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PRELIMINARY EVALUATION OF ORNL'S INDIAN POINT-3 ENTRAINMENT AND POPULATION DYNAMICS ANALYSIS

Representatives from Tech Review, DBER, and Environmental Projects have been requested (memo, Muller to Denton, dated 6/28/74) to assure the validity of ORNL's impact analysis for Indian Point-3 by performing an independent review of the Lab's newly developed entrainment and population dynamics models. Tech Review has also been requested by TAR No. 941 to review certain Indian Point reports and assist ORNL in preparing hearing testimony. The enclosed report is a preliminary response to the TAR as well as an interim panel report. Also enclosed is a memorandum from D. H. Hamilton of DBER, summarizing his impressions of the ORNL analysis.

The staff decision to require closed cycle cooling at Indian Point 2 was based in part on an entrainment analysis performed by ORNL which received some criticism by the Atomic Safety and Licensing Appeal Board. ORNL has responded constructively to the criticism by developing the new models and reevaluating positions taken during the Indian Point 2 proceedings. A briefing on the status of their current model development and impact assessment was presented by ORNL staff to the special review panel on August 9, 1974 (see enclosed participant list). The enclosed evaluation is based upon the initial briefing and subsequent review of the models by members of the Tech Review staff. In summary, the staff concludes:

(1) ORNL models should incorporate the most current environmental data. At the time of the briefing, ORNL did not have possession of the latest data collected by the applicant but were prepared to update their model results, if necessary, as the data became available. The quality and relevance of the data to the models are not yet determined.

(2) ORNL should supply the final updated models and results for panel review before completion of the FES. It is impossible to reach final conclusions at this time and impractical for the panel to review the intermediate updates. Only general comments on the underlying assumptions in the models are possible at this time.

Memo

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(3) The young-of-the-year and adult striped bass models have utility in the Indian Point case. An important use of the models is in defining issues (unknowns) where field and laboratory research is needed for more accurate assessment of impacts.

(4) The adult striped bass model is a reasonable approach. Two methods for describing probability of survival of young-of-the-year are proposed. The density-independent method appears more defensible in light of available data. In contrast, there does not appear to be sufficient information to allow a thorough treatment of density-dependent mortality rates.

(5) The young-of-the-year striped bass population model, although useful and necessary, may be so complex that "check-out" and tuning of the model with available data is impossible. Since it is expected that the applicant's consultant will present a similarly complex entrainment model, the ORNL staff should discuss (in the FES) the state-of-the-art of sampling accuracy and limits to incorporating crude data in sophisticated models.

(6) The young-of-the-year model ignores certain phenomena which are difficult to predict, e.g. (a) dependence of shoaling on turbidity, available food, and unpredictable instinctive behavior, (b) dependence of growth rate on food availability, (c) dependence of plant destruction factors on attraction to the intake as well as avoidance.

We recognize that some of the above comments relate to issues which cannot be treated adequately with current knowledge of aquatic ecosystems. However, the issues should be discussed and their disposition stated in the FES.

The concerns which have been noted in items (4), (5), and (6), above should forewarn of the potential for "...conflicting expert testimony" where, as in the Indian Point-2 proceedings, "[t]he experts recognized... that their predictions involved a considerable number of unknowns regarding the predicted impacts..." (ALAB-188, p. 5). The Appeal Board recognized that "...a rule of reason should apply in evaluating and predicting environmental effects when there are unknowns in the prediction and evaluation processes" (ALAB-188, p. 77). Anticipating that unknowns will persist in the evaluation process, we recommend that a "rule of reason" approach be considered by ORNL in the FES discussions of potential plant effects and cumulative effects of nearby existing and proposed plants on the Hudson River.

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We understand that the lab team will soon finalize the model assumptions, incorporating the latest biological data from the applicant. The panel should review the model assumptions and results prior to incorporation into the FES, after which time a consensus opinion will be prepared and issued.

Original signed by Ronald L. Ballard

Ronald L. Ballard, Chief
Environmental Specialists Branch
Directorate of Licensing

Enclosures (3):
As stated

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PRELIMINARY EVALUATION OF ORNL'S STRIPED BASS MODELS

INTRODUCTION

The Environmental Specialists Branch is reviewing ORNL's striped bass models which are being applied in the Indian Point 3 impact analysis. This report provides a preliminary evaluation with only general comments on the underlying assumptions in the model formulations. Many of these comments point out "unknowns" which are difficult if not impossible to predict and should not be construed as suggestive that all of these factors be incorporated. However, an effort should be made to incorporate as many as practicable.

ORNL has not finalized their models and impact analysis since data inputs from the applicant are incomplete. Final versions of the models with results and conclusions should be supplied by the Lab prior to preparation of the FES. A final evaluation by the Tech Review staff will be made at that time and recommendations supplied to Environmental Projects.

YOUNG-OF-THE-YEAR MODEL

The young-of-the-year (y-o-y) model is a deterministic, continuous-time model designed to predict the development and distribution of the striped bass population of age less than one year. The young-of-the-year are divided into six age groups: eggs, yolk sac, larvae, juvenile I, juvenile II, and juvenile III. The river is divided into discrete elements along its length and all results are considered to be averages over an element and over a tidal cycle. A set of equations is developed which combines the physical conditions of the river, the biological characteristics of striped bass, and the plant conditions.

The staff recommends that the following aspects of the model be given added consideration by ORNL:

Initial Population Distribution

The staff agrees with ORNL that existing data are limited and too crude for the design of the y-o-y model. Temporal and spatial distribution of the y-o-y striped bass has not been adequately sampled for any single year to establish initial conditions (egg distribution) compatible with the sophistication of the model. Furthermore, it has been shown in a two year study (Hudson River Fisheries Investigations, 1965-1968) that the temporal and spatial egg distribution can fluctuate significantly from one year to the next. To establish the range of fluctuation would require many years of sampling. ORNL should evaluate the applicant's latest data on egg distribution and discuss its accuracy and adequacy in terms of the model.

Shoaling

Shoaling is treated in the model by introduction of a term which characterizes the instinct of shoaling, $(C_{SH})_K$, a term which characterizes the shoaling areas of the estuary, R_{SH}, and other terms which characterize the physical conditions of the estuary and the swimming ability of the young fish. $(C_{SH})_K$ is considered to be constant for a given age group, K; however, this may be an oversimplification (e.g. it could vary with such physical factors as water temperature and turbidity). R_{SH} is assumed to depend only on the geometrical conditions of the estuary which are constant in time. In making this assumption, it is implied that the food supply is never a limiting factor in a shoaling area. The relationships between productivity and consumption of food in shoaling areas are not known, and until further studies are made it is impossible to model the shoaling tendency without assuming that the available food supply is independent of the rate of consumption. The shoaling phenomenon should be discussed in detail by ORNL in the FES.

Factors like temperature, salinity, and turbidity may significantly affect how an individual behaves in its environment; e.g., if the water temperature of a shoaling area is significantly higher than the water temperature in the river, the y-o-y fish may prefer to remain in a given location rather than leave in search of shoaling areas with greater food supplies as envisioned in the design of the model. In reality, the individuals may behave in very complex ways which may completely negate the results of the model.

Age Group Population Density Generation

Only salinity and temperature are considered as the important variables in natural growth rate and mortality rate. The food available is also an important variable in growth rate, an observation which is supported by ample data. To incorporate this into the model, the degree to which the food resources are saturated as a function of population density must be better understood. If the food supply is limiting, the growth rate should be smaller than the growth rate when the food supply is in excess, $(r_K)_{OPT}$. ORNL should discuss the dependency of growth rate on the food supply in the river.

Intake Conditions

The intake conditions are modeled by consideration of several factors, including: (1) a distribution factor to determine the effect of lateral and vertical variations, $(C_{DISTR})_i$, (2) an avoidance capability factor, $(C_{AVOID})_K$, (3) the intake velocity, $(v_{INT})_m$, and (4) the age group's swimming velocity, $v_K(\bar{T}_i)$. $(C_{DIST})_i$ is assumed to be a constant in time. It probably is highly dependent on the fishes behavior, which changes over time and under varying physical conditions. $(C_{AVOID})_K$ is assumed to be a positive constant for a given age group. The positive sign means that the fish always try to avoid the intake. However, it has been observed that small fish are often attracted to the intake current and it is not until they get near the screens that they try to escape. The behavior of small fish under these conditions should be reviewed and the model assumptions discussed.

Model Resolution

Planktonic organisms typically show considerable patchiness in their distribution. Because this patchiness is caused by weather conditions and other factors which cannot be predicted with confidence, it is essential that the size of the discrete elements be much larger than the characteristic length of the patchiness. Furthermore, the limit of the temporal resolution should be increased beyond one tidal cycle since the average weather conditions over a tidal cycle are highly variable from one tidal cycle to the next. A more reasonable temporal resolution limit would be 14 tidal cycles (1 week).

Consideration should be given to the temporal fluctuations and spatial patchiness in the river to establish the limit of the temporal resolution and the length of the discrete elements. ORNL should discuss its conclusions in terms of the Appeal Board's finding that a model with high temporal resolution (3 hr) best conforms to reality.

ADULT MODEL

The adult model is a deterministic, discrete-time model where the time and age units are both of one year duration. The female population is modeled as 16 annual age groups (population vector), where the oldest age group consists of these individuals 15 years and older.

The annual zero age class input is determined by means of an expression which relates the average number of eggs spawned to the age of a female. Other factors, such as age-dependent natural survival rates, fishing mortality rates, and impingement and entrainment mortality rates, are treated by similar empirical relationships.

The population vector is established from the latest field data, and serves as the initial condition in the model for the prediction of future population vectors. The total weight of striped bass available to the fishery for any future year can be determined from the population vector and, hence, the effect of the power plant on the fishery can be predicted for future years.

Some factors that should be considered in greater depth follow:

Compensation

McFadden (1972), in Indian Point 2 testimony, emphasized the importance of density-dependent factors operating on the striped bass population. He suggested that when the population is less dense, fish grow at a faster rate and become sexually mature at a younger age. The ORNL modelers ignore this by assuming growth rate and natural mortality for age classes 1-15 to be independent of population size. If McFadden is correct, the power plant could kill large numbers of y-o-y striped bass without a significant effect on the fishery; if ORNL is correct, a large kill at the power plant could reduce fish landings, and possibly have a long term effect on the population. A thorough investigation should be made of density-dependent compensatory mechanisms that operate on the age groups older than year zero and a discussion included in the report. If such mechanisms are important, they should be incorporated in the model.

Total Fishing Mortality

An elaborate discussion is presented out of which an expression evolves that incorporates a density-dependent mechanism for fishing mortality. At low population densities the fishing mortality rate is small and constant and represents exploitation by anglers. At high population densities the fishing mortality rate is large and constant and represents a recreational and commercial fishing effort which is limited by the amount of equipment available. At intermediate densities the fishing mortality rate increases, almost linearly, with the fishable population density and represents the situation where the effort is strongly dependent on the yield. A computer run was presented for illustration during the briefing and for that run the population density was in the intermediate range. Other runs should be provided to include conditions of low and high population densities with a discussion of the relevancy of each of these conditions to the Indian Point impact analysis.

Zero Age Class Mortality

The number of eggs spawned each year depends upon the population structure. The average number of eggs spawned by a female in a given age class is known and thus the total number of eggs is obtained by means of a sum of the products. One problem is to predict the number of young that will survive to the next year. This is done in two ways: The first is by consideration of a density-independent mechanism where the probability of survival from causes of natural mortality and from causes of the power plant are independent of the population size; the second is by consideration of a density-dependent mechanism which incorporates many important factors, but like the y-o-y model, is limited by a general lack of knowledge in this area. Weaknesses of the density-dependent approach should be discussed and the approach rejected if warranted.

Natural Fluctuations

Striped bass populations are thought to fluctuate by as much as 4x over periods of several years (McFadden, 1972) but the causes behind these fluctuations are not well understood. These fluctuations set the limit of accuracy of the model. To model them would require the use of a statistical model rather than a deterministic model. At this time, however, an attempt to develop a statistical model would be futile because the type of data required is not available. The phenomenon of natural fluctuation cited by McFadden should be considered in greater detail and discussed in the FES.

Migration

The adult striped bass model treats the Hudson River population as a closed system, i.e. no interchange among Atlantic stocks. The literature indicates that some interchange does take place. ORNL should discuss the possibility of mixing of migratory stocks in terms of limits set on conclusions drawn from the closed-system model.

CONCLUSIONS

Both of the ORNL models have use in the Indian Point-3 impact analysis. They have helped identify areas where information and research programs are inadequate. Based on the preliminary evaluation, the staff concludes that with the proper population vector, the adult model can forecast population trends with reasonable accuracy. The y-o-y model can be useful in comparing plant effects for different sets of initial conditions and model parameters.

The staff has identified some issues which require further attention. Many of these issues are poorly understood and not easily handled in the models. An effort should be made to incorporate as many of the issues as practicable. Additionally, ORNL should discuss the remaining issues in an attempt to establish limits placed upon the models by the fact that those issues are not incorporated.

Baseline data for supplying initial conditions and for refining and evaluating the models are limited. Inadequate sampling techniques (state-of-the-art) and poorly coordinated programs have not provided reliable data. ORNL should discuss these limitations after reviewing the applicant's latest field data. ORNL should then supply their final updated models and results for review by the Tech Review staff.

Hudson River Fisheries Investigations, 1965-1968, Evaluations of a Proposed Pumped Storage Project at Cornwall, New York, in Relation to Fish in the Hudson River. Hudson River Policy Committee, 1968.

McFadden, James T. Testimony on Indian Point Studies to Determine the Environmental Effects of Once-Through vs. Closed Cycle Cooling at Indian Point Unit No. 2, February 5, 1973.