 states that "it should be pointed out that in the roughly four years since Region 1 arrived at its conclusion regarding the BIP in Mount Hope Bay, the BIP has shown no sign of recovery." In fact, YOY winter flounder in Mount Hope Bay – the species and life stage on which Region 1 bases its summertime criterion, are currently exhibiting evidence of a possible recovery.[3] As shown in Figure 1, since 1993, the June-August index of abundance for YOY winter flounder has increased by an order of magnitude. This trend is consistent with Narragansett Bay-wide trends, including Mount Hope Bay, noted by Gibson et al. (2006) who stated that "[t]he abundance of 'young-of-the-year' winter flounder (Age 0) has increased in Narragansett Bay shallows based on DFW [Rhode Island Division of Fish and Wildlife] beach seine surveys" and,

> It may be that Bay conditions have recently changed such that the survival of young-of-the-year winter flounder has improved. This could be evidence of the beginning of a recovery.

3.2 Frequency of Critical Temperature Exceedance - Five Days

As detailed below, in their response to the five day issue, Region 1 misapplied the scientific literature and used studies unrelated to avoidance despite its statement on page 19 that it "decided to focus primarily on avoidance temperatures in the development of summer permit limits".

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[3] Increases in abundance of YOY winter flounder also suggest that intake effects are not preventing the recovery of the winter flounder in Mount Hope Bay because the YOY index includes the effects of entrainment of eggs, larvae and early juveniles, and impingement losses of older juveniles and adults are negligible due to this species' high rate of impingement survival (2001 Brayton Point Station §316(a) and (b) Demonstration; AR 555).

Region 1 looked to the scientific literature and its own guidance documents for information regarding the "exposure time required to elicit an avoidance response". Based on what Region 1 provides in the *Determination on Remand*, it did not find a single study that supported an exposure time of less than seven days. The only study that Region 1 refers to that is less than seven days in duration was a lab study that was conducted over a three day period, and as detailed below, it does not provide information on the time to elicit an avoidance response. The remaining studies referenced by Region 1 all involved durations of more than seven days and were focused on growth, not avoidance. Additional EPA guidance documents reviewed by HDR|LMS also suggest periods of seven days or more. As will be apparent from the discussion that follows, Region 1 did not find support for the five-day portion of its criterion.

3.2.1 Three Days as a Lower Bound Based on Misinterpretation of the Literature

Region 1 states on page 24 of the *Determination on Remand* that the scientific literature provides "a reasonable basis for concluding that by three days of exposure" to 24°C "juvenile winter flounder would likely choose to avoid waters at that temperature" and that a study by Casterlin and Reynolds (1982) (AR 385) supports that statement. However, a review of the Casterlin and Reynolds (1982) methodology makes it apparent the study was not properly designed to determine the amount of time required to elicit an avoidance response and that the results do not support 24°C as a critical threshold temperature for juvenile winter flounder in Mount Hope Bay during the summer.

Casterlin and Reynolds (1982) utilized a two-chambered shuttlebox (i.e., two aquaria separated by a narrow opening) where water temperature in the "hot-side" and "cold-side" are regulated by an aquarium heater and refrigerated water, respectively. Fish occupying the hot-side initiated heating of the water in the hot-side, while fish occupying the cold-side initiated cooling of the cold-side. As a result temperatures were continually either increasing or decreasing in parallel. Each of 16 winter flounder was tested individually for a three day period with documentation of its occupation of the range of temperatures observed in the shuttleboxes. Prior to the three day experiment the fish were held in the laboratory for at least two weeks at 15-17°C. Results are summarized in Fig. 1 of Exhibit 8 to the *Determination on Remand.*

Casterlin and Reynolds (1982) did not test for the amount of time that it would take to elicit an avoidance response; they simply conducted the experiment over a three day period, without any explanation as to why that duration was chosen. Furthermore, Casterlin and Reynolds (1982) provide no information regarding how the temperatures selected by the test fish changed over the three days of the study. Without this information one can only speculate as to how the fish would have behaved if the experiment was extended beyond three days.

Casterlin and Reynolds (1982) characterize the data in their Fig. 1 as "Pooled data for all the fish were used to construct a relative frequency distribution of voluntarily occupied (self-controlled) or preferred temperatures" suggesting that no avoidance occurred within the temperature range observed in the study, 8 to 27°C[4]. Importantly, an avoidance temperature, and thus the time required to elicit an avoidance response, cannot be measured with the testing apparatus employed by Casterlin and Reynolds (1982) because the overly simplistic environment of the shuttleboxes does not account for the multitude of competing factors an organism must consider when choosing which habitat to occupy. The Casterlin and Reynolds (1982) study determined preferred temperatures at the tested acclimation temperatures, and not temperatures that would be avoided in Mount Hope Bay and elsewhere. This concept is considered on page 265 of Coutant (1977) (AR 4010) where he points out the need for research to determine "under what conditions temperature selection is the major factor affecting distribution and under what conditions other factors (like habitat, feeding, avoidance of predators and other factors) interfere with temperature selection and...become the principal factors." Further confirmation that an avoidance temperature and thus the time required to elicit an avoidance response has not been determined by Casterlin and Reynolds (1982) is evidenced by the fact that YOY winter flounder are consistently collected in Mount Hope Bay and Narragansett Bay (Chapter 10, AR 4032, Section 3.3.5) at temperatures above the maximum observed in Casterlin and Reynolds (1982).

Casterlin and Reynolds (1982) results show that the fish acclimated to 15-17°C spent a total of approximately 16% of the three-day study period at temperatures of 24°C or greater. Thus, the

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[4] As discussed in Section 3.3.4, the upper end of this range (27°C) will increase with acclimation temperature.

Casterlin and Reynolds (1982) results do not, in fact, support Region 1's 24°C critical temperature.

Region 1's misunderstanding of the Casterlin and Reynolds (1982) study methods likely contributed to its incorrect interpretation of the study's results. Region 1 states on page 24 of the *Determination on Remand* that "Casterlin and Reynolds (1982) conducted a lab experiment which allowed juvenile winter flounder to select their preferred water temperature in a series of constant temperature shuttleboxes. Temperatures within any individual shuttlebox did not vary" and on page 25 "[t]he temperatures in the study's shuttleboxes were maintained at constant levels, whereas the water temperatures in Mount Hope Bay will fluctuate somewhat over the course of a day." In fact, as discussed above, temperatures in the shuttleboxes varied based on the movements of the fish.

It is apparent from the above discussion that Region 1's misunderstanding of the Casterlin and Reynolds (1982) study led them to erroneously conclude that it could provide information relevant to the time required to elicit an avoidance response. Clearly the study does not support Region 1's claim that after three days of exposure to 24°C juvenile winter flounder would choose to avoid that temperature.

3.2.2 Region 1 Relies on Studies of Growth to Assess Avoidance-Based Criteria

Although Region 1 has stated that the 24°C and five-day criteria were selected based on avoidance temperatures of juvenile winter flounder and the time to elicit an avoidance response, the Region used studies on growth in its attempt to support these criteria. One such work relied on by Region 1 is EPA's Gold Book (1986) (AR 4002).[5] The Gold Book presents an equation that the authors say can be used to estimate a limiting maximum weekly temperature given knowledge of the optimum growth temperature and upper incipient lethal temperature. Region 1 attempts to apply this equation and references Rose et al. (1996) (AR 4012) and Manderson et al. (2002) (AR 4016) as sources for an optimum growth temperature of 15°C. However, Rose et al.

[5] Region 1 states on page 26 of the *Determination on Remand* that "the Gold Book is a water quality standards-related document, rather than a CWA 316(a) variance related document".

(1996) conducted a modeling study and provides no data on optimum growth.[6] Manderson et al. (2002) reference the same Rose et al. (1996) modeling study and Armstrong (1995). Armstrong (1995), however, studied the effect of salinity on winter flounder growth and also does not provide optimum growth temperatures.

Based on the unsupported 15°C optimum growth temperature and an upper incipient lethal temperature of 29-30°C, Region 1 calculated a maximum seven-day average temperature of 20°C. However, this temperature is irrelevant because it is: (1) based on unsupported data, (2) not relevant to avoidance, which Region 1 states is the basis for its criterion, (3) well exceeded in juvenile habitat not influenced by the plant's discharge for long periods of time every summer, and (4) 12°C cooler than the temperatures at which winter flounder juveniles have been collected in Mount Hope Bay (Chapter 10 of AR 4032).

In a further attempt to link the 24°C and five-day criteria, Region 1 turns to additional studies on growth. Region 1 says that Sogard (1992) (AR 4011) "measured growth in caged juvenile winter flounder at a range of temperatures for 10 days and found a significant reduction in growth rates at temperatures of 24°C and above." Sogard (1992) makes no such statement. Sogard (1992) states that "warmer water temperatures in Little Egg Harbor could have been detrimental to winter founder growth in late June experiments". The average temperature for those experiments is reported in Sogard's Table 3 as 26.4 - 26.5°C, not 24°C. However, Sogard (1992) also says that contrasts, other than temperature, between the two estuaries she studied "may have affected growth patterns". In other words, due to the uncontrolled nature of the caging study could not isolate the influence of temperature on growth. In summary, the Sogard (1992) study does not support the five-day criterion or the 24°C threshold because: (1) the study was conducted over a ten-day period, (2) the influence of temperature on growth could not be separated from other differences in the study areas, and (3) there was no evidence of growth inhibition at 24°C.

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[6] Rose et al. (1996) does not support the 15°C value. Rose states that metabolic losses consist of a "routine component which depends on weight and temperature and an active component" and "[o]n the basis at which metabolic rates were reported ,T_r is set to 15°C for juveniles." In other words, Rose et al. (1996) uses the 15°C value in one of his equations because that is the temperature at which the routine metabolic rate (metabolism when the fish is not constantly swimming but only spontaneously active) was reported in Voyer and Morrison (1971). In their discussion of 15°C, Voyer and Morrison (1971) refer to the fact that McCracken (1963) did not find adult winter flounder in waters having temperatures greater than 15°C (Section 4.5).

Region 1 states on page 28 that "Meng et al. (2000) (AR 4013) measured growth rates in caged juvenile winter flounder in Rhode Island coastal lagoons and suggested that temperatures greater than 25°C negatively affected growth in experiments ranging from 10-15 days." Meng et al. (2000) reported that winter flounder growth was lowest at the Green Hill site in the third experiment, when temperatures exceeded 25°C. Importantly, Meng et al. (2000) also state that "Green Hill differed from the other ponds in size, flushing rate, and salinity, but it is likely that the high temperatures affected growth." Due to the uncontrolled nature of the experiment and the significant differences in habitat where the juveniles were caged, no definitive statement can be made regarding the effect of temperature on growth.

A more recent sampling study conducted by Meng et al. (2005) in Narragansett Bay found that winter flounder densities were "highest in coves and upper estuaries regardless of the amount of human disturbance." In explaining this result, Meng et al. (2005) state that "currents are less pronounced in coves and upper estuaries, and temperatures tend to be higher, enhancing growth." Temperatures during the study ranged to over 26°C. Meng et al. (2005) also state that "An estuarine life history – which includes adaptations to fluctuating salinities, temperatures, and dissolves oxygen – also allows winter flounder to exploit many habitats." This suggests that winter flounder have the physiological ability to adapt to thermal changes within their characteristic temperature range.

It is evident from the above review that even the studies referenced by Region 1 regarding growth do not support the 24°C, five-day criterion. None of the studies found growth inhibition at 24°C and all were conducted for periods two to three times as long as the five-day criterion. This is significant because growth inhibition typically occurs at lower temperatures than avoidance [7](AR 555, App., Figure 2-2). Hence, the fact that no effect on growth was observed at 24°C at 10- to 15-day durations provides further evidence that Region 1's criterion which it says is based on juvenile *avoidance* is overly conservative and restrictive and not supported by the scientific literature.

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[7] On page 19 of the *Determination on Remand* Region 1 says "the optimal growth temperature is lower than the avoidance temperature",

3.2.3 Other Support for Seven or More Days

HDR|LMS conducted its own review of existing 316(a) guidance documents and other associated EPA water quality documentation to determine if they provided any guidance regarding the period of time that should be considered for frequency of exceedance of thermal limits or the time to elicit an avoidance response. The following two documents were found to contain relevant information with respect to exposure temperature frequency and duration. A summary of the relevant statements from each document is provided below.

- **Temperature Criteria for Freshwater Fish: Protocol and Procedures (USEPA 1977)**[8] - This EPA protocol recommends a mean temperature value (expressed as the maximum weekly average temperature) that is designed to protect critical life stage functions such as spawning, embryogenesis, growth, maturation and development. The maximum weekly average temperature (MWAT) parameter is defined on page 10 as "the mathematical mean of…daily temperatures over a 7-day consecutive period."

- **"Redbook" Quality Criteria for Water (USEPA 1976)**[9] – On page 420 of this document EPA states, "For any time of the year there are two upper limiting temperatures for a location…one limit consists of a maximum temperature for short exposures…the second value is a limit on the weekly average temperature…" This weekly average water temperature is the value to be used for comparison to long-term non-lethal thermal limits like Criterion 2, the "critical temperature", in Region 1's thermal analysis for Brayton Point Station.

Similar to Region 1's review of guidance documents, the one performed by HDR|LMS found support for frequency of exceedance or durations of exposure of seven or more days, but none for five days or less when addressing avoidance or sublethal effects.

3.3 Selection of Critical Temperature – 24°C

Region 1 reiterates its justification of the 24°C threshold starting on page 18 of the *Determination on Remand.* The Region also reference new scientific studies in support of this threshold temperature. Errors contained in the *Determination on Remand* as they relate to this criterion are described below.

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[8] This document is cited on EPA's webpage (http://www.epa.gov/waterscience/criteria/wqcriteria.html) titled "Current National Recommended Water Quality Criteria," as footnote "M" under "Non Priority Pollutants."

[9] This document was cited on page B-21 of the *November 2001 USGenNE 316(a) and (b) Demonstration*, as well as on the above noted EPA webpage.

3.3.1 Acclimation Not Considered in Selection of 24°C

A fundamental error in Region 1's thermal discharge analysis is to select a single "critical" threshold temperature. Literature cited by Region 1 in prior submittals and in the *Determination on Remand* establishes that selection of a single threshold temperature ignores the phenomenon of acclimation. Region 1 states at page 22 of the *Determination on Remand* that [p]redicting thermal effects is a function of species, life stage, exposure temperature and exposure duration." Region 1's consultants Bevelhimer and Coutant (2001) (AR 3339) stated that "[a]ny criteria should account for variation in thermal tolerance among life stages, *thermal acclimation history,* duration of exposure, and chronic and acute effects" (italics added). Region 1 omitted thermal acclimation from the list of factors to be considered in its thermal discharge analysis for Brayton Point Station despite this concept's prevalence in the scientific literature and in the works of its own consultants.

For example, Bevelhimer and Bennett (2000) (AR 3201), cited by Region 1 on page 26 of the *Determination on Remand* state that "[i]t is common knowledge that the recent thermal history of a fish acclimates it to higher temperatures, thereby extending its tolerance limit (Parker and Krenkel, 1969; Jobling, 1994)" and page 252 of Coutant (1977)(AR 4010) states "[e]ach species of organism (and often each distinct life stage) has a characteristic physiological tolerance range of temperature as a consequence of acclimations (internal biochemical adjustments) made while at previous holding temperature" and "[t]he tolerance range is adjusted upward by acclimation to warmer water and downward by acclimation to cooler water." The Gold Book (1986) (AR 4002) states that "[t]he tolerance of organisms to extremes of temperature is a function of their genetic ability to adapt to thermal changes within their characteristic temperatures range, the acclimation temperature prior to exposure, and the time of exposure to the elevated temperature (Coutant, 1972)." By not considering the well-established phenomenon of acclimation and selecting a single temperature that would be exceeded in virtually every year without the plant operating, Region 1 has developed thermal restrictions that are unduly conservative and restrictive to protect the BIP.

3.3.2 22.2°C Lower Bound of Avoidance Temperature Range not Supported

In the *Determination on Remand*, Region 1 states on page 20 that the "the critical value for summer (24°C in bottom waters) was based on temperatures that would trigger *avoidance* by juvenile winter flounder of key nursery habitat." The EAB claims that Region 1 showed a range of avoidance temperatures from 22.2 to 27°C, but HDR|LMS has shown in AR 3263 that the 22.2°C does not represent an avoidance temperature.[10] Furthermore, the analysis of avoidance temperatures HDR|LMS performed based on a review of the scientific literature showed values to range from 26°C at an acclimation temperature of 15°C to about 31.5°C at an acclimation of 28°C (AR 555, App. B, Figure 2-2).

3.3.3 Sublethal Effects and Indirect Mortality not Supported

In the *Determination on Remand*, Region 1 attempts to provide support for the 24°C criterion by discussing the potential for sublethal effects and indirect mortality if juvenile winter flounder are "forced to avoid their preferred shallow habitat". In attempting to support its contention that juveniles prefer shallow habitat, Region 1 states that Manderson et al. (2004) (AR 4014) found that "the smallest size classes were in waters less than 1 meter deep." Region 1's statement is incorrect. In fact, Manderson et al. (2004) found the exact opposite. Manderson et al. (2004) reported that,

> ...as fish increased in size, the median and range of depth of occurrence gradually decreased. Large fish >35 mm SL [standard length] were concentrated in habitats ~1 m deep. [and] In May, large flounder were more strongly associated with shallow habitats than small fish.

Region 1 also states on page 18 that the "longer the period of time that juveniles stay within a size that is susceptible to predation, the greater the mortality from predation." Region 1 suggests

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[10] The reference to the lower limit of 22.2°C is based on misinterpretation of the scientific literature. EPA drew from Olla et al. (1969), a paper submitted by HDR|LMS earlier in support of the conservative assumption that, in response to elevated temperatures, winter flounder might burrow in the substrate instead of fleeing. HDR|LMS disagrees with EPA's supplemental interpretation of the Olla paper—namely, that the burrowing was an artifact of stress derived from the 22.2°C temperature (i.e., the temperatures that occurred at the time of the observation). Winter flounder have evolved to be able to hide by quickly burrowing in a shallow soft bottom. As stated in the Fisheries of Rhode Island Narragansett Bay Summit 2000 white paper (DeAlteris, Gibson, and Skrobe, 2000) [*Working Draft*], "when they are on soft bottom they usually lie buried, all but the eyes, working themselves down into the mud almost instantly when they settle from swimming. Flounders that live on the flats usually lie motionless over the low tide to become more active on the flood, when they scatter in search of food.... Though they spend most of their time lying motionless, they can dash for a few yards with astonishing rapidity. It is in this manner that they usually feed, not by rooting in the sand (Bigelow and Schroeder 1953)." Thus, winter flounder burrowing is a natural behavior and it is not "brought on" by temperatures in excess of 22.2°C.

that the thermal plume might slow growth rates and thus lengthen the time that juveniles are susceptible to predation. However, the opposite is more likely because, the marginally warmer temperatures from the plume will accelerate growth in the early life stages, giving them a survival advantage (Rose, 1996; AR 4012).[11]

3.3.4 Casterlin and Reynolds (1982) and Avoidance

Although, as explained in detail in Section 3.2.1, the Casterlin and Reynolds (1982) study was not properly designed to test for avoidance, they say their data suggest an upper avoidance temperature of 27°C. The sixteen juvenile winter flounder studied by Casterlin and Reynolds (1982) were acclimated for at least two weeks to 15-17°C, well below the summertime ambient temperatures in the portions of Mount Hope Bay[12] and adjacent waters uninfluenced by the thermal plume. The authors observed that the fish spent approximately 16% of the three day experimental period at temperatures of 24 to 27°C — i.e., 7 to 12°C above their acclimation temperature.

As discussed in Section 3.3.1, Bevelhimer and Bennett (AR 3201) and Coutant (AR 410) among many others have stated that tolerance temperatures are a function of acclimation temperature. Avoidance temperature for YOY winter flounder as a function of acclimation temperature is shown in Figure 2-2 of Appendix B of AR 555. The avoidance temperature for YOY acclimated to 15-17°C is shown to be 26-27°C. This is consistent with Casterlin and Reynolds' (1982) suggestion that avoidance could be initiated at or below 27°C. Thus, Casterlin and Reynolds' (1982) observation supports the thermal tolerance line used in the biothermal assessment performed by HDR|LMS (AR 555, App. B, Figure 2-2), not the single avoidance temperature, 24°C, used by Region 1 in setting the Brayton Point Station thermal limits.

3.3.5 Region 1 Does Not Consider Relevant Information on Collection Temperatures

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[11] Meng et al. (2005) states that "[c]urrents are less pronounced in coves and upper estuaries, and temperatures tend to be higher, enhancing growth."

[12] The hydrothermal model results for 1999 relied upon by Region 1 in setting the BPS thermal discharge limits show that 4.4% of the bottom layer volume exceeded 24°C for five days, demonstrating that ambient temperatures are well in excess of the 15-17°C used by Casterlin and Reynolds.

Actual collections of juvenile winter flounder in Mount Hope Bay, where these fish compete for food, avoid predation, and optimize growth, provide more useful information regarding avoidance than the studies relied upon by Region 1. In its analysis of juvenile avoidance temperature Region 1 does not consider the fact that YOY winter flounder beach seine collections conducted in Mount Hope Bay, and reported in the Brayton Point Station Annual Reports (AR 4032 and AR 4058), show that, contrary to Region 1's statements[13], juveniles are still using the shallow habitats in the upper Bay and have been collected at temperatures up to 32°C. Analyses of beach seine collections of YOY winter flounder conducted in the tributaries to Mount Hope Bay show that YOY winter flounder typically occupy, and likely seek out, temperatures well above 24°C. In 2005, the most recent year of data analyzed, YOY winter flounder were collected at the highest average abundance levels at 28°C, the warmest temperature recorded (Figure 2). This further suggests the influence of acclimation on avoidance temperatures (see Section 3.3.1) and demonstrates that neither 24 nor 27°C are critical threshold temperatures for YOY winter flounder avoidance.

Given that during 2005, YOY winter flounder were collected in relative abundance in late-July and mid-August beach seine samples (AR 4032, Table 7-7) where recorded temperatures were consistently 24°C or higher, it is also apparent that the 3-day duration of the Casterlin and Reynolds (1982) study provides no information or insight into the "time required to elicit an avoidance response" and certainly does not support the Region's statement that the study provided "a reasonable basis for concluding that by three days of exposure" to 24°C "juvenile winter flounder would likely choose to avoid waters at that temperature".

3.3.6 Summary of Findings Regarding 24°C Criterion

In its discussion of the 24°C criterion Region 1 has: 1) failed to consider that the scientific literature it references says that avoidance varies with acclimation, 2) misinterpreted the literature it relied on to support 24°C, and 3) not considered field data collected in Mount Hope showing that winter flounder still use the habitats it says have been vacated.

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[13] Region 1 states on page 19 of the *Determination on Remand* that it "concluded that the data indicate that the current thermal discharge from BPS is contributing to a shift in...juvenile winter flounder distribution in Mount Hope Bay from shallow water habitat to deeper water habitat based on temperature preference."

3.4 Maximum Areal Impact – 10% of the Bay

Region 1 discusses its justification of the 10% of the Bay criterion without introducing new data or analyses. This criterion continues to be unsupported by scientific data. Since errors in Region 1's analysis with respect to this criterion are already a part of the administrative record, they will not be reiterated here.[14]

4.0 OTHER ISSUES IN THE *DETERMINATION ON REMAND*

A complete list of errors noted by HDR|LMS based on our review of the *Determination on Remand* is contained in *Summary of Biological Errors in: U.S. EPA Region 1 Determination on Remand from the EPA Environmental Appeals Board Brayton Point Station, NPDES Permit No. MA0003654.* The following summarizes the more consequential of these errors not discussed as a part of the issues elucidated in the previous sections of this report.

4.1 Incorrect summarization of Casterlin and Reynolds (1982) Results

On page 25 of the *Determination on Remand*, the EAB is quoted summarizing Casterlin and Reynolds (1982) as "[f]ish apparently selected temperatures of 24, 25, and 26°C for about 4-5% of the time and a temperature of 27°C for about 3% of the time." This is not correct. In the Casterlin and Reynolds (1982) study, winter flounder selected temperatures of 24, 25 and 26°C a total of approximately 13% of the time (approx 4.2 to 4.8% for each degree within this range), not 4-5% of the time.

4.2 Accumulation and Dissipation of Thermal Stress

On page 26 of the *Determination on Remand*, Region 1 relies on Bevelhimer and Bennett (2000) (AR3201) to support its claim that "thermal stress in fish accumulates more quickly than it dissipates (Bevelhimer and Bennett, 2000) (AR 3201)". However, Bevelhimer and Bennett (2000) provide no data or prior studies to support this statement. It is simply an assumption they employed in their mathematical modeling study. The authors wrote that "[f]or this

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[14] The 10% criterion is arbitrary and appears to be "reverse engineered" (see, for example, AR #3263, Vol. II, Tab 11, p. I-15 to I-16).

demonstration, we assume that Z = 0.25; therefore, recovery occurs at a rate 25% of that at which it accumulates." Region 1 erred in failing to note that the authors acknowledged little is known on this topic. Bevelhimer and Bennett (2000) (AR 3201) stated,

> One aspect of stress accumulation of which little is known is stress recovery when exposure to high temperatures is removed. The temperature at which recovery occurs, the rate of recovery, and the length of time for full recovery are largely unknown....The effects of fluctuating temperature regimes on temperature tolerance, thermal stress accumulation and recovery, and growth are still largely a mystery.

4.3 Regional Finfish Abundance Declines

Region 1 discussed finfish declines in Mount Hope Bay without reference to the concomitant declines in the rest of Narragansett Bay. For example, on page 11 and 12 of the *Determination on Remand*, Region 1 states that,

> Relying on trawl data provided by the applicant, the Region observed that the average abundance of winter flounder, windowpane, tautog and hogchoker amounted to less than 1 fish caught per otter trawl sample. Id. at 6-55. In the case of winter flounder, this represents a 100-fold reduction over historical levels.

Region 1 fails to acknowledge recent studies that have determined that the declines in abundance of finfish including winter flounder in Mount Hope Bay are generally consistent with those in Narragansett Bay. For example, Rountree and Lynch (2003) reported that "[i]n conclusion, we find that changes in winter flounder abundance and in the fish assemblage between 1979 and 2001 in Mt. Hope Bay are similar to those observed in other parts of the greater Narragansett Bay system, and reflect processes operating on a Narragansett Bay-wide scale" and DeAlteris et al. (In Press)[15] reported that "[n]atural and anthropogenic stressors unique to Mount Hope Bay, including Brayton Point Station, have not caused Mount Hope Bay fish stocks to change at rates different from those observed for the same stocks in Narragansett Bay."

4.4 Region 1's Perceived BPS Thermal Impacts

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[15] The DeAlteris et al. (In Press) analysis has been conducted as a part of the 2004 and 2005 annual reports (AR 4032 and AR 4058) and supports the conclusions of the original analysis.

On page 11 of the *Determination on Remand*, Region 1 states that,

> The numerous adverse, thermally related impacts and ecosystem changes experienced in Mount Hope Bay and contributed to by BPS were summarized by the Board as follows: According to the Region, the most obvious and least contested of these are: negative effects on the phytoplankton (i.e., absence of normal winter-spring phytoplankton bloom, appearance of nuisance algal blooms), increased abundance of certain animal species in the bay (i.e., increased abundance of smallmouth flounder, overwintering of striped bass and bluefish in the discharge canal, and overwintering of the ctenophore (*Mnemipsis leidyi*), and decreased abundance of certain fish (i.e., thermal avoidance of most of the bay by adult winter flounder).

Each of these issues has already been addressed in detail in the Administrative Record and shown to be either unsupported by evidence (i.e., nuisance algal blooms, increase in smallmouth flounder and striped bass) (Page 55, 64 and 62-62, respectively, AR 3263) overstated (i.e., bluefish) (Footnote 117 on page 64, AR 3263), conjecture (i.e., ctenophore blooms) (Page 54, AR 3263; LMS, 2002), or misguided (i.e., avoidance by adult winter flounder) (see immediately below).

4.5 Adult Winter Flounder Seasonal Migrations are Not Considered

Another error made by Region 1 and the EAB on page 11 of the *Determination on Remand* regards the alleged "thermal avoidance of most of the bay by adult winter flounder". Adult winter flounder movements as related to temperature was fully explored and addressed in AR 3263, Vol. II, Tab 11 (pp. I-4 and I-10). Region 1 has not addressed the details and evidence provided in this response. AR 3263, Vol. II, Tab 11 (p. I-4) shows that it is well documented that adult winter flounder leave shallow shoreline waters when the temperatures reach approximately 15°C. There is no laboratory correlation between this temperature and a short-term avoidance response (i.e., no evidence of thermal discomfort). This is simply an evolutionary adaptation where 15°C acts as a cue signaling that Mount Hope Bay has begun its normal seasonal warming, a cue to which adult winter flounder respond by moving into the cooler ocean waters.

4.6 YOY Winter Flounder Growth Rates and Susceptibility to Predation

Region 1 states on page 18 of the *Determination on Remand* that,

> In addition, in early life stages, newly settled young-of-the-year winter flounder are vulnerable to a number of predators, including sand shrimp (Taylor and Collie, 2003) (AR 4022), green crabs (Fairchild and Howell, 2000) (AR 4015) and summer flounder (Manderson et al., 2004) (AR 4019). The longer the period of time that juveniles stay within a size that is susceptible to predation, the greater the mortality rate from predation. (Able & Fahay, 1998) (AR 692).

The Station's thermal discharge is likely to promote increased growth during the spring and early summer and may actually decrease the time period for which juveniles are susceptible to predation. Evidence of this is suggests by the following Taylor and Collie (2003) statements:

> [s]usceptibility to predation then gradually decreases after settlement until a refuge is attained when flounder reach 24 mm TL (Witting and Able 1995). Thus faster-growing flounder are likely to have a survival advantage because their exposure to the 'mortality window', a period lasting several months characterized by high predator-induced mortality, is shortened.

4.7 Winter Flounder Collection Temperature Data

Region 1 states on page 19 of the *Determination on Remand* that,

> The Rhode Island Department of Environmental Management (RI DEM) submitted data comparing winter flounder abundance with temperature (Reitsma, 2002) (AR 355). The data suggest that winter flounder response to water temperature is fairly dramatic. Figures 6.3-2 and 6.3-3 of the DPDD (AR 192) show that adult winter flounder abundance drops to nearly zero above 15°C and juvenile abundance declines in a similar fashion above 24 or 25°C. The response of these fish are dramatic and indicative of a temperature threshold effect.

See the discussion in Section 4.5 regarding adult winter flounder movements as related to temperature and why Region 1's comments are irrelevant to the avoidance question. AR 3263, Vol. II, Tab 11, p.1-5 details Region 1's misinterpretation and misapplication of the field data regarding juvenile winter flounder. Beach seine collections conducted in the tributaries to Mount Hope Bay show that YOY winter flounder continue to occupy shallow portions of the Bay near the plant throughout the summer. For example, in the most recent year of data analyzed (2005 collections), winter flounder were collected at the highest average abundance levels at the highest temperature recorded during summer sampling (28°C) (Figure 2). This finding suggests that these fish may in fact be searching out temperatures warmer than 24 and 25°C, not avoiding them.

5.0 SUMMARY OF FINDINGS

HDR|LMS' review of the *Determination on Remand* has focused on the following two biological issues that were remanded back to Region 1 by the EAB:

1. Region 1 was to place the production foregone re-analysis conducted by its consultant, Stratus Consulting Inc., in the administrative record, and
2. Region 1 was to supplement the record with its rationale for the five-day criterion or modify the value.

Our review of the *Determination on Remand* shows that Region 1 has not provided the production foregone re-analysis to the record and that the evidence provided does not support the five-day criterion used in its thermal discharge analysis for Brayton Point Station.

5.1 Production Foregone

As detailed in Section 2.0, Region 1 has not fully addressed the EAB's request for the details of the production foregone calculations and the corrected estimates of production foregone. It is very important the corrected values be entered into the record because the uncorrected estimates are grossly inflated and have continually been used to overstate the Station's impact.

5.2 Five-Day Criterion

As discussed in Section 3.0, Region 1's thermal discharge analysis for Brayton Point Station bases its determination of summer discharge limits on the following four combined criteria:

1. Maximum areal impact – 10% of the Bay

2. Critical temperature – 24°C
3. Frequency of critical temperature exceedance – five days
4. Reasonable worst case year temperatures – 1999

As discussed extensively in prior comments (e.g., AR 3263 and LMS, 2002), the assumptions and data upon which these criteria are based do not support Region 1's conclusions. Errors made by Region 1 in the development of its criterion have been documented elsewhere so here we have focused on the new information the Region has called upon in the *Determination on Remand* to develop support for the frequency of critical temperature exceedance of five days and the critical temperature of 24°C.

5.2.1 Frequency of Critical Temperature Exceedance – five days

In its rationale for the frequency of exceedance portion of its criterion Region 1 calls upon several studies. The first by Casterlin and Reynolds (1982) shows that juvenile winter flounder acclimated to 15-17°C spent 16% of a three-day experimental period at temperatures at or above 24°C. Although their experiment was not properly designed to test for avoidance or the time required to elicit an avoidance response, they suggest avoidance was "initiated at or below 27°C." This value is consistent with the acclimation-dependant avoidance temperatures for juvenile winter flounder used by HDR|LMS in its biothermal analysis of the Brayton Point Station discharge.

Region 1 also utilizes studies on growth to support the five-day criteria and the 24°C critical temperature, although the Region discusses in detail in the *Determination on Remand* why its criteria are based not on growth, but avoidance. The growth studies do not justify either criterion. They deal with growth temperatures and with durations of seven to 15 days, not the five days selected by Region 1. The first, the Gold Book (1986) provides a "rule of thumb" equation to provide a maximum seven-day average temperature. However, Region 1's effort to calculate this temperature is: (1) based on unsupported data, (2) not relevant to avoidance, which Region 1 says is the basis for its criterion, (3) exceeded in juvenile habitat not influenced by the plant's discharge for long periods of time every summer, and (4) 12°C cooler than the temperatures at which winter flounder juveniles have been collected in Mount Hope Bay.

Next Region 1 turns to studies that involved placing juvenile winter flounder in cages for 10-15 days at various locations in New Jersey and Rhode Island but ignore a more recent sampling study by one of the authors of the Rhode Island study which showed that juvenile winter flounder preferred disturbed, unvegetated areas in coves and upper estuaries where "temperatures tend to be higher, enhancing growth." The results of the caging studies do not support either the 24°C or the five-day criterion because they show no evidence for inhibition of growth at 24°C and were conducted over 10-15 days. Although they were irrelevant to Region 1's avoidance criterion, the fact that the studies did not show inhibition of growth at 24°C, which typically occurs at temperatures lower than avoidance[16], provides further evidence that Region 1's criterion is overly restrictive.

5.2.2 Critical Temperature – 24°C

Our review of the information provided in the *Determination on Remand* on the question of the critical temperature shows that Region 1 has not supported the selection of 24°C as the single threshold avoidance temperature for juvenile winter flounder. Region 1 errs in that: 1) the scientific literature that it references states that avoidance temperature varies with acclimation, 2) it has misinterpreted the literature it relied on to support its value, and 3) it has not considered field data collected in Mount Hope Bay showing that winter flounder are still using the habitats the Region says would have been vacated.

5.3 Other Issues

Region 1 provides incorrect information in the *Determination on Remand* on a number of other issues related to the thermal criteria. Among these is a reiteration of EAB's incorrect summary of the Casterlin and Reynolds (1982) study in terms of percent of the study period juvenile winter flounder spent at temperatures at and above 24°C. Region 1 also mischaracterized assumptions in Bevelhimer and Bennett (2000), made incorrect speculations regarding the

[16] The thermal tolerance polygon for juvenile winter shown in Figure 2-2 of AR 555 shows the upper end of the growth temperature range to be below the avoidance line and on page 19 of the *Determination on Remand* Region 1 says "the optimal growth temperature is lower than the avoidance temperature".

Station's indirect effects on predation, and did not consider recent studies finding no difference in fish abundance trends in Mount Hope Bay and Narragansett Bay (Rountree and Lynch, 2003 and DeAlteris et al., In Press), and YOY winter flounder collection temperature data for Mount Hope Bay which shows that during some years these fish likely seek out warm waters (e.g., 28°C) in Mount Hope Bay, rather than avoid them.

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7.0 FIGURES

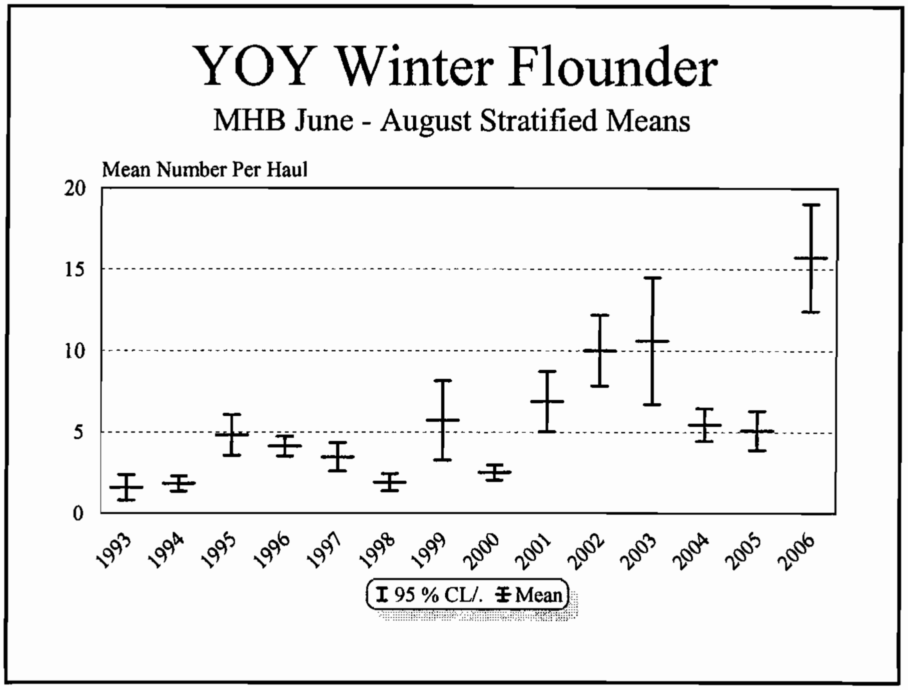

Figure 1. Stratified mean number of young-of-the-year (YOY) winter flounder collected per 50-ft beach seine haul for June through August Mount Hope Bay collections, 1993-2006 (Data collected by Normandeau Associates, Inc. [formerly Marine Research, Inc.])

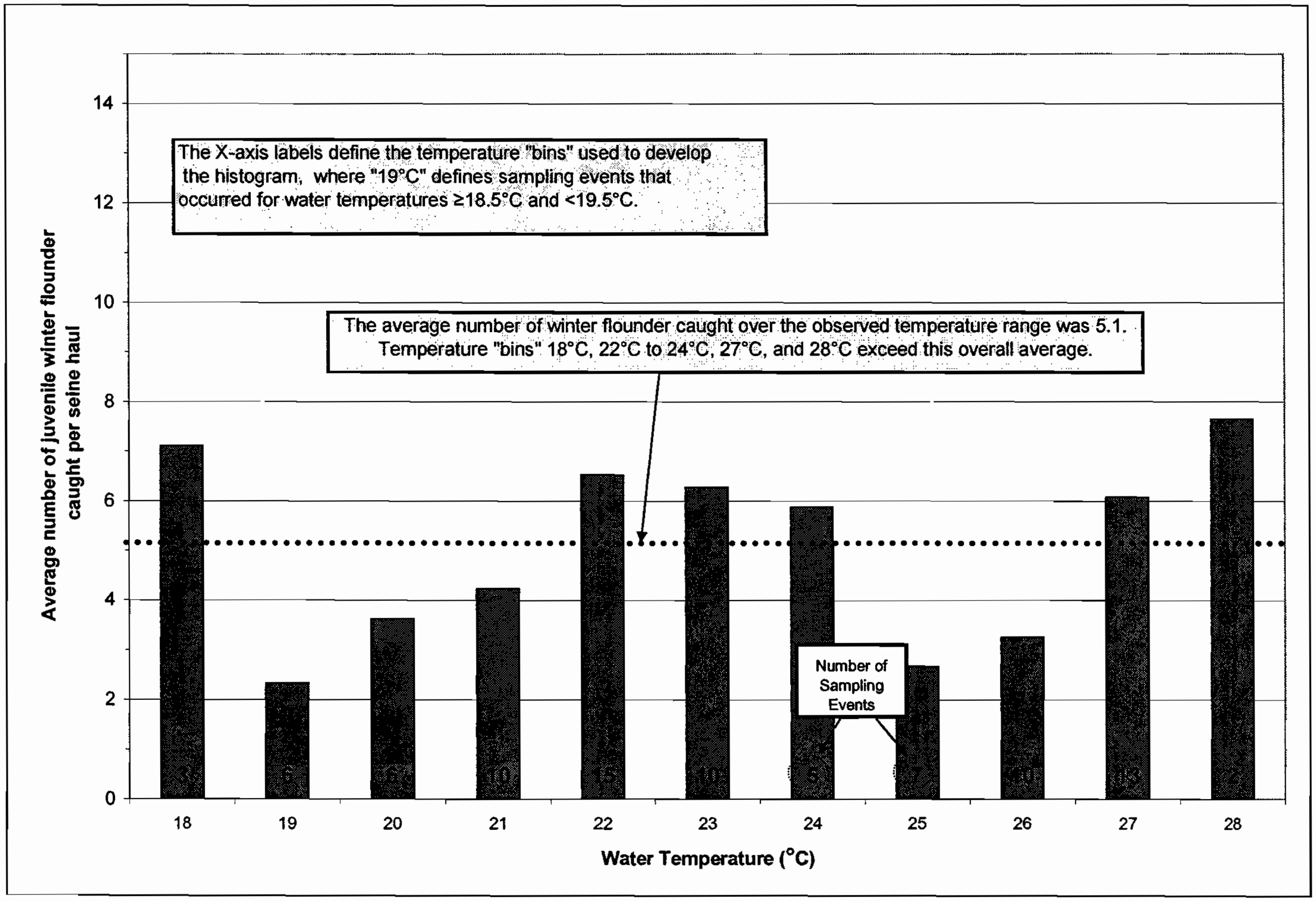

Figure 2. Average number of winter flounder caught per seine haul (and number of sampling events) for water temperatures represented in the 2005 50-ft beach seine data for Mount Hope Bay (Figure 10-2 from the Brayton Point Station 2005 Annual Hydrological and Biological Monitoring Report)

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Education

Doctor of Philosophy, Chemical Engineering, Princeton University, 1973

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Registrations

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Experience

Dr. Englert is a Vice President with HDR|LMS. During his 32-year tenure, Dr. Englert's professional practice has dealt principally with the study of the effects of power plant operations on the environment in the context of 316 demonstrations, environmental impact statements and power plant siting studies. Dr. Englert is a recognized expert on modeling of the effects of entrainment and impingement on fish populations and has had overall technical and administrative responsibility for preparation of major 316 (a) and (b) demonstrations as well as biological sampling programs to collect the supporting data. He has also had lead technical and administrative responsibility for intake technology evaluations, thermal surveys, modeling of thermal plumes and receiving water bodies and biothermal assessments of the effects of discharges from fossil fuel and nuclear generating stations on fish populations.

Dr. Englert has served as a technical witness before the New York State Article X Siting Board, U.S. Environmental Protection Agency (EPA), the New York State Department of Environmental Conservation (NYSDEC), the Nuclear Regulatory Commission (NRC), the Federal Energy Regulatory Commission (FERC), and the Michigan Department of Natural Resources (DNR) as well as local planning and town boards. His testimony before state and Federal agencies has dealt principally with the environmental impact of power plant operations and 316 related issues. He has managed and participated in cost/benefit analyses, comparing the value of natural resources with the costs of mitigating measures.

Representative projects include:

Mount Hope Bay, Rhode Island/Massachusetts. Dr. Englert provided managerial and technical direction and strategy development for 316(a) and (b) demonstrations, comments on the draft permit and response to comments from the regulatory agencies. He provided technical direction and supervision for analysis of intake and discharge effects of Brayton Generating Station on winter flounder and other fish species. This included extensive statistical analyses, equivalent recruit and CMR modeling, population modeling using RAMAS and biothermal assessments of the effects of the thermal plume. Dr. Englert provided technical consultation to USGen New England, Inc. technical and legal staff during the production of numerous scientific and legal documents related to the appeal of the Brayton Point Station National Pollutant Discharge Elimination System permit. Consultation included review of technical reports and models developed by regulatory scientists, review of USGen New England, Inc. scientific and legal staff reports and docket submissions, and preparation of technical analyses and reports. Review of regulatory scientists' analyses included re-creation and critique of biomass dynamic, production foregone and other impacts assessment models, summarizing inconsistencies in technical arguments, and prioritization of technical arguments. He also supervised the conduct of field studies to determine through plant survival of entrained organisms.

Salem Generating Station, New Jersey. Dr. Englert has provided managerial and technical direction for the preparation of 316 (a) and (b) demonstrations for four permit renewal cycles over a twenty year period. He directed modeling efforts to determine the effects of entrainment and impingement on fish populations, and the benefits of various intake technologies, operational changes and restoration measures. He formulated and presented the utility's technical position to New Jersey Department of Environmental Protection (NJDEP). He also directed nearfield and farfield thermal plume modeling and extensive thermal surveys of the Delaware

River. Dr. Englert has worked with a variety of PSE&G personnel, attorneys, consultants, and external experts in preparing the 1984, 1993, 1999, and 2006 NJPDES applications.

Hudson River. Dr. Englert evaluated entrainment, impingement, and discharge effects on eleven fish species at the proposed Athens Generating Station. He presented expert testimony in Article X hearing on fishery impacts, intake technologies and cost/benefit analyses.

316(b) Phase II Rule Compliance in New York. Dr. Englert is directing studies at four power plants in New York addressing all aspects of compliance under the 316(b) Phase II rule effective July, 2004. This includes preparing the PICs, performing entrainment and impingement sampling, evaluating compliance strategies, including intake technologies and restoration, and preparing the CDS documents.

CDS Preparation for Illinois Facilities. Dr. Englert is directing preparation of Comprehensive Demonstration Studies for three power plants in Illinois. This work is being done to meet the requirements of the 316(b) Phase II Rule. The effort includes the development of compliance strategies, evaluation of intake technologies, and restoration alternatives and performance of cost/ benefit studies.

Mississippi River. Dr. Englert was the partner in charge of a biothermal assessment of four representative important species for the Quad Cities Nuclear Generating Station, at river mile 506.5. The biothermal assessment, including a field survey to define the characteristics of the thermal plume, and CORMIX hydrothermal modeling. The thermal field survey included concurrent mobile waterside monitoring and aerial infra-red imaging of river water temperatures.

Cape Fear Estuary. Dr. Englert performed an assessment of entrainment and impingement effects at Brunswick Power Plant based on 10-year study. He supervised all modeling and reporting efforts, assisted in testimony preparation in support of 316 demonstrations.

East River. Dr. Englert directed an evaluation of entrainment, impingement, and discharge effects on sixteen fish species at the Ravenswood Generating Station. He also had overall technical and managerial responsibility for entrainment and impingement sampling studies at the station.

Hudson River. Dr. Englert directed an evaluation of entrainment, impingement, and discharge effects on five fish species at Indian Point, Bowline, Roseton, Lovett and Danskammer power plants. He provided expert testimony in 316 hearings before USEPA, and was lead technical representative for the utilities in settlement negotiations.

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Adsorption from binary liquid mixtures. First prize in the National Colloid and Surface Chemistry Contest, 1967.

John A.D. Burnett

Education
M.S., Fish & Wildlife Biology & Management, College of Environmental Science and Forestry, 2001

B.S., Biology, University at Albany, 1995

Professional Affiliations
American Fisheries Society

Professional Endeavors
HDR|LMS
2000-Present

Experience
Mr. Burnett is a senior environmental scientist in the Energy Section at HDR|LMS. He has a strong background in fisheries biology, environmental and biological statistics, and quantitative fisheries methods. He has worked with the Equivalent Recruit model, Empirical Transport Model, Empirical Impingement Model and RAMAS GIS/METAPOP in the assessment of power plant impingement and entrainment losses on fish populations. Mr. Burnett specializes in data management and statistics software programs, including: SAS, NCSS, ACCESS, EXCEL, @RISK, and RAMAS.

HDR Experience

Fisherman Outreach Program, Ecology and Environment Inc., New York. Broadwater Energy, a joint venture between Shell US Gas and Power, LLC, and TransCanada Pipeline, is proposing to construct a Liquified Natural Gas (LNG) terminal and an approximate 25 mile long marine pipeline that will connect the LNG to the existing Iroquois Gas Transmission System Pipeline about nine miles off the coast of Riverhead, N.Y. in the Long Island Sound. Mr. Burnett developed a fisherman outreach program in Long Island Sounds to collect information on commercial and recreational fishing activities as they related to the construction of the LNG terminal.

§316(b) Demonstration, USGen New England, Inc., Massachusetts. Mr. Burnett played a key role in the preparation of the 2001 §316(b) Demonstration for Brayton Point Station. Mr. Burnett implemented many of the technical analyses underlying the Demonstration, including calculation of entrainment and impingement losses accounting for through-plant and on-screen survival for selected species, conditional entrainment and impingement mortality rates, equivalent recruit losses through incorporation of then-current fishing rates and age-specific vulnerabilities to the fishery. This work culminated in the development of a RAMAS age-structured stock-assessment analysis for winter flounder that projected the stock into the future under varying scenarios of intake and discharge plant effects, fishery losses, and ambient temperature effects. Other important tasks related to this work included the development of vital rates (i.e., life tables), life history summaries, and physical tolerance data for approximately 25 species.

Scientific Consultation, USGen New England Inc., Massachusetts. Mr. Burnett provided technical consultation to USGen New England, Inc. technical and legal staff during the production of numerous scientific and legal documents related to the appeal of the Brayton Point Station National Pollutant Discharge Elimination System permit. Consultation included review of technical reports and models developed by regulatory scientists, review of USGen New England, Inc. scientific and legal staff reports and docket submissions, and preparation of technical analyses and reports. Review of regulatory scientists' analyses included re-creation and critique of biomass dynamic, production foregone and other impacts assessment models, summarizing inconsistencies in technical arguments, and prioritization of technical arguments.

Fish Abundance Trends Analysis, USGen New England Inc., Massachusetts. Mr. Burnett performed statistical comparisons of fish abundance trends in Mount Hope Bay and Narragansett Bay using a number of resource management agency and utility company trawl surveys to determine whether differences in abundance in these two areas might be attributable to Mount Hope Bay's Brayton Point

Generating Station. Statistical methodologies included Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), power analysis, and maximum likelihood. This work was accepted for publication in a peer-reviewed journal (DeAlteris et al., In Press; see Paper and Publications Section below for full citation).

Hydrological and Biological Monitoring Reports, Dominion Energy Brayton Point LLC, Massachusetts. Mr. Burnett managed the production of the Brayton Point Station 2002 through 2005 Annual Hydrological and Biological Monitoring Report. Tasks included data base management, extensive technical writing, and statistical analyses related to the seven major sampling programs conducted in the vicinity of the power station including water chemistry studies, heavy metal bioaccumulation studies, finfish studies (e.g., trawl, beach seines, etc), and ichthyoplankton monitoring.

Entrainment and Impingement Assessment, US Army Cops of Engineers, New York. Mr. Burnett estimated World Trade Center Redevelopment Site entrainment and impingement losses under the projected cooling water flow regime. Historical World Trade Center entrainment and impingement data were used, along with impingement rate/intake velocity functions from the scientific literature, to estimate losses under the proposed cooling water intake system.

Essential Fish Habitat Assessment, Knik Arm Bridge and Toll Authority, Alaska. As part of a larger effort to produce a Draft Environmental Impact Statement (DEIS) for the proposed Knik Arm Crossing project in Anchorage, Alaska, Mr. Burnett authored the Essential Fish Habitat (EFH) assessment for this project as required by the Magnuson-Stevens Fishery Conservation and Management Act as amended by the Sustainable Fisheries Act of 1996. Assessment of impacts to resident and migratory salmonids and groundfish was required. The assessment involved an evaluation of various build alternatives in terms of their impacts to EFH.

Biological Summary Reports, New York City Department of Environmental Protection, New York. Mr. Burnett produced biological summaries of New York-New Jersey Harbor area water ways including the Bronx River and Jamaica Bay. Tasks included summarizing biological data collected by the New York City Department of Environmental Protection (NYCDEP) as well as existing information on wetlands, water usage, and shoreline development. These summaries will be included in NYCDEP standards attainment reports related to combined sewer overflow (CSO) impact abatement.

Optimal Sampling Allocation, PSE&G, New Jersey. Mr. Burnett determined the frequency and optimal temporal allocation of entrainment and impingement samples required to calculate annual numbers of organisms entrained and impinged at the Salem Generating Station at predefined confidence levels using the Neyman Allocation statistical technique.

Trawl Avoidance, PSE&G, New Jersey. Mr. Burnett evaluated the relative gear avoidance exhibited by finfish for the primary pelagic and bottom trawls used in the Salem Generating Station Baywide Abundance Monitoring Program surveys. The study developed species- and length-specific probability of avoidance functions for each trawl that are used to improve estimates of finfish abundance and distribution in impact assessment models.

Gear Correction Factors, PSE&G, New Jersey. Mr. Burnett developed species- and length-specific algorithms to scale ichthyoplankton catches in the PSE&G baywide sampling nets to estimate absolute abundance. These algorithms accounted for reductions in catch efficiency attributable to avoidance of and extrusion through the PSE&G ichthyoplankton sampling gear.

Non-HDR Project Experience
New York State Department of Environmental Conservation, Cape Vincent, New York. Fisheries technician. While working toward the completion of his M.S. degree, Mr. Burnett evaluated the impact of double-crested cormorant predation on yellow perch abundance and life history in the eastern basin of Lake Ontario. Duties included report writing and presentation; statistical analysis; database analysis; extensive use of SAS, Access, and Excel; motorized boat operation; gill netting, trap netting, and trawling; otolith extraction and analysis; cormorant diet examination; fish age and growth analysis; and website design.

Blasland, Bouck, and Lee, Inc. Engineers and Scientists, Syracuse, New York. Fisheries technician. As part of Blasland's Aquatic Assessment Team, Mr. Burnett's job tasks included age and growth analysis of fishes, aquatic macroinvertebrate identification, maintenance of gill nets and fish containers, data entry, literature searches, and equipment maintenance.

Washington Department of Fish and Wildlife, Olympia, Washington. Fisheries technician. Mr. Burnett worked for the Freshwater Production and Survival Evaluation Unit's long-term wild coho salmon monitoring program. He built and installed weirs (smolt traps) on many small coastal streams and operated a fan trap on Bingham Creek, Washington. Laboratory and fieldwork included weighing, measuring, coded wire tagging, species identification, and data entry.

Washington Department of Fish and Wildlife, Tenino, Washington. Fisheries technician. Mr. Burnett's duties included the mass marking of juvenile coho salmon, statistical analysis of marking efficiency, equipment care and maintenance, and data collection.

Parametrix, Inc., Seattle, Washington. Fisheries technician. Mr. Burnett worked on a project to determine the species and amount of food items harvested from Elliot Bay by recreational anglers. Angler surveys, species identification, and collection of fish weight and length were the primary duties.

University of Washington, Seattle, Washington. Fisheries technician. Mr. Burnett worked on a project that compared the biological productivity of two forks of the Tolt River (Washington State) by comparing the growth rates of wild steelhead and physical factors of each fork. Mr. Burnett's duties included walking miles of stream with heavy equipment, assessing study sites, and collecting, weighing, measuring, and marking wild steelhead.

University at Albany, Albany, New York. Scientific technician. Mr. Burnett assisted a two-year edge effect research project conducted in the Albany Pine Bush Preserve. Duties included the planting and care of research plants, collection and measurement of field specimens, report editing, and entry of data into spreadsheets.

Papers and Publications
DeAlteris, J.T., Englert, T.L. and J.A.D. Burnett. *In Press*. Assessment of Trends in Fish Abundance in Mount Hope Bay Relative to Narragansett Bay. *Northeast Naturalist*

Englert, T.L., Simas, M.M., Moss, T.R., Burnett, J.A.D. and R. O'Neill. 2005. Proposed Innovative Cooling System for Heat and Flow at Brayton Point Station.

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O'Gorman, R. and Burnett, J.A.D. 2001. Fish Community Dynamics in Northeastern Lake Ontario with Emphasis on the Growth and Reproductive Success of Yellow Perch (*Perca flavescens*) and White Perch (*Morone americana*), 1978 to 97. *Journal of Great Lakes Research*. 27(3):367-383

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Burnett, J.A.D. and T.L. Englert. 2003. A RAMAS Population Model of Winter Flounder in Mount Hope Bay, Rhode Island-Massachusetts. 133th Annual Meeting of the American Fisheries Society, Quebec City, Canada

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Fish Orientation Behavior: An Electronic Device for Studying Simultaneous Responses to Two Variables

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REYNOLDS, W. W. 1977. Fish orientation behavior: an electronic device for studying simultaneous responses to two variables. J. Fish. Res. Board Can. 34: 300–304.

An electronic device ("Ichthyotron") is described that permits a fish to simultaneously and independently control (behaviorally regulate) two environmental variables by its movements along two axes, among four chambers. Sample data are given for simultaneous behavioral thermoregulation, light intensity preferences, and locomotor activity rhythms in largemouth bass, (*Micropterus salmoides*) and smallmouth bass (*M. dolomieui*).

REYNOLDS, W. W. 1977. Fish orientation behavior: an electronic device for studying simultaneous responses to two variables. J. Fish. Res. Board Can. 34: 300–304.

Nous décrivons un appareil électronique («ichtyotron») permettant à un poisson de contrôler simultanément et indépendamment (par comportement) deux variables de l'environnement par ses mouvements suivant deux axes, dans quatre chambres. A titre d'exemple, nous présentons des données sur la thermorégulation par comportement simultané, sur les préférences d'intensité lumineuse et sur les rythmes d'activité locomotrice chez l'achigan à grande bouche (*Micropterus salmoides*) et l'achigan à petite bouche (*M. dolomieui*).

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FISHES and other mobile organisms, by their movements, can exert considerable control over the environmental conditions they experience. Such habitat selection or orientation behavior has been studied in field and laboratory by a number of means, usually involving visual observations of the relative amounts of time spent by an animal in various available environmental conditions, as in a choice-chamber apparatus. Where the orientation behavior directly affects the physiology of the organism as an ultimate factor, the term "behavioral regulation" applies, e.g. behavioral thermoregulation. In its broadest sense, the term "orientation behavior" can be extended to the temporal as well as the spatial organization of an animal's activity, as in the case of locomotor activity rhythms.

Fry (1958) has reviewed various experimental gradient and choice-chamber designs going back to 1913 (Shelford and Allee), involving visual observation of the fishes' movements. Rozin and Mayer (1961) pioneered a new approach by allowing a fish to control water temperature by pressing a lever. Van Sommers (1962) employed a device in which fish controlled oxygen content of water by interrupting a photocell light beam. Kleerekoper (1967) used several different experimental chambers employing photocells to monitor fish movements. Various shuttlebox devices have been used by psychologists for many years to study avoidance conditioning, and these have also been used to study thermoregulation in lizards (Cabanac and Hammel 1971; Hammel et al. 1973) and fishes (Crawshaw and Hammel 1973). A shuttlebox device using photocells to monitor fish movements and control temperatures was described by Frank and Meyer (1971, 1974). Finally, Neill et al. (1972) described an improved electronic shuttlebox device for fish thermoregulation and suggested other possibilities for its use.

Responses of fishes to simultaneous opposed gradients of temperature and light in a single-axis gradient trough have been studied (DeVlaming 1971; Reynolds et al. 1977). For the study of simultaneous and independent responses to two variables such as light and temperature, a two-axis device is necessary. An early design (16 chambers, 4 × 4) requiring visual monitoring has been described (Reynolds 1973; Reynolds and Thomson 1974). The present communication describes a four-chamber, two-axis, electronically controlled device (the Ichthyotron) for crossed-gradient studies, with automatic data acquisition. This is the first full description of this device, with sources and costs of components, and sample two-factor regulation data.

Construction and Use — A schematic diagram of the arrangement of components in the device

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is shown in Fig. 1. The major electronic components (from Microswitch Division of Honeywell, Freeport, Ill. 61032) include TLS-3 adjustable focus light sources for detecting small objects ($9.90[1] each), TPC-O4F fast-response phototransistors ($18.50 each), and G4B control base with DPDT relay ($60 each) and LOG 3 logic function cards ($20 each) with immediate on–off response to light or dark. Total cost for eight each of the above was $867.20. Two Potter and Brumfield (Princeton, IN 47670 USA) 4PDT latching relays #KB17AG ($13.75 each) were also used. Esterline-Angus (POB 24000, Indianapolis, Ind. 46224) Minigraph Temperature ($195 each) and Event ($150 each) recorders were used; the temperature recorders also have event pens, making them dual-purpose.

The tank itself is constructed of plywood sealed with epoxy glue, painted with waterproof white epoxy paint. Silicone aquarium sealer was used for final waterproofing of joints. Glass windows permit passage of light beams for the phototransistors. Overall dimensions are 120 × 120 × 46 cm. Adjustable, sectioned, transparent plexiglass gates slide vertically in tracks between the light beams in the constrictions between chambers. These permit the openings between chambers to be adjusted to the size of the test animal, so that it can pass easily without missing the paired light beams. The openings can be at the bottom, middle or top of the water column in accordance with the habits of the species; the light sources and phototransistors are adjusted accordingly. By closing two of the gates, a two-chamber, single-axis configuration can be used to study responses to a single variable.

Immersion-type aquarium heaters are used for heating, and cooling is provided by pumping refrigerated water through Tygon tubing. The water in each chamber is well mixed and aerated with airstones, preventing thermal lamination. Temperature is varied by a simple "on–off" control and will continue to increase so long as the heaters are on in the "hot" chambers or to decrease so long as the refrigeration pumps are on for the "cold" chambers. Thus, the temperatures of the "hot-side" and "cold-side" chambers are continually either increasing or decreasing in parallel, and the differential between the two is controlled by thermal lag in heat transfer through the constrictions between the hot and cold sides. While the differential between chambers can be controlled more precisely by a comparator or some other arrangement (e.g. Neill et al. 1972), and the relative rates of heating and cooling can

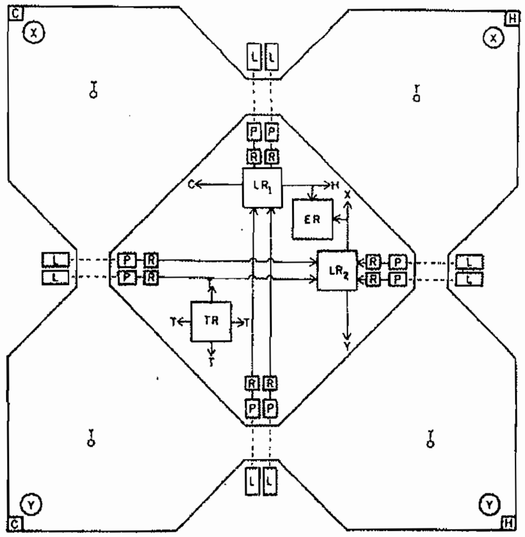

FIG. 1. Schematic diagram of the Ichthyotron (top view; 120 × 120 × 46 cm). L = light sources; dotted lines = light beams; P = phototransistors; R = phototransistor relays; LR = latching relays; C = cooling equipment; H = heaters; ER = event recorder (two channels); TR = temperature recorder (four channels); T = thermistors; X, Y = other variable(s) controlled by LR_2. As the fish moves between chambers, it sequentially interrupts two light beams, triggering phototransistor relays. The last relay activated determines the state of a bistable latching relay, which in turn controls the desired variable and activates the event recorder. The separate latching relays for each axis permit two variables to be controlled simultaneously and independently. The event recorder provides a continuous, unambiguous record of the animal's movements.

be varied (Beitinger 1976), these variables have been shown not to affect thermoregulatory performance of fishes, i.e. the fishes make appropriate adjustments in their shuttling behavior (Beitinger 1976). Therefore, these variables need not be precisely controlled. In fact, fishes will even learn to thermoregulate in such a device with no difference in temperature between the two chambers (a purely "temporal" gradient), but the instantaneous small spatial gradient of about 2°C caused by thermal lag helps to guide the fish to cooler water if it is too hot (thereby initiating further temporal cooling), or vice versa if it is too cold. This minimizes the learning time necessary for the fish to orient in the device, and species used to date have generally learned to use the device quickly (usually in <1 h).

At any one time, there are two different temperatures available in the device, the "hot-side"

[1]Prices quoted for 1974.

and the "cold-side" temperatures, usually differing by about 2°C. The mean of these two temperatures is the mean water temperature. The fish shuttles back and forth between these, but at any instant occupies either one or the other (the "occupied temperature"). The body temperature of the fish will generally lie between the two available water temperatures if it is shuttling rapidly, but will approach the occupied temperature if it remains in one chamber for long, depending on the size of the fish and its thermal equilibration rate in relation to the rate of change in the dynamic water temperature. The gut temperature of the fish can also be measured directly by telemetry, using a small ingestible temperature transmitter (Mini-Mitter Co., POB 88210-G, Indianapolis, Ind. 46208). While fishes have been shown to heat and cool at somewhat unequal rates due to temperature-dependent changes in heartbeat and ventilatory frequencies (Reynolds 1976, 1977), mean gut temperatures of fish over a period of time in this device do not differ significantly from mean occupied temperature or from mean water temperature over the same time period (Reynolds et al. 1976). Mean occupied temperature, determined with event and temperature records, takes into account the positions, and therefore, temperatures (there is a continuous record of both) occupied by the fish over time. Mean water temperature simply involves averaging the water temperature records of the hot and cold sides over the desired time period. These have been found not to differ significantly. Thus, mean occupied, water, and body temperatures over a period of time may be taken as essentially equivalent in this system. Occupied temperature is the variable most frequently used and is equivalent to preferred temperature. Statistics used to present the results can include mean, median, mode, range, midpoint, skewness, and kurtosis; the entire relative frequency distribution histogram may be shown (for a complete review of the relations among these measurements, see Reynolds and Casterlin 1976a).

The thermoregulatory system described above constitutes use of the circuitry in the "active" mode, essentially acting as an extended effector system of the fish. Any variable that can be controlled electrically or mechanically can be used in this way, i.e. heaters, refrigeration units, motors, pumps, solenoids, relays, rheostats, or valves can be used as the "effectors," and the only limitation on possible uses is one's imagination. Control can be "on–off" or variable. Rates of change and relative values in each chamber can be manipulated in various ways. Separate control systems can be used for each axis, as each has independent circuitry.

The device can also be used in a "passive" mode, in the manner of a classical choice chamber or shuttlebox, with automatic data acquisition through the photocell circuitry to monitor the movements of the test animal. In this mode, alternative fixed conditions are presented in each chamber. One axis can be used in the active mode, while the other is simultaneously used in the passive mode; for example, a fish can thermoregulate in the manner described above along one axis, with a choice of fixed light intensities along the other. Switching the light axis to the active mode, the fish can also turn the lights on or off by its movements along this axis. In any of the above modes or combinations of modes, the continuous activity record for each axis provides information that can be used to study locomotor activity rhythms. A timer can be used to provide any desired exogenous cycles, or the animal can be allowed to "free-run" under constant or self-controlled conditions.

Many other kinds of studies are possible with devices such as this one. The flexibility and automatic data-acquisition features of shuttlebox devices with electronic control and monitoring are certain to greatly facilitate future laboratory studies in orientation behavior. Fishes tested to date in the Ichthyotron include various centrarchids, ictalurids, catostomids, cyprinids, and esocids. Frog tadpoles (Reynolds and Covert 1976) and crayfish have also been successfully tested.

Examples of two-factor regulation by basses — Simultaneous responses to light and temperature were studied in largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieui*) (Fig. 2). With an exogenous 12 h L:12 h D light cycle, occupied-temperature distributions differed between night and day (Fig. 2A) for both species, an indication of thermoperiodism. Kurtosis of the distributions was greater during the "day" periods than during the "night" periods, and skewness also shifted between night and day.

During the "day" period of the light cycle bass were given a (passive-mode) choice between intensities of 1000 lx and 10 lx on the "light" axis. Largemouth bass spent much more time on the bright (1000 lx) side than did the smallmouth bass (Fig. 2B). At night the illumination in all chambers was about 1 lx, and the difference between species in proportions of time spent on each end of the "light" axis became insignificant.

The locomotor activity rhythms of both species showed a rather crepuscular pattern (Fig. 3), with the greatest hourly percentage of activity occurring just before or just after onset of the light period, depending on the species. The large-

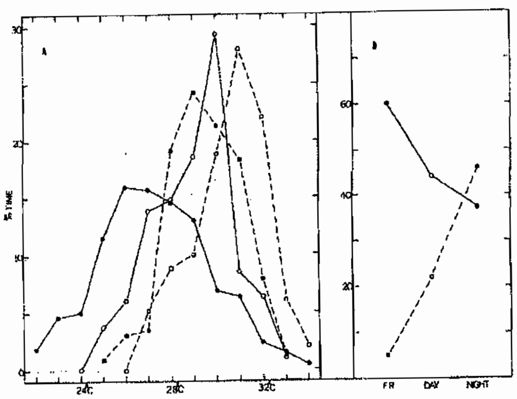

FIG. 2. Percentages of time spent by largemouth bass (*Micropterus salmoides*) (circles and solid lines) and smallmouth bass (*M. dolomieui*) (squares and dotted lines) A, at various temperatures and B, in the chambers which had the brightest light intensity (1000 lx) when the lights were on. Open symbols represent the normal "day" or lights-on period, closed symbols the normal "night" or lights-off period. Half-darkened symbols (FR) in B represent percent of time lights were on (1000 lx) when controlled by the fish, with no exogenous light cycle (free running). Each condition represents pooled data for five fish.

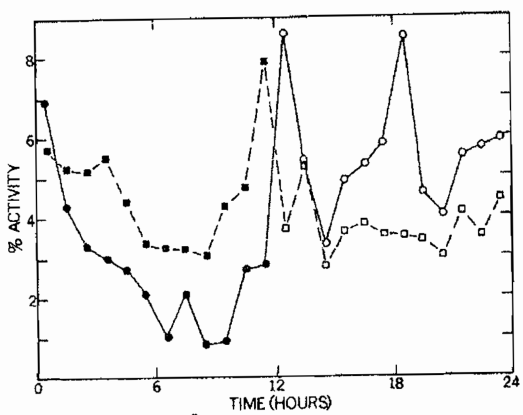

FIG. 3. Hourly percentages of total 24-h activity for largemouth (circles) and smallmouth (squares) basses, measured as total light-beam interruption events. Solid symbols represent normal hours of darkness ("night"), open symbols normal lights-on period ("day"). Pooled data for five fish of each species.

mouth bass showed greater activity during the light period than did the smallmouth bass, which showed a much greater degree of light avoidance. Other field and laboratory studies tend to confirm the preference of smallmouth bass for shadows, as well as the generally crepuscular nature of these predators (see Reynolds and Casterlin 1976b).

In another series of experiments, the bass were allowed to actively control the lights in an "on–off" manner along the light axis, while thermoregulating along the other axis. Light intensity was 1000 lx with the lights on and about 1 lx with the lights off. As expected, the smallmouth bass turned the lights on far less often (4% of the time) than did the largemouth bass (60%; Fig. 2B). The proportion of "lights-on" time bore no apparent relationship to time of day for either species, but the rate of on–off switching exhibited a characteristic crepuscular pattern similar to Fig. 3. This, along with other experiments in constant light conditions, indicated that the observed locomotor activity rhythms are endogenous (cf. Reynolds and Casterlin 1976b). This is further supported by investigations with another centrarchid, the bluegill (*Lepomis macrochirus*); these showed an endogenous diurnal locomotor activity rhythm which persisted under constant light or temperature conditions, or when either or both were controlled by the fish (Reynolds and Casterlin 1976c). The thermal preference rhythms and the locomotor activity rhythms seem to be endogenous in these centrarchid species, as they will persist in the absence of an exogenous cycle.

I have observed no indication of any significant interaction between the light and temperature responses, as similar thermoregulatory behavior occurred under different light regimes, either constant or endogenously or exogenously controlled. Similarly, light intensity preferences and locomotor activity rhythms (Reynolds and Casterlin 1976c) apparently do not differ significantly, whether the fish are actively thermoregulating or held at various fixed temperatures. In summary, evidence to date indicates no apparent interaction between light intensity and temperature responses along the two axes; responses to the two factors seem to be independent for the species studied.

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Differences in Swimming Performance Among Strains of Rainbow Trout (*Salmo gairdneri*)

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Swimming performance profiles, relating fish size to swimming time, were established for three strains of rainbow trout (*Salmo gairdneri*). No differences were found in slope of regressions; only in level at each size of fish. Swimming performances of New Zealand and Sand Creek strains did not differ, but were superior to the Manchester strain. In stamina results from

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[Article]

Relationships between Juvenile Winter Flounder and Multiple-Scale Habitat Variation in Narragansett Bay, Rhode Island

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Abstract.—A rapid random sampling method was used to relate densities of juvenile winter flounder *Pseudopleuronectes americanus* to multiple scales of habitat variation in Narragansett Bay and two nearby coastal lagoons in Rhode Island. We used a 1-m beam trawl with attached video camera, continuous global positioning system track overlay, and continuous recording YSI sonde to sample 163 sites in June and July 2002 and 2003. The YSI sonde recorded temperature, salinity, dissolved oxygen, depth, turbidity, and chlorophyll *a* throughout the tow, while the video camera recorded other habitat characteristics. Habitat patterns at larger spatial scales were assessed with aerial imagery and charted depth data. We caught 25 species and 977 fish, almost twice as many fish being captured in 2002 (596) as in 2003 (381). Winter flounder was the most common species in both years, comprising 60.2% of the catch in 2002 and 33.6% of the catch in 2003. Total fish and winter flounder were three times more abundant in the coastal lagoons than in the bay. We used stepwise multiple regression to develop a general model (all variables, including those affecting catch efficiency) and a habitat model (only habitat variables) describing the relationship between habitat quality and juvenile winter flounder density. The results of the stepwise regression on the general model explained only about 25% of the variability in catch, but they suggested that winter flounder densities were higher at sites in coves and that densities increased with human population density, greater percentages of algal cover, and higher percentages of mud. Densities were negatively correlated with dissolved oxygen and chlorophyll *a*. In the habitat model (r^2 = 0.16), densities were higher in coves, at sites with marsh or beach edges, and at sites with human disturbance. Similar to the general model, densities increased with algal cover and decreased with dissolved oxygen. At larger spatial scales, shorelines dominated by beaches and habitat diversity (as calculated by Simpson's diversity index) were positively correlated with higher juvenile winter flounder densities. Overall, the results suggested that juvenile winter flounder were most abundant in coves and upper estuaries. We conclude that these areas may provide beneficial nursery habitat for winter flounder despite apparent human disturbance.

Alteration and loss of coastal habitats, such as salt marshes and eelgrass beds, is believed to be one of the most important factors contributing to declines in populations of economically important fish, shellfish, and aquatic-dependent wildlife (Deegan and Day 1984). In response to this, the U.S. Environmental Protection Agency is developing methods to determine criteria needed to protect habitats critical to different life stages of species using estuarine and inshore habitats. In the northeastern United States, winter flounder *Pseudopleuronectes americanus* is a species of high commercial and recreational value (e.g., Collette and Klein-MacPhee 2002), and their life history traits make them suitable for research into habitat alteration and population response. Winter flounder spawn in the upper reaches of estuaries and settle into shallow estuarine areas as juveniles (Able and Fahay 1998; Collette and Klein-MacPhee 2002). These areas are particularly susceptible to many forms of habitat alteration, including riprapping, dredging, seagrass loss, marsh destruction, bulkheading, low dissolved oxygen, increased turbidity, nutrient pollution, and sediment changes which alter nutrient cycling. Further, the juveniles show a high degree of site fidelity, rarely moving far from the shallow settling habitat

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until the water cools in late fall (Saucerman and Deegan 1991).

Habitats known to be important to juvenile winter flounder include eelgrass beds, coves, upper estuaries, and unvegetated shallows (Poole 1966; Heck et al. 1989; Sogard and Able 1991; Curran and Able 2002; Goldberg et al. 2002; Meng et al. 2004), but it is unclear how anthropogenic disturbance affects the use of these habitats by winter flounder (Carlson et al. 1997, 2000; Meng and Powell 1999; Meng et al. 2001). The design of many studies identifies habitats to be sampled a priori, but this restricts information on other potential habitats which were not specifically identified. Our study used random sampling to seek new patterns and information on juvenile winter flounder habitat use with the goal of developing a model of how habitat alteration affects winter flounder populations.

Criteria to protect habitat are expected to be similar to water quality criteria in that habitat alteration is expected to stress a system and produce a response in aquatic species, such as a decrease in fish density. Models based on empirical relationships between habitat alteration (stressor) and fish density (response) face two challenges. First, methods of assessing habitat quality and how habitats change in response to human alterations (such as development, shoreline hardening, and dredging) must be identified. Then, a gear must be found that is effective at sampling fish in all habitats, including vegetated and unvegetated areas. The goal of our study was to develop a stressor-response model of the relationship between juvenile winter flounder densities and habitat quality for use in developing habitat criteria. An underlying assumption of the model is that high densities of fish indicate high habitat quality for those animals (e.g., Sogard and Able 1991; Rozas and Minello 1997, 1998; Minello 1999; Rozas and Zimmerman 2000). Because criteria protective of aquatic habitats may be used by regulators at shoreline scales that include a mosaic of larger features (such as marshes and beaches), we also assessed habitat at larger spatial scales using aerial imagery and charted depth data.

The null hypothesis was that juvenile winter flounder densities would not differ among habitats, regardless of the amount of anthropogenic impact.

Methods

Study site.—Narragansett Bay covers approximately 260 km^2 and is characterized by a narrow salinity range of 24–30‰, a large annual temperature range from -0.5°C to 25°C, weak seasonal stratification, and depths up to 40 m (Oviatt and Nixon 1973). Most of Rhode Island's population and industry center around the city of Providence at the head of the west passage of the bay (Figure 1), providing a distinct anthropogenic gradient from north to south (Nixon and Lee 1979; Olsen et al. 1980; Oviatt et al. 1984; Keller et al. 1999; Meng et al. 2001, 2002). The west passage receives significant amounts of sewage and nutrients from the Providence River and Greenwich Bay (Valente et al. 1992; Meng et al. 2001, 2002), which alter habitats by supporting abundant macroalgae (mostly *Ulva* spp.), lowering dissolved oxygen, and contributing to the accumulation of anoxic, organic rich sediments. Further, the Providence River has been dredged and much of the shoreline is artificially hardened for use by industries, such as shipping and scrap metal processing. Other areas along the west passage are mostly residential, with some shoreline hardening and many recreational marinas.

Ninigret and Point Judith ponds are two of Rhode Island's coastal lagoons, known locally as salt ponds, located on the south shore of the state and connected to Block Island Sound by single, narrow, permanent man-made breachways (Figure 1). They cover 645 and 785 ha, respectively (Meng et al. 2000). Point Judith Pond is slightly deeper, having an average depth of 1.8 m and a tidal range of 44.5 cm (Meng et al. 2000). Ninigret Pond has an average depth of 1.2 m, and a tidal rage of 13.7 cm (Meng et al. 2000). Temperature and salinity ranges are similar to those of Narragansett Bay. Because the ponds are shallow, they are well mixed. Point Judith Pond is the most developed due to residential, industrial, and agricultural activities, and harbors most of Rhode Island's fishing fleet (Lee and Olsen 1985; Meng et al. 2000). Although Ninigret Pond has moderate levels of residential development, many areas retain good water clarity, extensive eelgrass beds, and sandy substrates. Homes adjacent to Ninigret Pond are on septic systems and contribute nutrients to the pond (Lee and Olsen 1985; Meng et al. 2000).

Sampling.—We used probabilistic sampling in nearshore habitats in the west passage of Narragansett Bay, Rhode Island, and two nearby coastal lagoons. Our goal was to sample as many habitats as possible, and the random approach produced an array of sites, including unvegetated, macroalgae, seagrass, marinas, riprapped shorelines, marsh shorelines, and industrial areas. Depths ranged from less than a meter to more than 15 m. The

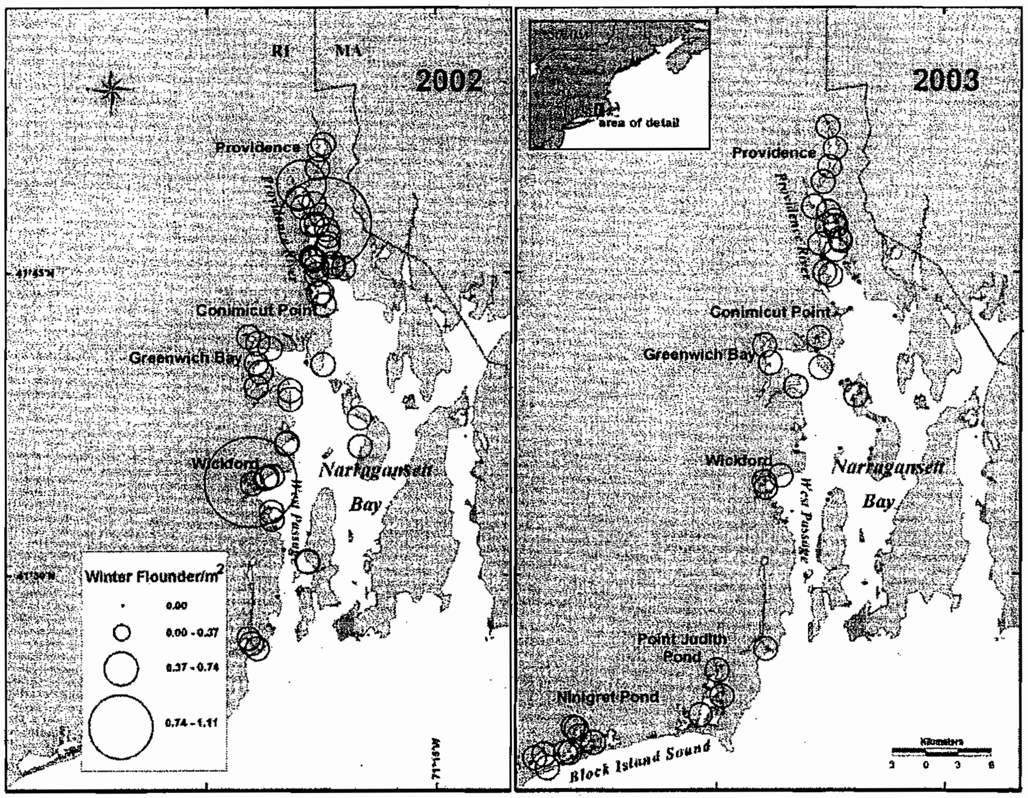

FIGURE 1.—Winter flounder/m² sampled at random locations in the west passage of Narragansett Bay and Ninigret and Point Judith ponds, Rhode Island, for June and July 2002 (left panel) and 2003 (right panel). The ponds were only sampled in 2003. Circles represent the densities of winter flounder captured at each site. Single points are locations where no winter flounder were captured.

probabilistic sampling was derived by digitizing the entire shoreline of the west passage of Narragansett Bay and Ninigret and Point Judith ponds, then digitally selecting random sampling points. These random points or "sites" were grouped by proximity to each other, and each block of six sites received a random number which determined the sampling routine. Blocks of sites in the Providence River were alternated with sites south of Conimicut Point (Figure 1) and the salt ponds (sampled only in 2003). In 2002 and 2003, we sampled 163 sites from June until the end of July (Table 1), the time window when juvenile winter flounder settle out into nearshore habitats in Rhode Island. All sampling was done within 3 h of high tide. At each site, the predetermined random location was located with a global positioning system (GPS) unit.

Many fish sampling gears are specific to certain habitats (see review by Rozas and Minello 1997 and papers cited therein), but we needed a gear that was effective for juvenile winter flounder in many habitats and that would allow us to evaluate habitats at the same time that fish were sampled. To accomplish these goals we used a 1-m beam trawl (4.8-mm mesh) mounted on an epibenthic sled. A high-resolution underwater videocamera with continuous GPS track overlay and a water quality monitor were attached to the sled. The 1-m beam trawl with attached video camera, continuous GPS track overlay, and continuous recording YSI sonde was placed at the water's edge and towed out perpendicular to shore. We used a 570-line, 0.1-lux analog color video camera with external halogen lighting, recorded digitally on the boat in mini-DV format. The video camera was mounted on top of the sled frame to face straight down into the mouth of the net. The halogen lights also faced straight down into the mouth of the net and this minimized disturbing fish before they were captured. The YSI sonde recorded tempera-

TABLE 1.—Summary of juvenile winter flounder sampling results in Narragansett Bay and Ninigret and Point Judith ponds, Rhode Island. Average air temperature and total rainfall are from the National Weather Service forecast office in Boston, Massachusetts (www.erh.noaa.gov/er/box/). Values in parentheses are ranges.

Variable	Narragansett Bay[a]	Narragansett Bay and Point Judith and Ninigret ponds[b]
Average air temperature (°C)	21.4	20.6
Total rainfall for June and July (cm)	9.6	23.2
Average water temperature (°C)	21.4 (14.4–26.1)	20.6 (13.4–26.4)
Average salinity (‰)	27.0 (3.5–31.5)	24.2 (11.4–30.8)
Average dissolved oxygen (mg/L)	8.6 (1.9–13.6)	8.6 (4.6–13.5)
Number of samples	76	87
Percent samples with winter flounder (%)	70	46
Winter flounder/total fish (%)	60.2	33.6
Winter flounder size ± SD (mm)	44.8 ± 13.7	47.3 ± 21.9
Total fish	596	381
Number of species	23	16

[a] 11 June–1 August 2002.
[b] 2 June–5 August 2003.

ture, salinity, dissolved oxygen, depth, turbidity, and chlorophyll *a* throughout the tow. Because our chlorophyll probe lost calibration quickly, we also analyzed 1 L of water for chlorophyll *a* at most sites with high-performance liquid chromatography. At sites without flat areas suitable for deploying the sled from shore (e.g., piers, rocky shores, rocky cliffs), the sled was lowered into the water from the boat as close to shore as reasonably possible. Tows were 30–120 s long (mean = 57 s) depending on the volume of macroalgae seen on the video screen during the tow. If macroalgae was abundant, tows were shortened to avoid filling the net, which decreased gear and sorting efficiency. Averages for tow speed and tow length were 0.8 m/s and 52 m, respectively. At the end of the tow, the net was landed on the boat and its contents were released into a large bin of water for processing. All fish were identified to species, measured (total length [TL]), recorded, and released. At each site latitude, longitude, time, weather, site description, tow description, and net contents (such as quantity and type of macroalgae) were recorded.

Data analyses.—To determine habitat characteristics, video data were analyzed on a laptop computer attached to a Sony digital videotape player. First, the length of the tow in seconds was determined, then the videotape was stopped at the beginning, end, and at four equally spaced intervals. On each frozen frame, a grid of 20 blocks was superimposed over the image and the percentage of mud, muddy sand, sand, cobble, rock, shell, and cover of macroalgae was determined. The continuous GPS track overlay on the video enabled us to determine towing speed and distance covered.

Aerial imagery and charted depths were used to assess habitat patterns at larger spatial scales. Orthocorrected 1-m pixel resolution digital aerial photographs from 1992 to 1995 were obtained from the U.S. Geological Survey–Rhode Island Geographic Information System (www.edc.uri.edu/rigis-spf/catalog2002.htm). On the aerial photos we measured distance to the nearest marsh or submerged vegetation (as identified in Narragansett Bay Estuary Program 2001). We also counted other variables within a 100-m radius of the sampling site, including number of buildings, number of roads, number of piers, percent of shoreline that was artificially hardened, and percent of shoreline that was rocky or sandy beach. We measured distance to the nearest water depth of 2 m or greater from digitized National Oceanic and Atmospheric Administration (NOAA) charts.

We used stepwise multiple regression at the default significance level of 0.15 (SAS Institute 1988) to develop a model for the relationship between habitat attributes and juvenile winter flounder density. For the first model (general model) we used 19 variables (Table 2), including factors that may have affected the catch such as year (2002 and 2003), tide (time of high tide minus sampling time in minutes), sampling day (numbered from the first day of sampling each year) and tow speed (m/s). Three variables were used as proxies for human disturbance: human population density within a 1-km radius landward of the site; distance to the nearest sewage outfall (m); and latitude, which reflected the north-to-south anthropogenic

TABLE 2.—(1) General model: variables were selected by stepwise multiple regression of a general model of the relationship between juvenile winter flounder/m^2 and year, cove (1 = cove, 0 = noncove), sampling day, tide, latitude, tow speed (m/s), temperature (°C), salinity (‰), dissolved oxygen (mg/L), depth (m), turbidity (ntu), chlorophyll *a*, algal cover (%), mud (%), muddy sand (%), sand (%), shell (%), human population density (persons/km^2), and distance to the nearest sewer outfall (m). (2) Habitat model: results are based on the relationship between juvenile winter flounder density and cove, habitat, temperature, salinity, dissolved oxygen, depth, turbidity, chlorophyll *a*, algal cover (%), mud (%), muddy sand (%), and sand (%). Sites were divided into three habitats and dummy variables were entered: low-gradient marsh or beach edges; deep with steep drop-offs; and impacted sites. (3) Large-scale model: results are based on the relationship between juvenile winter flounder density and number of buildings, roads, piers, percent of artificially hardened shoreline, percent of rocky or sandy beach shoreline, distance to the nearest water 2 m or deeper, distance to the nearest marsh or submerged vegetation, and Simpson's diversity index. The error terms for the general, habitat, and large-scale models had 151, 155, and 157 degrees of freedom, respectively.

Step	Variable entered and sign of coefficient	Cumulative r^2	*P*-value
	General model		
1	Human population (+)	0.059	0.001
2	Cove (+)	0.11	0.002
3	Year (−)	0.15	0.005
4	Algal cover (+)	0.18	0.041
5	Dissolved oxygen (−)	0.21	0.017
6	Shell (−)	0.23	0.053
7	Mud (+)	0.24	0.051
8	Chlorophyll *a* (−)	0.26	0.11
	Habitat model		
1	Habitat dummy variable 1 (−)	0.056	0.002
2	Algal cover (+)	0.091	0.014
3	Dissolved oxygen (−)	0.14	0.004
4	Habitat dummy variable 2 (+)	0.16	0.040
	Large-scale model		
1	Percent beach shoreline (+)	0.049	0.005
2	Simpson's diversity index (+)	0.075	0.037

gradient in the bay. The "cove" variable designated whether or not a site was in a cove (1 = cove, 0 = noncove). An area was defined as a cove if its length was at least two times greater than its mouth and its area was 4.6 km^2 or less. For the second model (habitat model), we included only the subset of factors that characterize habitats (Table 2), such as dissolved oxygen and substrate type. Eelgrass was not included as a variable because we only sampled six sites with or near eelgrass. In the second model we added "habitat" as a dummy variable. Sites were divided into three habitats: (1) areas with low gradient marsh or beach edges that were inundated at high tide, supplying refuge and forage for juvenile fish; (2) sites that were deep with steep drop-offs; and (3) human-altered sites, which included industrial areas, artificially hardened shorelines, and marinas.

Stepwise multiple regression was also used to assess relationships between large-scale features and fish density. Number of buildings, roads, piers, percent of artificially hardened shoreline, percent of rocky or sandy beach shoreline, distance to the nearest water 2 m or deeper, distance to the nearest marsh or submerged vegetation, and Simpson's diversity index (Lande 1996) were included in the large-scale features model (Table 2). Simpson's diversity index was used to characterize habitat diversity for each tow and was calculated as 1 − (proportion of algal cover)^2 + (proportion of mud)^2 + (proportion of muddy sand)^2 + (proportion of sand)^2 + (proportion of shell)^2 + (proportion of cobble/rock)^2. For all models, fish abundance was plotted against each variable and there was no evidence of nonlinearity indicating that the assumptions for linear regression were met.

Results

We caught 25 species and 977 fishes in 163 tows in 2002 and 2003. Almost twice as many fish were taken in 2002 (596) compared with 2003 (381). The number of species, 23 in 2002 versus 16 in 2003, also followed this pattern (Table 1). Winter flounder was the most common species in both years, making up 60.2% and 33.6% of the catch, respectively (Table 1). Winter flounder were taken in 70% of the tows in 2002 and 46% of the tows in 2003 (Table 1). The catch in 2002 had many uncommon marine species along with three tropical species likely transported north by the Gulf Stream (Table 3). In 2002, the second most common species was grubby, comprising 21.3% of the catch. A brackish water species, fourspine stickleback, was the second most common in 2003, comprising 16.3% of the catch. In 2003, there were also significant contributions from other brackish water species, mummichog (8.9%) and rainwater killifish (5.2%). Twice as much rain fell in June and July of 2003, and air and water temperatures were lower compared with the same period in 2002 (Table 1; National Weather Service forecast office, Boston, Massachusetts [www.erh.noaa.gov/er/box/]), which may have contributed to the difference in catches. Average salinity was also lower in 2003, whereas dissolved oxygen levels were similar in both years (Table 1).

Densities of winter flounder were highest in

TABLE 3.—Fish species caught in Narragansett Bay and Ninigret and Point Judith ponds in 2003 and 2004 with a 1-m beam trawl. Values in parentheses indicate the percentages each species contributed to the total catch.

Species	2002[a]	2003[b]
Winter flounder *Pseudopleuronectes americanus*	359 (60.2%)	128 (33.6%)
Grubby *Myoxocephalus aenaeus*	127 (21.3%)	42 (11%)
Naked goby *Gobiosoma bosc*	36 (6.0%)	7 (1.8%)
Northern pipefish *Syngnathus fuscus*	16 (2.7%)	14 (3.7%)
Cunner *Tautogolabrus adspersus*	14 (2.3%)	7 (1.8%)
Tautog *Tautoga onitis*	9 (1.5%)	47 (12.3%)
Atlantic tomcod *Microgadus tomcod*	6 (1.0%)	4 (1.0%)
Rock gunnel *Pholis gunnellus*	5 (0.8%)	8 (2.1%)
American eel *Anguilla rostrata*	4 (0.7%)	3 (0.8%)
Mummichog *Fundulus heteroclitus*	4 (0.7%)	34 (8.9%)
Windowpane *Scophthalmus aquosus*	3 (0.5%)	
Fourspine stickleback *Apeltes quadracus*		62 (16.3%)
Rainwater killifish *Lucania parva*		20 (5.2%)
Striped killifish *Fundulus majalis*		2 (0.5%)

[a] Species making up less than 0.5% in 2002: lined seahorse *Hippocampus erectus* (0.3%), Atlantic cod *Gadus morhua* (0.2%), black sea bass *Centropristis striata* (0.2%), spotfin butterflyfish *Chaetodon ocellatus* (0.2%), summer flounder *Paralichthys dentatus* (0.2%), striped killifish (0.2%), oyster toadfish *Opsanus tau* (0.2%), red hake *Urophycis chuss* (0.2%), red hind *Epinephelus guttatus* (0.2%), snailfish *Liparis* spp. (0.2%), northern searobin *Prionotus carolinus* (0.2%), and Atlantic silverside *Menidia menidia* (0.2%).

[b] Species making up less than 0.5% in 2003: northern kingfish *Menticirrhus saxatilis* (0.3%), red hake (0.3%), and northern searobin (0.3%).

coves and in the Providence River, Greenwich Bay, Wickford Harbor, and Point Judith and Ninigret ponds (Figure 1). Three times as many winter flounder/m² were captured at sites in coves (0.09 ± 0.02 [mean ± SE]) compared with noncove sites (0.03 ± 0.006). Similarly, approximately three times as many fish were captured per unit effort in the ponds compared with the bay (Figure 2). Average winter flounder/m² was 0.02 ± 0.005 in the bay versus 0.07 ± 0.02 in the ponds. Average total fish/m² was 0.07 ± 0.01 in the bay and 0.2 ± 0.06 in the ponds. Average winter flounder sizes were slightly higher in 2003 (Table 1), particularly in the ponds where the average size was 52 mm compared with 45 mm in the bay.

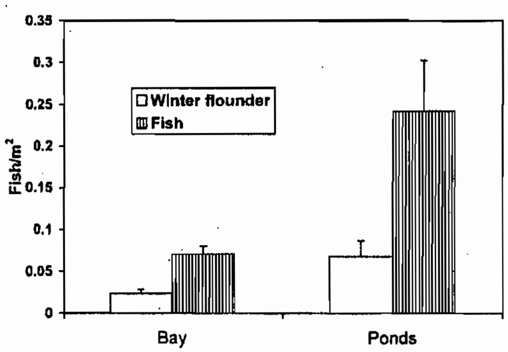

FIGURE 2.—Winter flounder and total fish densities captured in the bay and the ponds for 2003 (each error bar = 1 SE).

The results of the stepwise regression on the general model indicated that winter flounder densities were higher at sites in coves and that densities increased with human population density, greater percentages of macroalgal cover, and higher percentages of mud (Table 2). Densities were higher in 2002 and negatively correlated with dissolved oxygen and chlorophyll *a* (Table 2). Although eight variables entered the model at the default significance level of 0.15 (SAS Institute 1988), the model explained only about 25% of the variability in winter flounder catches (Table 2).

In the habitat model (Table 2), the habitat variable was important. Similar to the general model, densities increased with macroalgal cover and decreased with dissolved oxygen (Table 2). The habitat model explained only about 16% of the variability in winter flounder densities (Table 2). Densities were higher in coves and at sites with marsh or beach edges and human-altered sites (Figure 3). Deep sites (≥4 m) had the lowest catches (Figure 3). Of the variables measured at larger scales, only percent rocky or sandy beach within a 100-m radius of the site (r^2 = 0.049; P = 0.005) and Simpson's index characterizing habitat diversity (r^2 = 0.026; P = 0.037) had significant relationships with winter flounder densities. Distance to the nearest water depth of 2 m or greater, distance to the nearest marsh or submerged aquatic vegetation; the number of buildings, roads, piers; and the percent of shoreline that was artificially hardened were not significant.

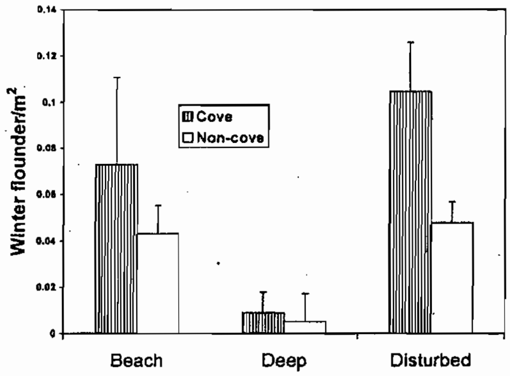

FIGURE 3.—Winter flounder densities captured in coves and noncove sites in three habitats: beach or marsh shorelines, deep water (≥4 m), and human-altered sites. Altered sites include industrial areas, artificially hardened shorelines, and marinas (each error bar = 1 SE).

Discussion

Although our habitat models explained little of the variability in fish abundance, some trends emerged. In our study, winter flounder densities were highest in coves and upper estuaries regardless of the amount of human disturbance. Catches were highest in altered areas compared with deep sites or those with marsh or beach shorelines. This may be because many altered areas are in coves or upper estuaries which are frequently targeted for development, such as construction of docks and marinas. The sheltered nature of coves and upper estuaries may attract human development and winter flounder. Many of the altered areas with high winter flounder densities—such as the Providence River, Greenwich Bay, and Wickford Harbor—are thought to be spawning sites for adults (Keller et al. 1999), and juveniles may simply settle out near spawning sites. The calm waters and muddy-sand substrates of these embayments are thought to be preferred by winter flounder for spawning (Able and Fahay 1998; Collette and Klein-MacPhee 2002).

One of the most interesting findings was the high densities of juvenile winter flounder in upper Narragansett Bay in the Providence River, near the city of Providence. This densely populated area is highly altered by dredging, development, and industry. Catches in some small coves off the Providence River adjacent to oil booms and industries such as scrap-metal processing were two to three times greater than those in the lower bay. We attribute this to the physical and chemical properties of the upper estuary. It has been proposed that the headwaters of estuarine nursery areas are used first by juvenile fishes and "fill up backward" during recruitment (Weinstein 1979; Rogers et al. 1984). Salinity is likely a key factor, with many estuarine-dependent fishes moving into low salinity water to spawn and rear (Weinstein et al. 1980; Holt and Strawn 1983; Rogers et al. 1984; Rozas and Hackney 1984; Allen and Barker 1990; Meng et al. 2001). Upper estuaries and coves also tend to have higher nutrient inputs and less flushing, which increases primary productivity and food availability for early life stages (Tsai et al. 1991; Nixon 1992). Currents are less pronounced in coves and upper estuaries, and temperatures tend to be higher, enhancing growth. Finally, water is shallower in these areas, providing refuge from predation for small fish (Ruiz et al. 1993; Manderson et al. 2004). Therefore, upper estuaries and coves may provide beneficial nursery habitat despite apparent human disturbance.

Other studies have found high winter flounder densities in upper estuaries and coves. Poole (1966) found that juveniles were more abundant in coves than in adjacent bay sites on Long Island from June through October. In Little Egg Harbor in southern New Jersey, newly settled winter flounder (10–45 mm TL) were more abundant in coves from May to mid-June, but densities in coves declined soon after settlement, suggesting that the coves were used for settlement but not as primary nurseries (Curran and Able 2002). However, in the Navesink River–Sandy Hook System, New Jersey, juveniles remained near settling areas in the upper estuary (Manderson et al. 2003). Densities of juvenile winter flounder are higher in Rhode Island's salt ponds (Crawford and Carey 1985; Meng et al. 2004; this study), and these lagoons have hydrodynamic features that retain the demersal eggs, larvae, and juveniles. Pearcy (1962) suggested that vertical movement contributes to the retention of larvae in a two-layer density current system typical of estuaries. These hydrodynamic features are likely the same mechanism that enhanced juvenile winter flounder densities in the upper estuaries and coves of our study.

Juvenile winter flounder are habitat generalists (Able and Fahay 1998), and shallow upper estuaries and coves provide plentiful food (Tsai et al. 1991) and refuge from predation (Carlson et al. 2000; Manderson et al. 2004). Carlson et al. (2000) found similar winter flounder abundances in natural intertidal and anthropogenically altered marina habitats in Connecticut. These habitats were similar in abiotic factors, substrate, and food availability. Both habitats also likely offered refuge from predation—the intertidal from large fishes and the marina from bird predators (Carlson et al. 2000). In New Haven Harbor, chronically altered by organic and inorganic nutrient disposal and shipping, winter flounder fed on the most active and abundant benthic species, regardless of a disturbed benthic assemblage (Carlson et al. 1997). In Jamaica Bay, New York, high nutrient loadings indirectly supported abundant populations of amphipod *Ampelisca abdita* which were fed on by juvenile winter flounder, resulting in high numbers of this fish (Franz and Tanacredi 1992). Winter flounder are opportunistic feeders that will thrive on whatever food is available (Steimle et al. 1993; Meng et al. 2000, 2001), although too much structure in altered areas will decrease food resources and may limit feeding efficiency due to low light levels (Able et al. 1999).

An estuarine life history—which includes adaptations to fluctuating salinities, temperatures, and dissolved oxygen—also allows winter flounder to exploit many habitats (Able and Fahay 1998). Of particular interest in our study was the relationship between winter flounder abundance and low dissolved oxygen. Other studies have noted that winter flounder grow well under low dissolved oxygen as long as levels don't drop below 2.2 mg/L (Bejda et al. 1992; Howell and Simpson 1994; Phelan et al. 2000; Meng et al. 2001). Their behavior also suggests tolerance of low dissolved oxygen. Winter flounder bury themselves in sediment both as refuge from predation and cold temperatures (Hayden et al. 1975; Collette and Klein-MacPhee 2002). It is likely they experience low oxygen levels when buried, particularly in muddy sediments for long periods against the cold (Hayden et al. 1975). In this study, the observed tolerance for low dissolved oxygen was probably related to the strong relationship between fish abundance and coves, where oxygen levels tend to be lower. Further, the combination of winter flounder life history and physiology contribute to their ability to use disturbed habitats. Winter flounder larvae are weak swimmers (Collette and Klein-MacPhee 2002), and juveniles move little in their natal habitats (Saucerman and Deegan 1991). Thus, larvae and juveniles remain in upper estuarine habitats where they are spawned. Their propensity for little or slow movement and burial in sediment probably reduces their demand for oxygen and opens up nutrient-rich, disturbed habitats for their use.

Juvenile winter flounder prefer substrates found in upper estuaries and coves such as unvegetated areas, with muddy sand and some macroalgae (Pearcy 1962; Sogard and Able 1991; Able and Fahay 1998; Meng and Powell 1999; Meng et al. 2004). Previous work indicates that juvenile winter flounder are less likely to be caught in eelgrass than in adjacent unvegetated areas (Heck et al. 1989; Sogard and Able 1991; Goldberg et al. 2002). In a study conducted in Ninigret Pond, small individuals (25–30 mm TL) were found in unvegetated areas with some macroalgae, whereas larger individuals were taken in eelgrass (Meng et al. 2004). In this study, many winter flounder were taken in areas with macroalgae which they likely use as a refuge from predation (Manderson et al. 2000). Several studies have compared growth of winter flounder in eelgrass and unvegetated habitats and concluded that juveniles grew equally or better in unvegetated areas (Sogard 1992; Meng et al. 2000; Phelan et al. 2000). Howell et al. (1999) noted that the only habitat consistently producing higher catches of juveniles in Connecticut estuaries was mud-shell litter, despite looking for relationships between catch and several variables (including salinity, water temperature, turbidity, depth, channel or nonchannel, and presence of sea lettuce). The lack of a relationship between catch and temperature and salinity may reflect changing influences of those variables over time (Manderson et al. 2002). ?

One of our accomplishments was the development of a rapid random sampling method that allowed us to sample many habitats across a relatively large area. The beam trawl mounted with a video camera and water quality sampling device allowed a three-person crew to sample an average of five sites per day. Fish and habitat characteristics could be sampled simultaneously and quickly. The random approach took us into areas not normally considered good habitat for fish. Upon locating a site with our GPS, we were often doubtful about sampling off a riprapped shoreline near a marina in a highly developed cove. Initially, we expected to catch little in disturbed areas, but as time went on we were less surprised by catches that were two to three times greater than those at undisturbed sites. Because our approach included areas not normally sampled for fish, the data we collected have proven valuable to local regulators assessing potential projects proposed in highly developed areas.

We attempted to assess multiple-scale habitat variation for winter flounder. We hoped to examine habitat on the video frame scale (~1 m^2), but low light levels and poor camera resolution made it difficult to see small fish. Larger scale patterns from aerial photos and charted depths partly supported the findings of the beam trawl–video transects. Habitat diversity (calculated by Simpson's index) and beaches were associated with greater winter flounder densities, similar to our findings based on the transects, but measures of human-altered habitats (e.g., number of roads, buildings, and piers) were not. This was somewhat surprising due to the high catches of winter flounder in disturbed areas with greater human population densities and suggests other measurements at larger scales may be more appropriate.

We attempted to build a stressor response model to describe how habitat alteration affects juvenile winter flounder, with the ultimate goal of contributing to the development of criteria protective of habitats critical to fish and other aquatic species. The results of our study suggest that stressor response models may not work well to quantify the effects of habitat alteration on species that are habitat generalists such as winter flounder. Further, our results suggest that current measures used by the states to protect habitat may not be useful for all species. Currently, water quality measures used to protect habitat are based on designating use of water bodies. For example, the state of Massachusetts classifies coastal and marine waters with SA, SB, and SC designations based on qualities such as dissolved oxygen, temperature, and fecal coliform concentrations. The highest quality waters are designated SA and within this designation are outstanding resource waters (ORW), a designation that also recognizes the societal value of these areas, such as presence of wildlife refuges. Waters designated ORW and SA receive the most protection from development. Many of the sites we sampled with the highest densities of fish would not be designated as ORW or SA waters under the current scheme, but these areas still need protection because they are important to juvenile winter flounder. Many efforts to protect resources focus on protecting pristine areas and allowing development in already disturbed areas. This approach is frequently based on a subjective judgment of what "good habitat" looks like. Although protecting pristine areas is critical, our results indicate that, for some species, disturbed and undervalued habitats are also important and that empirical methods are useful to establish links between habitat quality and wildlife.

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ABSTRACT

Temperature criteria for freshwater fish are expressed as mean and maximum temperatures; means control functions such as embryogenesis, growth, maturation, and reproductivity, and maxima provide protection for all life stages against lethal conditions. These criteria for 34 fish species are based on numerous field and laboratory studies, and yet for some important species the data are still insufficient to develop all the necessary criteria. Fishery managers, power-plant designers, and regulatory agencies will find these criteria useful in their efforts to protect fishery resources.

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TEMPERATURE CRITERIA FOR FRESHWATER FISH:

PROTOCOL AND PROCEDURES

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FOREWORD

Our nation's fresh waters are vital for all animals and plants, yet our diverse uses of water — for recreation, food, energy, transportation, and industry — physically and chemically alter lakes, rivers, and streams. Such alterations threaten terrestrial organisms, as well as those living in water. The Environmental Research Laboratory in Duluth, Minnesota, develops methods, conducts laboratory and field studies, and extrapolates research findings

--to determine how physical and chemical pollution affects aquatic life;

--to assess the effects of ecosystems on pollutants;

--to predict effects of pollutants on large lakes through use of models; and

--to measure bioaccumulation of pollutants in aquatic organisms that are consumed by other animals, including man.

This report discusses the history, procedures, and derivation of temperature criteria to protect freshwater fishes and presents numerical criteria for 34 species. It follows the general philosophical approach of the National Academy of Sciences and National Academy of Engineering in their Water Quality Criteria 1972 and is intended to make that philosophy practically useful.

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SECTION 2

INTRODUCTION

This report is intended to be a guide for derivation of temperature criteria for freshwater fish based on the philosophy and protocol presented by the National Academy of Sciences and National Academy of Engineering (1973). It is not an attempt to gather and summarize the literature on thermal effects.

Methods for determination of temperature criteria have evolved and developed rapidly during the past 20 years, making possible a vast increase in basic data on the relationship of temperature to various life stages.

One of the earliest published temperature criteria for freshwater life was prepared by the Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission (ORSANCO) in 1956. These criteria were based on conditions necessary to maintain a well-rounded fish population and to sustain production of a harvestable crop in the Ohio River watershed. The committee recommended that the temperature of the receiving water:

1) Should not be raised above 34° C (93°F) at any place or at any time;

2) should not be raised above 23° C (73° F) at any place or at any time during the months of December through April; and

3) should not be raised in streams suitable for trout propagation.

McKee and Wolf (1963) in their discussion of temperature criteria for the propagation of fish and other aquatic and marine life refer only to the progress report of ORSANCO's Aquatic Life Advisory Committee (1956).

In 1967 the Aquatic Life Advisory Committee of ORSANCO evaluated and further modified their recommendations for temperature in the Ohio River watershed. At this time the committee expanded their recommendation of a 93° F (33.9° C) instantaneous temperature at any time or any place to include a daily mean of 90° F (32.2° C). This, we believe, was one of the first efforts to recognize the importance of both mean and maximum temperatures to describe temperature requirements of fishes. The 1967 recommedations also included:

1) Maximum temperature during December, January, and February should be 55° F (12.8° C);

2) during the transition months of March, April, October and November the temperature can be changed gradually by not more than 7° F (3.9° C);

3) to maintain trout habitats, stream temperatures should not exceed 55° F (12.8° C) during the months of October through May, or exceed 68° F (20.0° C) during the months of June through September; and

4) insofar as possible the temperature should not be raised in streams used for natural propagation of trout.

The National Technical Advisory Committee of the Federal Water Pollution Control Administration presented a report on water quality criteria in 1968 that was to become known as the "Green Book." This large committee included many of the members of ORSANCO's Aquatic Life Advisory Committee. The committee members recognized that aquatic organisms might be able to endure a high temperature for a few hours that could not be endured for a period of days. They also acknowledged that no single temperature requirement could be applied to the United States as a whole, or even to one state, and that the requirements must be closely related to each body of water and its fish populations. Other important conditions for temperature requirements were that (1) a seasonal cycle must be retained, (2) the changes in temperature must be gradual, and (3) the temperature reached must not be so high or so low as to damage or alter the composition of the desired population. These conditions led to an approach to criteria development different from earlier ones. A temperature increment based on the natural water temperature was believed to be more appropriate than an unvarying number. The use of an increment requires a knowledge of the natural temperature conditions of the water in question, and the size of the increment that can be tolerated by the desirable species.

The National Technical Advisory Committee (1968, p. 42) recommended:

> "To maintain a well-rounded population of warmwater fishes .... heat should not be added to a stream in excess of the amount that will raise the temperature of the water (at the expected minimum daily flow for that month) more than 5° F."

A casual reading of this requirement resulted in the unintended generalization that the acceptable temperature rise in warmwater fish streams was 5° F (2.8° C). This generalization was incorrect! Upon more careful reading the key word "amount" of heat and the key phrase "minimum daily flow for that month" clarify the erroneousness of the generalization. In fact, a 5° F (2.8° C) rise in temperature could only be acceptable under low flow conditions for a particular month and any increase in flow would result in a reduced increment of temperature rise since the amount of heat added could not be increased. For lakes and reservoirs the temperature rise limitation was 3° F (1.7° C) based "on the monthly average of the maximum daily temperature."

In trout and salmon waters the recommendations were that "inland trout streams, headwaters of salmon streams, trout and salmon lakes, and reservoirs containing salmonids should not be warmed," that "no heated effluents should be discharged in the vicinity of spawning areas," and that "in lakes and reservoirs, the temperature of the hypolimnion should not be raised more than 3° F (1.7° C)." For other locations the recommended incremental rise was 5° F (2.8° C) again based on the minimum expected flow for that month.

An important additional recommendation is summarized in the following table in which provisional maximum temperatures were recommended for variou fish species and their associated biota (from FWPCA National Technical Adv: Committee, 1968).

PROVISIONAL MAXIMUM TEMPERATURES RECOMMENDED AS

COMPATIBLE WITH THE WELL-BEING OF VARIOUS SPECIES

OF FISH AND THEIR ASSOCIATED BIOTA

93 F:	Growth of catfish, gar, white or yellow bass, spotted bass, buffalo, carpsucker, threadfin shad, and gizzard shad.
90 F:	Growth of largemouth bass, drum, bluegill, and crappie.
84 F:	Growth of pike, perch, walleye, smallmouth bass, and sauger.
80 F:	Spawning and egg development of catfish, buffalo, threadfin shad, and gizzard shad.
75 F:	Spawning and egg development of largemouth bass, white, yellow, and spotted bass.
68 F:	Growth or migration routes of salmonids and for egg development of perch and smallmouth bass.
55 F:	Spawning and egg development of salmon and trout (other than lake trout).
48 F:	Spawning and egg development of lake trout, walleye, northern pike, sauger, and Atlantic salmon.

NOTE: Recommended temperatures for other species, not listed above, may be established if and when necessary information becomes available.

These recommendations represent one of the significant early efforts to base temperature criteria on the realistic approach of species and community requirements and take into account the significant biological factors of spawning, embryo development, growth, and survival.

The Federal Water Pollution Control Administration (1969a) recommended revisions in water quality criteria for aquatic life relative to the Main Stem of the Ohio River. These recommendations were presented to ORSANCO's Engineering Committee and were based on the temperature requirements of important Ohio River fishes including largemouth bass, smallmouth bass, white bass, sauger, channel catfish, emerald shiner, freshwater drum, golden redhorse, white sucker, and buffalo (species was not indicated). Temperature requirements for survival, activity, final preferred temperature, reproduction, and growth were considered. The recommended criteria were:

1. "The water temperatures shall not exceed 90° F (32.2° C) at any time or any place, and a maximum hourly average value of 86° F (30° C) shall not be exceeded."

2. "The temperature shall not exceed the temperature values expressed on the following table:"

AQUATIC LIFE TABLE[a]

	Daily mean (° F)	Hourly maximum (° F)
December-February	48	55
Early March	50	56
Late March	52	58
Early April	55	60
Late April	58	62
Early May	62	64
Late May	68	72
Early June	75	79
Late June	78	82
July-September	82	86
October	75	82
November	65	72

[a]From: Federal Water Pollution Control Administration (1969a).

The principal limiting fish species considered in developing these criteria was the sauger, the most temperature sensitive of the important Ohio River fishes. A second set of criteria (Federal Water Pollution Control Administration, 1969b) considered less temperature-sensitive species, and the criteria for mean temperatures were higher. The daily mean in July and September was 84° F (28.9° C). In addition, a third set of criteria was developed that was not designed to protect the smallmouth bass, emerald shiner, golden redhorse, or the white sucker. The July-to-September daily mean temperature criterion was 86° F (30° C).

The significance of the 1969 Ohio River criteria was that they were species dependent and that subsequently the criteria would probably be based upon a single species or a related group of species. Therefore, it is extremely important to select properly the species that are important otherwis the criteria will be unnecessarily restrictive. For example, if yellow perch is an extremely rare species in a water body and is the most temperature-sensitive species, it probably would be unreasonable to establish temperature criteria for this species as part of the regulatory mechanism.

In 1970 ORSANCO established new temperature standards that incorporated the recommendations for temperature criteria of the Federal Water Pollution Control Administration (1969a, 1969b) and the concept of limiting the amount of heat that would be added (National Technical Advisory Committee, 1968). The following is the complete text of that standard:

> " All cooling water from municipalities or political subdivisions, public or private institutions, or installations, or corporations discharged or permitted to flow into the Ohio River from the point of confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, designated as Ohio River mile point 0.0 to Cairo Point, Illinois, located at the confluence of the Ohio and Mississippi Rivers, and being 981.0 miles downstream from Pittsburgh, Pennsylvania, shall be so regulated or controlled as to provide for reduction of heat content to such degree that the aggregate heat-discharge rate from the municipality, subdivision, institution, installation or corporation, as calculated on the basis of discharge volume and temperature differential (temperature of discharge minus upstream river temperature) does not exceed the amount calculated by the following formula, provided, however, that in no case shall the aggregate heat-discharge rate be of such magnitude as will result in a calculated increase in river temperature of more than 5 degrees F:
>
> Allowable heat-discharge rate (Btu/sec) = 62.4 X river flow (CFS) X $(T_a - T_r)$ X 90%

Where:

T_a = Allowable maximum temperature (deg. F.) in the river as specified in the following table:

	T_a		T_a
January	50	July	89
February	50	August	89
March	60	September	87
April	70	October	78
May	80	November	70
June	87	December	57

T_r = River temperature (daily average in deg. F.) upstream from the discharge

River flow = measured flow but not less than critical flow values specified in the following table:

River reach		Critical flow in cfs[a]
From	To	
Pittsburgh, Penn. (mi. 0.0)	Willow Is. Dam (161.7)	6,500
Willow Is. Dam (161.7)	Gallipolis Dam (279.2)	7,400
Gallipolis Dam (279.2)	Meldahl Dam (436.2)	9,700
Meldahl Dam (436.2)	McAlpine Dam (605.8)	11,900
McAlpine Dam (605.8)	Uniontown Dam (846.0)	14,200
Uniontown Dam (846.0)	Smithland Dam (918.5)	19,500
Smithland Dam (918.5)	Cairo Point (981.0)	48,100

[a]Minimum daily flow once in ten years.

Although the numerical criteria for January through December are higher than those recommended by the Federal Water Pollution Control Administration they are only used to calculate the amount of heat that can be added at the "minimum daily flow once in ten years." Additional flow would result in lower maxima since no additional heat could be added. There was also the increase of 5° F (2.8° C) limit that could be more stringent than the maximu temperature limit.

The next important step in the evolution of thought on temperature criteria was Water Quality Criteria 1972 (NAS/NAE, 1973), which is becoming known as the "Blue Book," because of its comparability to the Green Book (FWI National Technical Advisory Committee, 1968). The Blue Book is the report o the Committee on Water Quality Criteria of the National Academy of Sciences a the request of and funded by the U.S. Environmental Protection Agency (EPA). The heat and temperature section, with its recommendations and appendix data, was authored by Dr. Charles Coutant of the Oak Ridge National Laboratory. Th materials are reproduced in full in Appendix A and Appendix B in this report. A discussion and description of the Blue Book temperature criteria will be found later in this report.

The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) contain a section [304 (a) (1)] that requires that the administrator of the EPA "after consultation with appropriate Federal and State agencies and other interested persons, shall develop and publish, within one year after enactment of this title (and from time to time thereafter revise) criteria for water quality accurately reflecting the latest scientific knowledge (A) on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water, including ground water; (B) on the concentration and dispersal of pollutants or their byproducts, through biological, physical, and chemical processes; and (C) on the effects of pollutants on biological community diversity, productivity, and stability, including information on the factors affecting rates of eutrophication and rates of organic and inorganic sedimentation for varying types of receiving waters."

The U.S. Environmental Protection Agency (1976) has published Quality Criteria for Water as a response to the Section 304(a)(1) requirements of PL 92-500. That approach to the determination of temperature criteria for freshwater fish is essentially the same as the approach recommended in the Blue Book (NAS/NAE, 1973). The EPA criteria report on temperature included numerical criteria for freshwater fish species and a nomograph for winter temperature criteria. These detailed criteria were developed according to the protocol in the Blue Book, and the procedures used to develop those criteria will be discussed in detail in this report.

The Great Lakes Water Quality Agreement (1972) between the United States of America and Canada was signed in 1972 and contained a specific water quality objective for temperature. It states that "There should be no change that would adversely affect any local or general use of these waters." The

International Joint Commission was designated to assist in the implementation of this agreement and to give advice and recommendations to both countries on specific water quality objectives. The International Joint Commission committees assigned the responsibility of developing these objectives have recommended temperature objectives for the Great Lakes based on the "Blue Book" approach and are in the process of refining and completing those objectives for consideration by the commission before submission to the two countries for implementation.

SECTION 3

THE PROTOCOL FOR TEMPERATURE CRITERIA

This section is a synthesis of concepts and definitions from Fry et al. (1942, 1946), Brett (1952, 1956), and the NAS/NAE (1973).

The lethal threshold temperatures are those temperatures at which 50 percent of a sample of individuals would survive indefinitely after acclimation at some other temperature. The majority of the published literature (Appendix B) is calculated on the basis of 50 percent survival. These lethal thresholds are commonly referred to as incipient lethal temperatures. Since organisms can be lethally stressed by both rising and falling temperatures, there are upper incipient lethal temperatures and lower incipient lethal temperatures. These are determined by removing the organisms from a temperature to which they are acclimated and instantly placing them in a series of other temperatures that will typically result in a range in survival from 100 to 0 percent. Acclimation can require up to 4 weeks, depending upon the magnitude of the difference between the temperature when the fish were obtained and the desired acclimation temperature. In general, experiments to determine incipient lethal temperatures should extend until all the organisms in any test chamber are dead or sufficient time has elapsed for death to have occurred. The ultimate upper incipient lethal temperature is that beyond which no increase in lethal temperature is accomplished by further increase in acclimation temperature. For most freshwater fish species in temperate latitudes the lower incipient lethal temperatures will usually end at 0° C, being limited by the freezing point of water. However, for some important species, such as threadfish shad in freshwater and menhaden in seawater, the lower incipient lethal temperature is higher than 0° C.

As indicated earlier, the heat and temperature section of the Blue Book and its associated appendix data and references have been reproduced in this report as Appendix A and Appendix B. The following discussion will briefly summarize the various types of criteria and provide some additional insight into the development of numerical criteria. The Blue Book (Appendix A) also describes in detail the use of the criteria in relation to entrainment.

MAXIMUM WEEKLY AVERAGE TEMPERATURE

For practical reasons the maximum weekly average temperature (MWAT) is the mathematical mean of multiple, equally spaced, daily temperatures over a 7-day consecutive period.

For Growth

To maintain growth of aquatic organisms at rates necessary for sustaining actively growing and reproducing populations, the MWAT in the zone normally inhabited by the species at the season should not exceed the optimum temperature plus one-third of the range between the optimum temperature and the ultimate upper incipient lethal temperature of the species:

$$\text{MWAT for growth} = \text{optimum temperature} + \frac{\begin{matrix}\text{ultimate upper incipient} \\ \text{lethal temperature}\end{matrix} - \begin{matrix}\text{optimum} \\ \text{temperature}\end{matrix}}{3}$$

The optimum temperature is assumed to be the optimum for growth, but other physiological optima may be used in the absence of growth data. The MWAT need not apply to accepted mixing zones and must be applied with adequate understanding of the normal seasonal distribution of the important species.

For Reproduction

The MWAT for reproduction must consider several factors such as gonad growth and gamete maturation, potential blocking of spawning migrations, spawning itself, timing and synchrony with cyclic food sources, and normal patterns of gradual temperature changes throughout the year. The protection of reproductive activity must take into account months during which these processes normally occur in specific water bodies for which criteria are being developed.

For Winter Survival

The MWAT for fish survival during winter will apply in any area in which fish could congregate and would include areas such as unscreened discharge channels. This temperature limit should not exceed the acclimation, or plume, temperature (minus a 3.6° F (2.0° C) safety factor) that raises the lower lethal threshold temperature above the normal ambient water temperature for that season. This criterion will provide protection from fish kills caused by rapid changes in temperature due to plant shutdown or movement of fish from a heated plume to ambient temperature.

SHORT-TERM EXPOSURE TO EXTREME TEMPERATURE

It is well established that fish can withstand short exposure to temperatures higher than those acceptable for reproduction and growth without significiant adverse effects. These exposures should not be too lengthy or frequent or the species could be adversely affected. The length of time that 50 percent of a population will survive temperature above the incipient lethal temperature can be calculated from the following regression equation:

$$\log \text{time (min)} = a + b \text{ (temperature in °C)};$$

or

$$\text{temperature (°C)} = (\log \text{time (min)} - a)/b.$$

The constants "a" and "b" are for intercept and slope and will be discuss later. Since this equation is based on 50 percent survival, a 3.6° F (2. reduction in the upper incipient lethal temperature will provide the safe factor to assure no deaths.

For those interested in more detail or the rationale for these genera criteria, Appendices A and B should be read thoroughly. In addition, Appe A contains a fine discussion of a procedure to evaluate the potential the impact of aquatic organisms entrained in cooling water or the discharge plume, or both.

SECTION 4

THE PROCEDURES FOR CALCULATING NUMERICAL TEMPERATURE CRITERIA FOR FRESHWATER FISH

MAXIMUM WEEKLY AVERAGE TEMPERATURE

The necessary minimum data for the determination of this criterion are the physiological optimum temperature and the ultimate upper incipient lethal temperature. The latter temperature represents the "breaking point" between the highest temperatures to which an animal can be acclimated and the lowest of the extreme upper temperatures that will kill the warm-acclimated organism. Physiological optima can be based on performance, metabolic rate, temperature preference, growth, natural distribution, or tolerance. However, the most sensitive function seems to be growth rate, which appears to be an integrator of all physiological responses of an organism. In the absence of data on optimum growth, the use of an optimum for a more specific function related to activity and metabolism may be more desirable than not developing any growth criterion at all.

The MWAT's for growth were calculated for fish species for which appropriate data were available (Table 1). These data were obtained from the fish temperature data in Appendix C. These data sheets contain the majority of thermal effects data for about 34 species of freshwater fish and the sources of the data. Some subjectivity is inevitable and necessary because of variability in published data resulting from differences in age, day length, feeding regime, or methodology. For example, the data sheet for channel catfish (Appendix C) includes four temperature ranges for optimum growth based on three published papers. It would be more appropriate to use data for growth of juveniles and adults rather than larvae. The middle of each range for juvenile channel catfish growth is 29° and 30° C. In this instance 29° C is judged the best estimate of the optimum. The highest incipient lethal temperature (that would approximate the <u>ultimate</u> incipient lethal temperature) appearing in Appendix C is 38° C. By using the previous formula for the MWAT for growth, we obtain

$$29^\circ\ C + \frac{(38-29^\circ\ C)}{3} = 32^\circ\ C.$$

The temperature criterion for the MWAT for growth of channel catfish would be 32° C (as appears in Table 1).

TABLE 1. TEMPERATURE CRITERIA FOR GROWTH AND SURVIVAL OF SHORT EXPOSURE (24 HR) OF JUVENILE AND ADULT FISH DURING THE SUMMER (° C (° F))

Species	Maximum weekly average temperature for growth[a]	Maximum temperature for survival of short exposure[b]
Alewife	—	—
Atlantic salmon	20 (68)	23 (73)
Bigmouth buffalo	—	—
Black crappie	27 (81)	—
Bluegill	32 (90)	35 (95)
Brook trout	19 (66)	24 (75)
Brown bullhead	—	—
Brown trout	17 (63)	24 (75)
Carp	—	—
Channel catfish	32 (90)	35 (95)
Coho salmon	18 (64)	24 (75)
Emerald shiner	30 (86)	—
Fathead minnow	—	—
Freshwater drum	—	—
Lake herring (cisco)	17 (63)[c]	25 (77)
Lake whitefish	—	—
Lake trout	—	—
Largemouth bass	32 (90)	34 (93)
Northern pike	28 (82)	30 (86)
Pumpkinseed	—	—
Rainbow smelt	—	—
Rainbow trout	19 (66)	24 (75)
Sauger	25 (77)	—
Smallmouth bass	29 (84)	—
Smallmouth buffalo	—	—
Sockeye salmon	18 (64)	22 (72)
Striped bass	—	—
Threadfin shad	—	—
Walleye	25 (77)	—
White bass	—	—
White crappie	28 (82)	—
White perch	—	—
White sucker	28 (82)[c]	—
Yellow perch	29 (84)	—

[a]Calculated according to equation:
maximum weekly average temperature for growth = optimum for growth + (1/3) (ultimate incipient lethal temperature − optimum for growth).

[b]Based on: temperature (° C) = (log time (min) − a)/b − 2° C, acclimation at the maximum weekly average temperature for summer growth, and data in Appendix B.

[c]Based on data for larvae.

SHORT-TERM MAXIMUM DURING GROWTH SEASON

In addition to the MWAT, maximum temperature for short exposure will protect against potential lethal effects. We have to assume that the incipient lethal temperature data reflecting 50 percent survival necessary for this calculation would be based on an acclimation temperature near the MWAT for growth. Therefore, using the data in Appendix B for the channel catfish, we find four possible data choices near the MWAT of 32° C (again it is preferable to use data on juveniles or adults):

Acclimation temperature (° C)	a	b
30	32.1736	-0.7811
34	26.4204	-0.6149
30	17.7125	-0.4058
35	28.3031	-0.6554

The formula for calculating the maximum for short exposure is:

$$\text{temperature } (^\circ\text{C}) = (\log \text{ time (min)} - a)/b$$

To solve the equation we must select a maximum time limitation on this maximum for short exposure. Since the MWAT is a weekly mean temperature an appropriate length of time for this limitation for short exposure would be 24 hr without risking violation of the MWAT.

Since the time is fixed at 24 hr (1,440 min), we need to solve for temperature by using, for example, the above acclimation temperature of 30° C for which a = 32.1736 and b = -0.7811.

$$\text{temperature } (^\circ\text{ C}) = \frac{\log 1,440 - a}{b}$$

$$\text{temperature } (^\circ\text{ C}) = \frac{3.1584 \quad -32.1736}{-0.7811} = \frac{-29.0152}{-0.7811} = 37.146$$

Upon solving for each of the four data points we obtain 37.1°, 37.8°, 35.9°, and 38.4° C. The average would be 37.3° C, and after subtracting the 2° C safety factor to provide 100 percent survival, the short-term maximum for channel catfish would be 35° C as appears in Table 1.

MAXIMUM WEEKLY AVERAGE TEMPERATURE FOR SPAWNING

From the data sheets in Apendix C one would use either the optimum temperature for spawning or, if that is not available, the middle of the range of temperatures for spawning. Again, if we use the channel catfish as an example, the MWAT for spawning would be 27° C (Table 2). Since spawning may occur over a period of a few weeks or months in a particular water body and only a MWAT for optimum spawning is estimated, it would be logical to use that optimum for the median time of the spawning season. The MWAT for the next earlier month

TABLE 2. TEMPERATURE CRITERIA FOR SPAWNING AND EMBRYO SURVIVAL OF SHORT EXPOSURES DURING THE SPAWNING SEASON (° C (° F))

Species	Maximum weekly average temperature for spawning[a]	Maximum temperature for embryo survival[b]
Alewife	22 (72)	28 (82)[c]
Atlantic salmon	5 (41)	11 (52)
Bigmouth buffalo	17 (63)	27 (81)[c]
Black crappie	17 (63)	20 (68)[c]
Bluegill	25 (77)	34 (93)
Brook trout	9 (48)	13 (55)
Brown bullhead	24 (75)	27 (81)
Brown trout	8 (46)	15 (59)
Carp	21 (70)	33 (91)
Channel catfish	27 (81)	29 (84)[c]
Coho salmon	10 (50)	13 (55)[c]
Emerald shiner	24 (75)	28 (82)[c]
Fathead minnow	24 (75)	30 (86)
Freshwater drum	21 (70)	26 (79)
Lake herring (cisco)	3 (37)	8 (46)
Lake whitefish	5 (41)	10 (50)[c]
Lake trout	9 (48)	14 (57)
Largemouth bass	21 (70)	27 (81)[c]
Northern pike	11 (52)	19 (66)
Pumpkinseed	25 (77)	29 (84)[c]
Rainbow smelt	8 (46)	15 (59)
Rainbow trout	9 (48)	13 (55)
Sauger	12 (54)	18 (64)
Smallmouth bass	17 (63)	23 (73)[c]
Smallmouth buffalo	21 (70)	28 (82)[c]
Sockeye salmon	10 (50)	13 (55)
Striped bass	18 (64)	24 (75)
Threadfin shad	19 (66)	34 (93)
Walleye	8 (46)	17 (63)[c]
White bass	17 (63)	26 (79)
White crappie	18 (64)	23 (73)
White perch	15 (59)	20 (68)[c]
White sucker	10 (50)	20 (68)
Yellow perch	12 (54)	20 (68)

[a] The optimum or mean of the range of spawning temperatures reported for the species.

[b] The upper temperature for successful incubation and hatching reported for the species.

[c] Upper temperature for spawning.

could approximate the lower temperature of the range in spawning temperature, and the MWAT for the last month of a 3-month spawning season could approximate the upper temperature for the range. For example, if the channel catfish spawned from April to June the MWAT's for the 3 months would be approximately 21°, 27°, and 29° C. For fall spawning fish species the pattern or sequence of temperatures would be reversed because of naturally declining temperatures during their spawning season.

SHORT-TERM MAXIMUM DURING SPAWNING SEASON

If spawning season maxima could be determined in the same manner as those for the growing season, we would be using the time-temperature equation and the Appendix B data as before. However, growing season data are based usually on survival of juvenile and adult individuals. Egg-incubation temperature requirements are more restrictive (lower), and this biological process would not be protected by maxima based on data for juvenile and adult fish. Also, spawning itself could be prematurely stopped if those maxima were achieved. For most species the maximum spawning temperature approximates the maximum successful incubation temperature. Consequently, the short-term maximum temperature should preferably be based on maximum incubation temperature for successful embryo survival, but the maximum temperature for spawning is an acceptable alternative. In fact, the higher of the two is probably the preferred choice as variability in available data has shown discrepancies in this relationship for some species.

For the channel catfish (Appendix C) the maximum reported incubation temperature is 28° C, and the maximum reported spawning temperature is 29° C. Therefore, the best estimate of the short-term survival of embryos would be 29° C (Table 2).

MAXIMUM WEEKLY AVERAGE TEMPERATURE FOR WINTER

As discussed earlier the MWAT for winter is designed usually to prevent fish deaths in the event the water temperature drops rapidly to an ambient condition. Such a temperature drop could occur as the result of a power-plant shutdown or a movement of the fish itself. These MWAT's are meant to apply wherever fish can congregate, even if that is within the mixing zone.

Yellow perch require a long chill period during the winter for optimum egg maturation and spawning (Appendix A). However, protection of this species would be outside the mixing zone. In addition, the embryos of fall spawning fish such as trout, salmon, and other related species such as cisco require low incubation temperatures. For these species also the MWAT during winter would have to consider embryo survival, but again, this would be outside the mixing zone. The mixing zone, as used in this report, is that area adjacent to the discharge in which receiving system water quality standards do not apply; a thermal plume therefore is not a mixing zone.

With these exceptions in mind, it is unlikely that any signficant effects on fish populations would occur as long as death was prevented.

In many instances growth could be enhanced by controlled winter heat additi but inadequate food may result in poor condition of the fish.

There are fewer data for lower incipient lethal temperatures than for the previously discussed upper incipient lethal temperatures. Appendix B contains lower incipient lethal temperature data for only about 20 freshwat fish species, less than half of which are listed in Tables 1 and 2. Conseq the available data were combined to calculate a regression line (Figure 1) which gives a generalized MWAT for winter survival instead of the species specific approach used in the other types of criteria.

All the lower incipient lethal temperature data from Appendix C for freshwater fish species were used to calculate the regression line, which ha a slope of 0.50 and a correlation coefficient of 0.75. This regression line was then displaced by approximately 2.5° C since it passed through the middl of the data and did not represent the more sensitive species. This new line on the edge of the data array was then displaced by a 2° C safety factor, th same factor discussed earlier, to account for the fact that the original dat points were for 50 percent survival and the 2° C safety factor would result in 100 percent survival. These two adjustments in the original regression line therefore result in a line (Figure 1) that should insure no more than negligible mortality of any fish species. At lower acclimation temperatures the coldwater species were different from the warmwater species, and the res criterion takes this into account.

If fish can congregate in an area close to the discharge point, this criterion could be a limit on the degree rise permissible at a particular si Obviously, if there is a screened discharge channel in which some cooling occurs, a higher initial discharge temperature could be permissible to fish.

An example of the use of this criterion (as plotted in the nomograph, Figure 1) would be a situation in which the ambient water temperature is 10° C, and the MWAT, where fish could congregate, is 25° C, a difference of 15° C. At a lower ambient temperature of about 2.5° C, the MWAT would be 10° C, a 7.5° C difference.

In some instances the data will be insufficient to determine each necessary criterion for each species. Estimates must be made based on available species-specific data or by extrapolation from data for species with similar requirements for which adequate data are available. For instance, this example includes the bigmouth buffalo and freshwater drum for which no growth or short-term summer maxima are available (Table 1). One would of necessity have to estimate that the summer criteria would not be lower than that for the white crappie, which has a spawning requirement as low as the other two species.

The choice of important fish species is very critical. Since in this example the white crappie is as temperature sensitive as any of the species, the maximum weekly average temperature for summer growth is based on the white crappie. Consequently, this criterion would result in lower than optimal conditions for the channel catfish, bluegill, and largemouth bass. An alternate approach would be to develop criteria for the single most important species even if the most sensitive is not well protected. The choice is a socioeconomic one.

Before developing a set of criteria such as those in Table 3, the material in Tables 1 and 2 should be studied for the species of concern. It is evident that the lowest optimum temperature for summer growth for the species for which data are available would be for the white crappie (28° C). However, there is no maximum for short exposure since the data are not available (Appendix C). For the species for which there are data, the lowest maximum for short exposure is for the largemouth bass (34° C). In this example we have all the necessary data for spawning and maximum for short exposure for embryo survival for all species of concern (Table 2).

During the winter, criteria may be necessary both for the mixing zone as well as for the receiving water. Receiving-water criteria would be necessary if an important fish species were known to have gamete-maturation requirements like the yellow perch, or embryo-incubation requirements like trout, salmon, cisco, etc. In this example there is no need for receiving-system water criteria.

At this point, we are ready to complete Table 3 for Example 1.

EXAMPLE 2

All of the general concerns and data sources presented throughout the discussion and derivation of Example 1 will apply here.

1. Species to be protected by the criteria: rainbow and brown trout and the coho salmon.

2. Local spawning seasons for these species: November through January for rainbow trout; and November through December for the brown trout and coho salmon.

3. Normal ambient winter temperature: 2° C in November through February; 5° C in October, March, and April.

TABLE 3. TEMPERATURE CRITERIA FOR EXAMPLE 1

Month	Maximum weekly average temperature, (° C (° F)) Receiving water	Heated plume	Decision basis
January	—[a]	15(59)	Figure 1
February	—[a]	25(77)	Figure 1
March	—[a]	25(77)	Figure 1
April	18(64)[b]	—	White crappie spawning
May	21(70)	—	Largemouth bass spawning
June	25(77)	—	Bluegill spawning and white crappie growth
July	28(82)	—	White crappie growth
August	28(82)	—	White crappie growth
September	28(82)	—	White crappie growth
October	21(70)	—	Normal gradual seasonal decline
November	—[a]	25(77)	Figure 1
December	—[a]	15(59)	Figure 1

Month	Short-term maximum	Decision basis
January	None needed	Control by MWAT in plume
February	None needed	Control by MWAT in plume
March	None needed	Control by MWAT in plume
April	26(79)	Largemouth bass[b] survival (estimated)
May	29(84)	Largemouth bass[b] survival (estimated)
June	34(93)	Largemouth bass[b] survival
July	34(93)	Largemouth bass[b] survival
August	34(93)	Largemouth bass[b] survival
September	34(93)	Largemouth bass[b] survival
October	29(84)	Largemouth bass[b] survival (estimated)
November	None needed	Control by MWAT in plume
December	None needed	Control by MWAT in plume

[a] If a species had required a winter chill period for gamete maturation or egg incubation, receiving-water criteria would also be required.

[b] No data available for the slightly more sensitive white crappie.

4. The principal growing season for these fish species: June through September.

5. Consider any local extenuating circumstances: There are none in this example.

At this point, we are ready to complete Table 4 for Example 2.

TABLE 4. TEMPERATURE CRITERIA FOR EXAMPLE 2

Month	Maximum weekly average temperature, (° C (° F)) Receiving water	Heated plume	Decision basis
January	9(48)	10(50)	Rainbow trout spawning and Figure 1
February	13(55)	10(50)	Normal gradual seasonal rise and Figure 1
March	13(55)	15(59)	Normal gradual seasonal rise and Figure 1
April	14(57)	15(59)	Normal gradual seasonal rise and Figure 1
May	16(61)	--	Normal gradual seasonal rise
June	17(63)	--	Brown trout growth
July	17(63)	--	Brown trout growth
August	17(63)	--	Brown trout growth
September	17(63)	--	Brown trout growth
October	12(54)	15(59)	Normal gradual seasonal decline
November	8(46)	10(50)	Brook trout spawning and Figure 1
December	8(46)	10(50)	Brown trout spawning and Figure 1

Month	Short-term maximum	Decision basis
January	13(55)	Embryo survival for rainbow trout and coho salmon
February	13(55)	Embryo survival for rainbow trout and coho salmon
March	13(55)	Embryo survival for rainbow trout and coho salmon
April	--	
May	--	
June	24(75)	Short-term maximum for survival of all species
July	24(75)	Short-term maximum for survival of all species
August	24(75)	Short-term maximum for survival of all species
September	24(75)	Short-term maximum for survival of all species
October	—	
November	13(55)	Embryo survival for rainbow trout and coho salmon
December	13(55)	Embryo survival for rainbow trout and coho salmon

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Office of Water and Hazardous Materials, Washington, D.C. EPA 4
76-023, 501 p.

How Are The Fish Doing?

Collaborators: Mark Gibson, Najih Lazar, Timothy Lynch, and J. Christopher Powell, RIDEM, and Lawrence Buckley, NOAA Fisheries

From an economic standpoint, fish, lobster, and shellfish are Narragansett Bay's most valuable resources. Yet those fisheries face many challenges. The recession of the winter flounder population, the troubles faced by the lobster industry ranging from oil spills to shell disease, and the ongoing closing of conditional shellfishing areas in the upper Bay after rain or snowfalls or other unexpected pollution events can make Bay management and planning a nightmare. And the impact is deeply felt in the wallets of the fishermen and associated industries that rely on a healthy Bay fishery.

From a scientific perspective, these animals are the living reflection of overall conditions in the Bay. From their position in the food web, their health as a group integrates all the other factors that affect the Bay. Any type of change, whether it be water quality, climate, planktonic plants and animals, or human fishing pressure, are ultimately reflected in the fish and shellfish populations. The Bay Window Program can provide coastal managers with the information they need to assess not only the effect these conditions have on those populations, but also what they can do to eliminate the harmful impacts.

Wake-Up Call

There are few people in Rhode Island who will forget August 20, 2003. That was the date of a massive fish kill, described as the worst in over a century, which left one million fish dead in the Bay. The cause was fairly simple: they had suffocated, deprived of the oxygen in the water that allowed them to breathe.

Bay Window researchers were perhaps the least surprised by the occurrence. Having tracked dissolved oxygen levels through the project's buoy monitoring and the "Insomniacs" oxygen-mapping program, there was evidence that this "perfect storm" of harmful factors was brewing. One researcher, the late Dana Kester, URI chemical oceanography professor, had predicted that period of August 2003 as being particularly vulnerable to severe low oxygen events.

The fish kill was a wake-up call not just to the public, but to the scientific community as well. There was recognition that the lack of oxygen (hypoxia) was part of a larger issue occurring throughout Narragansett Bay and not just confined to Greenwich Bay, where the fish kill occurred. To the scientific community, the wake-up call was that the fish kill was caused by a fatal mix of factors. Some factors, such as the weather, wind, and water temperature, are uncontrollable. Others, such as effluent from wastewater treatment plants and septic systems or storm-water runoff that brought nutrients or toxic pollutants, could be, and needed to be, better controlled.

Decisions needed to be made by coastal managers supported by the best science available, with backing from the public and policymakers. The public awareness of the number of factors needing to be addressed to prevent, or at least be prepared for, another such calamity as the fish kill, has grown since 2003. The Bay Window program has provided a model for showing how an integrated effort of monitoring and assessment, among a number of partner agencies, is the best way to proceed.

Death Out of Sight

A researcher from Brown University found billions of blue mussels dead after a 2001 low oxygen event in upper Narragansett Bay that was reported in the journal *Ecology* in 2006. In 2003, the public saw millions of dead fish—mainly menhaden—along the shores and beaches of Greenwich Bay during a summer low-oxygen period. But unseen beneath the surface of the bay were astronomical numbers of organisms that were unable to move out of harm's way and failed to float and be counted, says Bay Window benthic ecologist Candace Oviatt, URI oceanography professor. This dead marine life included blue mussels, worms, softshell clams, shrimp, crabs, sea stars, snails, amphipods, and lobsters.

Why is this so important to recognize? With the loss of these populations, Narragansett Bay loses the prey of bottom fish and sportfish, shellfish for human harvest, and the cleansing capacity of filter feeders. The Brown University findings noted that the filtering capacity by blue mussels had been reduced by 75 percent after the loss of mussel reefs to low oxygen in 2001. Bay Window fishery researcher Timothy Lynch, RIDEM fisheries scientist, while survey trawling from the *R/V Chafee*, noted he had never seen the Bay so clear as prior to the loss of the mussels in 2001. The Bay Window Program seeks to document, understand, and help plan the solutions for the low oxygen conditions that cause these massive mortalities out of the public view.

What is the net result?

In keeping with Bay Window's top priority of monitoring the health of Narragansett Bay, the R. I. Department of Environmental Management (RIDEM) conducts monthly and seasonal bottom trawl surveys aboard the *R/V John H. Chafee*. The excitement of a net spilling its bulging catch all over the deck might detract from the fact that this exercise is critical to determining which species are in trouble, which are thriving, and whether management efforts, such as catch restrictions, are working.

Bay Window fish trawls have continued RIDEM's fisheries work going back over 25 years. The continuous surveying is critical to making informed management decisions. Already, research is showing that protecting larger fish through fisheries management measures has given stocks the chance to recover. A recent 2005 spring trawl has also shown a spike in the Age 1 class of winter flounder that opened researchers' eyes. "The task now is to monitor the key area between the new age class moving out of shallow waters and becoming adult. This is where we may see the impact of nutrients or other factors," said Mark Gibson, RIDEM deputy chief for marine fisheries.

These are questions that the fish trawl survey prompts for Bay Window researchers. Is the habitat better? Is it improved water quality? Does chronic lack of oxygen in some spots make fish move around? Is the food supply shifting? As one scientist observed, "The fish aren't where they used to be."

It's finding the answers to these questions over time that make each and every trawl net full of fish a valuable piece of the puzzle.

Flip-flopping Fisheries

Bay Window data have been tracking a shift in Bay fisheries that has been a trend from the 1990s through the early 2000s. This trend shows that bottom-dwelling (demersal) fish have declined sharply, while off-bottom (pelagic) species have increased.

This has had economic implications as well as raised questions about what conditions in the Bay caused this flip-flop. Bottom-dwelling fish, such as winter flounder and tautog, command four to five times more money on the market than fish in the upper part of the water column, such as scup, squid, or butterfish. Although the economic loss has not been computed, it has a ripple effect—from the fishermen on the water to the wholesalers, restaurants, and retail markets. In addition, recreational fishing in the Bay has dropped off. RIDEM fisheries scientist Timothy Lynch estimates it may be down to one-tenth of what it was 20 years ago as the populations of prized fish such as winter flounder have dropped off.

"The mix of recreational opportunities and commercial value is not what it was," notes Gibson.

However, by 2005, the numbers of pelagic fish began to drop off, while demersals showed some increases, such as the spike in Age 1 winter flounder. Five years ago, Gibson said, "We might be seeing the beginning of another reversal, with pelagics trending down and demersals recovering—but we'll need another five to 10 years to know for sure whether this is a long-term, stable shift or just a temporary fluctuation."

As researchers and coastal managers struggle with how to adjust to changing fishery populations, are they facing challenges that they can actually do something about, or are there elements that are beyond their control, such as climate? Inevitably, the bigger picture is made of human-caused problems, ranging from increased fishing pressure, low dissolved oxygen, excess nutrient concentrations, increased water temperatures from power plants, habitat loss, such as eelgrass beds, and sediment contamination. Bay Window research is helping to ensure that everything within the control of manageable factors is being done, informed by the best science available.

SIDEBAR

A Place to Call Home

One of the areas in which the Bay Window Program is augmenting and fine-tuning beach seine and fish trawl surveys is by analyzing the production of winter flounder and its origin.

The questions being asked are whether there are different stocks or groups of winter flounder that spawn in various places, or do all Rhode Island juvenile flounder come from a single, genetically homogenous group of fish? Do certain groups return every year to the same spawning grounds such as Wickford Harbor, the Providence River, or Mt. Hope Bay? Bay Window researchers are investigating these questions to better understand the contribution of different portions of the Bay to juvenile winter flounder production and to help manage the species more effectively. If there is a rich, delineated stock structure composed of many different groups, the fish will return to the same location to spawn, which may eventually result in overfishing, due to concentrated effort in an area.

There are serious management implications in determining whether a single homogenous stock exists versus several more or less isolated stocks. Loss of essential habitat and overexploitation of local stocks may have contributed to the poor recruitment of Narragansett Bay winter flounder. Improved knowledge of stock structure and habitat use by juvenile winter flounder should result in new insight into the poor recruitment of winter flounder in Narragansett Bay and lead to better management of the species. For example, if a particular section of the Bay contributes a disproportionately large portion of winter flounder production, then special emphasis could be placed on maintaining and improving habitat in that area.

"Winter flounder were the first fish you caught in the year, and the last fish you caught."

—Timothy Lynch, RIDEM fisheries scientist, describing the abundance and constant presence of winter flounder in the past.

Winter Flounder: Turning the Tide?

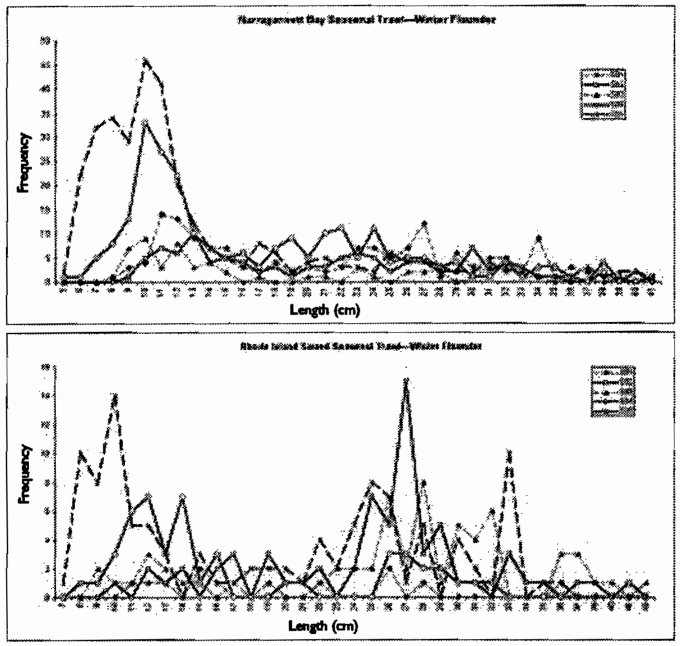
One of the more notorious charted collapses of a Narragansett Bay fishery is that of winter flounder. But as the Bay Window Program's monthly and seasonal trawl surveys by RIDEM have recently noted, there may be hope for a turnaround that would have not only ecological implications, but serious economic impacts for what was once a major source of revenue for commercial fishermen.

The winter flounder fishery in the Bay and coastal waters peaked in the late 1970s but crashed by 1993. RIDEM's Division of Fish and Wildlife (DFW) tagging studies from 1986 to 1990 showed high rates of exploitation of the popular recreational and commercial fish, indicating overfishing. Although some improvement has occurred, abundance remains low relative to historic levels as evidenced by DFW bottom trawl surveys. Persistent low abundance is perplexing to scientists because extensive local and regional management efforts have been directed at winter flounder. The abundance of "young-of-the-year" winter flounder (Age 0) has increased in Narragansett Bay shallows based on DFW beach seine surveys. These new fish, however, do not seem to survive to the older individuals sampled in deeper Bay waters by the bottom trawls.

The apparent survival bottleneck is unlikely related to fishing pressure since it occurs at young ages not yet part of the fishery. Recent Bay Window studies are pointing to other human-induced factors, including hypoxia, excess nutrient concentrations, and habitat loss, as plausible explanations. The fact that other demersal resident fish, including those not subject to fishing pressure, have declined sharply lends support to the results of these studies.

But what researchers have been seeing of late may be cause for hope.

Catches of winter flounder in bottom trawl surveys can be separated into age groups using length-frequency analysis—models developed with Bay Window funding. Fish caught in the spring trawl survey less than 15 centimeters (cm) in length are likely Age 1 fish. By convention, they would have been Age 0 fish in the summer seine survey a year before. Applying the Age 1 length cutoff to the time series of trawl data, one can examine the abundance of this year class over time. In doing so, Bay Window researchers found that the abundance of Age 1 fish was very low from 1998 to 2003, but has begun to increase. In fact, the 2005 catch of this age group was the highest in over a decade. It may be that Bay conditions have recently changed such that the survival of young-of-the-year winter flounder has improved. This could be evidence of the beginning of a recovery. While Mark Gibson, RIDEM deputy chief for marine fisheries, cautions that it may take another five to 10 years to confirm a recovery, Bay Window monitoring will be able to document the underlying changes occurring in the Bay and to aid fisheries scientists and managers in determining the relationship between water quality and fishery production.



A spike in the charting of the once-thriving winter flounder in spring 2005 is giving fisheries scientists hope for recovery. The winter flounder fishery is valuable both commercially and recreationally.

The 2005 catch of the Age 1 group was the highest in over a decade. It may be that Bay conditions have recently changed, so that the survival of young-of-the-year winter flounder has improved. This could be evidence of the beginning of a recovery.

TECHNICAL COMMENTS -- NOISE

Dominion Energy New England
Brayton Point Station, Somerset, MA

US EPA Determination on Remand
NPDES Permit No. MA0003654

Prepared for:
Foley Hoag LLP
155 Seaport Boulevard
Boston, MA 02210

Prepared by:
Epsilon Associates, Inc.
3 Clock Tower Place, Suite 250
Maynard, MA 01754

December 28, 2006

Epsilon Associates, Inc. (Epsilon) is pleased to offer comments related to noise on the US EPA Determination on Remand, NPDES Permit No. MA0003654. We have reviewed the following documents:

- Determination on Remand from the EPA Environmental Appeals Board (Brayton Point Station, NPDES Permit No. MA0003654), dated November 30, 2006.
- Addendum to Noise Impact Assessment, prepared by Hatch (report H322455-RPT-0001-CA01), dated November 20, 2006.

Determination on Remand

The US EPA "Levels" document is cited on pages 56-57. The day-night sound level (L_{dn}) of 55 dBA has been developed as a guideline value "to prevent undue annoyance or interference with activities outdoors in residential areas..." This guideline value is a well-established level often used to put total sound levels in an area into context. This may be done in jurisdictions with, or without, applicable noise regulations. The L_{dn} is a 24-hour value with 10 dBA added to the sound levels measured during the nine hours from 10 p.m. to 7 a.m. The appropriate way to measure the L_{dn} is over a full 24-hour period.

In the Determination on Remand, EPA concludes that the L_{dn} value of 55 dBA would not be exceeded as a result of the cooling towers and the power plant (p. 57). This conclusion was based on data collected in late winter and spring of 2002. However, the existing L_{dn} during the summer is already above 55 dBA. An estimate of the current L_{dn} level around BPS has been conducted as part of this review using the same technique as the Hatch report. Using the sound level data presented in the Hatch report (AR4005), the L_{dn} sound levels at the five closest residential receptors range from 54 dBA to 58 dBA as shown below. Since these levels represent the quietest nighttime sound levels, the daytime levels would have been higher, and therefore, the L_{dn} values shown below are likely conservative. These short-term data represent summer ambient sound levels as collected by Hatch in September 2003 (Table 5; Hatch Report of 11/20/06). One of the five receptors also had a 24-hour measurement taken (Home St/Kenneth Ave). The 24-hour data were collected September 6-7, 2003 and resulted in an L_{dn} level of 58 dBA (Figure 2 in Attachment A; Hatch Report of 11/20/06).

Receptor	Short-term Ambient	24-hr L_{dn}
Home St/Kenneth Ave	51.7 dBA	58 dBA
Jackson St.	50.2 dBA	57 dBA
Perkins St.	51.2 dBA	58 dBA
Bayside Ave.	49.1 dBA	56 dBA
New Gardners Neck	47.1 dBA	54 dBA

Details of each L_{dn} calculation are included in Attachment A. The figure graphically depicting the 24-hour data from the Hatch report is also included in Attachment A.

Addendum to Noise Impact Assessment

A review of the Addendum to Noise Impact Assessment raises a few questions and issues. One comment is that the continuous measurement was taken at the receptor farthest away from BPS (Home St/Kenneth Avenue). This location is more than twice as far from BPS as the Perkins Street neighborhood. Higher background sound levels have been consistently measured at Perkins Street as compared to Home St/Kenneth Avenue as seen in Table 3 of the Hatch report. Higher distance from BPS typically translates into lower sound levels depending on what other local noise sources are nearby. Distances from the main BPS stack to each receptor are summarized below.

Receptor	Distance
Home St/Kenneth Ave	5000 feet
Jackson St.	3700 feet
Perkins St.	2200 feet
Bayside Ave.	2500 feet
New Gardners Neck	3500 feet

In addition, Figure 2 in Attachment A of the Hatch report depicts several of the sound level parameters measured during this continuous period. However, the L_{90} was not directly measured. A footnote states that the L_{90} was "estimated using a running minimum of the following 10 $L_{eq,\ 1\ min.}$" Given that the L_{90} is defined as the background in Massachusetts, and that current sound level instrumentation is easily programmed to measure this parameter, it begs the question as to why the L_{90} was not directly measured. It also appears that the measurement period went approximately 21 or 22 hours (1:13 PM on 9/6/03 to 10:49 AM on 9/7/03). Is there a reason the equipment was not left out for a full 24-hour period which is common practice?

The Hatch noise analysis continues to rely on the 56-cell cooling tower scenario based on their "Manufacturer 2" design. This contradicts the Stone & Webster design which calls for a 72-cell cooling tower. The sound level modeling performed by Hatch has not evaluated a 72-cell tower. A higher number of cooling tower cells will translate into higher sound levels assuming the same reference sound level per cell. The fact that "Manufacturer 1" could not meet the MA DEP limits with several of its mitigation options, and "Manufacturer 2" could only meet the limits with its most extreme mitigation package, should be a cause for concern when it comes to noise compliance for a 72-cell cooling tower.

Attachment A

Ldn Calculations from Hatch Report Data

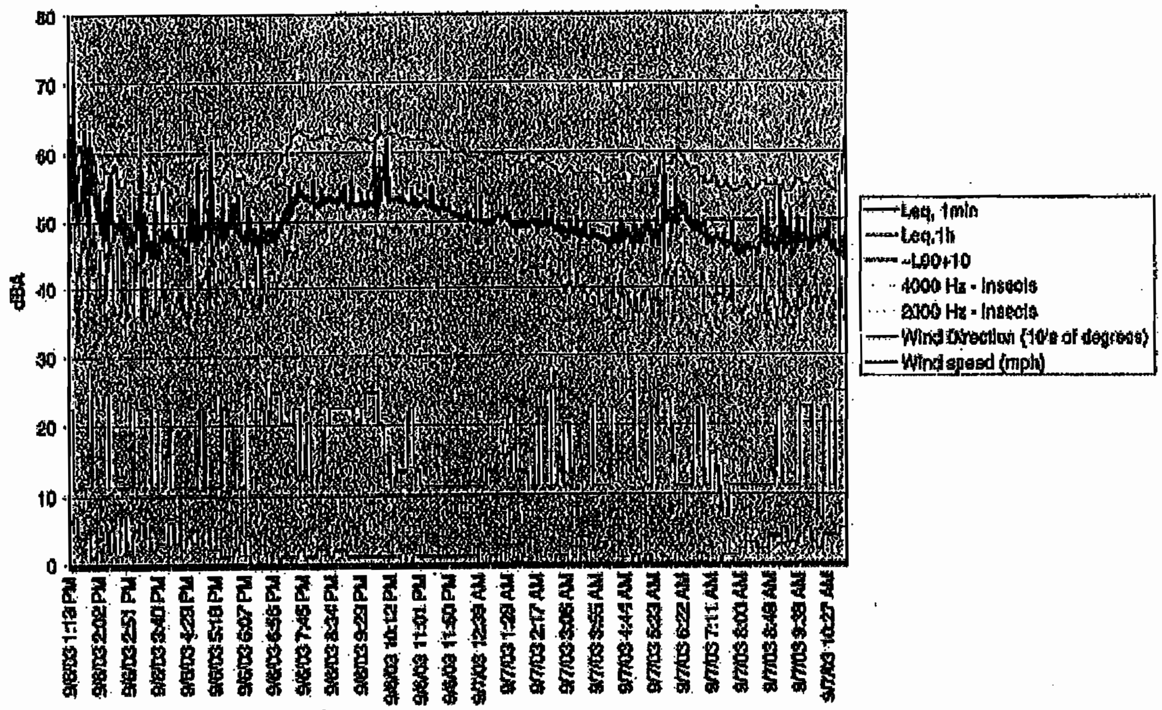


Figure 2: Kenneth Ave (at Home) Backyard Overlooking Power Plant, September 6-7, 2003

Ldn Calculation from 24-hour Sound Level Measurements -- Kenneth Ave/Home St., Somerset, MA Collected by Hatch, September 6-7, 2003

		From Figure 2. of 9/29/03 Hatch Report			
Hour	Hour	L_{eq}			
Beginning	Ending	(dBA)			
12:00 AM	1:00 AM	52			
1:00 AM	2:00 AM	50			
2:00 AM	3:00 AM	51			
3:00 AM	4:00 AM	50			
4:00 AM	5:00 AM	48			
5:00 AM	6:00 AM	47			
6:00 AM	7:00 AM	49			
7:00 AM	8:00 AM	52			
8:00 AM	9:00 AM	49			
9:00 AM	10:00 AM	46			
10:00 AM	11:00 AM	48			
11:00 AM	12:00 PM	47			
12:00 PM	1:00 PM	46			
1:00 PM	2:00 PM	53			
2:00 PM	3:00 PM	53			
3:00 PM	4:00 PM	51			
4:00 PM	5:00 PM	48			
5:00 PM	6:00 PM	50			
6:00 PM	7:00 PM	48			
7:00 PM	8:00 PM	50			
8:00 PM	9:00 PM	54			
9:00 PM	10:00 PM	53			
10:00 PM	11:00 PM	57			
11:00 PM	12:00 AM	53			
	L_{day}	**50.6**	(7:00 AM to 10:00 PM)		
	L_{night}	**51.8**	(10:00 PM to 7:00 AM)		
	L_{dn}	**58.1**	(Includes 10 dBA penalty)		

Ldn Calculation from Short-Term Sound Level Measurements -- Brayton Point area, Somerset, MA
Collected by Hatch, September 2003

		Home St.	Jackson	Perkins	Bayside Ave	New Gardners Neck			
Distance from stacks=		5000 ft	3700 ft	2200 ft	2500 ft	3500 ft			
Hour	Hour	L_{90}	L_{90}	L_{90}	L_{90}	L_{90}			
Beginning	Ending	(dBA)	(dBA)	(dBA)	(dBA)	(dBA)			
12:00 AM	1:00 AM	51.7	50.2	51.2	49.1	47.1			
1:00 AM	2:00 AM	51.7	50.2	51.2	49.1	47.1			
2:00 AM	3:00 AM	51.7	50.2	51.2	49.1	47.1			
3:00 AM	4:00 AM	51.7	50.2	51.2	49.1	47.1			
4:00 AM	5:00 AM	51.7	50.2	51.2	49.1	47.1			
5:00 AM	6:00 AM	51.7	50.2	51.2	49.1	47.1			
6:00 AM	7:00 AM	51.7	50.2	51.2	49.1	47.1			
7:00 AM	8:00 AM	51.7	50.2	51.2	49.1	47.1			
8:00 AM	9:00 AM	51.7	50.2	51.2	49.1	47.1			
9:00 AM	10:00 AM	51.7	50.2	51.2	49.1	47.1			
10:00 AM	11:00 AM	51.7	50.2	51.2	49.1	47.1			
11:00 AM	12:00 PM	51.7	50.2	51.2	49.1	47.1			
12:00 PM	1:00 PM	51.7	50.2	51.2	49.1	47.1			
1:00 PM	2:00 PM	51.7	50.2	51.2	49.1	47.1			
2:00 PM	3:00 PM	51.7	50.2	51.2	49.1	47.1			
3:00 PM	4:00 PM	51.7	50.2	51.2	49.1	47.1			
4:00 PM	5:00 PM	51.7	50.2	51.2	49.1	47.1			
5:00 PM	6:00 PM	51.7	50.2	51.2	49.1	47.1			
6:00 PM	7:00 PM	51.7	50.2	51.2	49.1	47.1			
7:00 PM	8:00 PM	51.7	50.2	51.2	49.1	47.1			
8:00 PM	9:00 PM	51.7	50.2	51.2	49.1	47.1			
9:00 PM	10:00 PM	51.7	50.2	51.2	49.1	47.1			
10:00 PM	11:00 PM	51.7	50.2	51.2	49.1	47.1			
11:00 PM	12:00 AM	51.7	50.2	51.2	49.1	47.1			
	L_{day}	**51.7**	**50.2**	**51.2**	**49.1**	**47.1**	(7:00 AM to 10:00 PM)		
	L_{night}	**51.7**	**50.2**	**51.2**	**49.1**	**47.1**	(10:00 PM to 7:00 AM)		
	L_{dn}	**58.1**	**56.6**	**57.6**	**55.5**	**53.5**	(Includes 10 dBA penalty)		

ROBERT D. O'NEAL, CCM, INCE

PRINCIPAL

Epsilon ASSOCIATES INC.

EDUCATION

M.S., Atmospheric Science, Colorado State University, 1987
B.A., Engineering Science, Dartmouth College, 1983

REGISTRATIONS

Certified Consulting Meteorologist, #578

PROFESSIONAL SUMMARY

A Principal of the firm, Mr. O'Neal is a Certified Consulting Meteorologist with over 19 years experience in the areas of community noise impact assessments and air quality modeling. Mr. O'Neal's noise impact evaluation experience includes design and implementation of sound level measurement programs for mobile and stationary sources, modeling of future impacts, conceptual mitigation analyses, and compliance testing. Rob has performed noise measurement and modeling assessments for power generation facilities in the Northeast, the mid-Atlantic region, and the Midwest. He has also provided expert witness testimony on noise impact studies and air pollution modeling in front of local boards, courts of law, and adjudicatory hearings. His air quality background involves applying air quality dispersion models for regulatory permitting applications, as well as for general air quality impact evaluations. He has experience with the CALMET/CALPUFF modeling system used to evaluate visibility and acid deposition impacts in Class I areas. Representative industries served include power generation, mining and aggregate handling, asphalt plants, paper mills, real estate development, and mobile sources.

PROFESSIONAL EXPERIENCE

Independent Power Projects

- *FPL Energy – Jamaica Bay Peaking Facility, Far Rockaway, NY.* Managed the noise impact study as part of an Environmental Assessment for a 50 MW natural gas-fired peaking plant utilizing two P&W combustion turbines. A compliance demonstration with the local noise ordinance was done utilizing the ambient background data and acoustical modeling. Follow-up noise monitoring was done to evaluate vendor performance specifications.

- *FPL Energy – Bayswater Peaking Facility, Far Rockaway, NY.* Managed the noise impact study as part of an Environmental Assessment for a 55 MW natural gas-fired peaking plant utilizing two P&W combustion turbines. A compliance demonstration with the local noise ordinance was done utilizing the ambient background data and acoustical modeling.

- *Besicorp-Empire Development Company – Rensselaer, NY.* Prepared interrogatory responses, and testimony for the Noise section of the Article X application for this proposed 505 MW combined-cycle gas-fired electric power generation facility, recycled newsprint manufacturing plant, and waste water treatment plant. Additional testimony was provided for Technical Conference hearings before a NYS DEC Administrative Law Judge.

- *Milford Power Co., LLC – Milford, CT.* Conducted post-construction ambient sound level measurements for a 544 MW combined-cycle gas-fired electric generating facility. The project utilizes two Alstom GT-24 combustion turbines, one steam turbine, and an 8-cell wet mechanical cooling tower. High-pressure steam blows and transformer noise were also measured during construction and assessed for community impacts.

- *Confidential Client – New York State.* Preparing the Noise section of the Article X application for this proposed 500 MW combined-cycle gas-fired electric power generation facility. The project will utilize two GE 7FA combustion turbines, one steam turbine, and an air-cooled condenser. Ambient sound level measurements and noise impact modeling will be performed in support of the Article X application and to show compliance with the local noise ordinance.

- *Sithe Energies – Heritage Station, Oswego, NY.* Conducted ambient sound level measurements and performed sound level modeling at the 1000 MW Independence Station power plant in support of permitting a proposed 800 MW combined-cycle electric generation facility adjacent to the existing station in Oswego. The proposed project will utilize General Electric's new "H" System combustion turbine technology, and a 16-cell wet mechanical cooling tower. A compliance demonstration with the local noise ordinance was done utilizing the ambient background data and acoustical modeling. Mr. O'Neal prepared the Noise section of the Article X Application in conjunction with the New York State Public Service Law as well as expert testimony on noise for the Article X public hearings.

- *PG&E – Mantua Creek, West Deptford, NJ.* Conducted single-station CALPUFF modeling for impacts at the nearest Class I area for a proposed 800 MW natural gas-fired combined-cycle electric power generation facility. The latest IWAQM Phase 2 guidance was followed for calculating ambient concentration, wet and dry deposition, and regional haze impacts at the Brigantine National Wildlife Refuge.

- *Duke Energy Power Services, LLC – OH, IN, IL, MO.* Conducted ambient sound level measurement programs and performed acoustical modeling for six proposed simple-cycle electric power generation facilities in the Midwest for Duke Energy. These 640 MW peaking stations were permitted for 8 GE 7EA combustion gas turbines. The results of the noise impact assessment were used to secure site plan approval from the local community.

- *Calpine Corporation – Ontelaunee Energy Center, Ontelaunee, PA.* Conducted 24-hour ambient sound level measurements at multiple sites for a proposed 543 MW natural gas-fired combined-cycle electric power generation facility utilizing two Westinghouse 501F combustion turbines. A compliance demonstration with the local noise ordinance was done utilizing the ambient background data and acoustical modeling. Post-construction sound level measurements were done on the turbines to confirm they met the vendor guaranteed noise limits.

- *Brockton Power, LLC – Brockton Power Station, Brockton, MA.* Conducted a 72-hour continuous ambient sound level measurement program at multiple sites for a proposed 270 MW natural gas-fired combined-cycle electric power generation facility. Acoustical modeling, including additional mitigation of the cooling tower, was performed to demonstrate compliance with the State noise regulation.

- *AES Corporation – AES Granite Ridge Energy Facility, Londonderry, NH.* Directed a 14-day continuous ambient sound level measurement program in support of local permitting requirements for a proposed 720 MW natural gas-fired combined-cycle electric power generation facility. The proposed project includes two Westinghouse 501G combustion turbines, two heat recovery steam generators, one steam turbine, and a wet mechanical cooling tower. Short-term daytime and nighttime sound level measurements were made with and without leaves and insects to characterize the variation in possible ambient sound levels.

- *Reliant Energy – Hope Energy Project, Johnston, RI.* Conducted ambient sound level measurements in support of state and local permitting requirements for a proposed 540 MW natural gas-fired combined-cycle electric power generation facility. The proposed project includes two Westinghouse 501F combustion turbines, two heat recovery steam generators, one steam turbine, and a wet mechanical cooling tower.

- *Vermont Marble Company, Proctor, VT.* Applied the ISC and VALLEY models using five years of refined meteorological data as part of state and PSD permitting for an 8 MW combustion turbine cogeneration project located at a marble processing plant in Vermont.

Linear Siting and Transmission Projects

- *BP/Amoco – Continental Divide EIS, Wyoming and Colorado.* Performed meteorological and air quality dispersion modeling for a proposed natural gas field development project in Wyoming using the CALMET and CALPUFF models. Extensive emission inventories were developed within a large domain (200,000 km^2) using state air agency records and permit file reviews. Ambient pollutant concentrations, wet and dry deposition, and visibility impacts at eight Class I areas from long-range transport were evaluated as a result of the project and the cumulative inventory.

- *New England Power, Dorchester and Quincy, MA.* Prepared a Noise Control Plan for construction activities related to the Dorchester-Quincy 115-kv Cables Project. This project involved ambient background noise monitoring at several residential receptors along the route connecting two electrical substations in Boston and Quincy, Massachusetts, calculation of expected construction noise impacts, a compliance evaluation with city noise regulations, and specification of contingency noise control measures.

- *Iroquois Pipeline Company, NY, NY.* Third Party contractor with the Federal Energy Regulatory Commission (FERC) for preparation of an Environmental Impact Statement for the Eastchester Pipeline Project filed with FERC by Iroquois Gas Transmission System. The project consists of a proposed new 30-mile pipeline from Northport across Long Island Sound into the Bronx, New York and four compressor stations in upstate New York. Responsible for air quality and noise existing conditions and future impact evaluation along various routes.

- *MWRA – MetroWest Tunnel, Loring Road Water Storage Tanks, Weston, MA.* As part of the technical review team on behalf of the local municipality, a review of the noise impacts resulting from a change in the proposed construction techniques of two new water storage tanks (capacity 20 million gallons) was conducted. Results of the analysis were presented in a public hearing before the MetroWest Growth Management Committee.

- *MWRA – Deer Island Sewage Treatment Project, Boston, MA.* Sound level measurements were performed at the fabrication shop for two high-volume mobile blower units to certify that the units met the project acoustical criteria prior to their acceptance for shipment to the site.

- *Algonquin Gas Transmission Company, NY and RI.* A noise analysis in support of a FERC filing was prepared for two existing natural gas compressor stations in Southeast, NY and Burrillville, RI. In order to increase the horsepower of the existing gas turbine compressors at each station, 24-hour noise measurement data were analyzed to reflect the new turbine ratings, and demonstrate that the change would safely meet FERC noise criteria. The results were written up in a Resource Report 9.

- *Air Products and Chemicals, Inc., Hopkinton, MA.* Developed, coordinated, and executed a staffed 24-hour ambient sound level measurement program at five receptors for a natural gas liquefaction station in support of a FERC application.

Transportation Projects

- *Massachusetts Highway Department, I-93/Route 125 Interchange, Wilmington, MA.* Interchange redesign is proposed on I-93 to support an area of developing industrial and commercial land uses. Predictive noise impact modeling was done using the Traffic Noise Model (TNM) for numerous alternative design options to assist in identifying the route with least noise impacts. The results of the modeling were included in the EA/EIR submittals.

- *Amtrak, Boston, MA.* Developed, coordinated, and executed a staffed overnight (8-hour) ambient sound level measurement program to measure rail yard noise from diesel engine switching and idling operations for Amtrak in South Boston.

- *Delaware Department of Transportation, New Castle County, DE.* Performed noise impact assessment and air quality analyses in support of an EIS for the reconstruction of a 15-mile stretch of US Route 301. The noise analyses were done using the latest version of the STAMINA/OPTIMA noise modeling software.

Rock Quarries

- *Aggregate Industries, Peabody, MA.* A Noise Management Plan was developed as part of the Special Permit requirements at this site. A method of correlating noise complaints with meteorological conditions were set-up. In addition, a series of Best Management Practices for noise reduction were implemented. An extensive community sound level monitoring program was developed and implemented. Mitigation measures to reduce noise from the quarry were designed and presented to city officials and the neighborhood.

- *Sour Mountain Realty, Inc., Fishkill, NY.* A sound level impact analysis was performed at the site of a proposed hard rock quarry in support of a NYS DEC Mined Land Reclamation Permit application in Dutchess County. Ambient background sound level measurements were collected around the site. Project-specific impacts of the excavation and processing equipment were measured at existing rock quarries and used to calculate future sound level impacts. Expert testimony on noise impacts was provided before a NYS Administrative Law Judge.

- *Paquette Pit, Center Harbor, NH.* A sound level impact analysis on rock-crushing and processing equipment, and electrical generators was conducted for a proposed quarry. The results were submitted to the Planning Board.

- *Middlesex Materials, Littleton, MA.* Ambient sound level measurements were conducted at residential locations around an existing hard rock quarry to test the effectiveness of various equipment noise reduction measures.

- *A.A. Wills Materials, Inc., Freetown, MA.* Ambient sound level measurements were conducted at residential locations around an existing 105-acre hard rock quarry along Route 140. Four days of continuous measurements were made with and without the quarry operating to determine the impact of the operations on ambient sound levels in the neighborhood.

Sand & Gravel Operations

- *Dalrymple Gravel & Contracting Co., Inc., Erwin, NY.* A sound level impact analysis was performed for a proposed sand and gravel excavation site ("Scudder Mine") at a site in Steuben County in support of the NYS DEC Mined Land Reclamation Permit and SEQRA process. Ambient background sound level measurements were collected around the site. Project-specific impacts of the excavation and haul equipment were measured at an existing excavation site and were used to calculate future sound level impacts. Expert testimony on noise impacts was presented before a NYS Administrative Law Judge.

- *Newport Sand & Gravel, Goshen, NH.* A sound level impact analysis was performed for a proposed 68-acre sand and gravel excavation site along Route 10 in Goshen. Ambient background sound level measurements were collected around the site. Project-specific impacts of the excavation and haul equipment were measured at existing excavation sites and used to calculate future sound level impacts. The results of this work were presented to the local Zoning Board of Appeals.

- *Ambrose Brothers, Inc., Sandwich, NH.* A sound level measurement program was performed for an existing sand and gravel excavation site in Sandwich. A future sound level measurement program will be conducted upon the opening of a new phase of the operation to determine the sound level change due to equipment relocation.

- *Granite State Concrete, Inc., Lyndeborough/New Boston/Mont Vernon, NH.* A sound level impact analysis was performed for a proposed 39-acre expansion of an existing sand and gravel excavation site in Lyndeborough. Ambient background sound level measurements were collected around the site. Project-specific impacts of the excavation and haul equipment were measured at the existing excavation site and used to calculate future sound level impacts. The results of this work were presented to the local Zoning Board of Appeals.

- *Palumbo Block Co., Inc., Ancram, NY.* A sound level impact analysis was performed for a proposed sand and gravel excavation site ("Neer Mine") in Columbia County in support of the NYS DEC Mined Land Reclamation Permit process. Ambient background sound level measurements were collected around the site. Project-specific impacts of the excavation and haul equipment were measured at existing excavation sites and used to calculate future sound level impacts. Expert testimony on noise impacts was presented before a NYS Administrative Law Judge.

- *P.J. Keating Co., Townsend, MA.* A sound level impact analysis was performed for a proposed sand and gravel excavation site. Ambient background sound level measurements were collected around the site. Project-specific impacts of the excavation and haul equipment were measured at existing excavation sites and used to calculate future sound level impacts. The results of this work were presented as expert witness testimony in Massachusetts Land Court in Boston.

Asphalt Plants

- *Tilcon Capaldi, Inc., Watertown and Weymouth, MA.* Air quality impacts from two asphalt-batching plants were evaluated based on best management practices and dispersion modeling. Both fugitive sources from materials handling and ducted combustion sources were reviewed and mitigation measures were recommended. Expert testimony was provided on matters before the MA DEP and abutters of the plants.

- *Pike Industries, Inc., Henniker, NH.* Air quality dispersion modeling, control technology evaluation, best management practice review, and meteorological data analysis were conducted for an asphalt batch plant in order to address a local odor issue. The results of this work were presented in meetings with the NH ARD and the neighbors.

- *Pike Industries, Inc., Ossipee and Madison, NH.* Air quality dispersion modeling was conducted for two asphalt batch plants in order to revise the State air pollution permit to allow the burning of specification used oil.

- *P.A. Landers, Inc., Plymouth, MA.* Full permitting was provided for a new 400-ton/hour drum mix asphalt plant. Emissions calculations, a BACT analysis, air quality dispersion modeling, and a full noise impact assessment were conducted for the MA DEP permit. Technical presentations on air quality and noise impacts were made at the local public hearings to obtain site plan approval for the Project.

- *Todesca Equipment Corporation, Boston, MA.* Full permitting was provided for a new drum mix asphalt plant. Emissions calculations, a BACT analysis, air quality dispersion modeling, and a full noise impact assessment were conducted for the MA DEP permit. Air quality and noise impact analyses were provided for the Environmental Impact Reports. Technical presentations on air quality and noise impacts were made at the local public hearings to obtain site plan approval for the Project.

- *Industrial Bituminous Development Corporation, Wrentham, MA.* Full permitting was provided for a new asphalt batch plant. Emissions calculations, a BACT analysis, air quality dispersion modeling, and a full noise impact assessment were conducted for the MA DEP permit.

Transfer Stations/Landfills

- *Wood Recycling, Inc., Southbridge, MA.* Prepared an ambient air quality monitoring plan for the existing Southbridge Landfill as part of the landfill gas and odor management requirements. MA DEP approval was obtained for the sampling locations and equipment specifications of three fixed hydrogen sulfide (H_2S) monitoring systems and an on-site meteorological station. Dispersion modeling was used to specify the appropriate detection limits for the H_2S equipment.

- *Resource Recovery of Cape Cod, Sandwich, MA.* Prepared a noise impact and mitigation assessment for an existing 600-ton/day construction & demolition transfer station on Cape Cod. This project involved extensive ambient background noise monitoring at sensitive receptors around the site, calculation of expected operational noise impacts from the processing equipment, a compliance evaluation with State noise regulations, and mitigation calculations.

- *Valley Mill Corp., Pittsfield, MA.* Prepared a noise impact assessment for a proposed 250-ton/day C&D transfer station in Pittsfield. This project involved ambient background noise monitoring at sensitive receptors around the site, calculation of expected operational noise impacts from the processing equipment, and a compliance evaluation with State noise regulations.

- *WSI, Oxford, MA.* Prepared a noise impact assessment for a proposed 750-ton/day C&D and MSW transfer station in Oxford, MA. This project involved ambient background noise monitoring at sensitive receptors around the site, calculation of expected operational noise impacts from the processing equipment, a compliance evaluation with State noise regulations, and expert testimony before the Board of Health during the site assignment hearings.

- *Merrimack Valley Processing Corp., Lowell, MA.* Prepared a noise impact assessment for a proposed 600-ton/day solid waste transfer station in Lowell, MA. This project involved ambient background noise monitoring at sensitive receptors around the site, calculation of expected operational noise impacts from the processing equipment, a compliance evaluation with State and city noise regulations, and expert testimony before the Board of Health during the site assignment hearings.

Industrial/Commercial Projects

- *Former Coal Tar Gasification Facility, Island End River, Everett, MA.* An extensive sound level measurement program was conducted for a thermal soil treatment plant in response to community noise complaints. Simultaneous overnight measurements were made at multiple locations with and without the plant operating to identify the possible sources of area noise. Digital audio tape recordings were collected and presented at the local zoning board meeting to demonstrate the low noise levels. Follow-up measurements were made to satisfy decibel limits imposed by the board in order to allow 24-hour per day operations.

- *Environmental Soil Management, Inc., Loudon, NH.* An extensive sound level measurement program was conducted for a thermal soil treatment plant in response to community noise complaints. Simultaneous overnight measurements were made at multiple locations with and without the plant operating to identify the possible sources of area noise. Digital audio tape recordings were collected and presented at the local zoning board meeting to demonstrate the low noise levels. Follow-up measurements were made to satisfy decibel limits imposed by the board in order to allow 24-hour per day operations.

- *Eastman Gelatine Corp., Peabody, MA.* A detailed sound level measurement program was performed to identify sources of community noise concerns around an existing manufacturing facility. Long-term continuous broadband and short-term narrow band sound level measurements were collected around the site. The narrow-band measurements allowed the annoying sources of noise to be identified and a mitigation program to be established.

- *Wingra Engineering, Inc., Tennessee.* Performed meteorological and air quality dispersion modeling in support of a multi-site evaluation for a proposed gray and ductile iron foundry project in Tennessee using the CALMET and CALPUFF models. Ambient pollutant concentrations, wet and dry deposition, and visibility impacts at four Class I areas from long-range transport were evaluated as a result of the project and background sources.

- *Dartmouth-Hitchcock Medical Center, Lebanon, NH.* As part of the state air quality permitting process, applied the ISC and VALLEY models to demonstrate compliance with the NAAQS for the new construction of a major New England hospital's boilers, incinerator, and diesel generators. Interactive modeling was required within the area of significant impact. Prepared original and renewal Title V Operating Permits for the hospital complex.

- *The Home Depot, Sutton, MA.* Ambient sound level measurements, noise modeling, and air quality modeling were conducted to evaluate the potential noise impacts from the operation of a new 24-hour per day 200-dock regional distribution center. The primary sources included the delivery trucks and yard dogs. Expert testimony on air quality and noise impacts were presented in Massachusetts Land Court.

- *The Stop & Shop Supermarket Company, Boston, MA.* Noise impacts from loading dock activity, truck traffic, and rooftop mechanical equipment were analyzed as part of the local approval process for a building expansion project at Stop & Shop Supermarket's 500,000 square foot regional distribution center in Boston. Twenty-four hour per day sound level measurements were made of the existing operations at nearby residential locations to assist in identifying mitigation measures. The results of the study were presented to interested abutters in a series of neighborhood meetings.

EXPERT TESTIMONY EXPERIENCE

Expert witness before NY DEC Administrative Law Judge for a cogeneration power plant, a hard rock quarry facility, and two sand and gravel excavation sites.

Expert witness for site assignment hearings on transfer stations in Lowell, MA; Marshfield, MA; Oxford, MA, Holliston, MA.

Expert witness in Massachusetts Land Court for a proposed sand and gravel pit, and cross-dock distribution center.

Expert witness for Vermont Act 250 Land Use process for ski areas.

Expert witness before MA DEP Administrative Law Judge for an asphalt plant.

Expert witness before municipal boards on issues of air pollution and noise impacts from local industries.

Invited specialty speaker on noise impact assessments for Boston University's Masters of Urban Planning degree program.

PROFESSIONAL ORGANIZATIONS

American Meteorological Society - Certified Consulting Meteorologist #578
Air and Waste Management Association
Institute of Noise Control Engineers (INCE)
Acoustical Society of America

PUBLICATIONS

O'Neal, R.D., 2001: The Impact of Ambient Sound Level Measurements on Power Plant Noise in Massachusetts: A Case Study. Air & Waste Management Association 94th Annual Meeting and Exhibition, Orlando, FL, June 24-28.

Hendrick, E.M., and R.D. O'Neal, 2001: A Case Study of Class I Impacts Using CALPUFF Screen. Air & Waste Management Association Guideline On Air Quality Models: A New Beginning, Newport, RI, April 2001.

Wu, Z.X., J.S. Scire and R.D. O'Neal, 1998: Comparison of One Year of MM5 and CALMET Meteorological Fields with Observations in the Western United States. Presented at the Eighth PSU/NCAR Mesoscale Model Users' Workshop, Boulder, CO, June 1998.

O'Neal, R.D., 1994: Indoor air sampling techniques used to meet workplace and ambient air toxic detection requirements. Air & Waste Management Association 87th Annual Meeting and Exhibition, Cincinnati, OH, June 19-24.

O'Neal, R.D., 1992: Estimating future noise levels from industrial noise sources. Acoustical Society of America 124th Meeting, New Orleans, LA, October 31 - November 4.

O'Neal, R.D., 1991: Predicting potential sound levels: A case study in an urban area. Journal of the Air & Waste Management Association, 41, 1355-1359.

O'Neal, R.D., 1991: Temporal traffic fluctuations and their impact on modeled peak eight-hour carbon monoxide concentrations. Air & Waste Management Association 84th Annual Meeting and Exhibition, Vancouver, B.C., June 16-21.

O'Neal, R.D., 1990: Noise barrier insertion loss: A case study in an urban area. Air & Waste Management Association 83rd Annual Meeting and Exhibition, Pittsburgh, PA, June 24-29.

McKee, T.B. and R.D. O'Neal, 1989: The role of valley geometry and energy budget in the formation of nocturnal valley winds. Journal of Applied Meteorology, 28, 445-456.

O'Neal, R.D. and T.B. McKee, 1987: Draining or pooling mountain valleys: A matter of geometry. Proceedings of the Fourth Conference on Mountain Meteorology, Seattle, WA, August 25-28.

PREVIOUS EMPLOYERS

Earth Tech, Inc. 1997-2000
Tech Environmental, Inc. 1987-1997

BEFORE THE ENVIRONMENTAL APPEALS BOARD
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

	)
In re: Dominion Energy Brayton	)
Point, LLC (formerly	)
USGen. New England, Inc.)	)
Brayton Point Station	)
	)
NPDES Permit No. MA 0003654	)
	)

CERTIFICATE OF SERVICE

I hereby certify that copies of the documents listed below, were served in hand on Linda Murphy, Director, Office of Ecosystem Protection, Environmental Protection Agency, Region 1, One Congress Street, Suite 1100, Boston, MA 02114-2023, this 3rd day of January, 2007:

1. Petition for Review of November 30, 2006 Determination on Remand Issued by Region 1 in Relation to NPDES Permit for Brayton Point Station;

2. Motion for Leave to Submit Brief in Connection with Petition for Review;

3. Motion to Exclude or to Strike Documents from the Administrative Record;

4. Motion to Supplement the Administrative Record;

5. Exhibits To Petition For Review Of November 30, 2006 Determination On Remand Issued By Region 1 In Relation To NPDES Permit For Brayton Point Station And Motion To Supplement The Administrative Record; and

6. this Certificate of Service.

John Stevens /CRD
John M. Stevens

Date: January 3, 2007

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