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IN THE MATTER OF:

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

(Indian Point Station, Unit No. 2)

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UNITED STATES OF AMERICA

ATOMIC ENERGY COMMISSION

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In the matter of :
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CONSOLIDATED EDISON COMPANY OF : Docket No. 50-247
NEW YORK, INC. :
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(Indian Point Station, Unit No. 2) :
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Regency Room
Springvale Inn
500 Albany Post Road
Croton-on-Hudson, New York

Monday, 4 Decembe7 1972

The above-entitled matter came on for further hearing, pursuant to noticac at 1:00 p.m.

BEFORE:

SAMUEL W. JENSCH, Esq., Chairman, Atomic Safety and Licensing Board.

DR. JOHN C. GEYER, Member.

MR. R. B. BRIGGS, Member.

APPEARANCES:

LEONARD M. TROSTEN, Esq., and EDWARD L. COHEN, Esq., 1821 Jefferson Place, N.W., Washington, D.C., 20036; on behalf of the Applicant.

MYRON KARMAN, Esq., and EDWARD LYLE, Esq., Office of General Counsel, United States Atomic Energy Commission, Bethesda, Maryland; on behalf of the Regulatory Staff.

BRUCE L. MARTIN, Esq., 112 State Street, Albany, New York; on behalf of the Atomic Energy Council of the State of New York.

ANGUS MACBETH, Esq., Finney Farm, Croton-on-Hudson, New York; on behalf of the Intervenor, Hudson River Fishermen's Association.

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PROCEEDINGS

CHAIRMAN JENSCH: Please come to order.

This proceeding is a further evidentiary proceeding in the matter of Consolidated Edison Company of New York, Incorporated, in reference to its application for operation of the Indian Point Station Unit No. 2, which is reflected in Atomic Energy Commission Docket No. 50-247.

Appearances should be entered on behalf of the Applicant. I note the presence of Mr. Trosten and Cohen. Hudson River Fisherman's Association, Mr. Macbeth. New York Atomic Energy Council, Mr. Martin. And the Atomic Energy Commission Regulatory Staff, Mr. Karman. If you will introduce the others --

MR. KARMAN: I would like to introduce Mr. Edward Lyle, a colleague of mine and counsel for the Regulatory Staff.

CHAIRMAN JENSCH: Thank you. Your appearance may be entered.

For the benefit of the persons who did not attend the conference which was held among the attorneys and the Board and other members of the public on November 22nd, reference should perhaps be made to the fact that a conference was held on November 22nd. This proceeding, however, today is convened in accordance with an order convening an evidentiary hearing which was issued October 16, 1972, which order was given the general public distribution which included publication in the

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Federal Register, which is the official government publication, notice publication as reflected by Volume 37 of the Federal Register, page 22637, and it was published on October 20, 1972.

There was also issued an order convening the conference which was held to which reference has been made and that order was given general public distribution which included a mailing to all persons who have requested copies of notices from the Atomic Energy Commission. The order convening this evidentiary hearing was likewise mailed to all persons who have requested notification of public proceedings in this proceeding -- in this case.

The conference which was held on November 22nd related solely to procedural matters. No evidence was received, no witnesses were sworn. There were discussions among the attorneys as well as by the Board in reference to this evidentiary hearing. Consideration was given to the anticipated scope of the evidence that each party would present at this proceeding, as well as the names of the witnesses and the subject matters which would be covered by the intended presentation.

Certain stipulations were reached. A request was made by the Hudson River Fishermen's Association, as well as by the Environmental Defense Fund, that certain factual matters be indicated to be within the scope of a contest or an agreement or any other qualifications to assertions of

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fact which -- for instance, the Hudson River Fishermen's Association had presented.

The Applicant agreed to review those assertions and has filed a response indicating the scope of its agreement or disagreement or its comment respecting the assertions made by the Hudson River Fishermen's Association and the Environmental Defense Fund.

The procedure which is of greatest, perhaps, importance to this session of the hearing is that it is expected that the witnesses for the Regulatory Staff of the Atomic Energy Commission will be first cross-examined after all of the parties have introduced their direct evidence. This procedure was established because of the fact that many of the witnesses for the Staff are required to be at another proceeding next week and it is expected that the cross-examination of the Staff witnesses may well utilize this first week.

In addition, there is the status of the case, in that insofar as the Staff is going ahead and offering its witnesses for cross-examination, that that does not affect the obligations and the responsibility of the Applicant to bear the burden of proof for the license to operate this plant.

The Staff has, since our last evidentiary hearing, submitted a Final Environmental Statement and in that

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statement the Staff has recommended that certain conditions be attached if any operation is authorized for the Indian Point No. 2 plant and that is that there be closed cycle operation of the plant. That has been construed, I think, somewhat generally as requesting a condition for cooling towers.

At the conference which was held in November, the Staff emphasized that its recommendation, however, was limited to a request for a condition for a closed cycle operation which may be accomplished in one of many ways, one of which may be cooling towers, one of which may be another method, but in any event, in view of the characteristics of the Final Environmental Impact Statement which has been filed by the Regulatory Staff of the Atomic Energy Commission, the Staff has in a sense the burden of going forward with the evidence to make its presentation in that regard.

That does not, however, limit or in anywise modify the obligation of the Applicant to sustain the burden of proof which devolves upon them by the rules and regulations of the Atomic Energy Commission.

As we understand the position of the Applicant, the Applicant does not object to a closed cycle operation of the Indian Point 2 plant if there are developed facts which justify that type of condition. It is the view of the Applicant, as we understand it, that the facts have not yet been presented to warrant the imposition of that kind of a condition; and the Applicant has proposed that further data be developed so that if there is shown to be adequate bases for a closed cycle operation, the Applicant does not have objection to it; but it does have objection to the imposition of any condition in that regard at this time because of the fact that in the judgment of the Applicant the facts have not been presented to warrant that condition and all of those matters will be developed in the course of this evidentiary proceeding.

Another aspect that was developed at the November 22nd conference which is of importance at the outset and which indicates the scope of the activities which have been undertaken by the attorneys in the several recesses, neither the Hudson River Fishermen's Association nor the Environmental Defense Fund object to the operation of the Indian Point No. 2 plant for the purpose of electrical generation provided, as they suggest, that conditions be attached for the operation which would require closed cycle operation of the plant.

The record of the discussions which were held on November 22nd is available for public review of the transcript which was made at that public conference held on November 22nd and that transcript is available for review at the public documents room of the Atomic Energy Commission in Washinton and also at the Henry Hudson High School here in -- I think

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it is Montrose or Croton-on-the-Hudson, whatever be the municipality designation; but it is available for the public review in this region and all members of the public are invited to review that transcript.

There will probably also be discussed in the course of this session of the evidentiary hearings some reference to the amendments which were made by the Congress to the Federal Water Pollution Control Act which will be the subject of some discussion, and I believe contention, as to whether the Atomic Energy Commission has any jurisdiction to impose a condition for closed cycle operation of the Indian Point No. 2 plant.

I think since this proceeding has started we have kind of gone the full circle on that matter.

(Laughter.)

At the outset, the Atomic Energy Commission stated its view that it did not have jurisdiction over thermal effluents from nuclear generating plants. Then in 1970, the National Environmental Policy Act was enacted and as interpreted by the so-called Calvert Cliffs decision involving the Baltimore Gas and Electric Company, the Court determined that the Atomic Energy Commission did have jurisdiction over thermal releases from nuclear powered plants and consideration should be given to the environmental impact of such thermal releases, if they occurred.

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Then in October of 1972, as I mentioned, the Congress enacted the amendments to the Federal Water Pollution Control Act and when I say Congress enacted it, it was over the veto of the President of the United States; so the Congress has determined that no federal agency can impose a condition to a license which would affect or alter or change any determination of thermal releases which had been made by the Environmental Policy Administrator.

So those are matters that the public will be hearing discussed here and there will be contentions as to the scope of those amendments as applicable to this proceeding.

There may be contentions that perhaps the request for a condition for closed cycle operation does not necessarily involve a thermal release consideration and the parties at the November 22nd conference were requested to submit briefs respecting these amendments and their application, if any, to this proceeding.

The Applicant undertook the burden of supplying the first brief, after which the parties will have an opportunity to file answering briefs and comments. There are some aspects of the legislative history that may be of importance to determine the application of these amendments that may be of concern; for instance, I believe the legislative history of the amendments to the Federal Water Pollution Act which were enacted in October of 1972, reflects that on

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the floor of the Senate, two Senators discussed the scope of this particular section as quite important here, Section 511, and both of those two Senators concluded that the Atomic Energy Commission could not impose a condition for a closed cycle operation, and I presume there will be some discussion of that in the briefs as to whether conversations between members of a legislative body are paramount in influence to the language of the act itself.

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Then I think the legislative history also reflects that this particular section, 511, which will be one of the focal points in the consideration of these amendments, was developed in a conference between the House of Representatives and the Senate of the U.S.; and as I understand the history reflected in the congressional record, there is a restriction or a prohibition on the House of Representatives in developing a new section of legislation in a conference; that is that a conference between the House of Representatives and the Senate is intended to be limited to the general scope of the differences between proposed versions of legislation from either the House or the Senate. But there is also a provision that the House of Representatives may waive that provision of restriction and the resolution was introduced in the House of Representatives to waive that restriction which would prohibit the development of the new section in a conference committee.

There is also a showing that a Congressman, in dealing with that resolution, said here are 12 reasons for which we need a waiver. Well, that language did not say here are the 12 reasons and only these 12 reasons are those for which we need a waiver of the restriction by the House of Representatives; but in any event, the 12 reasons given by that Congressman did not include this section, 511.

There may be inquiry as to whether that difference

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in presenting the request for a waiver excluded from validity the Section 511, and the Board is hopeful that those matters will be discussed in the briefs which will be filed. I presume that in connection with that may well arise the question of whether the procedures of the legislative branch are necessarily within the scope of review of the adjudicatory or judicial branches of the government and the separation of powers between the executive and the judicial and legislative. I think each group jealously guards its other prerogatives and it may well be that judicial determinations have already been made that would say that it is none of the business of the adjudicatory how the bill gets through the legislative branch.

On the other hand, there may be judicial determination that conformity with due process and reasonable procedures are a requirement for the legislative groups. We hope the briefs will cover those aspects, too.

That generally was the subject of our November 22nd conference.

At this time I think we have -- as we indicated, the parties have agreed that this opening of the evidentiary hearings, which we expect will be the last of the evidentiary hearings in this proceeding, all parties will introduce their direct evidence, after which we will proceed to a cross-examination of the Staff witnesses.

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Is that your recollection of the procedure, Applicant?

MR. TROSTEN: It is, Mr. Chairman.

CHAIRMAN JENSCH: Will you make your offer of your evidence, please?

MR. TROSTEN: Prior to making the formal offer, I have a few remarks I would like to make.

CHAIRMAN JENSCH: Proceed.

MR. TROSTEN: Mr. Chairman, the hearing which commences today before this Board is of vital importance not only to this community, but to the metropolitan area, and indeed to the nation at large. This is because what is really at stake is the basic philosophy and methodology that our government will employ in grappling with the environmental and energy supply problems that confront us today.

In the minds of most people, I think the basic question to be decided in this hearing is whether Con Edison should build cooling towers for the Indian Point 2 plant, and if so, on what schedule.

CHAIRMAN JENSCH: May I interrupt?

MR. TROSTEN: Yes, sir.

CHAIRMAN JENSCH: Is it your interpretation that the Staff recommendation necessarily is related to cooling towers? In view of the physical location of Indian Point 2?

MR. TROSTEN: It isn't absolutely related to cooling towers, Mr. Chairman, but I think, and perhaps we can explore this further, that the thrust of the Staff's recommendation is that cooling towers is probably the answer.

CHAIRMAN JENSCH: In other words, you don't have space for a cooling pond, for instance?

MR. TROSTEN: There is really not enough space for a cooling pond, and I think the other alternatives that are available are not very practical. I suspect the Staff agrees. I know the Intervenors feel cooling towers are probably the answer here.

CHAIRMAN JENSCH: Proceed, please.

MR. TROSTEN: There was no real doubt in anyone's mind whether the plant should be allowed to operate at all insofar as environmental protection problems are concerned, and the AEC Staff has in this respect correctly concluded that Indian Point 2 should be licensed to operate.

It is the conditions under which the plant should operate that are in issue here. Now as has been stated by Con Edison, many times in the past, the company is neither for nor against cooling towers for Indian Point 2. Such structures and equipment would be very expensive, and indeed we estimate they would add about ~~$120~~ 182 million to the cost of the plant in terms of extra capital expenditures and generating costs.

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Now to put this matter in perspective, Mr. Chairman, this sum of money is equivalent to the capital cost of building an oil-firing generating plant the size of Indian Point 2. Now there are obviously many other worthwhile uses to which such a sum of money could be applied, such as the construction of hospitals or pollution control facilities and obviously many other things.

Now, nevertheless, Con Edison is not opposed to building these structures at Indian Point if the evidence demonstrates that on balance they would be more of a social asset than a social liability. The basic problem is that not enough information is known to make this judgment yet. Not by Con Edison, not by the Intervenors in this proceeding, and not by the AEC Staff.

What Con Edison is asking this Board to do, in essence, is to recognize this factor and therefore to allow for adequate time to make the necessary studies and to evaluate the results.

Now the idea of not enough information is available to decide this question requires some explanation. After all, hasn't Con Edison been studying the Hudson River since the late 1950s, and hasn't Con Edison presented a vast amount of information to this Board already about all its studies and analyses and research?

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The answers to both of these questions is yes. But unfortunately, that isn't the same thing as saying that because of that, we know enough to decide this case. The fact is that the concern over the environmental and energy supply matters which looms so large now in thepublic consciousness is of relatively recent vintage. Perhaps even more important, the conception of the nature of the problems that we face has evolved with astonishing rapidity. The Chairman brought out that we perhaps have come the full cycle in this ~~hearing From~~ hearing from a legislative point of view, and exactly the same developments have developed from the technical side.

A year or two ago, the very term, entrainment, meant something entirely different than it does now to the biologists and the engineers both in the government and industry who are studying the problem of power plant design. It is little wonder then that with the vast amount of research that has already been carried out by Con Edison on the Hudson River, ~~still has~~ still this research has not answered some of the basic questions that need to be addressed although some of the previously addressed concerns have been layed to rest.

A little reflection on the complexity of these problems and the very nature of biological research indicates why this is so. One can legitimately ask how can it be that all of this research still needs to be done when the AEC

Staff has been able to conclude in the Final Environmental Statemen that a closed cycle ~~cycle~~ cooling system should be built, and when the Intervenors have two witnesses who think so too. We believe, Mr. Chairman, that there is a simple answer to that question. What the Staff and Intervenors have done is make a fundamental error of judgment on the basis of admittedly very inadequate data and rudementary models. They have speculated environmental damage may be done in the future to the Hudson River ecosystem by the once-through cooling system of Indian Point 2.

Then having assumed that this problem may occur, they have leaped to the conlcusion that a once-through cooling system probably 400 to 500 foot high cooling towers larger than the size of a football field turned on its end, should be built to solve these problems.

Now, they have reached that conclusion without stopping to analyze fully what kinds of environmental problems the cooling towers might themselves cause. The asthetic problems, the possible effects that billions of gallons of salty water evaporate into the atmosphere from the towers might cause to the people and property in this area and so forth, and without allowing adequate time for Con Edison to investigate these problems.

What the Staff and the Intervenors have said basically is this: "Never mind about these possible problems. Dam the torpedoes, full speed ahead. Have that alternative system installed right away."

Con Edison does not consider this is a responsible way for either the government or an electric utility to proceed. Therefore, what we are asking this Board to do is evaluate the evidence that will bepresented to it in this hearing. We are confident when this is done, the Board will conclude, as we have, that there is not an adequate factual justification at this time to require the installation of a closed cycle cooling system for Indian Point 2 and that indeed, all the available evidence indicates that any adverse effect from the once-through cooling system will be relatively minor. We ask you to conclude that the possibility of damage to the Hudson River ecosystem should be scientifically investigated over an adequate period of time consistent with the life cycle of the species in the Hudson River.

And that at the same time, the economic and environmental aspects of alternative cooling systems should be investigated as soon as practical. Con Edison considers that these actions can reasonably be taken in time to have an alternative cooling system installed, if that is ultimately determined to be necessary, within eight years. In the light of the best scientific information that is available to this company, Con Edison believes that any adverse effect on the Hudson River ecosystem during this period of time will not be irreversible.

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matter opened up.

CHAIRMAN JENSCH: And placed in a public hearing procedure?

MR. TROSTEN: Well, I find it a little difficult to answer that question, Mr. Chairman. Because in order to answer that, I would have to know what the data provides. Certainly there is the possibility that a hearing could be held on this. Whether that possibility would materialize in the particular place would depend upon the facts that have been presented and the procedures of the Atomic Energy Commission that were available at the time and the conditions of the license, and that is why it is rather an abstract question that you are asking me, Mr. Chairman, so I find it somewhat difficult to answer it purely in the abstract.

CHAIRMAN JENSCH: Let me take these factors and see if you can apply your judgment to this. Supposing the study is completed within a certain number of years and Con Edison says still no cooling towers are necessary, the Staff says we believe closed cycle should be applied to the operation of the plant, and the Intervenors here do too. Would on those facts, Con Edison have any objection to public proceeding procedures in reference to a consideration of the matter at the completion of the study period?

MR. TROSTEN: Well, if that situation were the case, I would presume that the Staff would institute public procedures. If Con Edison would not agree, it would seem to me if somehow w developed. Now, is it your thought in making that request that you would submit the data to the Atomic Energy Commission and to the parties in this proceeding who would have a right to inquire into the results of the study at the end of the time, whatever it be designated to be, and give them an opportunity to contest or affirm or whatever comment, in any respect, regarding those matters?

MR. TROSTEN: Certainly, Mr. Chairman. These data would be made available not only to the Atomic Energy Commission an d to the parties to this proceeding, but to all federal and state agencies and to the public at large.

CHAIRMAN JENSCH: You have no objection to having a proceeding instituted to test the results of the studies as you would present them, is that correct?

MR. TROSTEN: Let me put it this way, Mr. Chairman. The procedure that would be followed when the data were made available and as they became available would be determined by the applicable procedures of the Atomic Energy Commission and of the other agencies, both federal and state, having jurisdiction.

CHAIRMAN JENSCH: I just wondered what is your position? Would you have any objection to having the matter opened up say here at the Atomic Energy Commission to test these matters?

MR. TROSTEN: Would I have an objection to having the

I want to emphasize, Mr. Chairman, that the data from Con Edison's planned five-year study of the river would be made available to the federal agencies and the state agencies ~~whic~~ which have ~~jurisdiciton~~ jurisdiction so that they would have the information needed in a timely fashion to determine what, if any, changes are needed in the present cooling system.

Furthermore, should Con Edison conclude on the basis of this study that the need has been demonstrated for modification of the present cooling system for Indian Point 2 the company would, on its own initiative, propose such a modification to the governmental agencies having jurisdication over that matter.

MR. Chairman, we ask that this Board consider carefully the evidence to be presented to you in this hearing. In Con Edison's view, that evidence demonstrates that the INdian Point 2 facility should be licensed with the present cooling system and the other programs for the protection of the environment,that have been outlined in our testimony,should be carried out.

Thank you, sir.

CHAIRMAN JENSCH: Let me ask you, what do you envision as the procedure. You have noted that there has been concern with the fact that Con Edison has been studying the Hudson River since 1950 and if you are allowed just a few more years, you think the necessary answers will be couldn't agree. I would have to admit there is the possibility that we could not agree under those circumstances. I would like to think if it was so clear from this that Con Edison itself would have concluded without the Staff drawing that conclusion that we should go in this direction. But if for some reason we had not been able to reach agreement on this, and the Atomic Energy Commission chose to institute further hearing procedures or a requirement that the company install these procedures, yes, we would have to go along with that, Mr. Chairman.

CHAIRMAN JENSCH: That wasn't quite my question. My question was assuming in the formulation of the judgment whether there would be any hearings, would Con Edison have any objection if it would so indicate to the Atomic Energy Commission that public proceeding procedures may be instituted to test the results of the studies undertaken on the Hudson River?

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MR. TROSTEN: Would we object if public procedures were instituted?

CHAIRMAN JENSCH: Yes. Would you have any objection to the testing of the validity of the results of the studies on the Hudson River?

MR. TROSTEN: I would have to answer the question that I suppose we would not object to that, Mr. Chairman. In a purely abstract sense, I guess I would have to say the answer is no, we would not object. You understand the difficulty that I am having with a hypothetical question like that, Mr. Chairman?

CHAIRMAN JENSCH: I really am not having an understanding of your difficulty. I understand your statement that you are having difficulty.

(Laughter.)

MR. MACBETH: Mr. Chairman, I think this is a very practical question rather than abstract one, and I think it is one which I certainly would like to have a very clear answer from the Applicant. What the Applicant has asked for from this Board is a license to operate Indian Point 2 40 years at full power with no conditions. No conditions to undertake research; no conditions to build cooling towers after five years if the five-year study should have this or that result. They have asked for a license with no conditions. If the Applicant is now saying that it wants to have conditions in the license for research, wants to have conditions in the license for some sort of review, I would like to have that clear before this Board. The Applicant is about to offer testimony to the Board which involves that research program. I think that in terms of what the Applicant has asked for as a license from the Hearing Board, that testimony is irrelevant. I think the good part of what Mr. Trosten has said in what I take to be an opening statement is essentially irrelevant. They have not asked for any condition for a reserach program. They are simply asking this Board to take that into account. Relevant to what, I am not sure. Presumably relevant to the good faith of Con Edison.

Mr. Trosten quite rightly said $128 million could be spent for other purposes, orphanages, pollution control facility. I would have thought the cooling towers would have been characterized as a pollution control facility.

I think that spending the money for an orphanage is an equally irrelevant thing for this Board to consider unless the Applicant is asking to have some condition in this license which will require it to do research, will require it to make some sort of review, and will keep that review a public one before this Board and before the Intervenors and the Staff, and constantly in his response, Mr. Trosten referred to the Staff's beginning further proceedings,

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not the Intervenors. I can assure you the Intervenors are very much aware of this situation and very interested in it, and will remain so. I would like a clear answer from Mr. Trosten as to whether he is proposing conditions of that sort.

CHAIRMAN JENSCH: Well, I think that perhaps one of the concerns that there may be regarding these matters can probably better be determined after the presentation of evidence. Whether the Applicant is requesting a condition or not is not of primary concern to the Board. If the Board believes the condition is advisable, the Board will do it, whether the Applicant asks for it or not. We don't feel we are guided at all by what the Applicant asks for here. It is by what the facts seem to justify in the judgment of the Board as advisable for the operation of this plant insofar as environmental concerns are concerned and of importance.

MR. MACBETH: I have confidence the Board will do what the facts require of it. It is just that I have a great deal of difficulty understanding what position the Applicant is arguing for from time to time in his consistent emphasis on research when no conditions for research appear to be requested. It has me confused constantly. I really don't see the relevance of the research, the position the Applicant has taken. It is as much to make that clear in my own mind for the other parties that I would like to see that clarified.

CHAIRMAN JENSCH: You heard the Applicant say that he's having some difficulty thinking of these things in the abstract because he felt they were in the abstract.

MR. MACBETH: I have the same difficulty, I take it, as the Board did in understanding why they were abstract or why the Applicant had so much difficulty with them. I would certainly hope in the next few days the Applicant could try to bring this down to a level of practicality and make up his mind in a clear and straightforward matter.

MR. TROSTEN: Perhaps I can clarify the matter immediately without waiting a day or two for Mr. Macbeth. I thought I made it clear from what I said that Con Edison has no objection to whatever procedure is determined to be appropriate at the time, including public hearings, Mr. Chairman, if that is the appropriate procedure. We recognize fully the public interest in this, and the need to satisfy that interest, and if public hearings are the required procedure at that time, then that's what the required procedure will be. We have no objection to that. I hope that responds to what Mr. Macbeth has said.

MR. MACBETH: I would like to respond, if I could, to some of the other points Mr. Trosten raised.

CHAIRMAN JENSCH: Proceed.

MR. MACBETH: What is at stake here is the question of some alternative cooling system, and the reason that that is at stake is that Con Edison has done some research in the past on the Hudson River. They are largely responsible for the research done by Carlson McCann in the Hudson River Fisheries Investigation undertaken in connection with the Storm King Plant. It is really that basic research that all the parties to this proceeding, the Applicant, the Staff, and the Intervenors, have used to analyze the life cycle and the movement of striped bass in the Hudson River.

It is on the basis of that and the vast amount of other evidence in the literature and elsewhere that the Intervenors have concluded that through entrainment and impingement, the Indian Point 1 and 2 facilities are likely to kill 40 percent of the annual striped bass production of this river, and the Staff has concluded that through entrainment, the plant Indian Point 1 and 2 will kill off 30 to 50 percent of the annual striped bass production of the Hudson River.

That analysis does not include a great number of other fish in the river, Atlantic silversides, smelt, herring, tomcod, simply because not enough research has been done on this fish. A great deal is known about the striped bass and in many ways, thanks to Consolidated Edison.

It is on the basis of that analysis and that knowledge that both the Staff and the Intervenors have proposed that cooling towers or alternative closed cycle cooling system must be constructed at Indian Point, and every step must be taken to protect that fishery.

There are two further reasons why the protection of that fishery is important as it is.

The striped bass fishery of the Hudson River is one of great value to sports and commercial fishermen, both on the Hudson, Long Island, and up and down the eastern coast of the U.S. The striped bass is one of the great salt water game fishes of these waters. It is also an extremely important commercial fish.

Further, it seems altogether likely that the Hudson is the principal or one of the dominant spawning and nursery grounds, not only for the striped bass fishery in the New York area and Long Island Sound, but for larger areas in the mid-Atlantic, mid-Atlantic Coast, not the center of the Atlantic Ocean.

That makes this plant and this spawning ground extremely important to fishermen up and down this coast. That fishery is extremely important not only for recreational purposes, but for commercial purposes in the larger sense of the amount of money that is spent on tackle and gear and fishing expeditions. This includes -- has an influence on the livelihood of people who run marinas and sports fishing establishments up and down the east coast of the U.S.

The other major reason that this particular plant in this proceeding is so important is one that is discussed briefly at the November 22nd meeting. At the present time we are witnessing an immense exploitation of the Hudson River for cooling purposes for electrical plants. Not only is this enormous plant at Indian Point 2 about to start operation, Indian Point 3 stands behind it. The large fossil fuel plant at Bowling Point and Roseton on the opposite side of the river, one five miles from this site and the other 22 miles from this site, will, over the course of the next 18 months, be making their demands on the water of the Hudson River.

What we face is the situation in which this part of the picture, this slice of the pie, would account for 40 percent of the striped bass fishery. Those additional plants could account for a much greater quantity. We face a really dramatic and dangerous situation on the Hudson River.

Against this, the Applicant raises the spector of dangers from the cooling tower of some sort, visual intrusion, salt deposition. I think there is no question, and the Applicant himself has said this: that visual intrusion is a subjective matter that cannot be quantified in any very clear way. There will be some visual intrusion if cooling towers are constructed. But the Applicant himself has made studies of the question of salt deposition and other kinds of environmental damage from the cooling towers or from any alternative closed cycle system, and has found virtually no environmental damage. I think the Board should bear that in mind as they listen to the evidence that is presented here, that the alternative is one that will be costly. We certainly don't think it is costly as what the -- as the figures the Applicant has produced. We don't think that the costs anywhere match the vast cost to the fisheries in this region that the operation would produce.

But there are vritually no other kinds of burdens that would be put on this community. It would not be rusting out of automobiles or the decimation of the vegetation from salt in the air. There would not be fogging along the ground. There would not be unacceptable noise. I think that should be carefully weighed by the Board.

I think that when the facts have been developed fully in this proceeding, both through direct testimony and through cross-examination, the Board will find that the construction of some alternative closed cycle system, probably cooling towers, should be undertaken as rapidly as possible, and in the meantime, during the crucial periods of the year, in the dead of winter and in the June and July spawning season, the plant should be operated on a restricted basis so that it is available to provide power that is absolutely essential to the consumers in the Con Edison system, but not so that it is run unnecessarily with the kinds of damage to the Hudson River, to its aquatic life and its entire ecosystem.

I think the facts as presented both by the Staff and the Intervenors and through the cross-examination of the Applicant's witnesses will show will take place if this plant is licensed to operate at full power for 40 years with no conditions.

Thank you.

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CHAIRMAN JENSCH: Do you know what the cost was of the cooling towers for the Vermont Yankee Nuclear Plant?

MR. MAC BETH: I don't off hand, no, Mr. Chairman.

CHAIRMAN JENSCH: I don't know. I don't have a present recollection. I was wondering if it was something in the region of $60 million. I don't know. I have wondered whether any figures like that are persuasive at all for the kin of construction proposed here.

MR. MAC BETH: In the testimony that the Intervenors will be presenting through Dr. Eric Ainsley, figures are provided, comparative figures with other plants, and I think Dr. Ainsley would be able to supplement those somewhat on cross-examination. I don't know whether he is familiar with the cost situation of Vermont Yankee in particular but he has had wide experience in the Midwest and will be ready to answer questions as to the costs when he is here.

MR. TROSTEN: Mr. Chairman, I might just point out those were mechanical draft towers.

CHAIRMAN JENSCH: Yes. I don't know which is the better for this situation or would be considered by the parties.

This was one other thing, though. We did discuss at the November 22nd conference something about the possible alternatives for power supply, and while as I understand it, the Hudson River Fishermen's Association, Environment Defense Fund, raise no contention as to the need of power in this area, I am wondering had the possibility of power, say, from Canada would bear upon any terms or conditions of -- if the Board were to suggest that there be conditions for the operation of the plant.

In the respect, if you could get power from Canada, would there be an easing off, let me say, of the contentions about the length of the study? Now, as I understand Applicant's counsel, eight years, Staff, I think has suggested another figure, and Judson River Fishermen's Association even another figure. If there were power from Canada available, it might affect the length of time that the study might be undertaken, would it not?

MR. MACBETH: Mr. Chairman, if the plant was not to operate during the crucial times of the year, or especially from our point of view, the pumps to pump the water to the condensers were not to operate, then we would have no objection to however long the Applicant chose to study. Our concern is with the direct impact on the aquatic life of the river. As long as the pumps of the river do not operate, whatever other method the Applicant has for bringing power are of no concern to us. If they could procure water from Canada to cool the condenser tubes, that would be perfectly sufficient.

(Laughter.)

CHAIRMAN JENSCH: Well, under the Morton case, as I understand it, you are to consider all alternatives.

(Laughter.)

Pipe lines -- pipe lines for water, if not gas, would be of some importance. I don't know.

Have you concluded your statement?

MR. MACBETH: I have.

CHAIRMAN JENSCH: May we hear from the New York State counsel.

MR. MARTIN: We have no statement, at this time.

CHAIRMAN JENSCH: Regulatory Staff?

MR. KARMAN: I had not intended to make an opening statement. Our position, of course, is that the Regulatory Staff of the Commission has evaluated the environmental impacts of the operation of Indian POint 2 on the biota of the Hudson River. We have come to some conclusions which are summarized in this Final Environmental Statement which will be our direct evidence in this proceeding and as a result of our evaluation, there are certain conclusions that we have come to about the possibility of severe impact upon the biota of the Hudson and have recommended that certain conditions be attached to any license for the operation of such plant; namely, of course, the installation of a closed cycle cooling system. We have also indicated that we would expect the Applicant to evaluate and assess the impact of such operation on the Hudson during the actual operation of the plant and we have set certain time frame conditions for the submission by the Applicant of designs for a closed cycle cooling system and also allowed the Applicant an opportunity after making its studies to come back to the Commission and if need be -- and if it finds that the severe environmental impact which we anticipate with a once-through cooling cycle does, in effect, not happen, that they cuold come back to the Commission and file an appropriate application for an amendment of a license which is -- which will require installation of a closed cycle cooling system by a certain date.

We have submitted this evidence, Mr. Chairman, and we have our panel of witnesses to respond to any cross-examination with respect to that, confident of the fact that our evaluation and analysis will be confirmed.

CHAIRMAN JENSCH: Thank you.

Let me ask the Applicant, what do you propose to do to stop the fish kill? As I understand it, we just cannot avoid fish kill under the present operation. What do you propose in order to stop the fish kill?

MR. TROSTEN: There are several things we propose, Mr. Chairman. It is correct that so far as I am aware, it is impossible to avoid killing any fish at Indian Point. There are several things that we are doing. Perhaps the most important thing that is being done is to operate under a plan of reduced flow, 60 percent flow for the month of, I believe, October through March. Another important matter that is being done is to install these air bubble curtains in front of the intake of the plants, in front of the intakes of the plant. We are also in accordance with the agreement that we have with the State of New York, investigating a screened lagoon for the intakes for the plants. These are, I would say -- the two first ones I would say, are the two principal matter that are under consideration at the present time, not just under consideration. The reduced flow is in effect. That capability exists and that would be put into effect. The air bubble curtains ~~levers~~ are being installed and the screened lagoon is being investigated in accordance with a time schedule agreed upon with the Department of Environmental Conservation of the State.

CHAIRMAN JENSCH: Thank you.

Now, in view of that statement, let me ask the Hudson River Fishermen's Association, assuming that one of those possibilities proves to be feasible, and if I understand the air bubble approach, whatever that be, that that be like a steel screening balloon out under the river through which would come the water needed but it would be so large that there wouldn't be such an impact from the velocity of the water coming through, and that it would tend to lessen the fish kill.

Would the Hudson River Fishermen's Association have any objection if that type of approach were adopted?

MR. MACBETH: Well, Mr. Chairman, first the kills at the screen are only a part of the total problem here. The Staff of the Commission has analyzed the deaths due to entrainment which are very small fish eggs, young juveniles, sufficiently small so they simply pass through the wire mesh of the screen. They have estimated that entrainment alone would kill 30 to 50 percent of the annual production of striped bass in the Hudson on an annual basis. Now, none of these methods just described by the Applicant have any effect on entrainment. Our own expert has estimated entrainment loss and it comes to a figure somewhat less than the Staff's but still very, very large.

So the entrainment kills are a very large part of what we are concerned about here and neither air bubbles or reduced flow, especially since reduced flow is not proposed for the spring and summer months when the spawning is going on and the young juveniles are present, would meet our concerns.

Obviously, especially in any period of operation before closed cycle system is constructed and in operation, any action the Applicant can take to reduce kills at the stream, we think would be an improvement. We agree with the Applicant that reduced flow in the winter will somewhat reduce the fish kills in the spring. Less water being taken in, less fish sucked up and killed against the screens.

We are very dubious that air bubble curtains, which as I understand them, are pipes out in the river out of which air is shot that in some ways affects the behavior of fish that they don't come up against the screens -- we are very dubious that that will have any major effect on the kills from impingement. Investigation of a lagoon is simply an investigation. It seems to be one of those investigations that's been going on a long time. Some of the early documents we received from Con Edison, maps of lagoons were drawn that were being investigated and looked into.

Now they are under an order to produce some kind of final investigation from the Department of Environmental Conservation and maybe we will come to a head with a lagoon idea. I remain very dubious about simply an ongoing investigation into lagoons and again lagoons would not affect the entrainment problem. It has yet to be shown they would in any substantial way affect the impingement problem.

CHAIRMAN JENSCH: Anything further?

MR. TROSTEN: Yes. I think it would be well to bring this point to the fore, Mr. Chairman. In the first place, we are operating under a very distinct schedule with the State to study the screening lagoon. I will have the date for you in just a minute.

In addition to that fact, we are investigating other systems such as substituting traveling screens for the

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continuous washing of the fixed screens and there are a series of remedial measures which we are considering and which could be brought to bear to further correct the fish impingement problem at the screens. We will be prepared to discuss this further, of course, during the course of the hearing.

I would also like to say that the experience that we have had with the air bubble curtain, which as Mr. Macbeth directly points out, is a device that shoots a powerful current of air bubbles in front of the screens and creates a strong current before them, tending to move things away from the screens. The experience that we have had with the air bubblers has been quite favorable. I really wanted to add that, Mr. Chairman.

CHAIRMAN JENSCH: Very well.

All parties ready to introduce evidence?

Applicant, will you proceed, please?

MR. TROSTEN: Yes.

Mr. Chairman, at this time I would like to offer in evidence the following written documents that have previously been prepared and have been submitted to all parties. These documents are the testimony of Edward C. Raney on the striped bass -- I am just going to summarize the titles, Mr. Chairman -- dated October 30, 1972; the testimony of Dr. James McFadden on the impact of entrainment and impingement, dated October 30, 1972; the testimony of Dr. Gerald J. Lauer of New

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York University on the effects of Indian Point Units 1 and 2 operation on the Hudson River biota dated October 30th; the testimony of Carl Newman, Vice President of Consolidated Edison on alternative closed cycle cooling systems at Indian Point 2, dated October 30th; and finally the testimony of Dr. John P. Lawler on the effect of entrainment and impingement at Indian Point on the populations of the Hudson River striped bass dated October 30th, 1972.

In addition to those pieces of prepared testimony, I wish to offer in evidence at this time the following appendices to the letter from Mr. Harry Woodbury to the AEC's director of the Division of Radiological and Environmental Protection dated May 30, 1972, which appendices are reproduced in Volume 2 of the September, 1972, Final Environmental Statement for Indian Point 2. These appendices are Appendix B-1, detailed comments on thermal discharge aspects of AEC draft statement dated April 13, 1972; Appendix C, general comments on dissolved oxygen; Appendix E, comments on statements on entrainment; and Appendix G, the scope of work for ecological studies at Indian Point.

The first three appendices are being offered under the sponsorship of Dr. John P. Lawler. The last one, Appendix G, is being offered under the sponsorship of Mr. Harry Woodbury.

At this time, I would like to have my witnesses stand, Dr. Lawler, Dr. Lauer, and Mr. Woodbury, stand and

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approach me, please.

By stipulation with the other parties, we have only three of our witnesses here.

CHAIRMAN JENSCH: All of these gentlemen have been sworn, as I recall, is that correct?

MR. TROSTEN: Yes, sir, they have.

Whereupon,

GERALD J. LAUER

JOHN P. LAWLER

HARRY WOODBURY

were recalled to the stand as witnesses on behalf of the Applicant, and, having been previously duly sworn, were examined and testified further as follows:

DIRECT EXAMINATION

MR. TROSTEN: Gentlemen, I show you the testimony and you have previously reviewed the testimony which I have identified which will be sponsored by you, and I ask if this testimony was prepared by you or under your supervision and direction, and are the contents of these written documents true and correct, to the best of your knowledge?

WITNESS LAUER: Yes, they are.

WITNESS LAWLER: Yes.

WITNESS WOODBURY: Yes.

MR. TROSTEN: Do you desire that these documents which I have identified as being sponsored by you, be received

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in this proceeding as your testimony?

WITNESS WOODBURY: Yes.

WITNESS LAUER: Yes.

WITNESS LAWLER: Yes.

MR. TROSTEN: Mr. Chairman, at this time, I ask that the documents which I have previously identified -- and I will summarize them again -- the testimony of Dr. Lauer dated October 30, the testimony of Dr. Lawler dated October 30, Appendix B-1, Appendix C, and Appendix E sponsored by Dr. Lawler, and Appendix G to be sponsored by Mr. Woodbury, be received in evidence in this proceeding and included in the transcript as if read.

MR. MACBETH: Any objection?

CHAIRMAN JENSCH: Any objection?

MR. MACBETH: I object to three parts of the testimony. Appendix G in its entirety, pages 26 to 33 of Dr. McFadden's testimony, and pages 79 and 80 of Dr. Lawler's testimony beginning where it says a study should be designed. All of those three pieces of testimony relate to proposed research program by Consolidated Edison, and I consider them to be irrelevant to the license for which Con Edison has applied which is a full term, full power operating license with no conditions requiring research.

I object to the -- to that part of Con Edison's testimony on the grounds it is irrelevant to the case they

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are trying to prove.

CHAIRMAN JENSCH: Let me see if I understand your statement. You are objecting insofar as these portions of testimony are -- relate to a research effort and your objection is since it has been suggested that there be this research, it should be with a condition; and lacking that phrase of "with a condition," you object?

MR. MACBETH: Yes. I think Con Edison has to really bite the bullet. I think they mean research, in which case they are asking for a condition in the license for research; or they don't want a condition. They are free from doing any research and this testiony is irrelevant and for all I know, is a smoke screen. I don't want to get into saying the company doesn't intend to do the research; but if they intend to do it, I don't see why they don't ask for a condition in the license that requires them to do it.

As long as they are not asking for such a condition, I think all this discussion of research is irrelevant to the license they are applying for.

CHAIRMAN JENSCH: Your objection is really to the form of commitment rather than the scope of research, is that correct?

MR. MACBETH: Yes. Obviously I would cross-examine about parts of the research program. My objection goes to the fact that Con Edison has not asked for any condition requiring mil

research be done.

CHAIRMAN JENSCH: Doesn't that come down to a question of the weight of the evidence that if it is as strong as you think it should be, that would warrant, in your opinion, the imposition of a condition; if it is not as strong as you think it should be, then it is a commitment that Con Edison apparently will undertake, but without the obligation of responding -- the condition to the operation of the plant?

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MR. MACBETH: What really baffles me at this point is that the party which says that no condition for research is needed is offering testimony which would seem to indicate that research is needed. I find it very difficult to make any coherence out of excatly what position Con Edison is taking that is relevant to the license conditions they have asked for.

CHAIRMAN JENSCH: One of your objections was, as I recall it, pages 26 to 33 of the McFadden testimony?

MR. MACBETH: Yes.

CHAIRMAN JENSCH: That hasn't been offered?

MR. TROSTEN: It will be in a moment.

CHAIRMAN JENSCH: You are anticipating that.

MR. MACBETH: It is the same objection in each case. So far we have only had Dr. Lawler and Appendix G, and I will for the moment restrict my objection to those two pieces.

(Board conference.)

CHAIRMAN JENSCH: The objections are overruled. The Board will give consideration to the importance, the weight, and the validity of the evidence when it has been thoroughly presented, and despite the request of the Applicant, either for a condition or not.

MR. KARMAN: We had no objection.

CHAIRMAN JENSCH: The Board believes it can be --

if the Board believes the condition should be imposed, it will be imposed.

Any further objections?

MR. KARMAN: We have no objections.

MR. MARTIN: No objections.

CHAIRMAN JENSCH: Taking each party serially, I will overrule and dispose of their objections.

Therefore the request of the Applicant is granted, and the testimony as reflected in the various forms described by Applicant's counsel for Witnesses Lauer, Lawler and Woodbury are received in evidence as if read, and may be incorporated within the transcript as if orally presented.

(The documents follow.)

APPENDIX G

Scope of Work for Ecological Studies at Indian Point

INDIAN POINT FIVE YEAR ECOLOGICAL STUDY

PROJECT SCOPE

The proposed five year ecological study will begin at full intensity on April 1, 1972.

The scope of work is proposed to accomplish the following major objectives:

(1) Evaluate the biological significance of impinging fishes at our intakes.

(2) Evaluate the biological significance of passing non-screenable organisms through the plants.

(3) Evaluate the biological changes in the Hudson River ecosystem due to thermal and chemical discharge.

Objective 1 - will be accomplished by estimating population density, natural mortality, age distribution of the population, food habits, movements and migration routes, growth rates, exploitation rate on the screens, etc. These estimates will be made by mark-recapture procedures, aging of the population, etc. from the Haverstraw Bay area to the Beacon Bridge by collecting fish with trawls, seines, fish traps, gill nets, etc.

Objective 2 - will be accomplished by determining the mortality rate of all nonscreenable organisms passing through the plants and predicting the biological significance of such a mortality rate on the Hudson River fishery.

Objective 3 - will be accomplished by a biological survey of all acquatic organisms, physical and chemical measurements at the Indian Point area compared with control regions and determining species diversity and biomass per area in each region.

These studies were recommended to Con Edison by the Lower Hudson River Policy Committee which is composed of members from agencies with regulatory responsibilities for the natural resources of the Hudson River. The studies will yield pertinent data necessary to evaluate the continuing environmental impact of Units No. 1, 2, and 3.

Radiological Investigation of the Aquatic Habitat of Hudson River

Project Scope: To determine radiological effects of Indian Point operation on the ecosystem. This is a continuing study, which originally commenced July 1969, which traces the fate of radionuclides released from the plant through the aquatic environment. This study, which commenced in July 1971 and continues through April 1973, consists of the following major study areas:

1. Routine sampling and analysis of water and sediment, rooted vascular plants and fish for radionuclides.
2. Provide an inventory of major long lived gamma emitting radionuclides.
3. Study the effect of salinity variation on the removal of radionuclides for the sediment.
4. Study of radionuclide content of phytoplankton and zooplankton.

More specifically, the radionuclide studies (1 above) conducted over the past two years have provided important information concerning the fate of radionuclides released to the Hudson River from the operation of the Indian Point facility. This current program will provide a continuing record of radionuclide levels which can be compared with past sampling results and will serve to provide baseline data for evaluating releases from Units 2 and 3 as they go into operation. The remaining three portions of the study are considered exploratory as opposed to monitoring. These three studies are expected to provide answers to the following questions:

1. What is the total inventory of radionuclides in the sediments of the lower Hudson River estuary? What fraction of Indian Point liquid radionuclide discharges deposit in the sediments, and in which location does most of this deposition occur?
2. What is the variation in radionuclide inventory of the bottom sediments along a longitudinal section of the river? Can quantitative differences in sediment radioactivity at points along this longitudinal section be correlated with difference in salinity?
3. To what extent do the phytoplankton and zooplankton of the estuary accumulate radionuclides of natural and artificial origin? How do such accumulated levels in the plankton relate to radionuclide concentrations in higher links in the food chain, and especially in fish which may be consumed by man?

This program has provided considerable information on the fate of radionuclides released to the Hudson River from the operation of the Indian Point facility. In particular, the studies have given perspectives to the relatively small quantities of these operational releases compared to radionuclides from weapons testing fallout and natural sources. A continuation of this program is necessary for two reasons. Foremost, the monitoring phase of this program is necessary to determine compliance with the Atomic Energy Commission radionuclide release limits as put forth in 10 CFR Part 20. Second, far more information is necessary of the pathway of radionuclides to man and the ultimate potential exposure to man from releases at Indian Point.

The information from this program is considered to be essential in preparing for AEC hearings upcoming of Unit 3 and conversion of the provisional Unit 1 license to a permanent license.

The importance of the information to date has already been shown in Unit 2 hearings where, based on information from these studies, the intervenors did not raise the question of radiological releases. It is essential, therefore, that this program be continued.

Fathometer Studies at Indian Point

Project Scope: The proposed study is a continuation of a survey of the density and distribution of fish in the vicinity of Indian Point. The specific objectives of the study are:

1. Describe and quantify the distribution of fish in relation to the termal discharge and intake screens.
2. To compare the density of fish in the vicinity of the plant with the quantity of fish removed from the intake.
3. To attempt to monitor the density of fish in the vicinity of the intakes during specific fish tests.

The echosounder will also be used by Texas Instruments in their five year ecological study so that fish density can be monitored during the sampling of fish with trawls.

Objectives 1 and 2 will be accomplished by surveying a set pattern of transects which include the entire plant site. The fish recorded on the echosounder tape are counted by areas and then a fish density figure is computed based on the area covered by the echosounder. A density of fish by volume will be computed and compared with the number of fish per volume removed to the intake screens.

Objective 3 will be accomplished by mounting the transducer of the echo-sounder to beam across an intake structure and to record fish approaching the intake.

Part 1 - Analysis of Fish Mortality Data at Indian Point

Project Scope: Data has been collected on fish impingement at Indian Point since April 1970 under the direction of the Office of Environmental Affairs. The number of fish caught on the screens has fluctuated over a wide range. The variables that could have affected the number of fish caught are various parameters of plant operation, such as flow, tempearature rise through the condensers, number of pumps and condensers in use, etc., and various environmental factors such as the influence of night versus day, the influence of tidal conditions, fresh water flow and associated salt water intrusion, temperature, etc. It is likely that some or several of these factors may have highly significant bearing on the fish impingement at Indian Point. The fish impingement data will be analyzed in accordance with standard statistical procedures using the facilities of a computer.

Part 2 - Fish Sampling at Indian Point Intakes

Project Scope:

1. Gather data on the seasonal occurrence, species composition, and size composition of the fish collected at the intakes.
2. Conduct tests of various fish protection devices and modes of operation.
3. Monitor fish at the intakes in order to document the rate of withdrawal.
4. Recover marked fish from the intake screens to establish a rate of exploitation by the intakes on selected fish populations.

Monitoring of fishes impinged at our intakes at Indian Point has been requested by the New York Department of Environmental Conservation. Also, to estimate the exploitation rate of fishes on our screens, the number of marked fishes (part of study A) collected on the screens has to be determined. The fish monitoring on the screens is also a pertinent part of the overall testing procedure, which is needed to determine the best intake design and mode of plant operation to reduce the impact of plant operations on fish populations.

Part 3 - Indian Point Flume Study

The proposed flume study at Indian Point is designed to investigate the behavior of white perch and other species in relation to water flows and fish protection devices.

Scope of Work:

1. Evaluate the behavior of white perch in relation to fixed and traveling screens.
2. Study the behavior of white perch at various velocities in order to predict behavior of fish at proposed common intake.
3. Evaluate the fish protection value of various devices proposed for Indian Point:
    a) horizontal traveling screen
    b) air bubbler
    c) sound

Objective (1) will be accomplished by exposing test groups of white perch (and other species) to various screen arrangements and observing (and recording on video tape) their avoidance responses. Factors which may influence the behavior of fish such as water temperature, diurnal activity cycle, salinity and size of fish will be tested. The high percentage of white perch collected at the screens indicates that they may display some unique behavioral problems.

Objective (2) will be accomplished by exposing test fish to a series of approach velocities (velocity immediately in front of screens) to determine if the fish will avoid the screens at the proposed common intake structure. Objective (3) will be accomplished by exposing test fish to various fish protection devices and recording their avoidance responses.

The study of the fish problem at Indian Point has revealed thus far that a reduction in approach velocity is an effective way of reducing the number of fish impinged on the intake screens. However, velocity reduction has not eliminated the problem and is only available as a method of fish protection during the winter months.

Laboratory tests of the swimming ability of white perch have indicated that the fish, in sizes caught in the intake screens, can swim at a speed in excess of the approach velocity now existing at Unit 1. This indicates that there is a behavioral problem since the fish does not exercise its ability to escape.

Attempts have been made to observe the behavior of fish in front of the screens with a diver and using underwater television. In both cases the turbidity of the water prevented visual observation of the fish. A test device (the flume) is designed to permit observation and recording of fish behavior.

Appendix C

General Comments on Dissolved Oxygen

QLM's measurements of dissolved oxygen in the vicinity of the Lovett Power Plant during summer in 1969 and 1970 and in the vicinity of Bowline Point during summer 1970 indicate that the majority of observed dissolved oxygen concentrations are above 5.0 mg/l (see attached table).

QLM analyzed the data and procedures of dissolved oxygen (D. O.) measurement by the Automatic Environmental System at Indian Point. This analysis indicated that the D. O. measurement systems from the intake and discharge were not calibrated at the same time, and the calibration was made approximately once a month. This is probably the reason for large differences between the intake and discharge readings of D. O. concentrations.

QLM made careful simultaneous measurements of the intake and discharge dissolved oxygen concentrations at Indian Point Unit #1 in December 1971. The tests and analytical determinations of D. O. were made in accordance with the most recent edition of Standard Methods for the Examination of Water and Waste Water. Water temperatures were measured using precision thermometers certified by the National Bureau of Standards.

During the survey, Unit No. 1 was operating at rated capacity and the cooling water flow was 204,000 gpm, i.e., throttled to about 85% design flow and average cooling water temperature rise was 16.4°F. The observed average intake concentration of D.O. was 10.48 mg/l and corresponding discharge concentration was 10.3 mg/l. This indicated average loss of D.O. of 0.18 mg/l in the Unit #1 cooling system. These measurements and QLM's mathematical model for D.O. were used for prediction of the dissolved oxygen loss in the Indian Point Unit No. 1 & 2 cooling system. The results of calculations indicate that the loss of oxygen in the system increases with increasing intake concentration of D.O. while the intake temperature is hold constant. For example, during severe summer conditions, when ambient temperature is 79°F, the loss of oxygen in the water cooling system would be as follows:

Intake D.O. mg/l	Loss of D.O. in the system mg/l
5.0	0.05
6.0	0.13
7.0	0.21

The response of the river to such a "sink" of dissolved oxygen was simulated by a mathematical model which included all major mechanisms affecting the river dissolved oxygen concentrations. Results of this model work were reported in a document entitled, "Effect of Indian Point Plant on Hudson River Dissolved Oxygen." A copy of this report is attached. It was determined, for example, that during summer conditions, with the river temperature of 79°F and D.O. concentration of 6.5 mg/l, the loss of dissolved oxygen in the Indian Point Unit #1 & 2 system would be 0.17 mg/l. This loss of oxygen would decrease the river D.O. at Indian Point by about 0.02 mg/l. If the Hudson River concentration is less than 6.5 mg/l, the loss in the system will be less than 0.17 mg/l and decrease of the river D.O. would be lower than 0.02 mg/l. Such an effect of the plant on D.O. is practically undetectable, using accepted procedures for D.O. measurements in flowing streams and can be neglected.

Besides the loss of D.O. in the plant water cooling system, the heat rejected to the river can affect the river concentrations of D.O. The analysis presented in QLM report entitled "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution, January 1968" indicate that the river D.O. concentration for the heated condition can be expected to be approximately 0.3 mg/l lower than that for the unheated condition

More detailed discussion of the dissolved oxygen effects of plant operation are included in testimony on this subject presented by Dr. Lawler to the ASLB on <u>January 11, 1972</u>, (Tr. 4428-4430).

HUDSON RIVER DISSOLVED OXYGEN CONCENTRATIONS OBSERVED BY QUIRK, LAWLER AND MATUSKY ENGINEERS

A) OBSERVATIONS AT LOVETT DURING AUGUST AND SEPTEMBER 1969

INTERVAL OF DISSOLVED OXYGEN CONCENTRATION mg/l	NUMBER OF OBSERVATIONS	PERCENT OF TOTAL OBSERVATIONS %
4.0	0	0
4.0-5.0	0	0
5.0-6.0	11	25.50
6.0-7.0	20	46.50
7.0	12	28.00
TOTAL	43	100.00

Ambient Temperature range: 77.5°F-68.3°F

Observed maximum 9.1 mg/l
Observed minimum 5-1 mg/l

B) OBSERVATIONS AT LOVETT DURING AUGUST THROUGH SEPTEMBER 1970

INTERVAL OF DISSOLVED OXYGEN CONCENTRATION mg/l	NUMBER OF OBSERVATIONS	PERCENT OF TOTAL OBSERVATIONS %
4.0	3	3.65
4.0-5.0	10	12.15
5.0-6.0	39	47.55
6.0-7.0	19	23.20
7.0	11	13.45
TOTAL	82	100.00

Ambient Temperature range: 79.0°F-71.0°F

Observed maximum 7.7 mg/l
Observed minimum 3.3 mg/l

C) OBSERVATIONS AT BOWLINE DURING JULY THROUGH SEPTEMBER 1970

INTERVAL OF DISSOLVED OXYGEN CONCENTRATION mg/l	NUMBER OF OBSERVATIONS	PERCENT OF TOTAL OBSERVATIONS %
4.0	0	0
4.0-5.0	18	17.50
5.0-6.0	71	68.90
6.0-7.0	14	13.60
7.0	0	0
TOTAL	103	100.00

Ambient Temperature range: 80.0°F-69.5°F

Observed maximum 6.6 mg/l
Observed minimum 4.3 mg/l

Consolidated Edison Company of New York, Inc.

EFFECT OF INDIAN POINT PLANT
ON HUDSON RIVER DISSOLVED OXYGEN

QL&M Job No. 115-19

February 1972

QUIRK, LAWLER & MATUSKY ENGINEERS
Environmental Science & Engineering Consultants
415 Route 303, Tappan, New York 10983

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SUMMARY OF FINDINGS AND CONCLUSIONS

1. The Indian Point nuclear generating station is located on the east bank of the Hudson River some 43 miles above the Battery. Cooling water withdrawn from the river removes excess heat from spent steam. The heated water is discharged back to the river at a point over 1,000 feet downstream from the intake structure.

Water passing through the power plant cooling system is exposed to an increase in temperature and to less than atmospheric pressure, both of which may affect the quantity of dissolved oxygen (D.O.) in the cooling water and subsequently, the D.O. concentrations in the river.

Gassing of oxygen from water will begin to occur at a point in the cooling system at which the oxygen concentration in the water is higher than the saturation concentration of oxygen corresponding to the temperature and pressure at that point. Gassed oxygen from the water creates bubbles which are carried by the water to the discharge, at which point they are released to the atmosphere. Some recompression of these bubbles may occur downstream of the condenser as the pressure increases back to its original condition. The effect of this process is considered to be small because of the short travel time in this section of the cooling system and because the reaeration is a slower process than the gassing.

The purpose of this report is to describe the effect on the dissolved oxygen content of the Hudson River water resulting from loss of D.O. during passage of the water through the plant.

The solution to this problem was developed in two phases. During the first phase (Item I), the loss of oxygen in the plant cooling system was calculated. The second phase utilizes the result of the conclusions reached in Phase I to calculate the corresponding changes in the Hudson River dissolved oxygen distribution (Item III).

2. The mathematical model of dissolved oxygen loss in the cooling system which was developed for the study recognized a linear relationship between the D.O. change over a certain period of time and the difference between saturation concentration and a given concentration of D.O. Dissolved oxygen solubility (saturation) is primarily a function of water temperature and pressure. Water temperatures and pressures in the cooling system were calculated using available cooling system characteristics and were expressed as functions of location in the system and were related to cooling water travel time between the intake and discharge.

For purposes of calculation, the cooling systems of both generating units were divided into several reaches. All calculations were initiated at the upstream reach with the entering dissolved oxygen concentration equal to the river concentration at the intake. The concentration at the end point of the first reach was used as an initial concentration for the subsequent reach. The calculations were repeated until the final D.O. concentration in the effluent from the condensers were determined. Loss of oxygen in the total system was computed as a difference between the intake and discharge values.

The rate coefficient of oxygen gassing was determined using the model and QL&M measurements of dissolved oxygen taken at the intake and discharge structures of Indian Point Unit No. 1. The tests and analytical determinations of dissolved oxygen were made in accordance with the most recent edition (13) of Standard Methods for the Examination of Water and Waste Water. Water temperatures were measured using precision thermometers certified by the National Bureau of Standards.

During the D.O. measurement survey, Unit No. 1 was operating at rated capacity and the cooling water flow was 204,000 gpm, i.e., throttled to about 85% of design flow and average cooling water temperature rise was 16.4°F. The observed average intake concentration of dissolved oxygen of 10.48 mg/l and the average loss of 0.18 mg/l in the cooling system indicates a rate coefficient of oxygen gassing of 9.0×10^{-3}/sec. which corresponds to 780/day.

3. Modelling of the Hudson River response to the inplant dissolved oxygen loss included mechanisms of (a) municipal and industrial liquid waste discharge, (b) transport by advection and dispersion, (c) first-order bio-oxidation, (d) reaeration, (e) benthic oxygen uptake and (f) a zero-order constant to account for other mechanisms such as addition of B.O.D. due to organism mortality, addition of D.O. by algal photosynthesis, etc.

For purposes of this model, the Hudson River was divided into 25 segments between the Troy Dam and the Battery. Material balances of B.O.D. and D.O. were developed for each segment and a set of 56 simultaneous equations were generated by inserting the segment B.O.D. and D.O. solutions into the appropriate boundary conditions. The simultaneous equations were solved on a digital computer using matrix inversion.

The effect of the Indian Point plant was introduced into the model as a direct withdrawal of oxygen from the segments adjacent to the plant. For each condition studied, runs with and without the plant in operation were modelled to determine the differences of river dissolved oxygen content and concentrations.

4. Further broadly catagorized summer and winter conditions were used to reflect the seasonal differences in river freshwater flow, dispersion and temperature with the corresponding river dissolved oxygen concentrations and saturations and the difference in the plant operational characteristics such as rate and in-plant temperature rise of cooling water flow.

The prediction runs were made for the 1971 and future (1990) levels of river dissolved oxygen concentrations. The future conditions were characterized by an increase in river dissolved oxygen recognizing a planned higher level of wastewater discharge treatments in the future.

Analytical results of the effects of in-plant loss of D.O. on river water under all conditions used in this report are summarized in Table S-1.

5. The results of the analyses indicate that the loss of dissolved oxygen

TABLE S-1

EFFECT OF INPLANT DISSOLVED OXYGEN LOSS ON HUDSON RIVER

DISSOLVED OXYGEN DISTRIBUTION AT INDIAN POINT

Item	Present Condition			Future Conditions		
	Summer	Winter		Summer	Winter	
RIVER PARAMETERS						
River ambient temperature, °F	79	33	50	79	33	50
Freshwater flow, cfs	4,000	12,500		4,000	12,500	
River ambient D.O. concentration at I.P., mg/l	6.5	11.3	9.0	7.5	11.7	9.7
PLANT PARAMETERS						
Intake temperature, °F	79	33	50	79	33	50
Plant cooling water temp. rise, °F	14.8	24.7	24.7	14.8	24.7	24.7
Discharge Temperature (rounded), °F	94.0	58.0	75.0	94.0	58.0	75.0
Cooling water flow, cfs	2,500	1,500*	1,500*	2,500	1,500*	1,500*
D.O. saturation, mg/l						
- at intake	8.2	14.4	11.3	8.2	14.4	11.3
- at discharge	7.2	10.3	8.5	7.2	10.3	8.5
INPLANT LOSS OF DISSOLVED OXYGEN FROM THE COOLING WATER						
Intake D.O. concentration i.e., ambient conditions, mg/l	6.5	11.3	9.0	7.5	11.7	9.7
Discharge D.O. concentration (rounded), mg/l	6.3	10.9	8.6	7.2	11.2	9.3
Inplant loss of D.O.						
- lb/day	2,300	3,400	2,500	3,500	3,800	3,200
- mg/l	0.17	0.42	0.31	0.26	0.47	0.40
EFFECT ON HUDSON RIVER DISSOLVED OXYGEN DISTRIBUTION						
River ambient D.O. concentration at I.P., mg/l	6.5	11.3	9.0	7.5	11.7	9.7
River D.O. concentration at I.P. including plant operation (rounded), mg/l	6.48	11.27	8.88	7.47	11.67	9.67
Decrease in river D.O. concentration at I.P.						
- mg/l (rounded)	0.02	0.03	0.02	0.03	0.03	0.03
- % of ambient concentration	0.30	0.26	0.24	0.35	0.28	0.28
% of total Lower Hudson River Content	0.07	0.06	0.03	0.07	0.06	0.06

* The cooling water flow throttled to about 60% of full flow during winter months

of about 0.2 mg/l during summer and 0.4 mg/l during winter in Indian Point Units 1 and 2 water cooling systems will decrease Hudson River dissolved oxygen concentrations at Indian Point by about 0.3% (0.02 mg/l) and 0.25% (0.03 mg/l) during summer winter months, respectively. The corresponding decrease in total Hudson River dissolved oxygen content will range from 0.06% to 0.07% of the ambient content without the plant in operation.

These effects are insignificant in comparison with other deoxygenation processes and are below the minimum detectable concentrations of dissolved oxygen, using accepted procedures for D.O. measurement in flowing streams.

The New York State standard for dissolved oxygen in tidal waters is 5 mg/l. The present D.O. levels in the Hudson River at Indian Point are normally well above this value. Even if such an occassion were to occur in which the river D.O. concentration falls to 5 mg/l, no observable effect of the inplant D.O. loss on dissolved oxygen in the Hudson River would occur.

Memo To: Dr. Anthony J. Sartor, Office of Environmental Affairs
Consolidated Edison Company of New York, Inc.

From: Dr. Karel A. Konrad, Project Engineer

Date: February 4, 1972

Subject: Effect of Indian Point Plant on Hudson River Dissolved Oxygen

The nuclear power plant at Indian Point is located on the east bank of the Hudson River some 43 miles above the Battery. Cooling water withdrawn from the Hudson River is used to remove excessive heat from spent steam. Heated water is discharged back into the river more than 1,000 feet downstream of the intake structure. Figures 1 and 2* show the location of the Indian Point site and details of the intake and discharge structures.

The cooling water flow of Indian Point Units Nos. 1 and 2 is 1,120,000 gpm. The heat transferred into the cooling water in the condensers increases the water temperature by about 15°F. Additionally, water passing through the cooling system experiences changes in pressure. In some regions of the cooling water system, this pressure drops below that of the atmosphere. This is due to the design of the system taking an advantage of the well known siphon effect. The advantage of such a design is that less power is needed to circulate water through the system.

The plant temperature rise and pressure changes affect the concentration of dissolved oxygen.

The purpose of this memorandum report is to estimate the change of dissolved oxygen concentration in water passing through the Indian Point Units Nos. 1 and 2 cooling water system and subsequently, the effect of the plant operation on the Hudson River dissolved oxygen concentrations.

I. Change of Dissolved Oxygen Concentration in Water passing through the Indian Point Units #1 and 2 Cooling Water System

A. Theoretical Considerations

Considering a non-variable quality of water in the cooling system, the solubility (saturation) of oxygen in water is determined by the pressure in the pipe and by the temperature of water.

If, at a given point, the solubility of oxygen is less than the actual concentration of dissolved oxygen in the water particles passing the point, oxygen will tend to be released from water (gassing). The rate of change is proportional to the difference between the saturation and actual concentration of oxygen. This can be expressed by a differential equation as follows:

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* Report figures and tables follow the text.

$$\frac{dC}{dt} = K(C_s - C) \qquad \text{...(1)}$$

where:

C_s = the saturation of oxygen in water at a given temperature and pressure
C = the actual concentration of dissolved oxygen (D.O.)
t = time
K = coefficient

For purposes of this study, the cooling system of both units 1 and 2 can be divided into five consecutive regions. (See Figure 3)

Region 1 - Suction pipe of cooling water pumps

The temperature of water passing through the suction pipe is equal to the river temperature and is constant along the pipe.

The pressure decreases from the intake to some minimum just before the cooling water pumps. This decrease of pressure (below the atmospheric pressure) can cause gassing of oxygen. However, the travel time through the suction pipe is very small and the amount of oxygen released from the water will be small. Furthermore, in the second part of the cooling system the oxygen loss will be recovered due to relatively high pressure. Therefore, Region 1 of the cooling system will be omitted in the calculations.

Region 2 - Pipe downstream of the cooling water pumps up to the inlet to the condenser

This part of the cooling system is characterized by constant water temperature equal to the river temperature and pressure decreasing from a maximum just after the pumps to a minimum at the entrace to the condenser. This minimum pressure is generally less than atmospheric pressure.

From a location where the pressure is dropping below the atmospheric pressure (or more accurately, from a location where C_s=C) the oxygen will again be released from water creating bubbles over the entire cross-sectional area. These bubbles will be transported by the flow through the condenser to the discharge channel which has an open surface, where they will be released to the atmosphere.

Region 3 - The Condenser

The condenser region is characterized by an increase of temperature from a minimum at the inlet ($T=T_R$) to a maximum at the outlet box of the condenser ($T=T_R+\Delta T_D$). The pressure decreases from the inlet to the outlet box due to the friction losses in the condenser. The gassing of dissolved oxygen continues throughout this region.

For practical calculation, this part is simplified in such a manner as to compute conservative results, i.e., the increase in cooling water temperature due to the condenser is assumed to occur instantaneously at the inlet, and the temperature is constant through the condenser. However, as will be shown later the temperature rise effect is not significant compared to the pressure drop influence.

Region 4 - Pipe between the condenser and the discharge channel

The water temperature is constant and is equal to temperature in the condenser ($T_P = T_R + \Delta T_P$).

The pressure increases from a minimum at the condenser outlet box to a maximum (atmospheric) at the outlet of the pipe.

Some recovery of oxygen loss should be expected due to an increase of the pressure. The travel time through this pipe, however, is small and, therefore, this effect is neglected in the calculations.

Region 5 - Discharge canal with a free water surface

The temperature as well as the pressure, is assumed constant along the channel and the oxygen bubbles formed in Region 2 begin transport across the free water surface.

The solubility of oxygen in water can be approximated using Henry's Law:

$$X_A = \frac{P_A}{H} \qquad \ldots(2)$$

where:

X_A = mole fraction of oxygen in the water
P_A = partial pressure of oxygen in air, atm.
H = Henry's factor, which is a function of the temperature and pressure

Henry's factor is considered constant for a given temperature of water and for pressures equal to or less than 1.0 atm.[1]

The relationship between the mole fraction of oxygen dissolved in water and the solubility of oxygen is as follows:

$$X_A = \frac{\frac{C_s}{32}}{\frac{C_s}{32} \quad \frac{10^6}{18}} \qquad \ldots(3)$$

where:

C_s = the solubility (saturation) of oxygen in water, ppm (or mg/l)
32,18 = molecular weights of oxygen (O_2) and water, respectively.

Solution of Equation 3 for C_s yeilds:

$$C_s = \frac{X_A}{(1-X_A)} \frac{32}{18} 10^6 \qquad \ldots(4)$$

Because the mole fraction of oxygen under consideration will always be small (in the order of 10^{-6}), equation 4 can be simplified:

$$C_s = X_A \frac{32}{18} 10^6 \qquad \ldots(5)$$

Substitution of Equation 2 into Equation 5 yields:

$$C_s = \frac{P_A}{H} \frac{32}{18} 10^6 \qquad \ldots(6)$$

In regions of interest to this study, i.e., regions 1, 2... the partial pressure of oxygen is always less than 1.0 atm. and, therefore, Henry's constant will only be a funtion of the water temperature.

Furthermore, the water temperature is considered to be constant for each region. This means that for a given region of the cooling water system, Henry's constant is fixed.

The partial pressure of oxygen in air can be expressed as follows:

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of)
)
Consolidated Edison Company of) Docket No. 50-247
New York, Inc.)
(Indian Point Station, Unit No. 2))

Testimony of
Gerald J. Lauer, Ph.D.
New York University
on
Effects of Operations of Indian Point Units 1 and 2 on Hudson River Biota

October 30, 1972

Summary

This testimony presents the results of studies performed by New York University from April 1971 to September 1972 at Indian Point for the purpose of determining the effects of Indian Point Unit 1 and 2 plant operations on bacteria, phytoplankton, zooplankton, and fish eggs and larvae and my conclusions based upon these results and related studies. This testimony supplements my testimony of April 5, 1972 on "Effects of Elevated Temperatures and Entrainment on Hudson River Biota."

In summary, it is my opinion that:

1. The plants will have a negligible impact on the river populations of bacteria.

2. Phytoplankton metabolisms will be stimulated during most of the year and will be inhibited under certain circumstances during the summer months (both as measured by carbon 14 uptake). No significant changes in abundance or composition of phytoplankton populations in the Hudson River will occur as a result of planned operations of the two units.

3. No significant effect on zooplankton abundance in the Hudson River (particularly Gammarus and Neomysis) will result from planned operation of both units.

4. In view of the foregoing, there should not be a significant adverse impact on the aquatic food web as the result of the effects of the plants on bacteria, phytoplankton and zooplankton.

5. Laboratory temperature tolerance studies show that striped bass eggs and larvae will be able to tolerate the temperatures experienced passing through Indian Point Units 1 and 2. The exceptions are the newly hatched larvae and the latter portion of the occurrence of post yolk-sac larvae occurring at Indian Point each season that may experience temperature elevations while passing through the plant 1 to 4°F higher than their maximum safe temperatures. A first approximation of the effects of passage of white perch and striped bass larvae through Indian Point Unit 1 is that approximately 54% survive in apparently healthy condition.

Introduction

Evaluation of thermal impact and its regulation must be done on a site by site basis because of the unique characteristics of each site. This is the informed professional opinion contained in committee reports of the National Technical Advisory Committee to the Secretary of the Interior (1968), the National Academy of Engineering (1971), and the National Academy of Science (1972).

It follows that data from studies conducted at the site of a power plant, expecially an operating power plant of similar design, are most relevant for evaluating the potential impact on aquatic life by a new plant such as Unit 2 at Indian Point.

During the past two years approximately twelve full-time and up to seven part-time researchers have been conducting studies specifically to determine the actual effects of Indian Point Unit 1 operation and the probable effects of Unit 2 operation on Hudson River bacteria, phytoplankton, invertebrate zooplankton and fish eggs and larvae. This is one of the most intense and comprehensive study-efforts ever conducted at a single power plant site. A voluminous amount of data have been gathered. I am presenting in support of my conclusions in this testimony graphs and tables which contain a very condensed summary of these data, in order that the most pertinent finding be distinguishable from what would otherwise be a confusing profusion of data.

Optimum temperature for growth of aquatic bacteria is 95°F, based on literature. The maximum temperature through the Unit 2 condensers during the ambient summer temperature condition is 93-94°F. Since the ambient river temperature is lower than optimum for growth, the elevated temperature through the cooling system of the Indian Point plant would tend to stimulate metabolism and growth, but any net growth would be moderate due to the relatively short time that water borne bacteria would be exposed to elevated temperature.

Laboratory temperature tolerance data reported in my testimony of April 5, 1972 indicated that Hudson River bacteria numbers counted by the membrane filter method would not be reduced by the maximum temperature rises produced by Unit 2 in winter (29.5) or in summer (15.1°F).

This was verified by Adenosine tri-phosphate (ATP) measurements of samples taken at the Unit 1 intake, condenser water boxes and discharge canal locations designated on Figure 1 from September through December, 1971. ATP concentration is a measure of total viable biomass. The samples were filtered prior to extraction in order to remove organisms larger than 76μ. The ATP concentrations were essentially the same at all locations (Figure 2) except during periods of chlorination. Reduction during periods of chlorination is evident in Figure 3. The chlorination schedules planned for Unit 1 and 2 combined would involve six hours per week or approximately 4 percent of the time. Con Edison is testing a schedule of reduced application of chlorine which would reduce chlorination to less than 2 percent of the time. The maximum cooling water requirement of Units 1 and 2 (2635 cfs) is about

1.0 to 1.5% of the total average

Schematic of Indian Point Cooling Water System

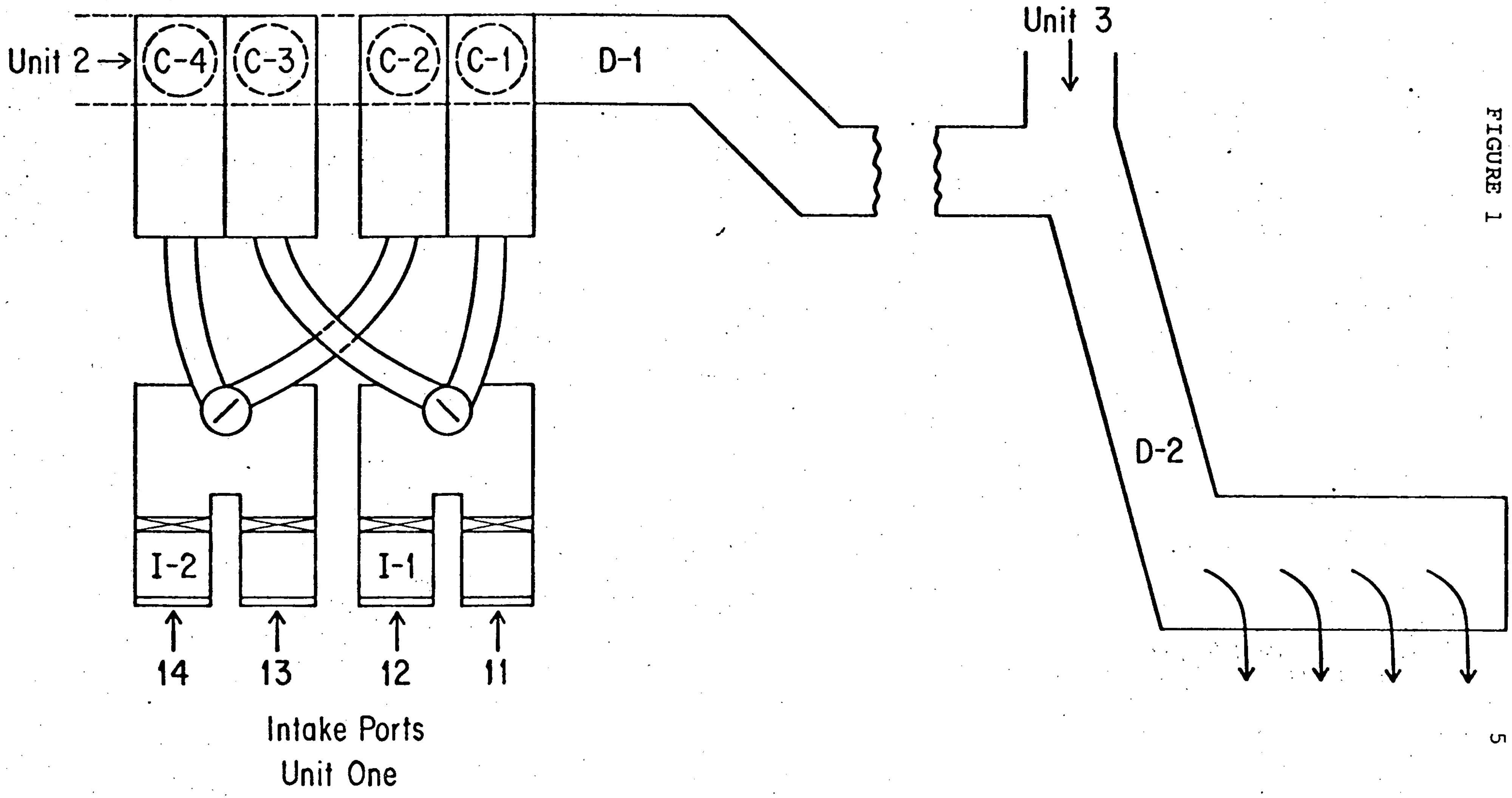


FIGURE 1

FIGURE 2

ATP Content of Unchlorinated Cooling Water at Indian Point Unit 1 on the Hudson River Estuary

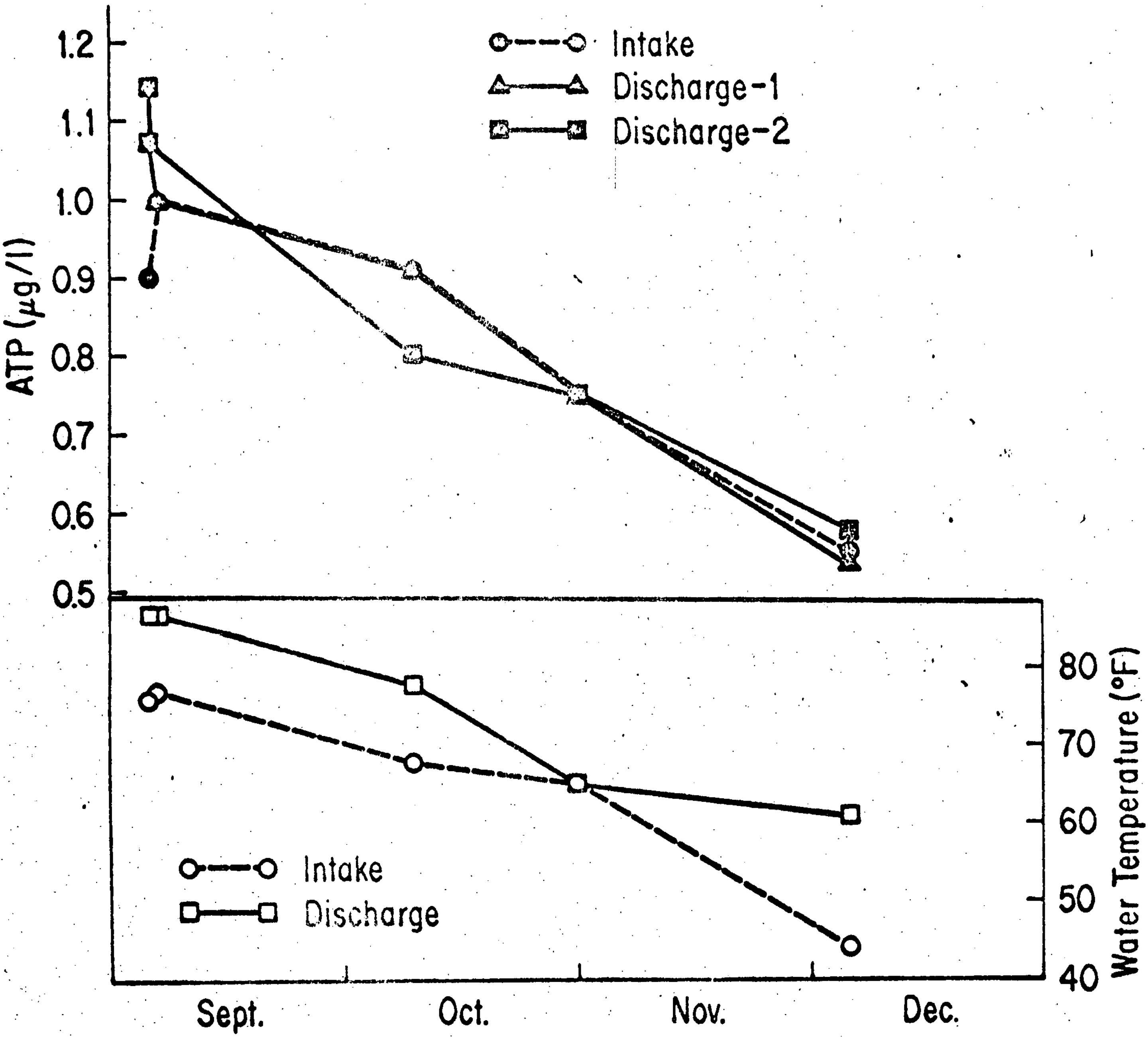
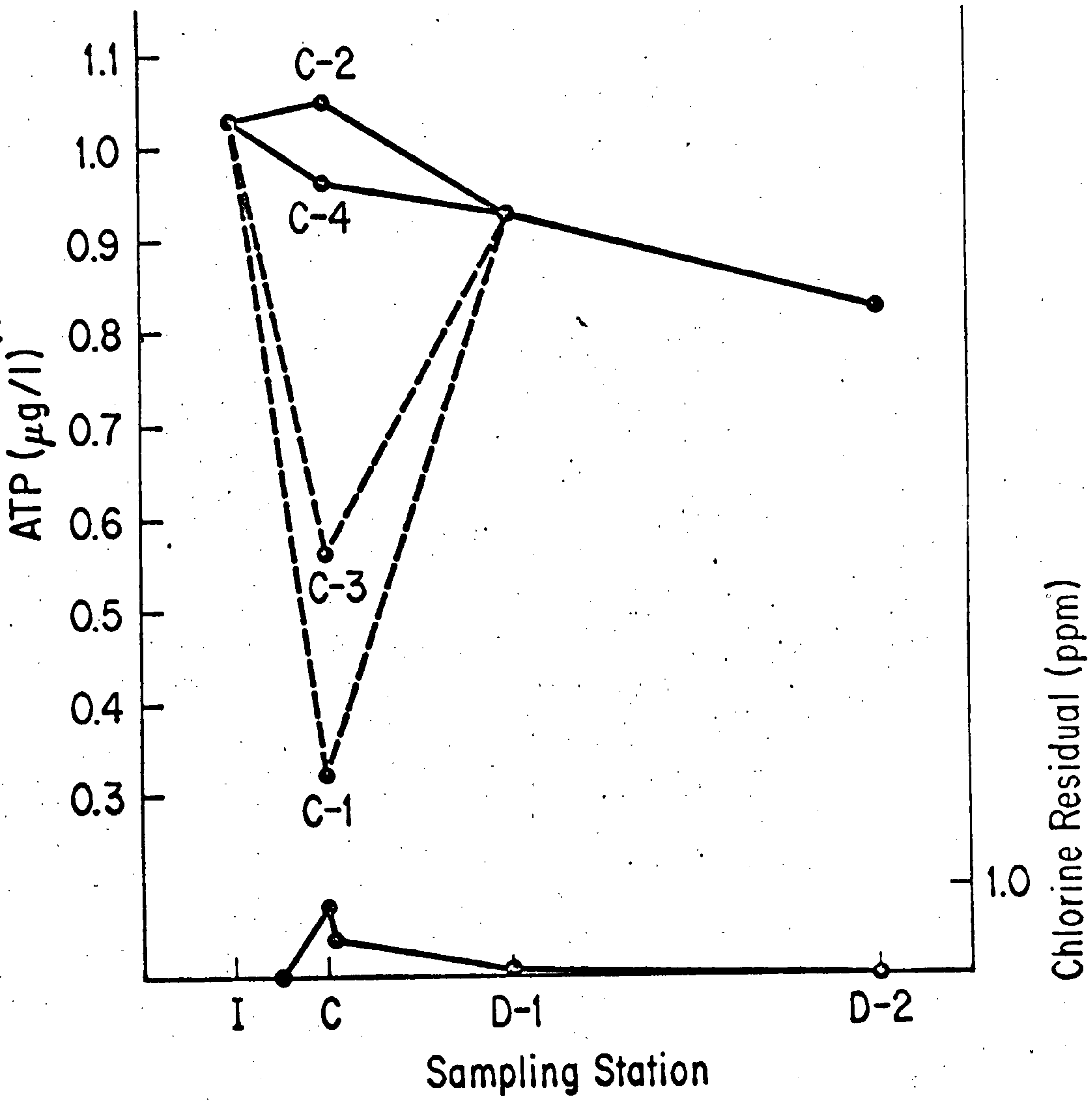


FIGURE 3

ATP in Cooling Water System of Indian Point Unit 1 on the Hudson River Estuary

7 September 1971
Ambient Temp. 77°F.; ΔT=11°F.
Condensers 1&3 Chlorinated
Condensers 2&4 Not Chlorinated



(1) Each point is mean of 3 samples; 5 replicates per sample.

river flow past the plant. Considering these very small percentages, the short generation time of bacteria, and the tendency of the elevated temperature to stimulate growth during the other 96% of the time when chlorine is not used, the net impact of Indian Point Unit 1 and 2 operation on river populations is expected to be negligible.

Phytoplankton

Laboratory thermal tolerance data from 1971 based on ^{14}C uptake capability, which I reported in my April 5 testimony, indicated that Hudson River phytoplankton could tolerate the maximum temperatures expected through Unit 2 in the summer.

During 1972, flows in Unit 1 have been reduced on specified days to ΔT's equivalent to those expected for Unit 2. Comparison of ^{14}C uptake capability of samples from the Unit 1 intake with those from the condenser water boxes and discharge canal stations D-1 and D-2 completed so far in 1972 usually indicated stimulation of ^{14}C uptake in the water box and discharge canal samples when the circulating water temperatures were less than 90°F. Results were more variable at temperatures above 90°F but frequency of inhibitions increased (Table 1).

At rated capacity operating ΔT of 15.1°F, the temperature through the Unit 2 condensers during 1971 would have exceeded 90°F from about July 1 through September (Figure 4) when the ambient river temperature exceeded 75°F (24°C).

TABLE 1

1972

		Temperature °F					Elevated Temperature only, % change in ^{14}C uptake compared to Intake					Elevated Temperature plus chlorine, % change in ^{14}C uptake compared to Intake					Total Chlorine Residual (ppm)				
Date	Ambient Temp.	WB	D$_1$	D$_2$	Plume$_1$	Plume$_2$	WB	D$_1$	D$_2$	Plume$_1$	Plume$_2$	WB	D$_1$	D$_2$	Plume$_1$	Plume$_2$	WB	D$_1$	D$_2$	Plume$_1$	Plume$_2$
1/11*	36	56	43				+13					-100	-66				.8	.1	.1		
5/24*	59	68	68	68				+34	+38			-100	-92	-99			.6	.1	.1		
5/30*	63	70	68	68				+59	+15			-89	-87	-92			.6	.1	.1		
6/5*	66	77	77	77				+21	+37			+2	+9	+7			.6	<.1	<.1		
6/6*	68	78	78	78				+15	+13			+26	+28	+5			.5	<.1	<.1		
6/15*	68	75	73	73								-70	+2	-64			.7	.1	.1		
6/20*	69	69	69	69								-51	-50	-37			.3	<.1	<.1		
6/29*	68	68	68	68								-54	-61	-100			.15	<.1	<.1		
7/10*	71	76	76	76								-24	-55	+11			.6	.1	.1		
7/20	76	87	86	86			+19	+65	+31												
8/1	78	93	92	91			-7	-59	-53			-79	-39	-100			.45[1]	.21[1]	.13[1]		
8/3	78	88	88	88			+53					-69	-76	-58			.35	.12			
8/8	78	85	88	85			+11	+1	+16			-74		-30			.3	.09	.075		
8/10	76	90	90	90	84	82	-11	-3	-11	+6		-66	-48	-25	+45	-53	.24	.08	.045	0	0
8/15	76	91	88	88			-16	-30	-10			-64	-51	-21			.28	.1	.07		
8/17	76	92	91	91			+61	+52	+51			-93	-55	-42			.2	.06	.09		
8/29	77	89	88	88			-35	+17	-32												
	77	93	91	91			+47					-98	-76	-42			.22	.08	.11		
9/5	78	93	92				+9	+23													
	78	93	93	92	85	80						-82	-100	+16	-13	-15	.26	.12	.01	0	0
9/12	75	89	86	86	80	78	-15	+23	-5	+26	+19										
	75	88	81	81	80	78						-100	-65	-16	-2	-20	.23	.06	.11	0	0

TABLE 1 (cont'd)

* Dates when chlorine determination done by Consolidated Edison.

(1) Chlorine residual data above this line were determined by the method, data below ere determined by the amperometric method.

Surface Temperature and Dissolved Oxygen Levels in the Hudson River in the Vicinity of Indian Point, 1971

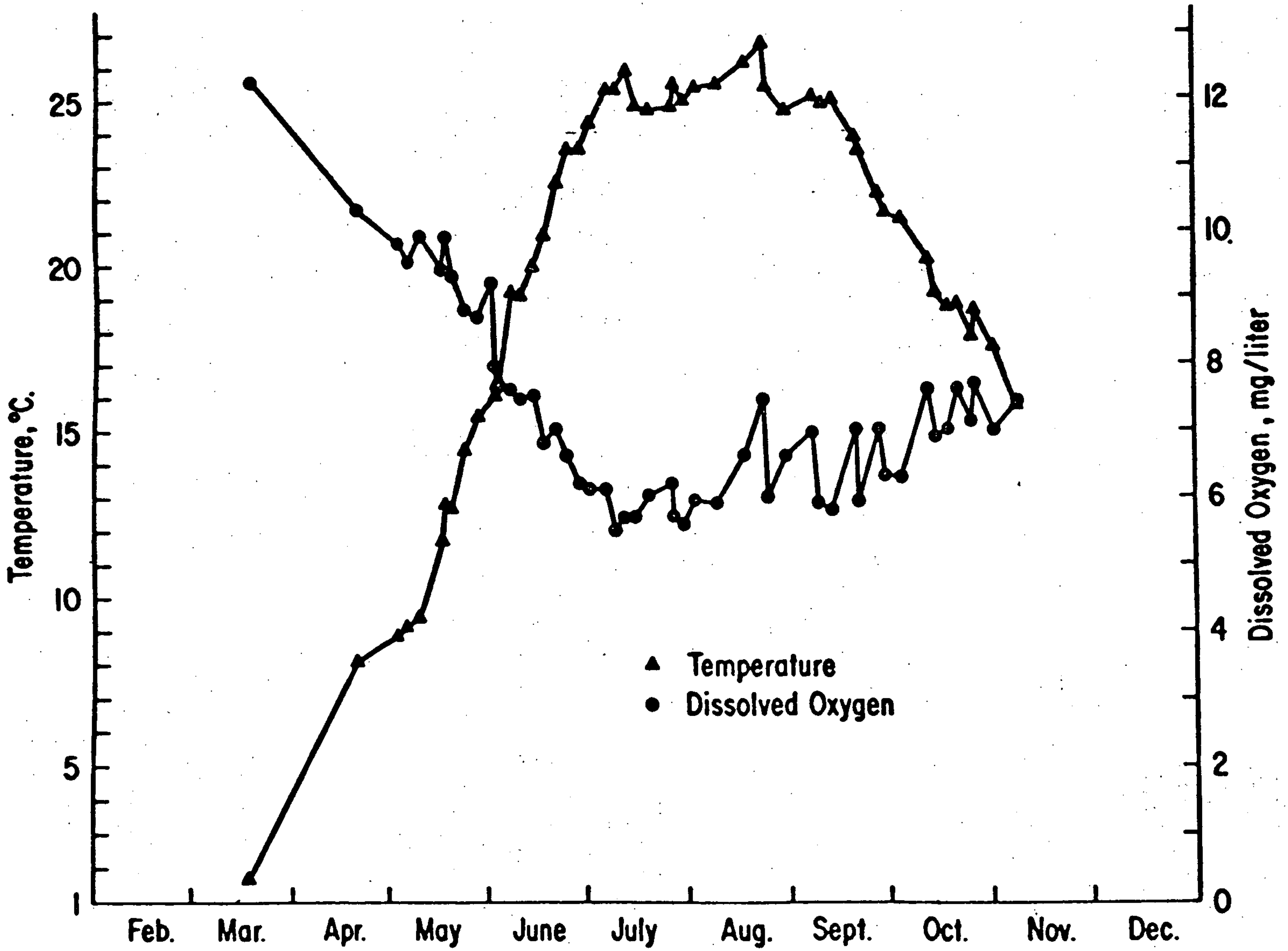


FIGURE 4

Uptake of ^{14}C by phytoplankton in samples taken during chlorination was usually inhibited to a substantial degree. There was frequently a tend toward decreased inhibition with passage from the condenser water box to station D-1. The samples from the water box had not been diluted whereas the water from the chlorinated condenser bank had mixed with water from the unchlorinated bank by the time it reached discharge canal stations D-1 and D-2. What degree and kind of damage ^{14}C uptake inhibition reflects is uncertain.

The Unit 1 ΔT was not high enough in 1971 to produce condenser temperatures higher than 90°F, but chlorine was used.

The average number of phytoplanktonic organisms per liter for all 7 field stations (abundance) by collection date, for both night and day, is shown in Figure 5 for 1971. Calculation of the arithmetic mean (60,908) and geometric mean (32,055) was based on all the daytime results only.

Analysis of variance of the logarithms of phytoplankton abundance indicate no significant differences in variance attributable to station effects in either the day or night results at the 0.05 level of significance. Student-Newman-Keuls analysis (Q=0.05) indicate no significant differences between stations for day-time results. Usage of the t-test for paired results indicated no significant difference in abundance between the night and day results at the 0.05 level. This means that phytoplankton abundance at station E nearest the discharge structure was not significantly different from

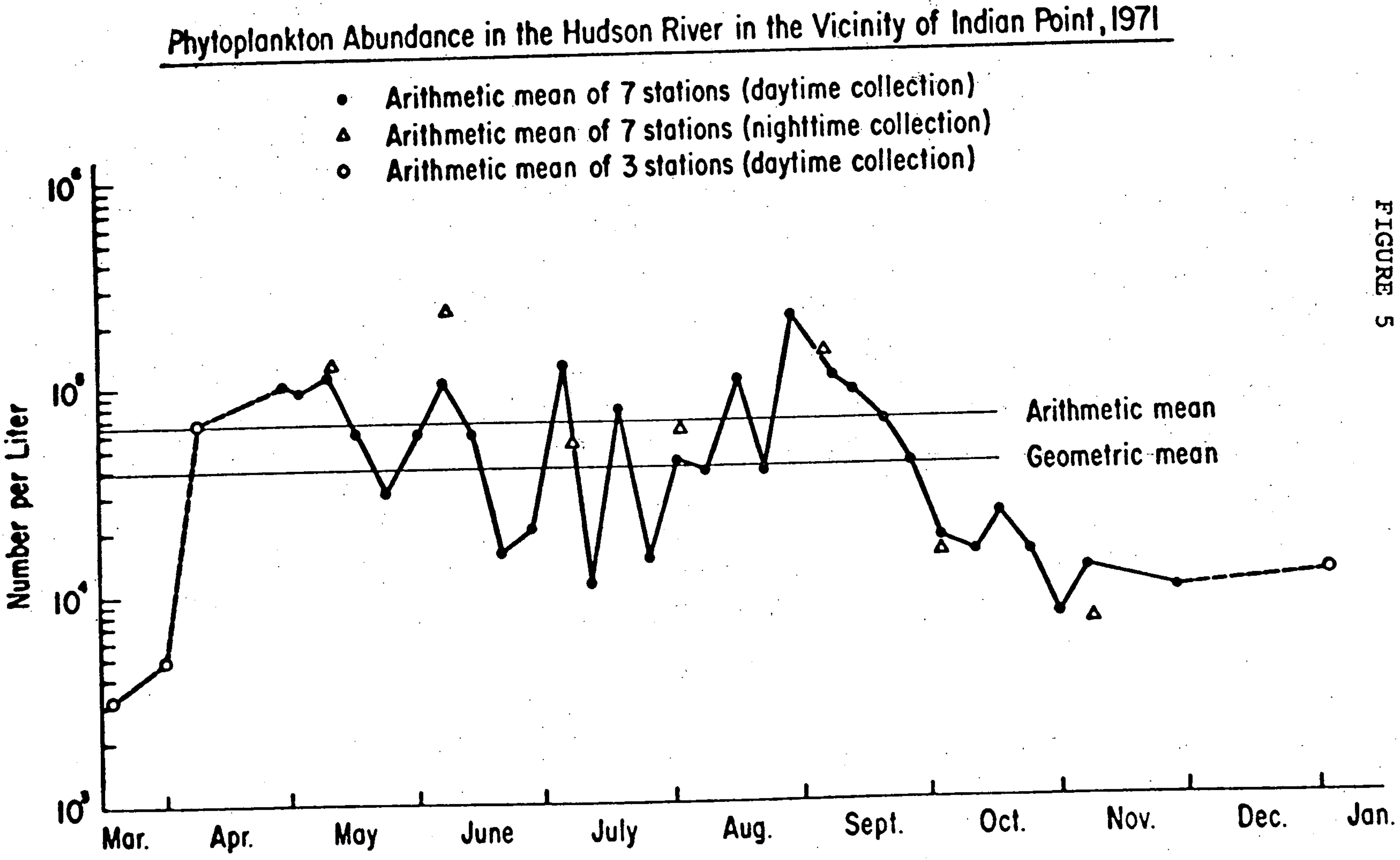
Phytoplankton Abundance in the Hudson River in the Vicinity of Indian Point, 1971
● Arithmetic mean of 7 stations (daytime collection)
△ Arithmetic mean of 7 stations (nighttime collection)
○ Arithmetic mean of 3 stations (daytime collection)
Number per Liter
10^6
10^5
10^4
10^3
Arithmetic mean
Geometric mean
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.

FIGURE 5

the other stations farther away (Figure 6).

Similar results (no significant differences) were found for the percentage composition by the major algal groups for both night and day results (Analysis of variance of arcsin transformations). Figure 7 shows the seasonal pattern of dominance for all stations during 1971.

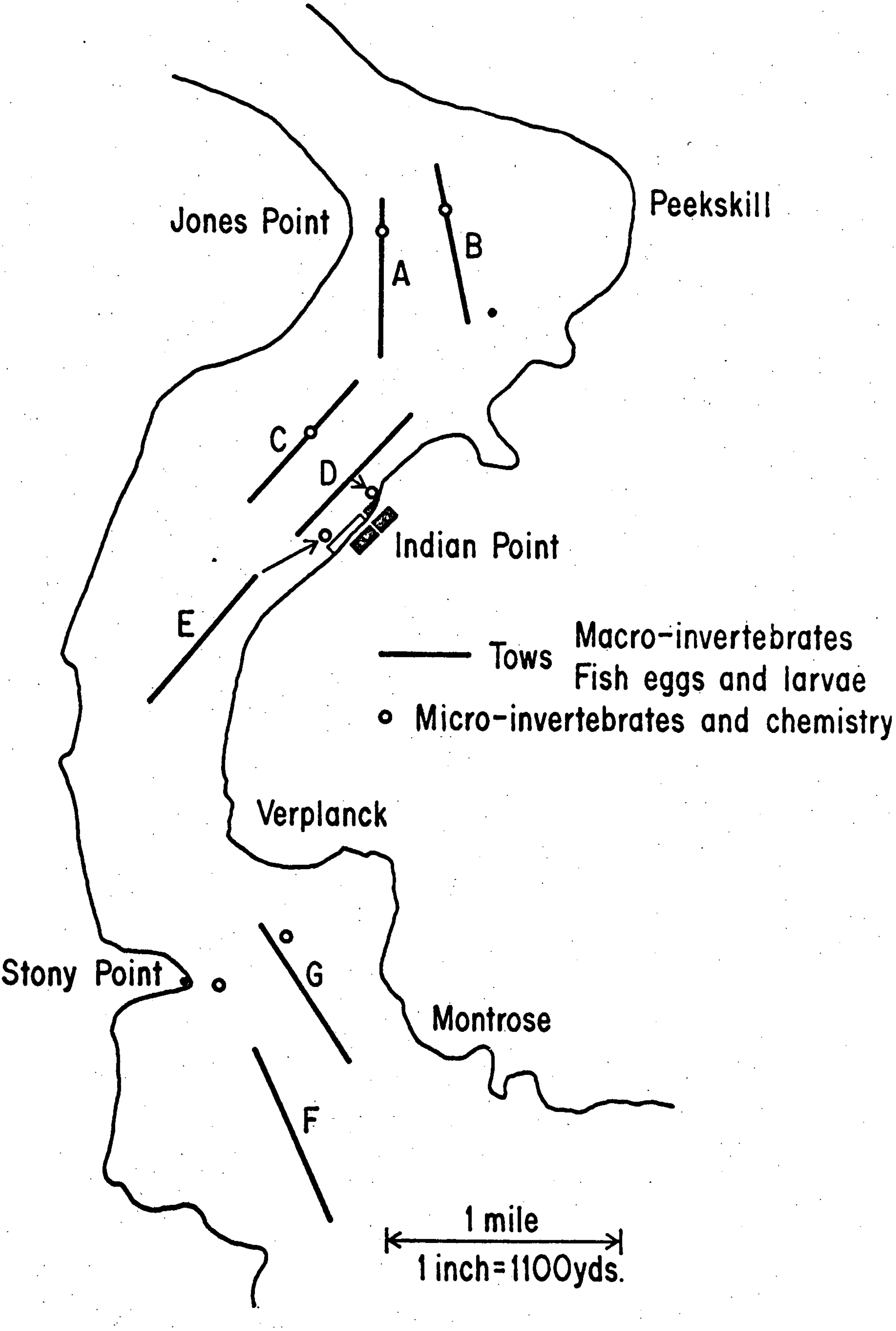
Of the 125 species or growth forms observed, 58 were found at all seven sampling sites, and, while station F had the fewest (79), station E had the highest (95) number of species. New York University studies during 1968-70 indicate that this seasonal pattern occurs at least as far upstream as Hyde Park (mile 77), far beyond any possible influence of Indian Point. It appears to develop upstream and move down into the Indian Point area. Indian Point Unit 1 did not operate during the summer of 1970 but the seasonal change in species composition occurred as usual.

As reported in the April 5 testimony for other years, Unit 1 caused no evident changes in Hudson River phytoplankton populations near the plant compared to more distant sampling points during 1968-70. The 1972 ^{14}C uptake rate studies indicate that the higher ΔT of Unit 2 when operating at full capacity would cause inhibition of photosynthetic rate by entrained phytoplankton during a period of about three months in the summer, and during chlorination.

The elevated temperature will tend to stimulate photosynthesis of entrained phytoplankton when the Unit 2 ΔT is less than $12^{o}F$ in the summer, and throughout the other approximately

FIGURE 6

New York University
1971 Hudson River Sampling Stations



Phytoplankton - Percent Composition, Hudson River - 1971

(mean of 7 sites of daytime collections)

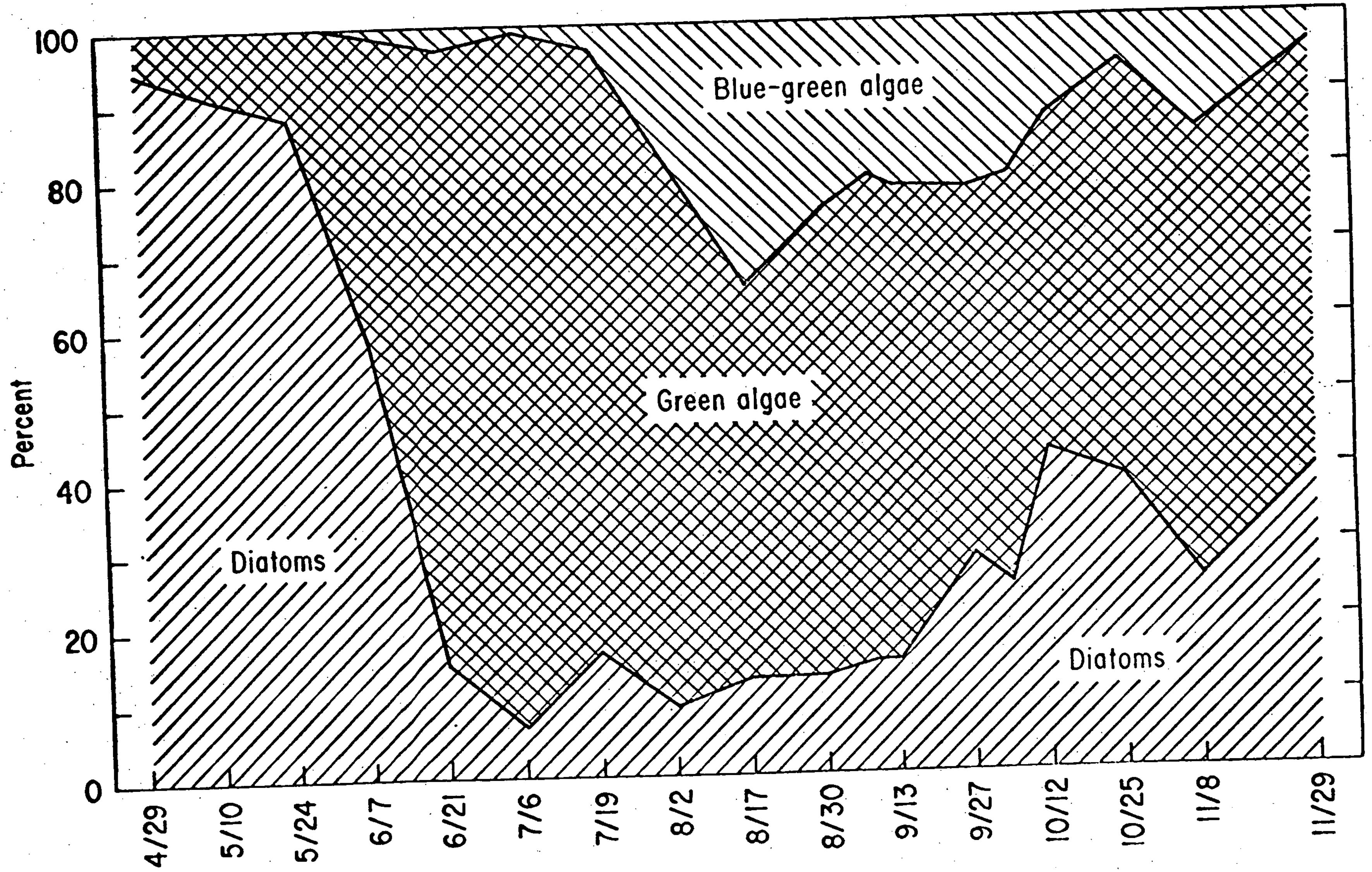


FIGURE 7

nine months of the year. Water temperature elevations in the plume from Units 1 and 2 will tend to stimulate photosynthesis throughout the year.

The Hudson River phytoplankton populations will experience no significant changes in abundance or species composition due to the operation of Units 1 and 2 in my opinion. The bases of this opinion are: 1) the lack of evident changes during four years of study at the site due to operation of Unit 1; 2) The short time that phytoplankton organisms will be exposed to elevated temperature of more than 4 degrees during passage through the plant and plume (a few hours at most) relative to the probable generation time of phytoplankton in the river (one or more days). Actually, photosynthesis in the Hudson River appears to be so limited by turbidity that there is little potential for net growth in cell numbers except in the shallow waters and bays. 3) The small percentage of the total river flow (1.0-1.5% per pass) that will be used by the two-unit operation, compared with other streams much more heavily used for cooling water without significant effect; and 4) the relatively moderate effects on the entrained phytoplankton projected for Unit 2, compared with that at other plants of larger capacity sited on smaller streams that have not experienced damage.

Micro-invertebrate Zooplankton

The temperature tolerance data for micro-invertebrates such as rotifers, copepods and cladocera collected during this past summer permit me to raise the figures for the temperature tolerance of the copepods Eurytemora and Halicyclops. This revision reinforces my ealier conclusions about lack of significant effect of Unit 2 operations on populations in the river.

Improved techniques of exposing the organisms to ΔT were employed during 1972 which avoided the problem of over-shooting the desired temperature that was experienced by the old method. The upper temperature tolerance of the copepods determined by the improved method is approximately 93°F for a 30-minute exposure in the summer. The upper temperature tolerated increases with decreases in exposure time. As a consequence, whereas in my April 5 testimony I projected mortality of up to 25 percent of the entrained copepods when the cooling water rose above 90°F in the summer, I now believe there will be no such mortalities up to 93°F.

Survival of micro-invertebrate zooplankton was essentially the same in intake and discharge samples from Unit 1 throughout the full range of temperatures (up to 92°F) studied, except during chlorination (Table 2). This survival of entrained organisms agrees with tolerance limits predicted from laboratory studies. Organisms entrained through Unit 2 in the summer may occasionally be exposed to temperatures of 93 to 94°F, but for exposure times 4 to 6 times less than experienced by the organisms passing through Unit 1 when operated in a throttled-flow condition to produce the ΔT's above 11° indicated in Table 2. This shorter exposure time for organisms entrained through Unit 2 will enable them to tolerate the maximum temperatures expected with little or no mortality.

TABLE 2

Viability of Entrained Micro-invertebrate Zooplankton
Indian Point Unit 1

Water Temperature °F			Cl	Percent Survival						Number of Samples(1)
				Intake		Discharge-1		Discharge-2		
Ambient	T	Discharge		Range	Mean	Range	Mean	Range	Mean	
52-61	6.4-11	63-69	No	92-100	97	93-100	97	78-100	95	18
			Yes			87-99	92	50-97	72	6
63-70	0-6.6	67-70	No	76-94	83	73-100	87	56-96	85	19
			Yes			34-91	80	25-96	73	13
71-73	0-	71-76	No	68-96	87	82-91	87	54-79	63	13
			Yes			20-76	54	8-70	45	6
75-78.3	8.6-11	86-88.3	No	83-100	96	95-99	97	92-100	97	30
			Yes			75-98	91	93-99	97	10
76-78.9	12.8-15	91-92	No	97-100	98	96-98	96	92-95	94	16
			Yes			77-98	90	79-94	89	10

(1) Two sub-samples examined from each sample.

The variable survival data in Table 2 for both intake and discharge samples at the 63-70 and 71-73°F ambient temperature conditions was caused by sample storage time before examination. This effect due to crowding of organisms in the concentrated samples was eliminated by adjusting the sample frequency so that each sample could be examined immediately after collection.

Survival of entrained micro-zooplankton organisms during chlorination varied widely among individual samples. At station D-2 nearest the point of discharge to the river, the mean survival for samples in each data grouping in Table 2 ranged from 45% in the 71-73°F ambient temperature grouping to 97% in the 75-78.3°F grouping. A mean survival of 89% was observed in the 76-78.9°F grouping during chlorination. The lower mean survivals in the 63-70°F and the 71-73°F groupings than at higher temperatures may have been the result of the previously described crowding effect while samples were standing before examination, a complication subsequently avoided by almost immediate examination of the samples.

No significant delayed mortalities of micro-invertebrate zooplankton have been observed after passage through Unit 1. The rate of decline in survival was about the same in intake and discharge samples (Table 3), after having been exposed to cooling system temperatures of 91-92°F alone and these temperatures plus chlorine.

Organisms from these discharge canal samples as well as from laboratory temperature tolerance experiments have been

Table 3

Survival (%) of micro-invertebrate zooplankton at Indian Point Unit 1

Temperature conditions: ambient 76 + 15°F ΔT[1]
ambient 79 + 13°F ΔT

Time elapsed (hours)	Percent Survival		
	Intake	Discharge (ΔT)	Discharge (ΔT + Chl)
0	98.8	94.3	93
0.5	100.0	-	-
1.0	97.8	-	93
1.5	97	92.1	95
2.0	99	-	98
2.5	96	-	-
3.0	-	85,92,88	-
3.5	97	-	94.1
4.0	91	-	-
4.5	-	-	86.4
5.0	95,90	-	-

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[1] The data on survival is a composite of data from two days observation during which these were the temperature conditions.

observed to reproduce successfully. The comparative rates of reproduction by entrained and control specimens are still to be determined.

An analysis of variance was performed on the logarithms of plankton data from the seven field stations. A two way ANOVA table was formed by dates of collection and station. The resulting "residual" mean square was used as an estimator of the parametric variance of the data. The F ratio $\left(\frac{\text{mean square of stations}}{\text{residual mean square}}\right)$, was then calculated in order to determine any differences among the stations. Separate ANOVA were computed for the species *Eurytemora affinis*, *Acartia tonsa*, *Diacyclops bicuspidatus*, *Halicyclops fosteri*, *Moina* sp., *Bosmina longirostris*, *Daphnia pulex* and *Diaphanosoma brachyurum*, in addition ANOVA's were calculated for the plankton groups Rotifera, Protozoa and the larval forms of copepods.

The F ratios determined in all of the tests proved to be less than the upper critical value F ($\alpha = .01$). The conclusion is that, within the limitations of the conditions specified for the analyses, there was no significant difference in abundance or composition of micro-invertebrate zooplankton in the river resulting from Indian Point Unit 1 operations.

Operation of Indian Point Units 1 and 2 are not expected to significantly alter micro-invertebrate zooplankton populations in the Hudson River because data from studies of the biota from the Hudson River at Indian Point show that; 1) The laboratory studies indicate that micro-invertebrate zooplankton can tolerate the cooling system and plume temperatures expected throughout the year with the possible exception of the summer when cooling water system temperatures and times of exposure may slightly exceed (1-2°F) the tolerance of the more sensitive species. 2) Survival of the micro-invertebrate zooplankton in discharge canal samples was similar to survival in intake samples from Unit 1 when Unit 1 flows were throttled to produce ΔT's approximating the ΔT expected from Unit 2. 3) The above temperature tolerance and intake-discharge survival studies clearly demonstrate that the Hudson River micro-invertebrate zooplankton can tolerate temperatures higher than will be present at any time or place in the plume from Unit 1. 4) Mortality caused by chlorination is moderate; chlorine will be applied to Units 1 and 2 less than 4% of the time, and the generation times of most species included in this category are relatively short, which increases capability to compensate. 5) Populations in the plume from Unit 1 have been found not significantly different from those at stations more distant from the plant.

Macro-invertebrate Zooplankton

Studies of the macro-invertebrate zooplankton since preparation of the April 5 testimony show that the amphipod Gammarus can tolerate a ΔT of almost 36°F for 30 minutes in the winter at an ambient temperature of 36.5°F. Tolerance to ΔT declines to 19°F over an ambient temperature of 77°F (25°C) in the summer (Figure 8). This tolerance capability exceeds the ΔT expected from Unit 2 throughout the year.

Survival data from the intake and discharge canals indicate no increase mortality of Gammarus in the discharge canal at ΔT's up to 15°F over the summer ambient temperature, which confirms the validity of the projections from the laboratory thermal tolerance (Table 5).

Many breeding pairs of Gammarus are observed in discharge canal samples throughout the year. Pairs collected from the highest discharge temperatures observed (93.7°F) and survivors from the chlorinated samples have been observed to produce broods of young. Quantitative studies of reproductive success are planned. Gammarus taken from the elevated temperature condition in the discharge canal experienced no higher delayed mortality than specimens collected from ambient temperature intake water (Table 6).

Mortalities and stunned Gammarus were observed during chlorination. The average initial percent mortality ranged from 5.2% to 18% in discharge canal Station D-1 samples and from 4.7% to 8.1% in Station D-2 samples (Table 5). The reasons for the smaller mortality in Station D-2 samples are not yet known. Apparently healthy specimens taken from the discharge canal samples, which were categorized initially as alive, displayed no higher delayed mortality than specimens taken from the intake canal. About 68% of these organisms listed as stunned subsequently died within two hours (Table 6).

Gammarus placed into various dilutions (96% to 20%) chlorinated discharge canal water in static bioassay conditions experienced no higher mortalities after seven days than specimens in the unchlorinated control (Table 7). This experiment was performed to determine the toxic potential of chlorine residual that organisms might experience in various portions of the plume. Gammarus was selected as the test organism because of the sensitivity to chlorine it has displayed in the intake-discharge canal survival studies. The static bioassay condition provided for no subsequent dilution, so was probably more harsh than would be experienced by organisms coming into contact with the plume water, which does experience progressive dilution with time.

Temperature tolerance data for Neomysis americana indicate a tolerance limit of about 87-89°F (31.7°C) for a 30 minute exposure over an ambient river temperature of 75-78°F (25.5°C). The TL_{95} tolerance limit for Neomysis for a 5 minute exposure is 32.5°C (90.5°F) from an ambient temperature of 78°F (Figure 9).

The survival data for Neomysis from the intake-discharge canal studies indicate no decreased percentage survival in the discharge canal stations compared to the intakes at an ambient temperature of 70-78° when the ΔT was between 7-10°F, but

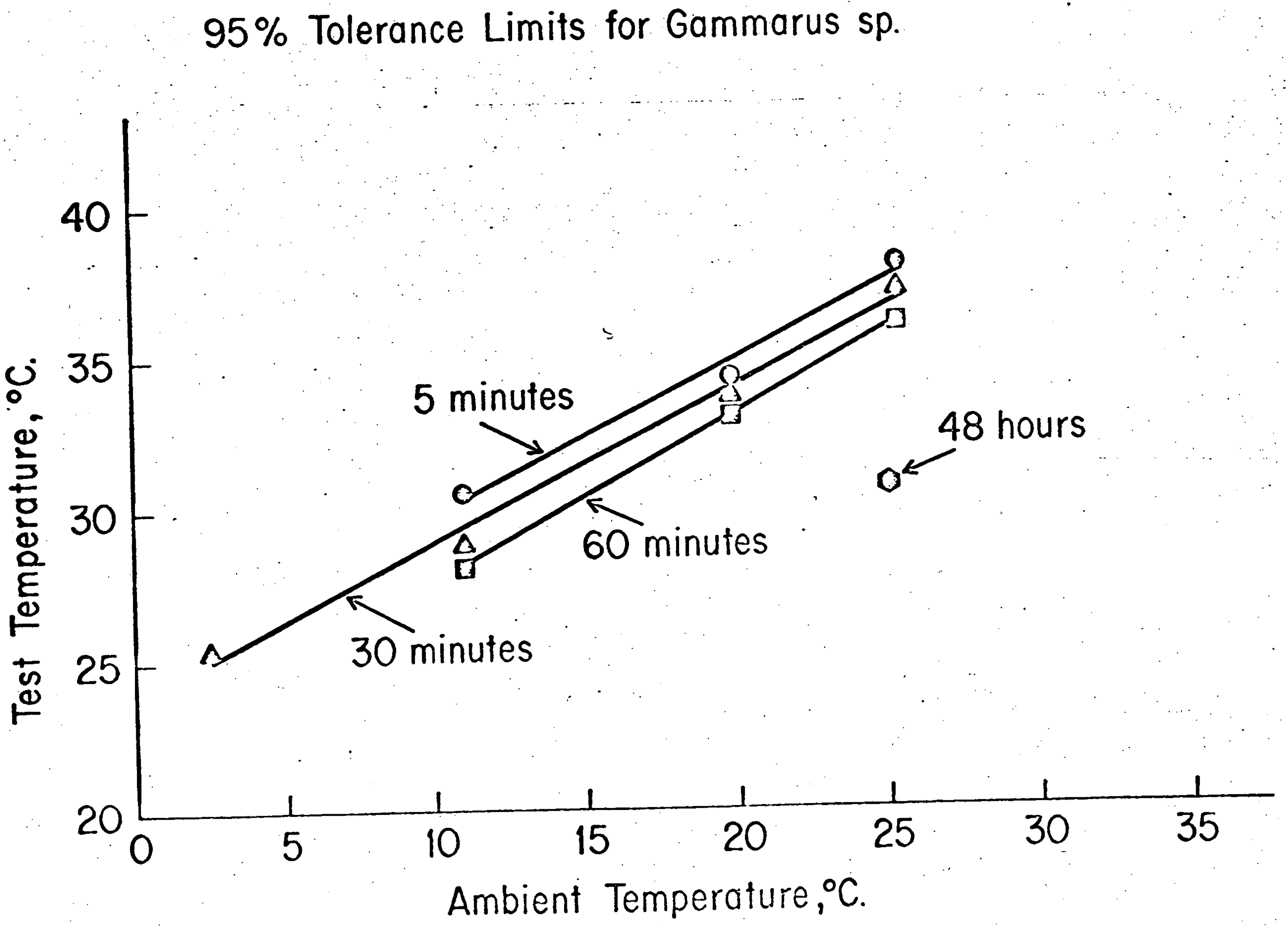

95% Tolerance Limits for Gammarus sp.
Test Temperature, °C.
40
35
30
25
20
0
5
10
15
20
25
30
35
Ambient Temperature, °C.
5 minutes
30 minutes
60 minutes
48 hours

FIGURE 8

TABLE 5

Viability of Entrained Gammarus sp.

						Condition of Organisms (% of total from Station)											
		Water Temperature (oF)				Intake 1			Intake 2			Discharge 1			Discharge 2		
No. of Organisms	No. of Samples	Ambient	T(°F)	Discharge	Cl	Alive	St.	Dead	Alive	St.	Dead	Alive	St.	Dead	Alive	St.	Dead
3091	19	68-71	0	68-71	NO	97	0.5	2.2	93	1.4	5.5	97	0.8	1.8	98	1.7	0.3
					YES	-	-	-	-	-	-	82	12	5.2	90	5.6	4.7
4925	30	76-78	10-11	86-88	NO	98	0	2.5	98	0.7	1.5	92	2.9	4.6	93	2.0	5.0
					YES	-	-	-	-	-	-	78	9.0	13	86	5.4	8.1
13580	30	76-79	13-15	90-92	NO	99	0.2	1.0	98	0.2	1.3	99	0.3	0.5	99	0.3	0.6
					YES	-	-	-	-	-	-	58	24	18	89	5.9	5.3
21596	79																

All numbers are percent of organisms examined.

ST = Stunned

TABLE 6

Survival of Gammarus two hours after collection from the Indian Point Intake and Discharge Canals.

No. of Samples Analyzed (25 Organisms/Sample)	Source of Organisms (Station)	Chlorination	Initial Condition	Mean % Survival	Range
6	Intake	No	Alive	99	69-100
4	Discharge-1	No	Alive	100	100
7	Discharge-1	Yes	Alive	98	92-100
11	Discharge-1	Yes	Stunned	32	12-64

TABLE 7

Survival of Gammarus sp. in Various Dilutions (1) of Chlorinated Discharge Water from Indian Point Unit 1(4)

Percent Chlorinated Discharge	No. of Organisms(3)	Chlorine Residual			Percent Survival	
		Initial	2 days	7 days	2 days	7 days
0	75	0	0	0	96	76
20	75	not detected(2)	-	-	92	73
33.3	75	<0.01	-	-	88	72
50	75	0.02	not detected(2)		92	77
95.8	50	0.07	not detected(2)	-	96	84

(1) dilutions prepared with non-chlorinated Hudson River water

(2) <0.01 ppm

(3) 25 specimens per jar

(4) Held at ambient river temperature which ranged from 66% to 62°F during experiment.

Temperature Tolerances for Neomysis americana at an Ambient Temperature of 25.5°C.

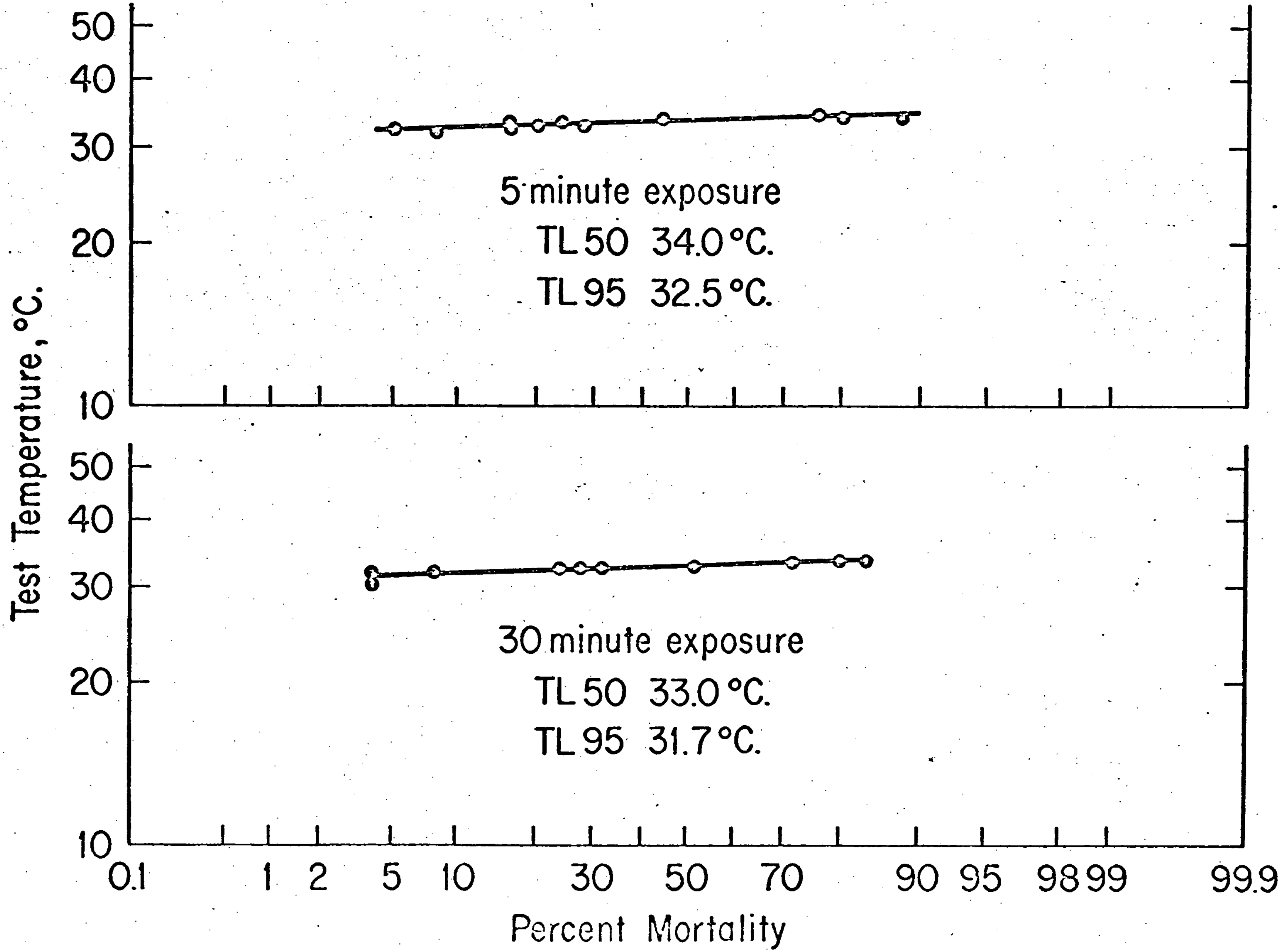


FIGURE 9

when the ΔT was increased from 12.8 to 14.2°F there was a noticable increased mortality at the discharge canal station D-1, D2 compared to the intake stations (Table 8). This survival data indicates that sizable percent mortalities of Neomysis may occur in the discharge canal when the temperature exceeds 90°F. However, it is evident from Figure 9 that the temperature tolerance of Neomysis increases with decrease in exposure time. When Unit 2 comes on line the flow velocities in the discharge canal will be considerably greater than they were while this data was being collected with Unit 1 in a throttled flow condition. This increased velocity will reduce the exposure time to the elevated temperature, which should in turn reduce the mortality rate of Neomysis.

As indicated in my previous testimony the occurrence of Neomysis in the vicinity of the Indian Point plant is related to the presence of the salt-front in that part of the river. According to the data for 1971, Neomysis was present in significant numbers in the vicinity of the Indian Point plant only when the salinity exceeded about 0.5 parts per thousand (Figure10). Due to the very heavy rains which we experienced in this area in 1972, the movement of Neomysis into the vicinity of the Indian Point plant did not occur until approximately one month later than in 1971. This dependance upon the location of the salt-front for longitudinal distribution within the estuary greatly reduces the time during which Neomysis is susceptible to the intakes at Indian Point.

As indicated previously, Neomysis as well as the other dominant macroinvertebrate zooplankton species in the Hudson

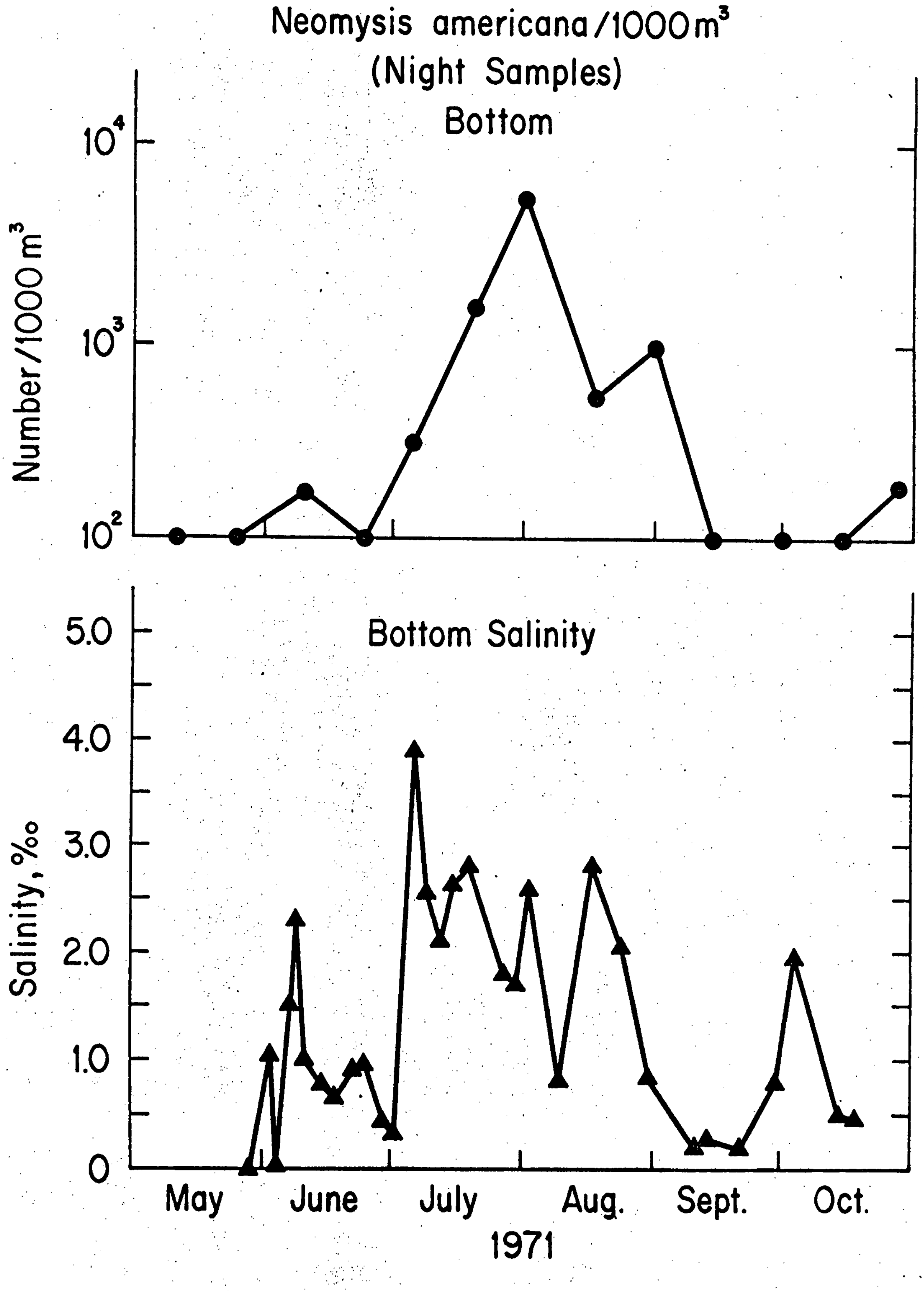
TABLE 8

Viability of Entrained *Neomysis*

		Water Temperature (°F)				Condition of Organisms (% of total from Station)							
						Intake 1		Intake 2		Discharge 1		Discharge 2	
No. of Organisms	No. of Samples	Ambient	T(°F)	Discharge	Cl	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
11,600	105	70-78	7.0-14	83-88	NO	91	9.0	93	7.0	85	15	91	9
1,990	39	-	-	-	YES	-	-	-	-	58	42	76	24
1,420	63	77-79	13-14	90-92	NO	97	3.0	96	4.0	53	47	72	28
371	24	-	-	-	YES	-	-	-	-	54	46	72	28

FIGURE 10

Seasonal Occurrence of Neomysis and Salinity At Indian Point



River exhibits a very dramatic diurnal vertical distribution pattern in the river. Figure 11 shows the difference in numerical abundance relative to hours of the day for Neomysis and Gammarus in samples taken in front of the dock at Unit 1 compared to samples in the discharge canal. These data indicate that the susceptibility of Gammarus and Neomysis to the intake is dependent upon its distribution in the vertical column of the water in the river. The result is about a 5-fold lower abundance during the 14-16 hours of daylight compared to the 8-10 hours of darkness.

It is evident from the comparison of the seasonal mean abundances in the daytime versus the night-time collections of Neomysis, Gammarus, Monoculodes shown in Figures 12, 13 and 14 that this day versus night difference in vertical distribution pattern exists throughout the period of occurrence for each of these species in the vicinity of Indian Point. These three species combined compose about 90% of the macroinvertebrate zooplankton abundance in the Hudson River at Indian Point. Gammarus is the most consistently occurring and abundant component of the macroinvertebrate zooplankton in the vicinity of Indian Point. It contributes about 60% of the total annual mean abundance of macroinvertebrate zooplankton.

The level of mortalities of Gammarus observed during chlorination of Unit 1 and likely to occur during chlorination of Unit 2 will not significantly effect the population in the river in my opinion. The bases for this opinion are

FIGURE 11

Diurnal Distribution at Indian Point

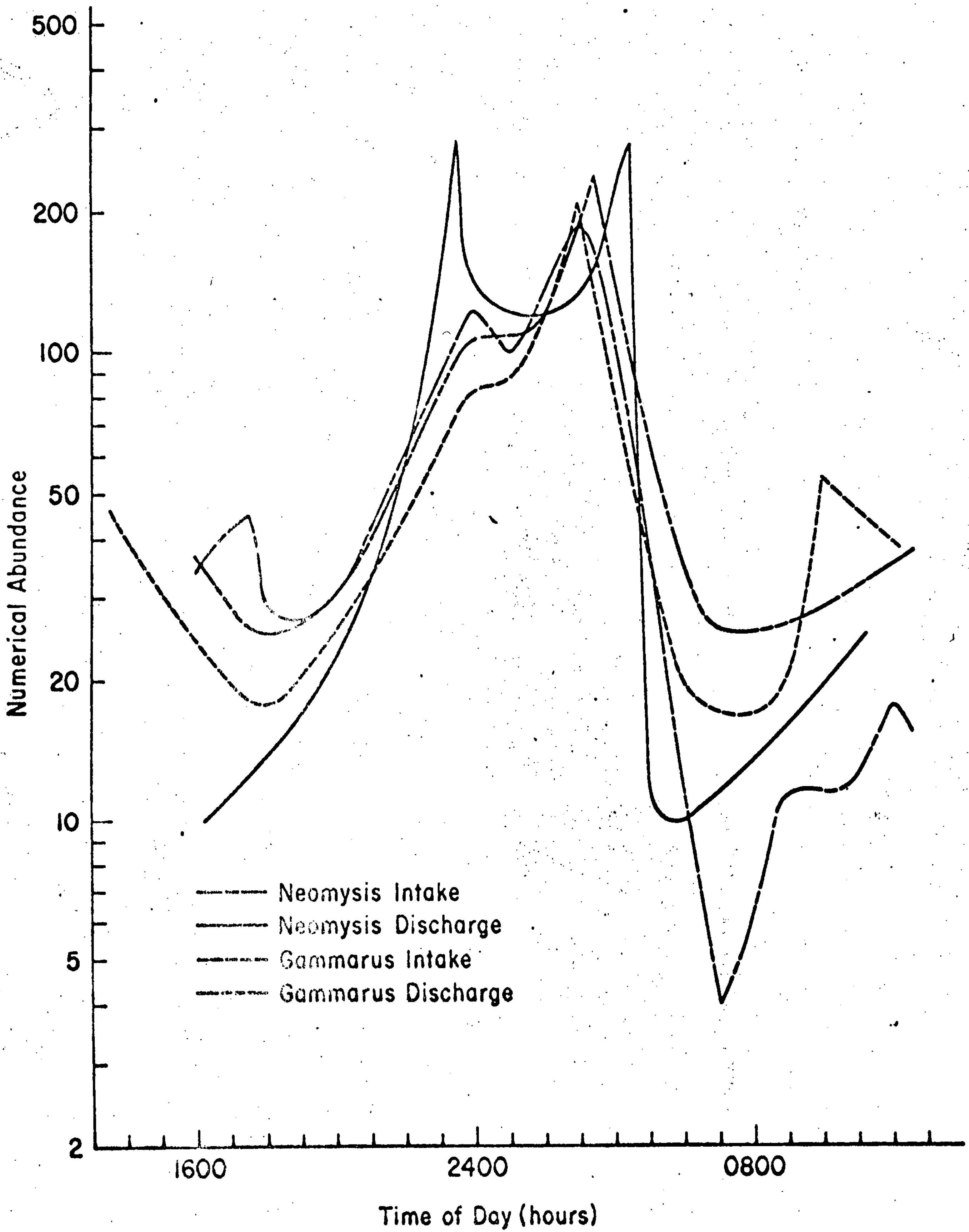


FIGURE 12

Day/Night Vertical distribution. Average of abundances of all collection stations throughout collection period for Surface, Mid-Depth and Bottom

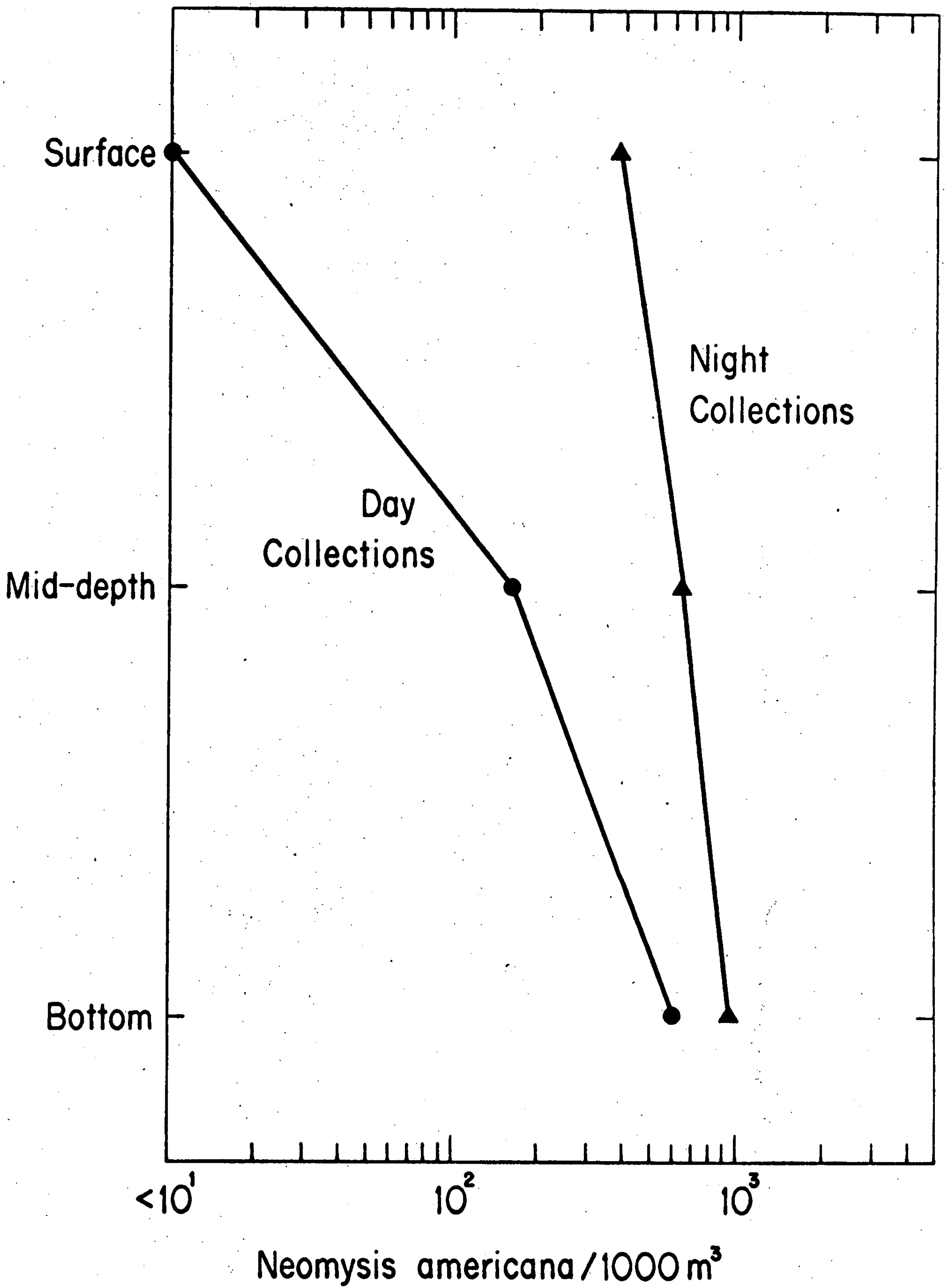


FIGURE 13

Day/Night Vertical distribution. Average of abundance of all collection stations throughout collection period for Surface, Mid-Depth and Bottom

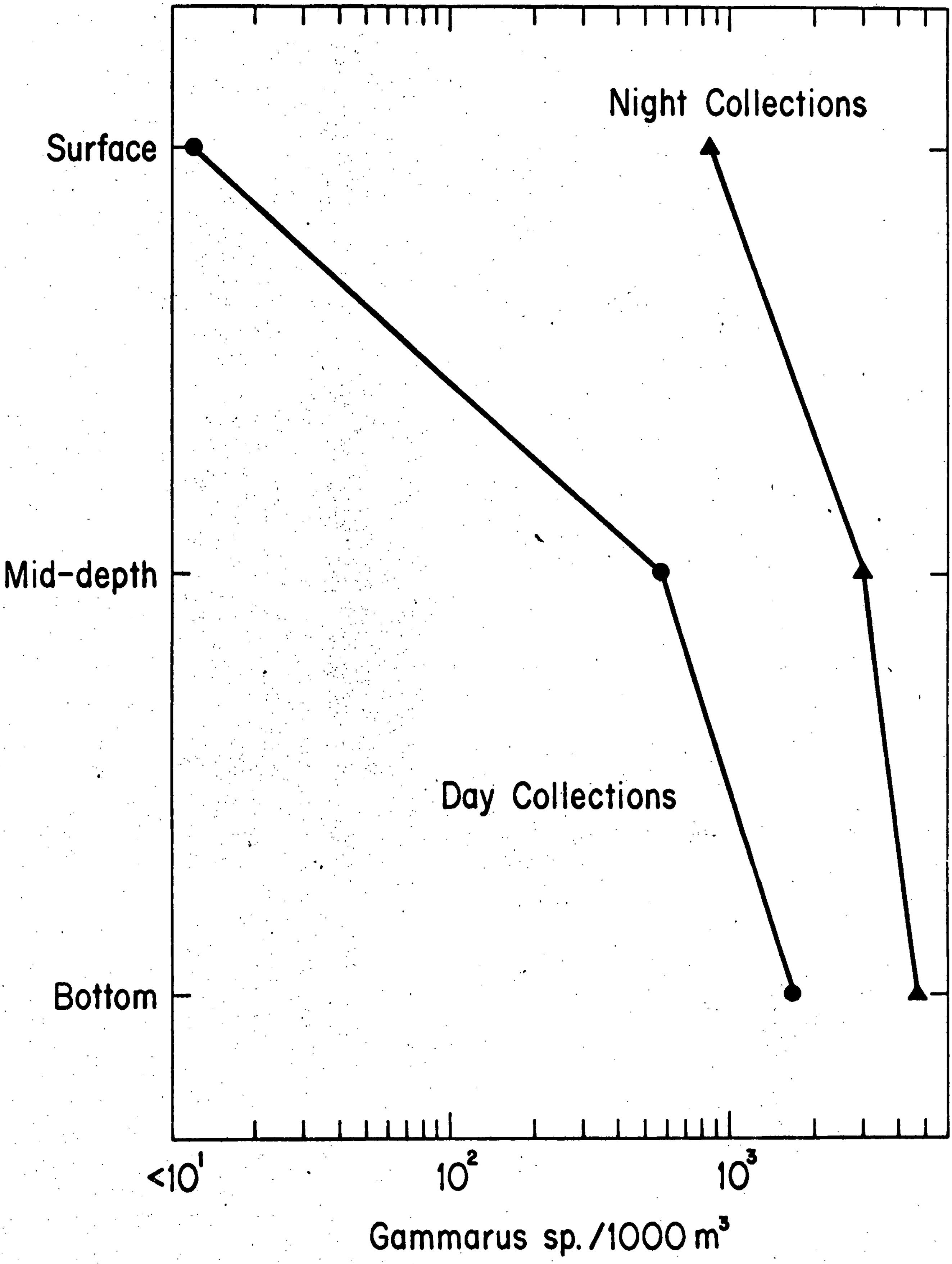
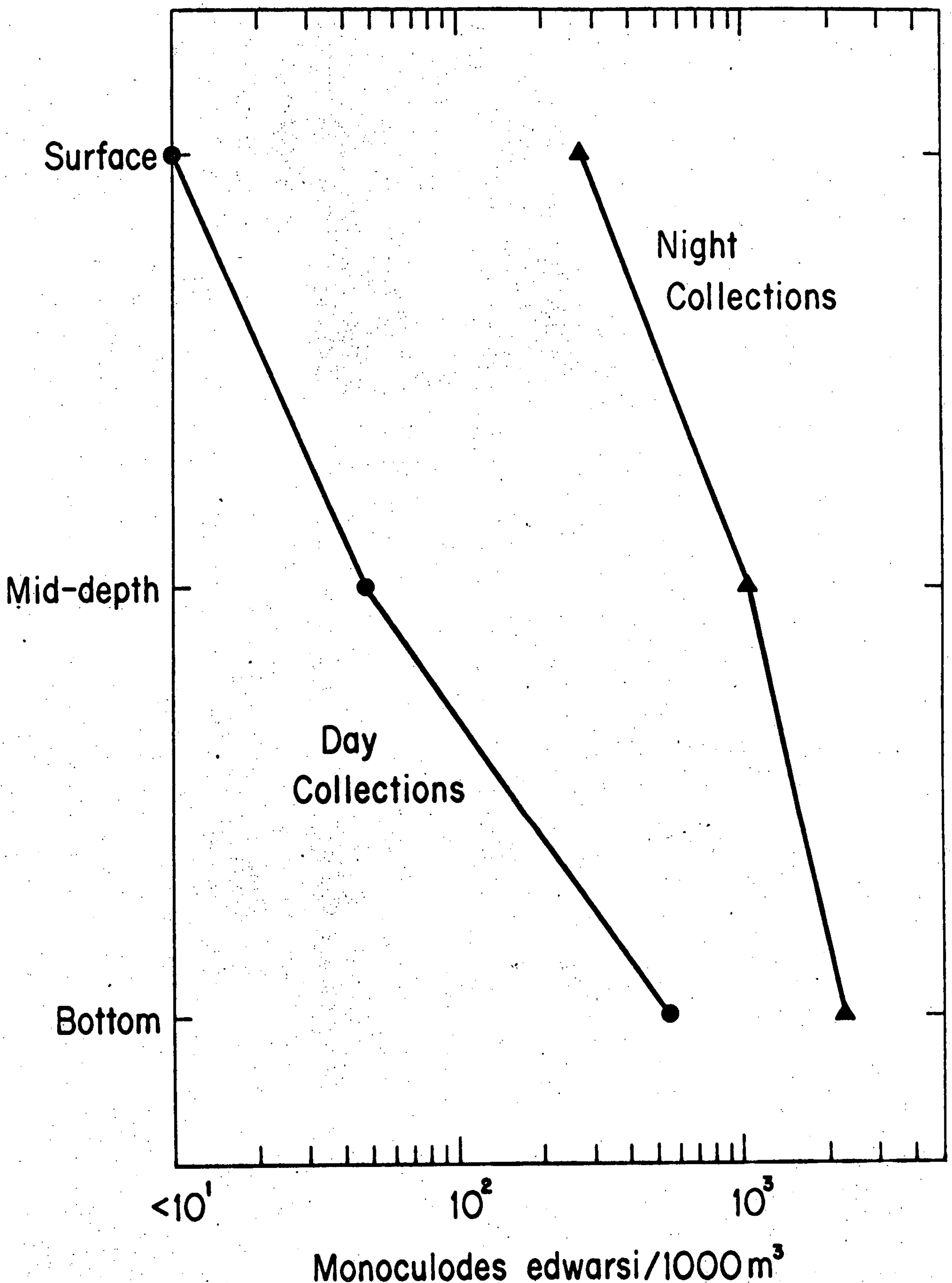


FIGURE 14

Day/Night Vertical distribution. Average of abundance of all collection stations throughout period of collection for Surface, Mid-Depth and Bottom



the data presented, which indicate no reduction in survival in the discharge canal samples except during chlorination. Chlorine will be applied during only about 4% of the time. Chlorine will be applied during the day when the greatest abundance of Gammarus are located in the deep water of the river so that numbers coming through the plant are minimal. The total chlorine residual from Unit 1 dissipates rapidly as indicated in Table 1, such that it is generally less than 0.1 part per million at station D-2, and has not been present in detectable amounts at the plume station, where the temperature ΔT has been approximately 1/3 of the ΔT in the discharge canal. Exposure to initially full-strength (0.07 ppm) chlorinated discharge canal water for seven days caused no increased mortality compared to controls. The chlorine residual declined below detectable limits (0.01 ppm) by the second day.

Assuming the same application rates of chlorine for Unit 2, the discharge concentrations to the river will be less with Unit 1 and 2 operating due to increased dilution. Further, if there were to be detectable chlorine residual in the plume, its distribution would tend to be similar to that of the plume itself which moves to the upper layers of the water column during most of the year. This is the area of least abundance of Gammarus during the day (Figures 11-14).

Therefore, the numbers of Gammarus which are killed during the time of chlorination in the discharge canal are an extremely small part of the population in the immediate vicinity of Indian Point; and are an even smaller portion of the total river population, which occupies at least a 10 to 15 mile length of the river at any given time. Moreover, we have observed that Gammarus reproduce throughout the year in the Hudson River. Based on the literature females can be expected to produce a new brood at the time of each molt, or up to 5 to 7 broods per year. This reproductive strategy provides protection against serious population effects by intermittent impacts such as chlorination.

Neither in my opinion, will Neomysis populations in the river be significantly effected by the entrainment mortalities that may occur during passage through Unit 2, although the fact that Neomysis may experience a higher percent mortality (temperature and chlorine) than Gammarus (chlorine only) increases the potential for such effects. Additional bases for this opinion to those given for Gammarus are: 1) A segment of the Neomysis population in the river will be subject to entrainment by Indian Point Units 1 and 2 during only a portion of the year. The time and duration of occurrence in the Indian Point area will vary from year to year, but the duration of occurrence will probably be on the order of about six months. 2) The data (Table 7) indicate that entrained Neomysis may experience appreciable mortality only when the condenser and discharge canal water temperature exceeds 90°F, and during chlorination. The condenser and discharge canal water temperature will exceed 90°F during about three months of the summer when Unit 2 is operated at full rated capacity. 3) The exposure time to the elevated temperatures in the condenser and discharge canal will be reduced with Unit 2 operating. 4) A longitudinal profile of sampling was undertaken in 1972 after Neomysis began to occur at Indian Point. This sampling indicates that Neomysis was present at least as far south as Yonkers (mile 15), and as far north as Newburgh (mile 58), depending upon the northward location of the salt-front. This wide distribution of Neomysis helps to assure that entrainment mortality at Indian Point will have no significant effect on the river population. 5) The diurnal vertical distribution pattern of Neomysis is such that its susceptibility to the intake is substantially reduced during the hours of daylight compared to the hours of darkness.

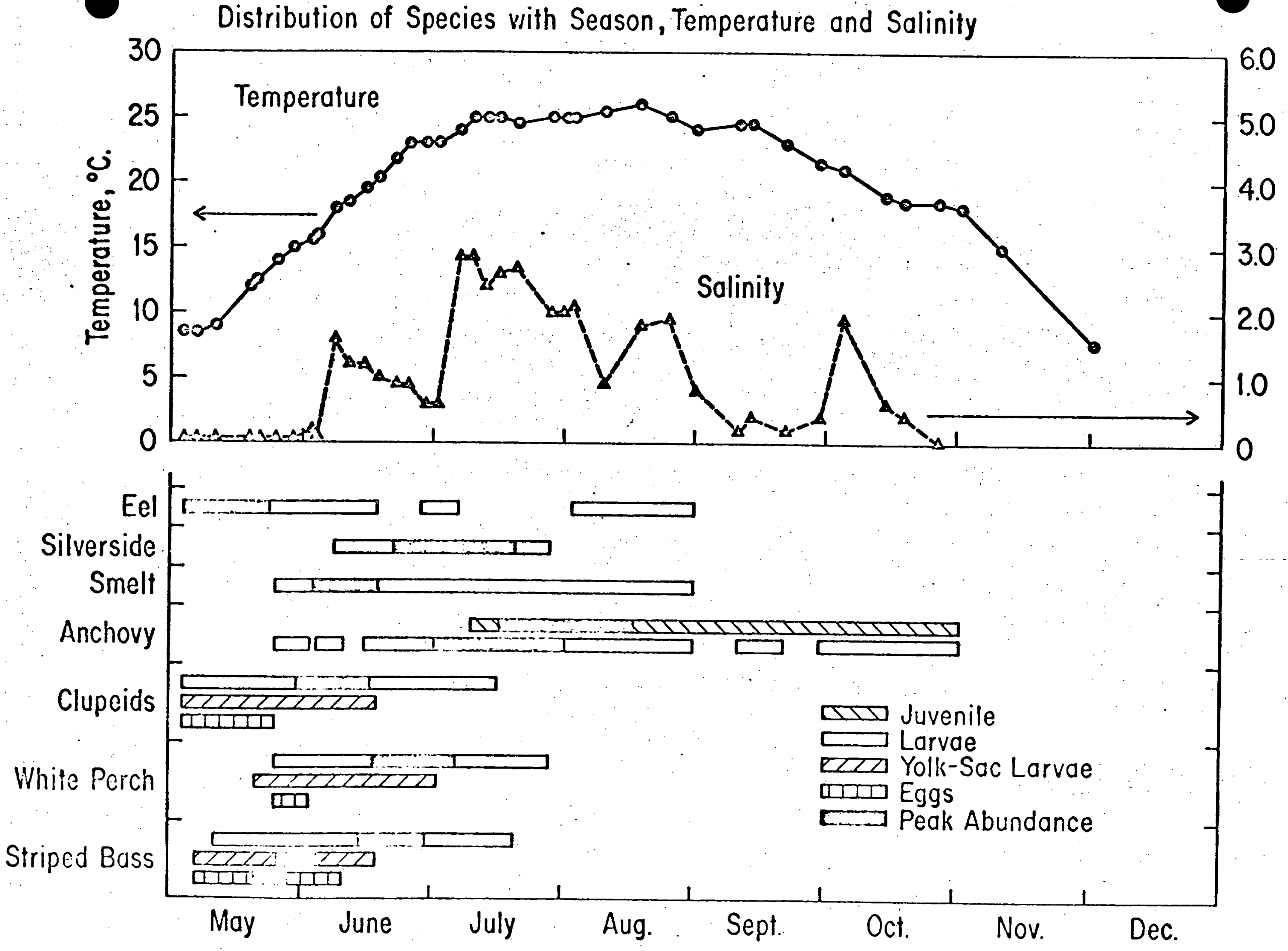
Future studies will include thorough monitoring of Neomysis population dynamics in the River, which would detect any significant effects if they were to occur. Studies of the life history, especially factors affecting location and rate of reproduction, generation time and turn-over rates, to determine compensatory capability will also be undertaken.

Fish Eggs and Larvae

The seasonal occurrences of the most abundant planktonic fish eggs and larvae in the Hudson River at Indian Point during 1971 are shown in Figure 15. Metered one-half-meter diameter, 500μ mesh nets were towed simultaneously just below the surface, at mid-depth (between 15 and 25 ft deep), and approximately two feet off the bottom at each of the seven sampling sites indicated on Figure 6 to collect the fish eggs and larvae. Each station was sampled twice each week during the day and once every other week at night from May through August, and at less frequent intervals during the remainder of the year when the River was navigable.

The principal focus here will be on the striped bass eggs and larvae because of the special interest in this species. The peak abundance of striped bass eggs at Indian Point occurred during the last two weeks of May in 1971 when the river water temperature ranged from 53 to 59^{o}F. The peak abundance came during the same period in 1972 when the water temperature ranged from 53^{o}F to 63^{o}F.

Very few eggs were present in the surface samples in 1971. Eggs were clearly most abundant near the bottom in both the day and night collections (Figure 16), meaning that they are less available to the Indian Point plant intakes than they would be if they were evenly distributed from top to bottom.



Distribution of Species with Season, Temperature and Salinity

FIGURE 15

FIGURE 16

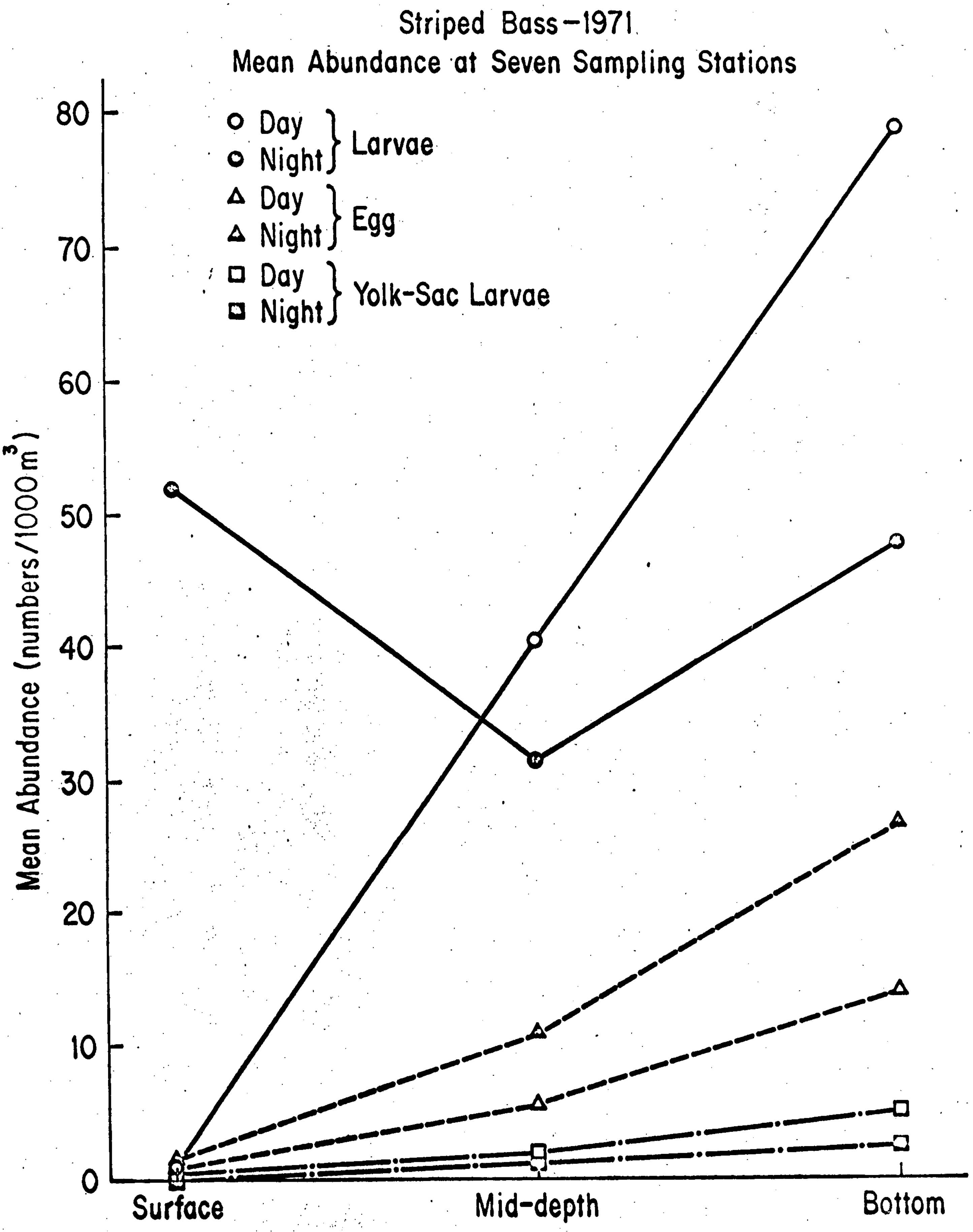

Striped Bass-1971
Mean Abundance at Seven Sampling Stations
Day
Night
Larvae
Day
Night
Egg
Day
Night
Yolk-Sac Larvae
Mean Abundance (numbers/1000 m³)
80
70
60
50
40
30
20
10
0
Surface
Mid-depth
Bottom

FIGURE 17

Maximum Safe Temperature[1] for Striped Bass Eggs and Larvae from Monks Corner, S.C. Hatchery Stock

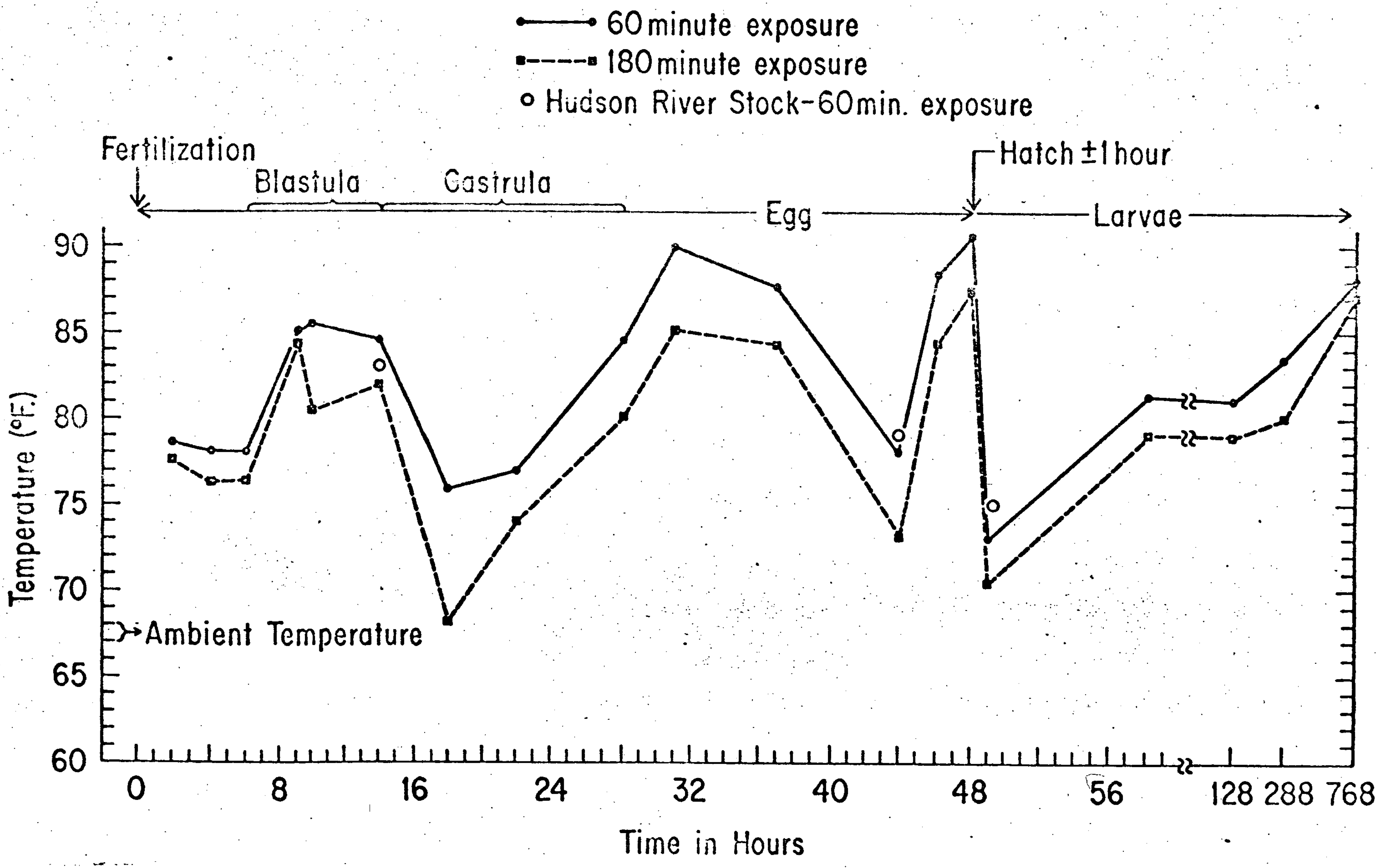


FIGURE 17

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[1] Safe temperature is the maximum temperature of exposure which did not result in increased mortality or abnormal development compared to controls.

Results of laboratory temperature tolerance studies (Figure 17) utilizing eggs and larvae from the Cooper River, South Carolina stock (spawned at Monck's Corner Hatchery) indicate that all developmental stages of striped bass eggs should be able to tolerate the 15°F Δ T while passing through Indian Point Unit 2. The 15°FΔT added to the 53-63°F ambient temperature that accompanied the presence of most of the striped bass eggs at Indian Point in 1971 and 1972 yields Indian Point Unit 2 cooling system water temperatures of 68 to 77°F. The 77°F temperature would exceed by 2°F the sixty-minute-exposure maximum tolerated temperature only during the gastrula stage.

The transit time for cooling water passage from the Unit 2 condensers back to the River at rated capacity operation will be 10.5 minutes, considerably less than the sixty minute exposures used to determine the temperature tolerance of striped bass eggs. The conservative effect of using the longer exposure time should more than compensate for the fact that the ambient or acclimation temperature was higher at Monck's Corner than the 53-63°F ambient temperature in the Hudson during the period of peak egg abundance.

Eggs were exposed to abrupt changes of pressure ranging from +5 psi to +100 psi. No increase in mortalities or abnormal development of eggs or larvae was observed.

Newly hatched yolk-sac larvae are the most temperature sensitive of the developmental stages of striped bass eggs and larvae (Figure 17). They begin to incur mortality at temperatures above 73°F when exposed for sixty minutes. Thereafter, temperature tolerance rapidly increases, such that 10-hour-old larvae tolerate up to 83°F for sixty minutes without increase in mortality or abnormal development.

Striped bass yolk-sac larvae were taken in plankton nets at Indian Point from early May through mid-June in 1971. By far the majority of the year's catch was taken during the period from May 24 through June 7, when the River water temperature ranged from 59°F to 64°F. The rated capacity Indian Point Unit 2 ΔT of 15°F added to those ambient tempertures yields cooling water temperatures ranging from 74°F to 79°F that might be experienced by yolk-sac larvae passing through the plant.

The newly hatched yolk-sac larvae passed through Unit 2 during the first two to three weeks of May, 1971, would not have experienced temperatures in excess of the sixty-minute tolerance limit. Those passed through the plant during the remaining two weeks of yolk-sac larvae occurrence would have experienced temperature from one to six degrees higher than the sixty minute tolerance limit when the plant was operated at full-rated capacity, and probably would have experienced some level of temperature induced mortality unless the relatively short exposure time would enable them to survive the temperature.

The yolk-sac striped bass larvae were most abundant in the samples just above the bottom in both the daytime and night time collections, in 1971. Approximately eight times more yolk-sac larvae were taken in the near-bottom samples than in the mid-depth samples during the day. None were taken in the surface samples during the day. Abundances in the night collections were a bit more evenly distributed, but there were still from 3.5 to 4 times more in the middle and bottom collections than at the surface. This pattern of highest abundance in the deepest water probably makes the yolk-sac larvae considerably less available to the Indian Point plant intake than could be the case if they were evenly distributed from top to bottom.

The sixty-minute-exposure maximum temperature tolerance of the striped bass larvae increased from 83°F for the 10-hour-old larvae to 88°F for 30 day old (768 hour) larvae (Figure 17). The tolerance level remained at about 88°F for larvae beyond this age.

Post yolk-sac larvae were taken in plankton samples in the vicinity of Indian Point from early May through mid-July in 1971, when the River water temperature ranged from 50°F to 77°F. The Unit 2 rated-capacity ΔT of 15°F added to these ambient temperatures yields cooling water system temperatures ranging from 65°F in early May to 92°F in mid-July. Thus the cooling water temperatures would be lower than the sixty-minute temperature tolerance limits for striped bass larvae, except near the end of the larvae season in July when some temperature-induced mortalities may occur.

Organisms passing through Indian Point Units 1 and 2 are exposed to abrupt changes in pressure ranging from 6.62 to 20.58 pounds per square inch. Striped bass larvae up to 30 days old exposed to abrupt pressure changes ranging from 5 to 100 pounds per square inch (psi) fed immediately after the exposures, and suffered no mortality or behavioral aberrations compared to controls through twelve hours of post experiment observation.

Older larvae and juveniles of striped bass, white perch, clupeid species, anchovy and tom cod have been exposed to abrupt pressure increase up to 500 psi above ambient, held at those elevated pressures for up to two hours, then abruptly brought back down to ambient pressure. All of these have fed shortly after the exposure, and suffered no mortality or behavioral aberrations compared to controls.

As in the case of the striped bass eggs and yolk-sac larvae, the very high concentration of post yolk-sac larvae near the bottom relative to the surface during daylight hours probably reduces the potential for passage through the Indian Point plant below what it would be if the larvae were evenly distributed from top to bottom (Figure 16).

The condition of all Morone sp (striped bass and white perch) larvae collected in intake and discharge canal samples at Indian Point during 1972 is summarized in Table 9. Certainly this data indicates that larvae passed through Indian Point Unit 1 are not all killed. However, a first approximation of the percent survival of larvae passed through the plant was computed by assuming that if the sampling effort and mortality due to collection were equal, then approximately the same number of live larvae should have been taken in the discharge canal samples as in the intake. Dividing the number of live larvae in the discharge samples by the number of live larvae in the intake samples $\left(\frac{177}{327} \times 100\right)$ yields 54% as a first approximation of survival for striped bass and white perch larvae passed through Unit 1. Much additional analysis of data must be done to refine the estimate, which could increase or decrease the percent survival estimate somewhat depending upon the net effect of the variables which must be considered.

TABLE 9

Condition of *Morone sp* (Striped Bass and White Perch) Collected From the Intake and Discharge Canal at Indian Point

Intake				Discharge			
Alive	Stunned	Dead	Total	Alive	Stunned	Dead	Total
327	105	225	657	177	55	167	399

Appendix B-1

Detailed Comments on Thermal Discharge Aspects of AEC Draft Statement, April 13, 1972

The Draft Statement addresses the environmental aspects of the combined thermal discharge from Indian Point Units Nos. 1 and 2. This appendix clarifies several misconceptions in the Statement, apparently engendered by earlier, less comprehensive analyses which had been submitte to the AEC Staff.

These comments are supplied in support of the applicant's contentions that the Statement is erroneous in its evaluation of the following four topics:

1. Net nontidal flow
   a. The Staff states on page III-35 "The magnitude of the net nontidal flow for different freshwater flows needs to be determined." Similar and sometimes contradictory remarks are made in sections III E 1 d(3), III E 1 f(4), III E 1 g(5), and Appendix II-1.

   b. The Applicant has demonstrated through extensive analyses using several independent methods (see Chapter V, reference 9), how the nontidal flow depends on freshwater flow. The final two unit predictions (reference 11) use the minimum (most conservative) estimates of the nontidal flow that can be obtained. The efforts of the applicant's consultants represent a significant advancement in methods of modeling such estuaries.

2. Maximum river ambient temperature
   a. Staff concludes on page III-35 "the maximum river temperature can be above 81° F in August." This conclusion is subsequently used to imply probable noncompliance with 90° F maximum surface temperature criterion.

   b. Applicant has demonstrated and will outline in these comments:

      (1) The source of error in the Staff analysis.

      (2) The applicant's consultant statistical analyses of ambient temperature.

3. Far-field heat dissipation
   a. Staff maintains on page III-37 "The adjustments made to the original model by arbitrarily using correction factors so that the results will agree with only one set of observed data from operation of Indian Point Unit 1 and extrapolating the model to predict the effects of Units Nos. 1, 2, and 3 together is unjustified."

b. Applicant used all available data to calibrate the models presented. The models have now been tested in numerous applications and have been verified. The model development and verification has at all time been beyond the "state-of-the-art". The summary analyses in reference 11 employ no empirical adjustments; they are theoretical predictive models which show remarkable agreement with the independent physical models.

4. Physical model results

   a. Staff makes reference to the extensive physical modeling program only in twelve lines on page III-34, apparently disregarding those results.

   b. Applicant maintains, as in the original 1969 report, that the mathematical and physical models are independent, illustrate remarkable agreement and should be reviewed and interpreted as complimentary predictions.

1. Net Nontidal Flow

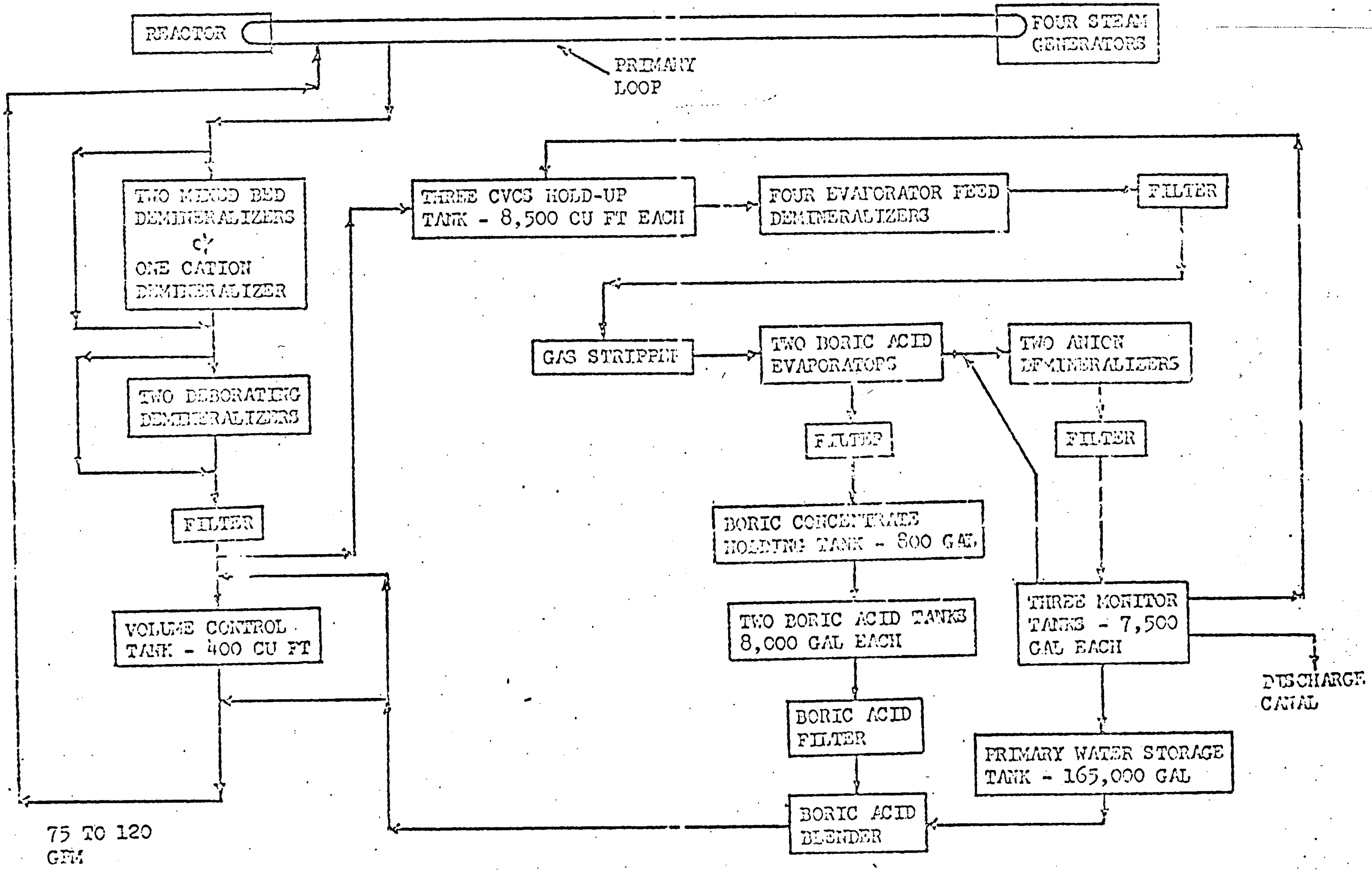
The Draft Statement, in its discussion of Net Nontidal Flow, attempts to summarize and evaluate the application of this concept to the Hudson River at Indian Point. The Statement does not convey a consistent evaluation as to how the concept should be applied.

Table 1 summarizes results of the density induced circulation studies detailed in references 8 and 9. The table compares the velocity and salinity approaches. In general, the salt approach exhibits several favorable characteristics such as relatively more stable and predictable distribution, more independence of temporary meteorological and local eddy conditions, simplicity and availability of more precise detection instruments. The end result of these advantages is, of course, a more reliable measurement which makes the use of salt more attractive from a practical standpoint.

The salt approach results were also used to introduce some degree of perspective to the problem and to determine seasonal variation of upper layer flows since most of the available current observations were made during the summer months.

When the freshwater flow exceeds 20,800 cfs at Indian Point, the river changes from a two-layer to one-layer system having a net flow in the downstream direction from top to bottom. This flow value represents the incipient salt flow at Indian Point and may occur during May during certain years. This critical value of freshwater flow may be obtained from Figure 1. The long term monthly average upper layer flows are shown in Figure 2.

In conclusion several methods of estimating the net nontidal flow have been evaluated. The Staff recommends use of salinity data on page III-27 of the Draft Statement and the applicant concurs. Statistical analyses using different methods of interpreting salinity data lead to estimates of upper layer flow from 35,000 to 92,000 cfs. Since the less accurate velocity method resulted in lower values of upper layer flow, the applicant has used this most conservative value obtained, approximately 21,000 cfs in their evaluation. The applicant's methods of analyses have employed established principles to advance the scientific state of estuarine prediction techniques.



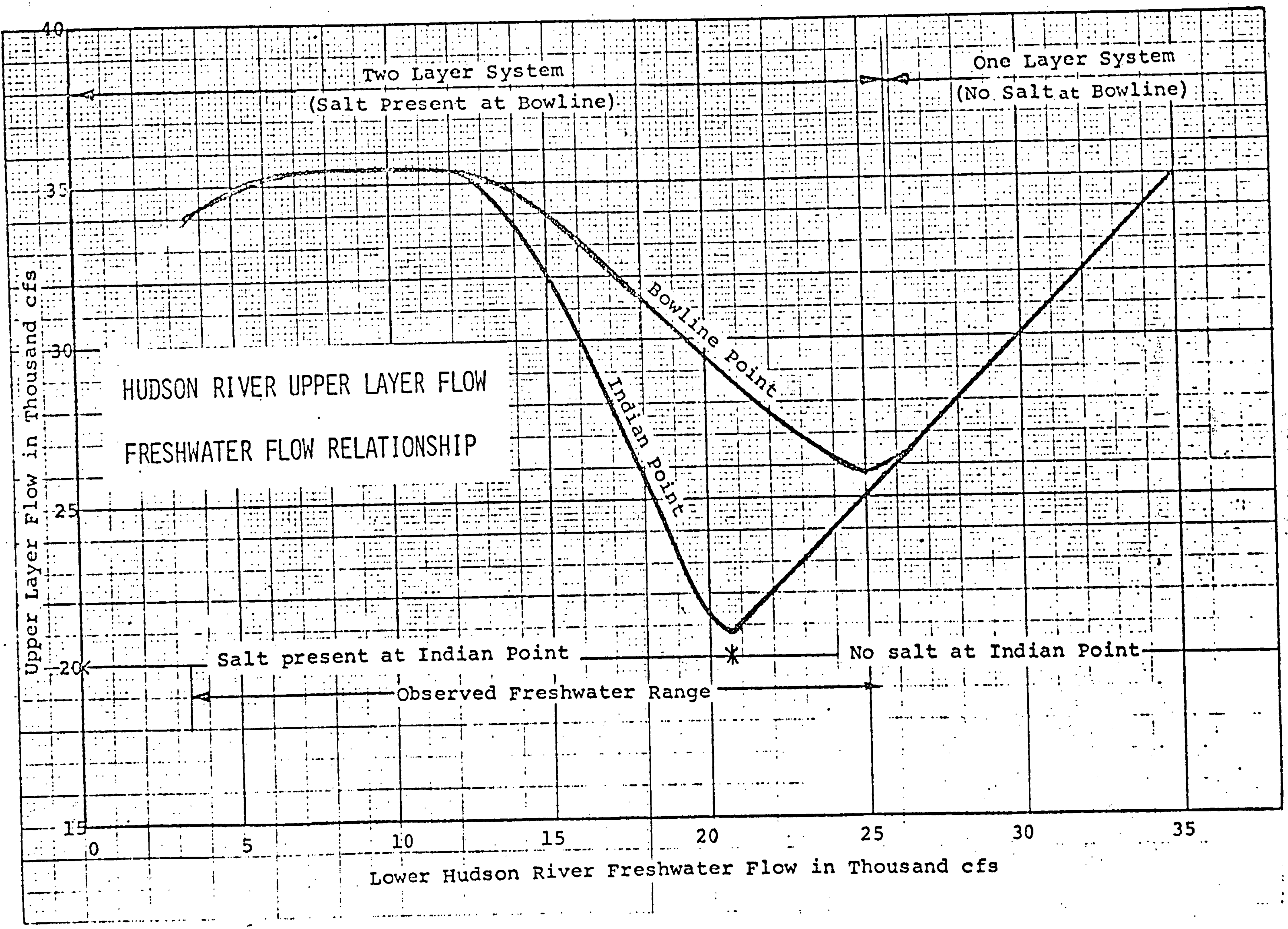
PRIMARY COOLANT PURIFICATION
IN CHEMICAL AND VOLUME CONTROL
SYSTEM - INDIAN POINT UNIT NO. 2

FIGURE 2

TABLE 1

COMPARISON OF LOWER HUDSON UPPER LAYER FLOW USING SALINITY AND CURRENT OBSERVATIONS

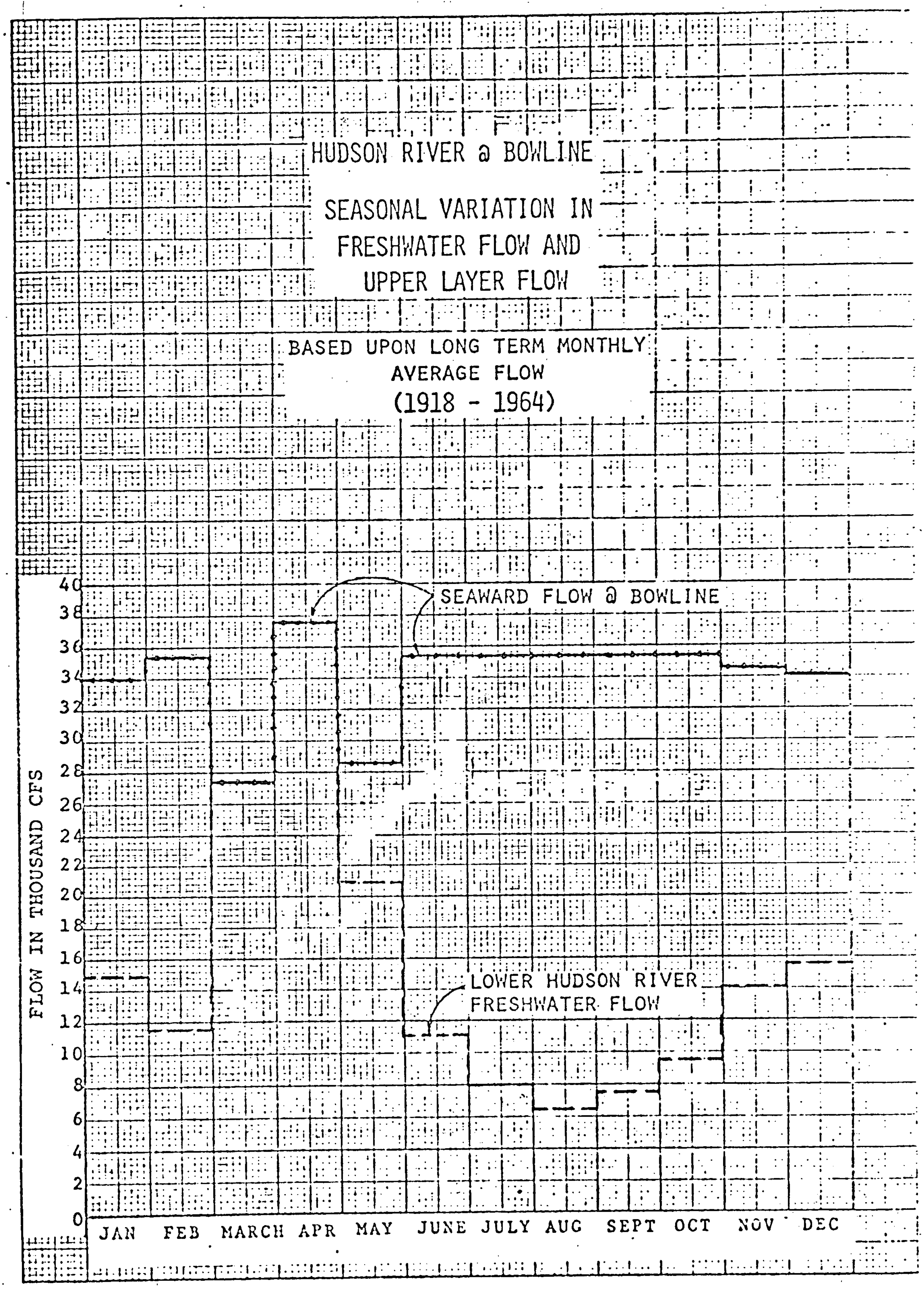
			Upper Layer Flow, Thousand cfs -- Summer Conditions --
	Method	Reference 8 Figure No.	Indian Point
1.	Current Observations	7	21.5
2.	Salinity Surveys		
	a) Salt Budget Method		
	1964	22	90.0
	1967	23	92.0
	b) Two Layer Flow Method		
	All Salinity Surveys	24	35.0
	Generalized Salinity	26	35.4



HUDSON RIVER UPPER LAYER FLOW

FRESHWATER FLOW RELATIONSHIP

FIGURE 2



HUDSON RIVER @ BOWLINE

SEASONAL VARIATION IN FRESHWATER FLOW AND UPPER LAYER FLOW

BASED UPON LONG TERM MONTHLY AVERAGE FLOW (1918 - 1964)

2. Maximum River Ambient Temperature

The Draft Statement maintains that "Report of Inquiry into Allegation Concerning Operation of Indian Point 1 Plant of Consolidated Edison Company" shows river ambient temperatures of 81° F. Certainly it is clear that an extensive body of temperature data exists beyond this simple source. Our consultants have analyzed all existing data and these analyses have been described in Dr. Lawler's Supplemental Study dated May 1972 (reference 12, pages I-3 through I-5). The comments below are, in part, based on that report.

The New York State regulations define ambient temperature implicitly in NYCRR 704.1 where estuarine thermal criteria are specified. With regard to the 4° F heating limitation that section reads in part: "...shall not be raised to more than 4° F over the temperature that existed before the addition of heat of artifical origin..." The data presented in the Staff reference indicating a temperature of 81° F were obtained while Lovett and Indian Point were operating and were not measured at the Indian Point site. Thus, these temperatures measure thermal plume effects, not ambient intake temperature. Furthermore, the data were accumulated with uncalibrated thermometers normally accurate to only ±1° F at best. By contrast the applicants' consultants' data analysis in reference 12 was based on measurements using Bureau of Standards calibrated thermometers and employed statistical methods in documenting the use of the 79° F maximum ambient river temperature at the site.

The Draft Statement references Attachment B-3 of the Report of Inquiry referred to above for its finding of the 81° F intake temperature. The same report contains an exhibit designated Attachment B-2 which shows temperatures specifically at the intake of Indian Point 1 for the summer periods of 1967 and 1968. The highest temperature indicated is 80° F which occurred on six days in 1967 and no days in 1968. Since the present outfall structure had not been constructed, recirculation effects would be greater at that time than would be expected from the present configuration. The Draft Statement makes no mention of Attachment B-2.

The Draft Statement uses the 81° F hypothetical ambient temperature to criticize the applicant's conclusions that the 90° F maximum surface temperature criterion will not be exceeded. The applicant's submerged discharge model is fully explained and documented in the Supplemental Study of May 1972 (reference 12). We understand that this document was not available to the Staff when it prepared the Draft Statement. The model is conservative, uses published parameters where needed, and agrees with physical model results, from the undistorted model of the outfall. The physical model tests are more fully described in the comments below. (See #4). The models predict a maximum surface temperature of 88° F.

In summary, the applicant maintains (1) that the maximum ambient river temperature is 79° F, based on statistical analyses of available data; and (2) that the effluent will be diluted to ~~easily~~ meet the 90° F maximum surface temperature limit.

3. Far-Field Heat Dissipation

The Staff Draft Statement critically reviews one of the applicant's first generation models used to predict the expected temperature distribution associated with three unit operation. The Lawler Testimony submitted to the ASLB on April 5 (reference 11) is a much more concise and complete description of the essence of these models. We understand that this document was not available to the Staff when it prepared the Draft Statement. In fact, the April testimony employs no empirical corrections to arrive at predictions that two units will meet the 4° F New York State Thermal Criteria.

In point of fact, the applicant has supported the extensive development of the heat dissipation model by the consultant, QLM. Subsequent to the 1969 reports, apparently used by the Staff in their preparation, the model has been applied to numerous other outfalls and has been verified using field data as outlined below.

A. Applicability of the Overall Mathematical Models to Thermal Discharges

The heat dissipation mathematical models, and in some cases modified versions of these models, have been used to evaluate a number of existing and planned effluents and waterbodies, including the following:

1. Existing Plants
    - Albany Steam Station
    - Danskammer Station
    - Lovett Unit 1-5
    - Indian Point Unit 1
    - Arthur Kill Plant
    - Astoria Units 1-5
    - Ravenswood Plant
2. Proposed Plants
    - Roseton
    - Indian Point Units 2 and 3
    - Standard Brands, Inc.
    - Astoria Unit 6
    - Bowline Point
    - a number of other future generation sites
3. Water Quality Models
    - The Hudson River - NYSDEC
    - The New York - New Jersey Estuarine Complex - ISC, NYC, NJDH
    - The East River - NYC
    - several waterbodies outside New York State

In addition, subsequent analysis, summarized in Table 2, of available temperature measurements in the vicinity of other Hudson River existing plants indicated existence of upper layer flows close to those computed using the above described tidal current and salinity approaches. These results support the capability of the density induced circulation concept to explain temperature observations.

TABLE 2

Plant	Survey	Observed $\overline{\Delta T}_o$, °F	Heat Load, BBTU/Day	Upper Layer* flow, cfs
Danskammer	1969 QL&M	0.146	47.3	32,000
Lovett	1969 QL&M	0.152	57.0	37,800
Lovett	1970 QL&M	0.175	41.7	26,200
Indian Pt. 1	1966 NBI	0.200	37.4	20,900

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* Computed using temperature observations

B. Presentation of Study Results

In order to select the most severe set of hydrology and meteorology that can occur in the vicinity of Indian Point and to compare results of the various models used in this study, a plane of discharge counterpart of the mathematical model may be used. For a given location outfall design and known fluid characteristics, this model reduces to:

$$\Delta \bar{T}_o = \frac{\alpha H}{\sqrt{Q^2 + \beta \bar{K} E}} = \frac{\alpha H}{Q_d}$$

in which:

$\Delta \bar{T}_o$ = Area-average temperature rise at the plane of discharge, °F. It is used here as a measure of the response of the Hudson River to thermal discharges.

H = Thermal discharge, BBTU/Day

$\bar{K}$ = Heat transfer coefficient, BTU/sq. ft. day °F. It is used in this model to define the influence of meteorological conditions on the distribution of temperature.

Q = River freshwater flow, thousand cu. ft./sec.

E = Longitudinal dispersion coefficient, sq. miles/day

Q_d = A heat dissipation parameter reflecting the influence of flow available for dilution of thermal discharges and of heat transfer to the atmosphere. In the case of the convection-dispersion mathematical models, Q_d combines the influence of Q, K and E. In dealing with a tidal smoothed temperature rise averaged over the entire cross-section within a salt-intruded reach of an estuary, Q_d reflects the influence of the seaward directed upper layer flow, Q_u, and landward directed lower layer flow, Q_L. This definition of Q_d has been selected to insure consistent comparison of the convection-dispersion and density induced circulation model results. However, since an inherently stratifying discharge, such as is a thermal effluent, rises to the surface and tends to stay in the upper layer, only the upper layer flow may be used to predict the distribution of temperature in the seaward directed layer.

α & β = Constants defining the influence of river geometry (A,B), outfall design (TSF), and water quality (ρ,C_p). At indian Point, use of A, B, TSF, ρ, C_p of 160,000 sq. ft. , 4,000 ft., 1.5, 62.4 lb/cu. ft. and 1 BTU/#°F respectively, yields $\alpha = 0.185$ and $\beta = 0.23$.

A comparison between the various hydrological and meteorological conditions and models presented using this equation is given in Table 3. The study results of Table 3 indicate that an incipient salt flow condition occurring during certain winter months represents the most severe set of hydrology and meteorology that can be expected at Indian Point. The thermal effect is less critical during the other months due to availability of high freshwater flow and heat transfer rate and/or density induced circulation associated with ocean-derived salt intrusion. In order to predict the maximum expected effect, the incipient salt flow conditions were used in this study.

The combined effect of rated capacity operation of Lovett Units 1 through 5 and of Indian Point Unit 1 and 2 is expressed in terms of and compared with the New York State thermal discharge criteria in Table 4.

These values have been computed using an overall convection-dispersion model capable of handling variable system parameters, including heat loads, within a number of consecutive river segments. To convert the overall response to near field behavior and to permit evaluation in terms of the NYSDEC thermal discharge criteria, the exponential decay model (from reference 3) has been employed.

The surface width criterion, that no more than 67% of the river's surface width may experience temperature rises in excess of 4° F, is the most difficult of the criteria to meet. This conclusion has been found to be valid in numerous cases including Albany, Danskammer, Roseton, Lovett, Bowline, Arthur Kill, Ravenwood and Astoria Plants.

The results of Table 4 indicate that in all cases, the predictions are substantially less than the New York State thermal discharge criteria. Table 4 results correspond to rated capacity operation of Indian Point Units 1 and 2 as well as the existing Lovett Units 1 through 5.

TABLE 4

PREDICTION OF 4°F AREA AND SURFACE BOUNDARIES AT INDIAN POINT FOR THE MAXIMUM SEVERE CONDITIONS

A. Conditions

Incipient Salt Flow	20,800	cfs
Heat Transfer coefficient	90	BTU/ft^2 day °F
Dispersion coefficient	6	sq. miles/day
Thermal Stratification factor	1.5	
Critical tidal phase to tidal average location ratio	1.35	
Heat Load (Rated Capacity)		
Indian Point Unit 1	265 MWE or 47 BBTU/Day	
Indian Point Unit 2	873 MWE or 153 BBTU/Day	
Lovett Units 1 - 5	503 MWE or 57 BBTU/Day	

B. Study Results

Parameter	Tidal Phase	Percentage at Lovett	Percentage at Indian Point	NYSDEC Criterion
% Width bounded by 4°F	Tidal Average	24	23	67
	Critical Tidal Phase	32*	31	
% Area bounded by 4°F	Tidal Average	16	15	50
	Critical Tidal Phase	22	21	
Maximum surface Temperature, °F	Critical Tidal Phase	87		90
Area average Temp. rise, °F	Tidal Average	1.79	1.75	-
Surface average Temp. rise, °F	Tidal Average	2.69	2.62	-

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* This value is based upon a maximum surface temperature rise (ΔT_{sm}) of 8°F. To generalize the results, other rises have been investigated. Use of ΔT_{sm} of 6, 7, 9 & 10°F would yield a maximum critical tidal phase % width bounded by 4°F of 28, 30, 33 and 33.5%, respectively.

4. Physical Model Results

The Draft Statement refers to the existence of a physical model (on page III - 34), but does not interpret the results or critically review the data. Significant aspects of the physical model program are outlined below.

In the winter of 1967-68 a model (Model II) of the Hudson River simulating 9000 feet above and below Indian Point was constructed at Alden Research Laboratories, Worchester, Massachusetts. The layout of Model II which was scaled 1:250 in horizontal dimension and 1:60 in the vertical, is shown in Figure 3. In order to optimize the outfall design, an Outfall Model was constructed at Alden. The Model was undistorted, scaled 1:50 and simulated 900 feet along the east shore and 400 feet of the river's 4,000 foot width. Tests of various outfall designs were conducted using the model through the Fall of 1968 and Spring of 1969.

The current thermal criteria led to selection of the outfall with 18 feet submergence. The predicted temperature distribution created by the plant discharge through the outfall is presented in Figure 4. The expected near-field dilution at the point where the plume reaches the surface was shown by this model to be approximately 1:2.

Tests in the distorted Model II were conducted with this submerged outfall. These tests simulated two unit and three unit plant operation and indicated that the transient thermal plume would comply with the thermal criteria. The model results are presented in the Alden Report: "Indian Point Cooling Water Studies, Model No. 2" (May 1969), reference 10.

A subsequent critical review of the results, however, suggested a need to confirm the near-field results in that they appeared to indicate less than theorectically predicted mixing from the submerged discharge, and hence distortion in the results observed in Model II. The undistorted model was expanded in 1971 to simulate 1800 feet of the river's width including 2500 feet downstream from the Indian Point outfall and 1400 feet upstream at a scale of 1:50 including the features of bottom topography.

Recent re-testing in the expanded model of the outfall with 18 feet submergence confirmed the 1:2 dilution which had been measured in the smaller Outfall Model. In an effort to further improve the efficiency of the outfall, tests were run simulating a wide variety of new outfall configurations. As a result of these tests the decision was made to raise the ports to a submergence of 12 feet, to improve effluent dilution. The near-field temperature distribution for the raised port scheme, according to the Outfall Model tests, is shown in Figures 5.

The mechanism by which this increased jet efficiency occurs is entrainment of cool water from beneath the ports. Whereas previously entrainment was limited by the presence of the bottom, the outfall design with raised ports indicates substantially increased dilution, especially at points several hundred feet from the outfall.

Figure 5 shows that the dilution affected by the raised port outfall scheme will result in a maximum surface temperature approximately 8° F above the intake temperature. With recirculation amounting to 1° F average, and a maximum river ambient temperature of 79° F, the maximum surface temperature is not expected to exceed 88° F. It should also be noted that the surface area of maximum water temperature is exceedingly small, approximately 0.1 acres.

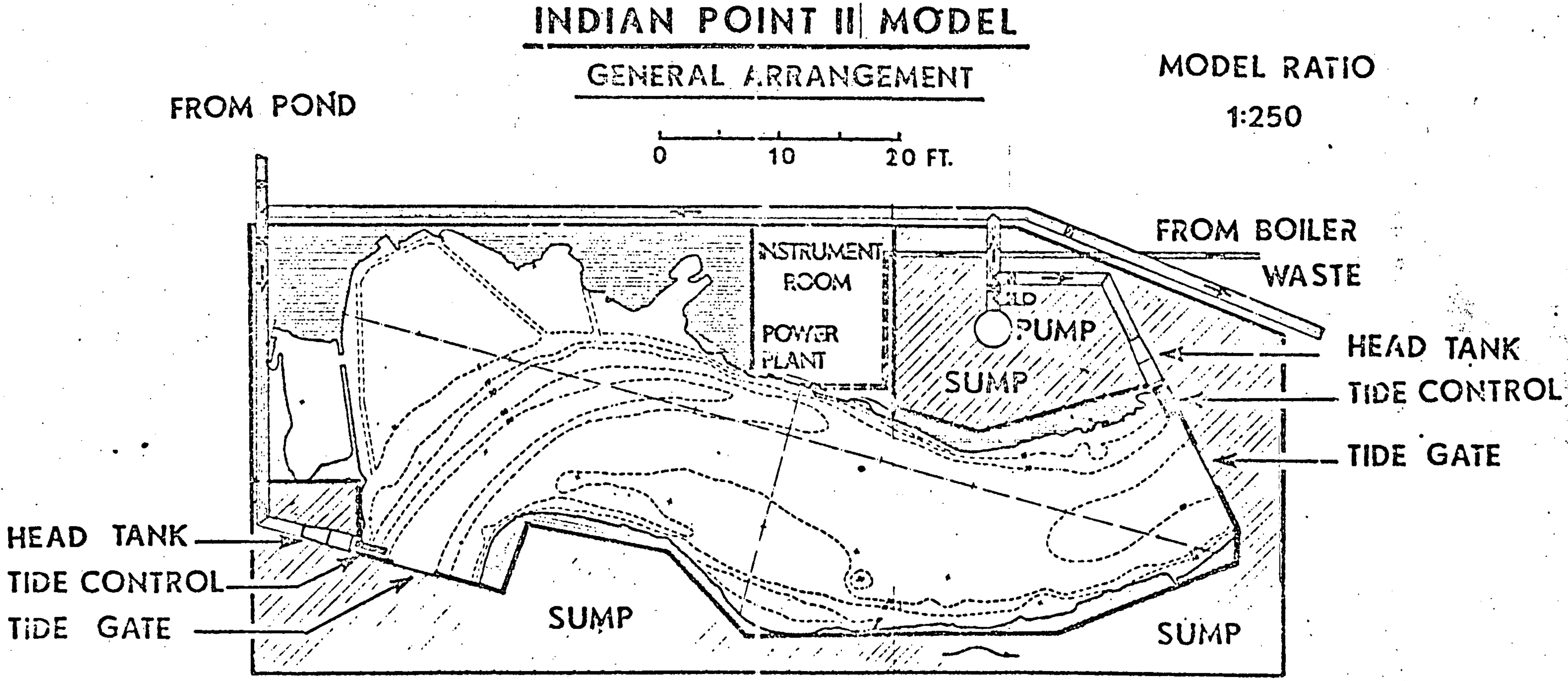


Figure - 3 Indian Point II Model - general arrangement.

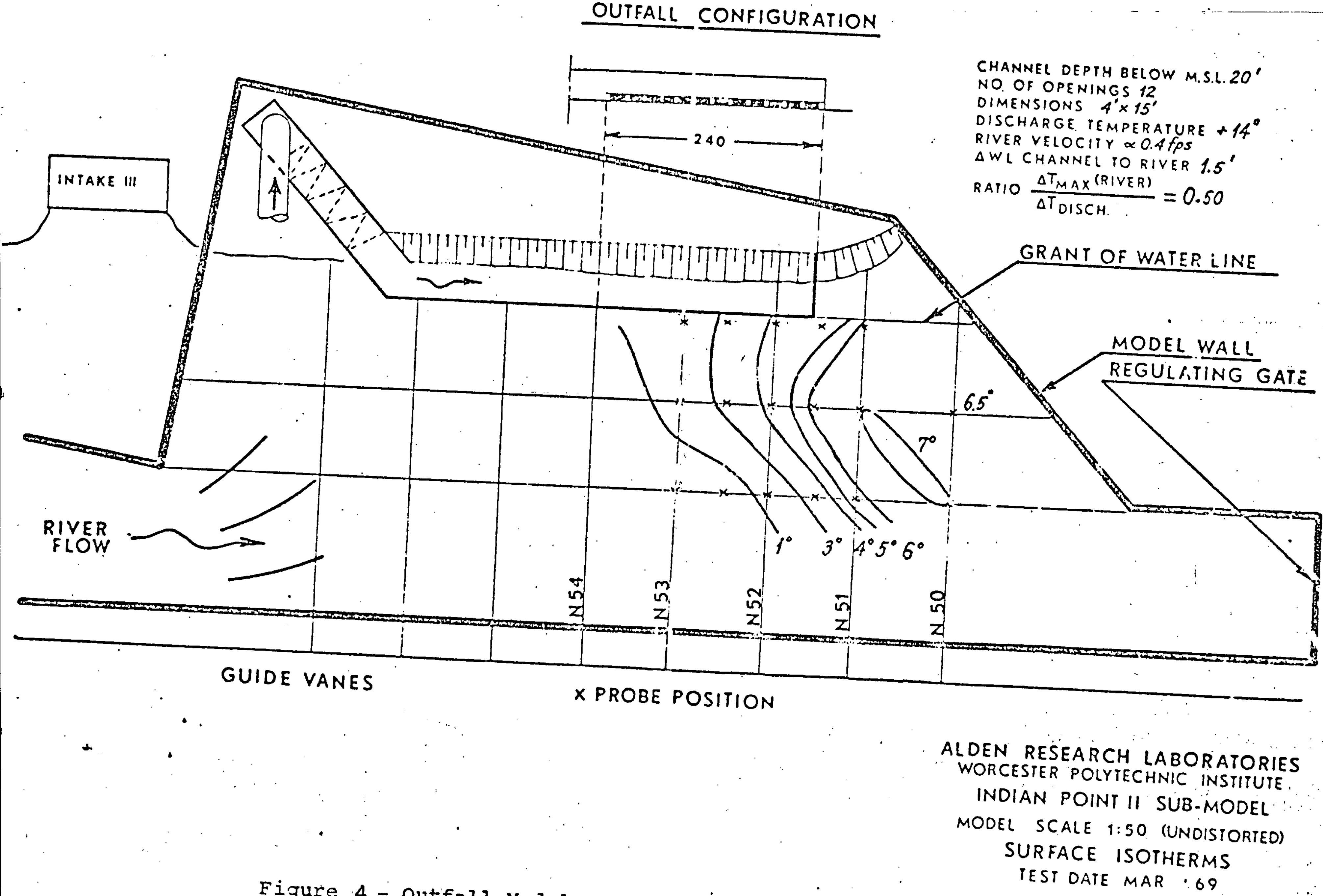
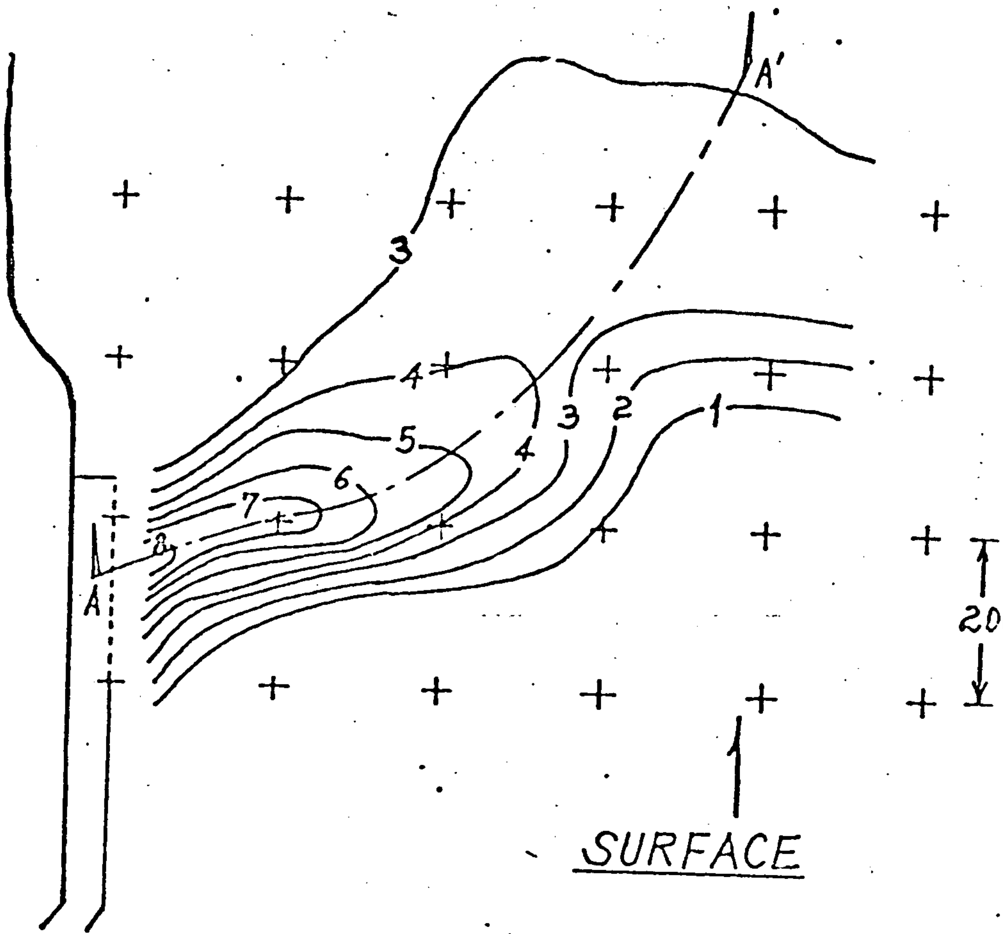
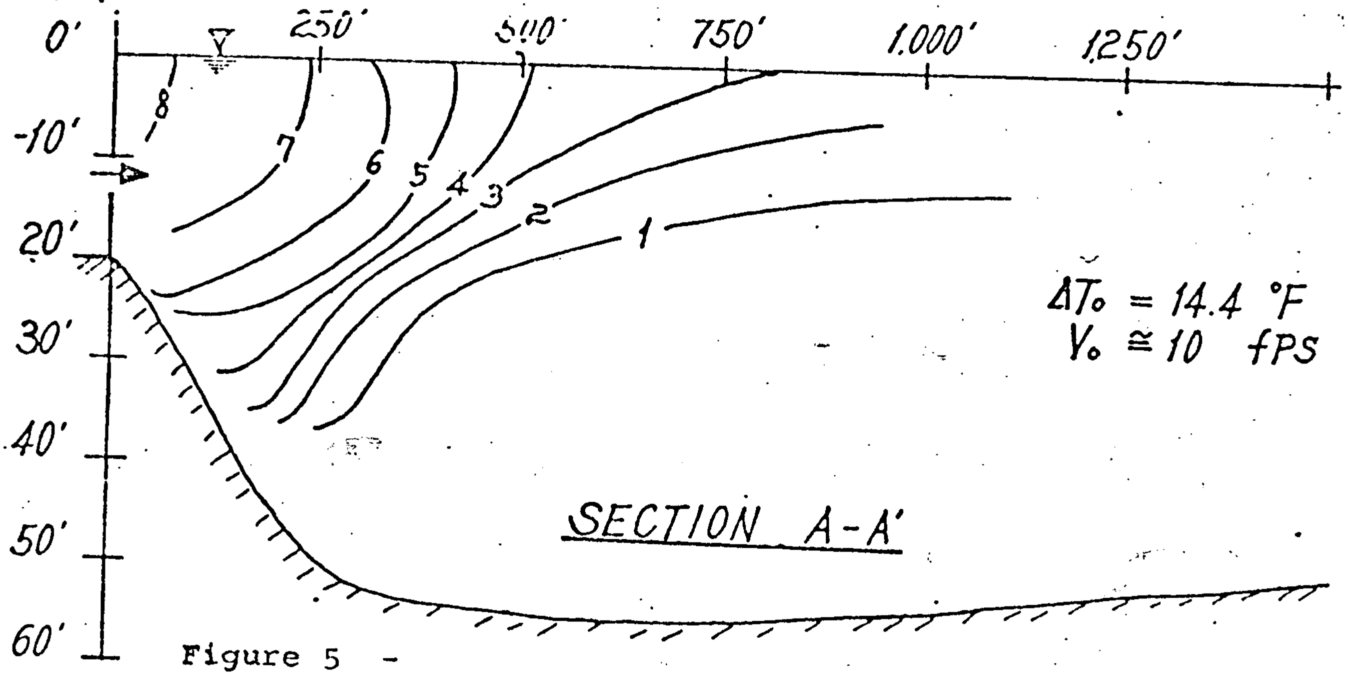


Figure 4 - Outfall Model - surface isotherms with ports at 18' submergence



SURFACE



SECTION A-A'

Figure 5 -
TEMPERATURE PATTERN – REVISED DESIGN AT 0.4 FT/SEC CURRENT, 1/50 SCALE MODEL

TABLE III-9
THE DISCHARGE OF CHEMICALS TO THE HUDSON RIVER FROM INDIAN POINT UNITS NOS. 1 AND 2[(a)]

Chemical Discharged	Max. Sustained Releases, lbs/day		Max. Conc. at Discharge Point to Hudson River[b] (ppm)		Max Releases from Both Units[c] (ppm)	NYS Allowable Conc. Chemical Discharges
	Unit No. 1	Unit No. 2	Unit No. 1	Unit No. 2		
Lithium hydroxide[d]	2.5	2.5	~~0.01~~ 0.0001	~~0.001~~ 0.00005	~~0.1~~ 0.001	–
Boric acid (Boron)[d]	600	600	~~7.5~~ 0.2	~~0.7~~ 0.06	~~50~~ 0.6	–
Sodium hydroxide	156	12	1.2	~~1~~ 0.01	~~10~~ 4	e
Sulfuric acid (SO_4)	450	–	~~6~~ 3	—	~~10~~ 9	e
Sodium Phosphate (PO_4)	~~24~~ 15	~~15~~ 24	~~0.0013~~ 0.001	~~0.07~~ 0.003	~~1.54~~ 0.03	–
Hydrazine	24	5	0.006	~~0.007~~ 0.0005	~~0.1~~ 0.02	–
Cyclohexylamine	2.5	12	~~0.0004~~ 0.0007	~~0.003~~ 0.001	~~0.1~~ 0.01	–
Morpholine	2.5	12	~~0.0004~~ 0.0007	~~0.003~~ 0.001	~~0.1~~ 0.01	–
Sodium sulfate	Neutralization product of NaOH and H_2SO_4		~~4.6~~ 2.5	~~0.7~~ —	~~10~~ 7.5	~~e~~
Sodium carbonate	~~2~~ 1000	~~20~~ —	~~1.3~~[f] 8.5	–	~~7~~[f] 1.7	~~e~~
Chlorine	~~15%~~ —	~~15%~~ —	0 to 0.5[h]	0 to 0.5[i]	0.5	0.5
Potassium chromate (Cr VI)	~~Intermittent use~~ —	30	~~0.35~~ —	~~0.05~~ 0.008	~~0.05~~ 0.025	0.05
Detergent[g]	~~1.5~~ 3.0	~~1.5~~ —	~~0.12~~ 0.01	~~0.01~~ —	~~1.0~~ 0.03	–

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[a] Sulfate, caustic soda, and soda ash together represent 5 to 10% of the permissible concentrations of the total dissolv solid (TDS) that can be discharged into receiving waters.

[b] Discharge during full power operation with 300,000 gpm for Unit No. 1 and 870,000 gpm flow for Unit No. 2 of condenser coolant in the discharge canal.

[c] Values normalized to a nominal flow of condenser coolant in the discharge canal of 100,000 gpm.

[d] These releases would occur only in the event of evaporator breakdown.

[e] These represent the concentration of dissolved solids that can be discharged into the river.

[f] Soda ash used in a 2% solution for 3 hours to wash the Unit No. 1 flue gas passages of the superheaters, economizers a reheaters, 4 times per year and discharged continuously during the cleaning period at ~~7~~ gpm into a flow of 20,000 gpm service cooling water during Unit No. 1 shutdown. 17 gpm

[g] Alkyl benzene sulfonate.

[h] Chlorination treatment for 30 minutes of each inlet water box 3 times per week.

[i] Intermittent discharge - 1 hour, 3 times per week for a 30 minute treatment of each water box of 3 condensers.

In summary, the physical model results cannot be ignored in any realistic evaluation of the thermal discharge from units 1 and 2. The far field data presented in the Alden Report (reference 10) constitute an accepted engineering prediction of the plume. It is a tribute to the veracity of both the physical and the mathematical heat dissipation models that their agreement is excellent. With respect to the accuracy of the near-field temperatures associated with the raised port design, the expanded Outfall Model is the most accepted method in the field of hydraulic engineering for evaluation of such schemes. The Staff is correctly aware of the assumptions required in the mathematical model, yet does not recognize the significance, accuracy and simplicity of the physical model results for both near and far field temperature distributions.

APPENDIX A

LIST OF REFERENCES *

1. Quirk, Lawler & Matusky Engineers. "Effect of Contaminant Discharge at Indian Point on Hudson River Water Intake at Chelsea, New York," Report to Consolidated Edison of New York, Inc., May 1966.

2. Quirk, Lawler & Matusky Engineers. "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., January 1968.

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5. Quirk, Lawler & Matusky Engineers. "Influence of Hudson River Net Non-Tidal Flow on Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., October 1969.

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8. Quirk, Lawler & Matusky Engineers. "Circulation in the Hudson Estuary," a technical bulletin prepared by QL&M in 1971.

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* References 1, 2, 3, 4, 5, and 10 appear in Con Ed's Environmental Report as Appendices A, I, J, L, M and N respectively.

9. Quirk, Lawler and Matusky, Engineers, "Environmental Effects of Bowline Generating Station on the Hudson River," Volume I-IV, QL&M Project No. 169-1, March 1971.

10. Alden Research Laboratories. "Indian Point Cooling Water Studies: Model No. 2," May 1969.

11. Quirk, Lawler and Matusky, Engineers, "Testimony of John P. Lawler, The Effect of Indian Point Units 1 and 2 Cooling Water Discharge on the Hudson River Temperature Distribution," April 5, 1972.

12. Quirk, Lawler and Matusky, Engineers, "Supplemental Study of Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution," May 1972.

BEFORE THE UNITED STATES
ATOMIC ENERGY COMMISSION

IN THE MATTER OF

CONSOLIDATED EDISON COMPANY OF
NEW YORK, INC.
(Indian Point Station, Unit 2)

DOCKET NO. 50–247

TESTIMONY OF

JOHN P. LAWLER, Ph.D.
QUIRK, LAWLER & MATUSKY ENGINEERS

ON THE

EFFECT OF ENTRAINMENT AND IMPINGEMENT AT INDIAN POINT ON THE POPULATION OF THE HUDSON RIVER STRIPED BASS

Modifications and Additions to Testimony
of April 5, 1972

October 30, 1972

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APPENDIX I - LIST OF REFERENCES

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SUMMARY OF FINDINGS AND CONCLUSIONS

1. Testimony presented on April 5, 1972 before the Atomic Safety and Licensing Board by John P. Lawler, Ph.D. relating to the operation of the Consolidated Edison Company of New York's Indian Point Unit 2 plant described an initial study which evaluated the impact of both existing Unit 1 and Unit 2 on the Hudson River striped bass population.

2. The "completely mixed" type mathematical model reported upon in the previous testimony acknowledged certain sources of imprecision in the impact evaluation.

3. Since that date, additional studies have been undertaken by QL&M with the objectives of modifying and adding to the analyses to provide a more accurate and complete evaluation of the impact on the striped bass.

4. To carry out these objectives, a transport model which interrelates river hydrodynamics to the life cycle of the striped bass was established.

5. The transport model includes the notion of biological compensation. Compensation partially offsets the impact of new influences on the river, whether such influences tend to increase or decrease existing fish population levels.

6. By use of the transport model, predictions of the possible reduction in juvenile striped bass caused by operation of Indian Point Units 1 and 2 were made.

7. The parameters used as input into the model are divided into three categories: fish life cycle parameters, transport parameters and plant and impact parameters.

8. A determination has been made of the dominating mechanisms involved in the operation of the model.

9. Comparison between model predictions and field data indicated that the model has been successful in simulating striped bass behavior in the river, by showing that it can progress through a whole series of stages properly by taking a given spawning rate as a function of river location and calendar time, and from this, via internal transport mechanisms, generating egg, early larvae, and later larvae-early juvenile distributions, all of which agree reasonably well with the corresponding measured data.

10. The effect of two unit operation at Indian Point on the reduction of the Hudson River striped bass population was evaluated for a condition described as "current best estimate of impact," and for a condition described as "apparent maximum impact."

    The "current best estimate" condition employs data on the actual distribution of eggs, yolk-sac larvae and later larvae in the general vicinity of Indian Point and computes impact parameters that are considered to be reasonable though conservative.

The "apparent maximum estimate" condition maximizes estimates on intake area distribution, replenishment of fish to the area of Indian Point upon draw down of the Indian Point population by the plant and cropping during plant passage, and minimizes intake avoidance by early free swimmers.

In both cases, impingement was set at 46,000 striped bass. This impingement value obtained by adjusting Indian Point Unit 1 impingement data upward for specimens lost, and scaling upward in direct proportion to two unit flow. A reduced flow from October through March and full flow for the remainder of the year is used.

Results are given in Table S-1. These results show clearly that operation of Indian Point Units 1 and 2 should be expected to cause neither a substantial nor an irreversible adverse impact on the river's striped bass population, particularly during the first 10 years of operation.

11. At the present stage of its development, the transport model is considered to be able to generate a reasonably accurate description of the life history of the striped bass in the Hudson River, and in particular, the early stages of the bass and the effect of the plant on the young of the year recruitment.

It should be recognized that, as in the use of most models during the developmental stage, certain limitations exist. For example, plant recirculation, variable stage mortality, compensation in the adult stage reproductive parameters, and fluctuating year class

TABLE S-1

EFFECT OF TWO UNIT PLANT OPERATION ON HUDSON RIVER STRIPED BASS POPULATION

Age Group	Percentage Reduction after Years of Operation 1 Year	 5 Years	 10 Years
Run #1 - Current Best Estimates of Impact*			
1 Year Olds	2.5	3	3.5
Years 1 to 13	2	3	3.5
Run #2 - Apparent Maximum Impact*			
1 Year olds	4	5	6
Years 1 to 13	3	5	6

* The primary parameters controlling these estimates are the distribution of early stages in the Hudson River near Indian Point, the ability of at least some of these stages to avoid the intake, and the degree of cropping which takes place during plant passage. These have been designated "f" factors. Selection of values is discussed in detail in Chapter III.

recruitment are some of the factors which do not appear in the version of the model reported on in this testimony. Similarly, data gaps exist, notably in certain larval ages. Egg concentrations in several ways do not appear to be consistent with either larval or adult population estimates. A minimum of data is available to estimate plant impact parameters, particularly plant passage cropping rates, intake avoidance and draw down replenishment factors.

These limitations on both the available data and the model strongly suggest that field investigation and model analysis continue to permit substantially more confidence in the prediction of the impact of the plant on the river than is now possible.

I. NATURE OF THE ISSUE AND SPECIFICS TO BE CONSIDERED

Steam-electric generating stations operating on the Hudson River are equipped with circulating water systems which operate on the principle of once-through cooling. Large volumes of water are drafted from the river through intakes and circulated through condensers, at which point heat from spent steam is added to this water. This steam condensation process has the effect of raising the circulating water temperature by approximately 15°F when the plant is operating at full load and the circulators are at full flow. These heated waters are finally discharged back to and mixed with the main body of the Hudson River.

At certain times of the year, the early life stages of Hudson River fishes, including the egg stage, the larval stage, and the very early juvenile stage, are subject to entrainment or carriage into the circulating water system because they cannot yet swim independently and are thus at least partially subject to prevailing currents in the river, and are too small to be screened out. Later juvenile stages are too large to be entrained, but are still subject to impingement, that is, they can be caught on the screen.

Once entrained, these organisms would be subjected to rapidly changing mechanical, thermal, and pressure stresses as the water moves through the intake, the circulating water pump, the condenser, and the discharge line. As the water is lifted up to the condenser, its pressure drops rapidly below atmospheric pressure, and as heat is transferred to it from the spent steam, its temperature rises rapidly. These rapid changes in pressure and temperature, plus inevitable abrasion, are thought to have an adverse effect on many of the organisms contained in the circulating water.

The manner in which these stresses affect the early stages of Hudson River fishes which are entrained in the circulating water flow of Indian Point Unit 1 has been the subject of recent studies. Preliminary findings of studies initiated in late spring and early summer of 1972, during the spawning and early development season of the striped bass, indicate that the survivability appears to increase with age, the young larvae being most vulnerable and the later stage showing greater ability to condition to the impact.

Meanwhile, in parallel with these studies of actual damage, QL&M has been working to develop an analytical means to evaluate the potential for direct loss from both entrainment and impingement of eggs, larvae, and juveniles, and also the potential impact of that loss on the adult population **of striped bass in the river. We aim at predicting quantitatively the number or percentage of organisms in any stage that may be removed from** the river system each year, and secondly and more importantly the ultimate, long-term impact of this removal on the river fishery population.

A. PREVIOUS TESTIMONY: ITS PURPOSE AND SCOPE

On April 5, 1972, testimony in this regard entitled "*Testimony of John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers on the Effect of Entrainment at Indian Point on the Population of the Hudson River Striped Bass*" [1]* was submitted before the Atomic Safety and Licensing Board. This submission was in connection with hearings before that Board relating to

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*Numerals in brackets [ ] refer to corresponding items in Appendix I, References.

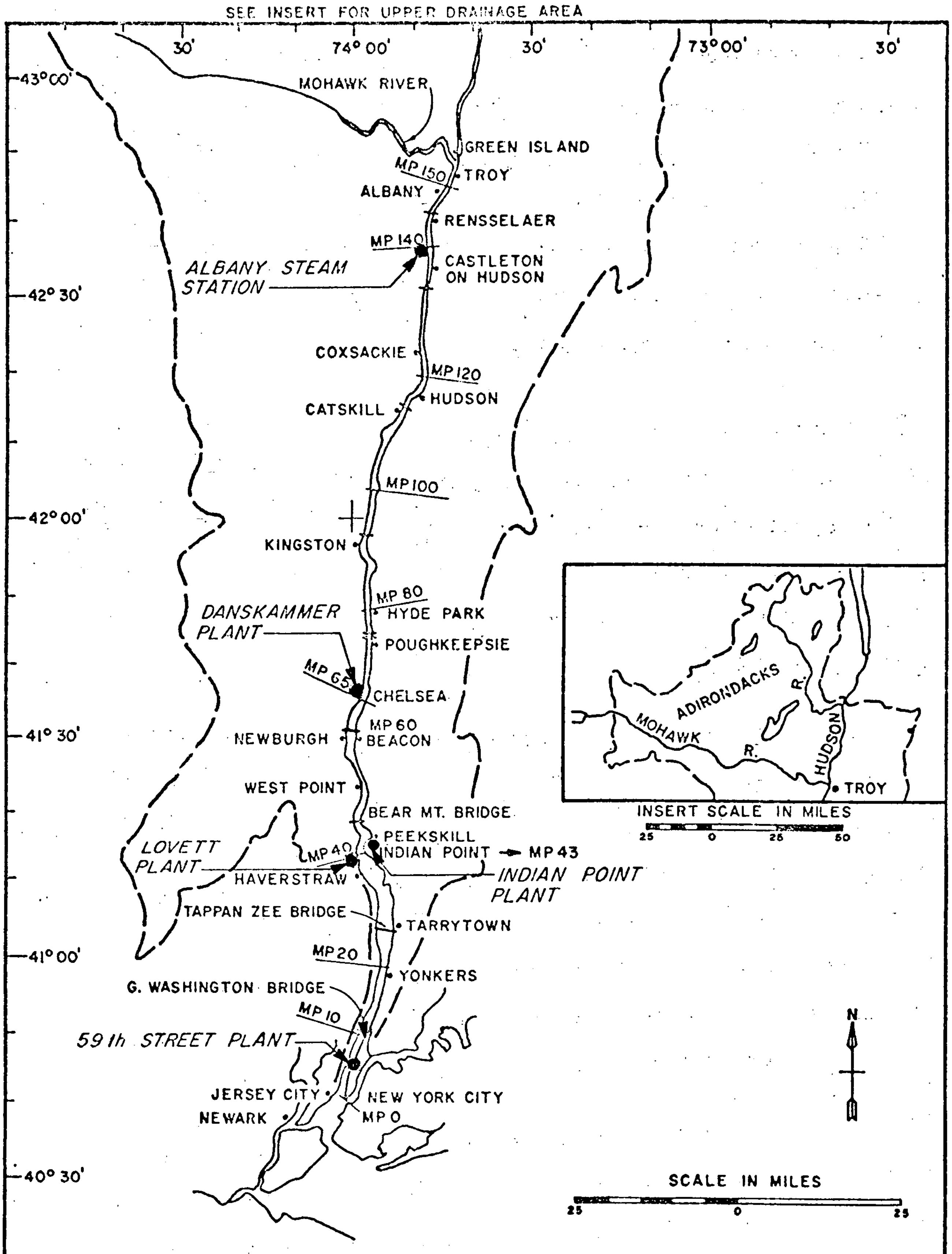
the initial testing operation of the Consolidated Edison Company of New York's Indian Point Unit 2 plant. That testimony described a study whose chief purpose, like that of the present study, was to evaluate the impact of the Indian Point nuclear generating station, comprising both the existing Unit 1 and Unit 2, on the Hudson River striped bass population. Secondarily, the roles of other existing generating units on the river were also considered.

The methodology employed is applicable to other estuaries as well as to other species of fish. The striped bass was singled out for that study and subsequent studies because more information is available on this species than on most other species in the Hudson River, and also because the striped bass is generally considered to be the species of greatest importance in the river.

Figures 1 and 2 and Table 1 are reproduced from the previous testimony. Figure 1 is a map showing the location of all the electric generating stations which have been operating for a number of years along the Hudson River, Figure 2 is a map showing the location of all such stations, including Indian Point Unit 1, that exist within the reach of the river between Coxsackie and Croton Point. This reach is of major concern in our studies, since the entrainable stages of the striped bass have not been observed outside of it [2 and 27].

Thus, as Figure 2 shows, three plants considered in our studies were: Orange and Rockland Utilities' Lovett generating station, located on the west bank approximately 1.5 miles below Indian Point; Central Hudson Gas and Electric Company's Danskammer station, located on the west bank

FIGURE 1



EXISTING HUDSON RIVER STEAM ELECTRIC POWER GENERATING STATIONS

FIGURE 2

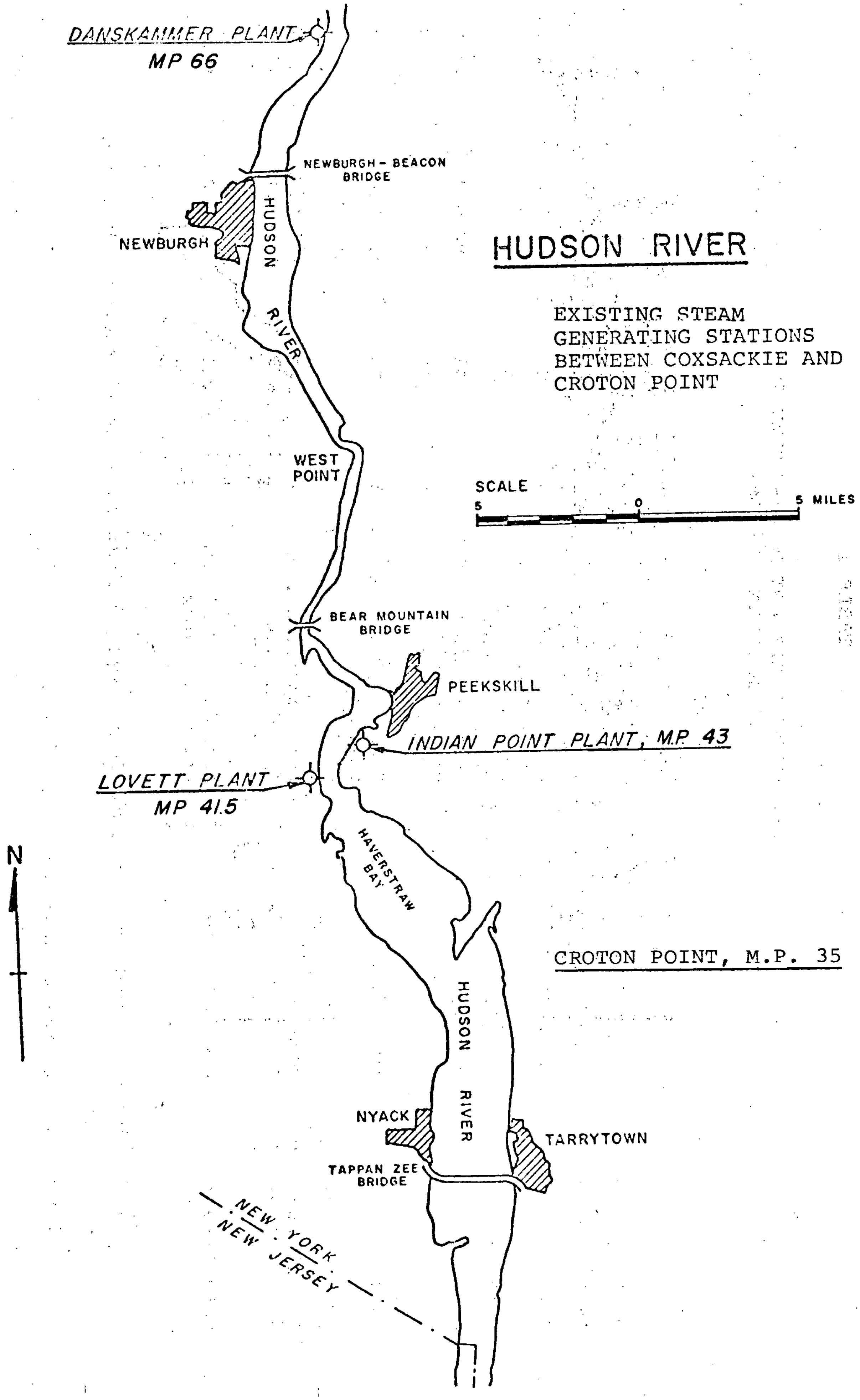

HUDSON RIVER
EXISTING STEAM GENERATING STATIONS BETWEEN COXSACKIE AND CROTON POINT
DANSKAMMER PLANT
MP 66
NEWBURGH - BEACON BRIDGE
NEWBURGH
HUDSON
RIVER
WEST POINT
SCALE
5
0
5 MILES
BEAR MOUNTAIN BRIDGE
PEEKSKILL
INDIAN POINT PLANT, M.P 43
LOVETT PLANT
MP 41.5
N
HAVERSTRAW BAY
CROTON POINT, M.P. 35
HUDSON
RIVER
NYACK
TARRYTOWN
TAPPAN ZEE BRIDGE
NEW YORK
NEW JERSEY

TABLE 1

EXISTING HUDSON RIVER STEAM ELECTRIC GENERATING STATIONS

Station Name	Location Village or Town	Location Mile Point	Utility Owner	Number of Units	Rated Capacity all units (Megawatts)	Total Plant Flow, (gpm)	Plant Temperature Rise at Rated Capacity (°F)
Albany	Glenmont	140	Niagara Mohawk Power Corp.	4	400	352,000	11.0
Danskammer	Newburgh	66	Central Hudson Gas & Electric	4	508	308,000	14.5
Lovett	Stony Point	42	Orange & Rockland Utilities	5	503	323,000	14.8
Indian Point #1	Buchanan	43	Consolidated Edison Co. of New York	1	265	318,000	14.0
Indian Point #2	Buchanan	43		1	873	870,000	15.1
59th Street	New York City	5	Consolidated Edison Co. of New York	7[1]	221[1]	168,000	6.0[2]

[1] Of this total, 4 units, totaling 91 MW, do not employ condenser but provide steam for in-city use.

[2] Monthly average operation, summer 1969.

just north of Newburgh and approximately 23 miles north of Indian Point; and Consolidated Edison's Indian Point Unit 1, located on the east bank about 43 miles north of the Battery. Field observations reflect the impact of these plants since they were in operating during the field work.

Niagara Mohawk's Albany steam station in Glenmont, New York, and Con Edison's 59th Street station in mid-Manhattan are considered to have no effect on the early stages of the striped bass since they lie outside the relevant reach.

Table 1 shows the operating characteristics of these generating stations.

B. MODIFICATIONS AND ADDITIONS TO PREVIOUS TESTIMONY

The April 5, 1972 testimony was specifically directed at predicting the impact on the bass of one full year of operation of Indian Point Units 1 and 2. It shows that, with the maximum entrainment loss possible under study conditions, and under the unrealistic assumption of no compensation in any life stage, one year's full flow operation of Indian Point Units 1 and 2 could reduce the population of striped bass aged 1 year or more by about 2.5% to 3.5%.

These estimates were derived from an analytical model of the so-called "completely mixed" type; the study acknowledged certain sources of imprecision in that model. During the last six months, considerable effort has been expended by QL&M to refine it. Our objectives included:

1. Construction of a Hudson River transport model. The Hudson River is not a completely mixed body, as had been assumed for computational purposes in the earlier testimony, but rather is a tidal

estuary which varies significantly along its length in geometry, mixing, and flow characteristics. These characteristics, coupled with observed striped bass spawning and juvenile development behavior in the Hudson River, necessitated construction of a model which could reproduce the changing density (concentration) of striped bass at various stages of their life, both along the river's longitudinal axis and in time.

2. Incorporation of the notion of biological compensation into the transport and completely mixed models, since any biological system must, over a period of time, compensate for new impacts which tend to either increase or decrease the existing population level.

3. Demonstration of the consistency of the transport model by showing that it can reproduce the extensive information on striped bass behavior in the Hudson River developed by Carlson & McCann in *"Hudson River Fisheries Investigations, 1965-1968"* [2].

4. Use of the transport model to make a more refined prediction of the percentage reduction of juvenile striped bass at various stages of development caused by variations in sets of plant operating conditions, hydrodynamic characteristics of the river, and the movements of the striped bass themselves.

5. Incorporation of the transport model into the fish life-cycle model to make a more refined prediction of both the short- and long-term impacts of plant operation on the adult (1 year and older) striped bass population.

Like that in the previous testimony, this methodology is also applicable to other estuaries and other species of fish.

The data assembled by Carlson & McCann [2] in the years 1965 through 1968 are used for the striped bass population distribution in the Hudson, although the transport model is capable of accepting any set of data on this distribution.

C. REPORT FORMAT AND SCOPE

This testimony describes the development and calibration of the transport model, then uses it to evaluate both the short- and long-term impact of continuous two-unit operation at Indian Point on the river striped bass population. It is divided into the following chapters, each of which begins with a brief summary of its contents.

1. Chapter II describes the development of the transport model, including the introduction of compensation mechanisms, and shows how this new, more complex model is expected to predict with greater refinement the impact of the two-unit operation on the striped bass population.

2. Chapter III gives an account of the selection of model input parameters and describes each briefly.

3. Chapter IV tests the transport model by showing that it is capable of reproducing the actual behavior of the striped bass as it appears in the Carlson & McCann study.

4. Chapter V, finally, makes use of the model to evaluate the impact of operation of Indian Point Units 1 and 2 on the Hudson River

striped bass population. Estimates of impingement and entrainment losses are made by combining the data the model produces with measured actual information on the behavior of the fish and the river at Indian Point.

A tabulation of references cited in this testimony and a list defining the symbols used in the mathematical equations are contained in Appendices I and II, respectively.

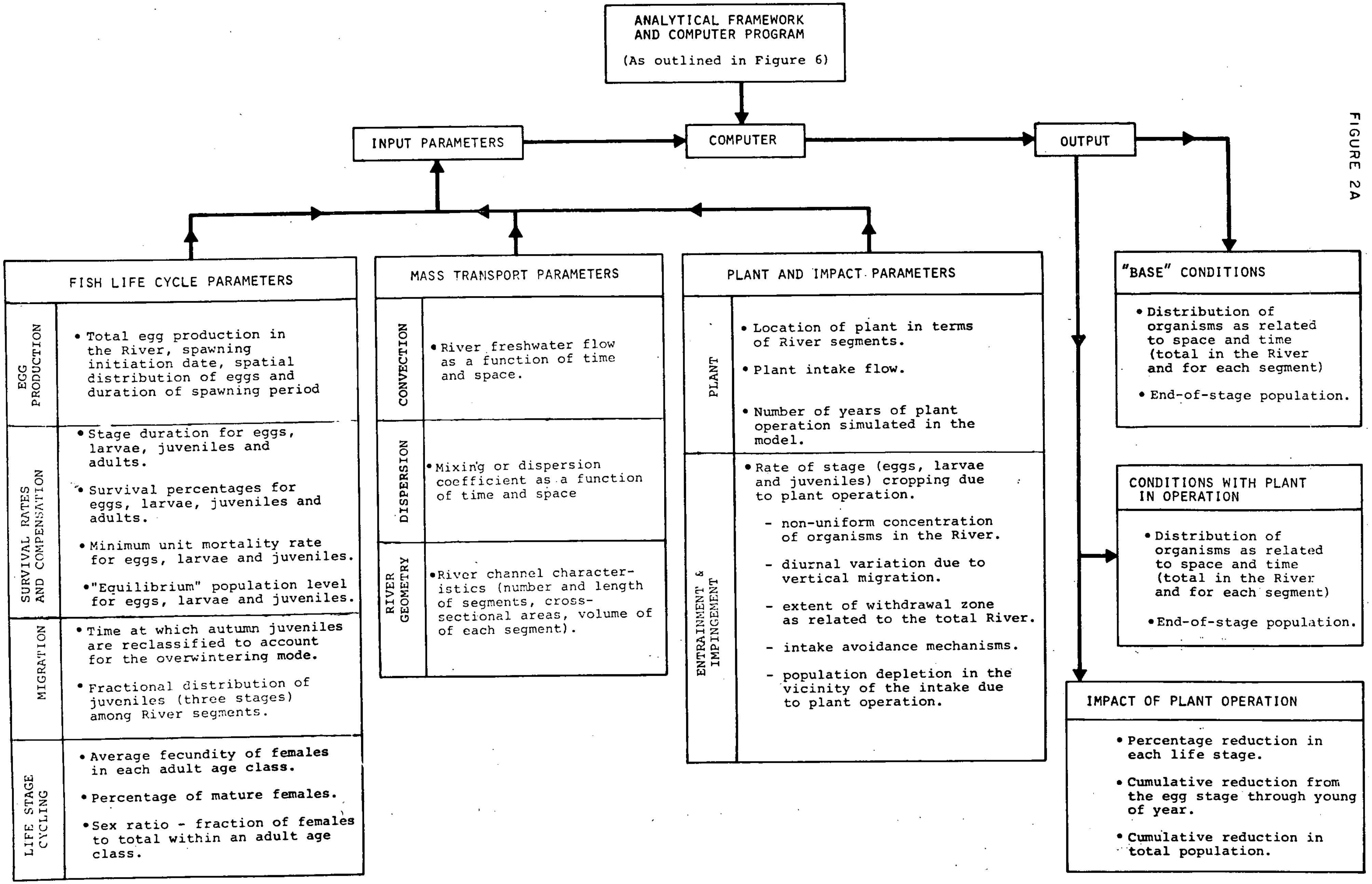
Figure 2A shows in picture form the whole procedure. First, the model is developed as a mathematical statement of the complex interrelationships of two large sets of parameters: one embracing all aspects of the life cycle of the fish — egg production, survival rates, migration facts, etc., and the other embracing physical aspects of the river — its rate of flow, its dispersion, its complicated and varied geometry.

Values for all these parameters are then placed as input into the computer, which solves the equations in the model, producing as output a series of values which represent the basic natural conditions we seek to know - how eggs, larvae, and juveniles are concentrated in the river at any particular time and in any particular place.

At this point, the model is tested with the Carlson & McCann data; this is not a further step in the procedure, but rather a repetition of the previous steps from a different direction - the consistency of the model is checked by comparing it with a set of measured data.

Then, a further set of parameters embracing all aspects of plant operation, and including various aspects of observed behavior of the fish and the river at the site of the plant, is placed as input into the computer.

HUDSON RIVER STRIPED BASS
TRANSPORT MODEL PARAMETERS



FISH LIFE CYCLE PARAMETERS

EGG PRODUCTION
- Total egg production in the River, spawning initiation date, spatial distribution of eggs and duration of spawning period

SURVIVAL RATES AND COMPENSATION
- Stage duration for eggs, larvae, juveniles and adults.
- Survival percentages for eggs, larvae, juveniles and adults.
- Minimum unit mortality rate for eggs, larvae and juveniles.
- "Equilibrium" population level for eggs, larvae and juveniles.

MIGRATION
- Time at which autumn juveniles are reclassified to account for the overwintering mode.
- Fractional distribution of juveniles (three stages) among River segments.

LIFE STAGE CYCLING
- Average fecundity of females in each adult age class.
- Percentage of mature females.
- Sex ratio - fraction of females to total within an adult age class.

MASS TRANSPORT PARAMETERS

CONVECTION
- River freshwater flow as a function of time and space.

DISPERSION
- Mixing or dispersion coefficient as a function of time and space

RIVER GEOMETRY
- River channel characteristics (number and length of segments, cross-sectional areas, volume of of each segment).

PLANT AND IMPACT PARAMETERS

PLANT
- Location of plant in terms of River segments.
- Plant intake flow.
- Number of years of plant operation simulated in the model.

ENTRAINMENT & IMPINGEMENT
- Rate of stage (eggs, larvae and juveniles) cropping due to plant operation.
  - non-uniform concentration of organisms in the River.
  - diurnal variation due to vertical migration.
  - extent of withdrawal zone as related to the total River.
  - intake avoidance mechanisms.
  - population depletion in the vicinity of the intake due to plant operation.

"BASE" CONDITIONS
- Distribution of organisms as related to space and time (total in the River and for each segment)
- End-of-stage population.

CONDITIONS WITH PLANT IN OPERATION
- Distribution of organisms as related to space and time (total in the River and for each segment)
- End-of-stage population.

IMPACT OF PLANT OPERATION
- Percentage reduction in each life stage.
- Cumulative reduction from the egg stage through young of year.
- Cumulative reduction in total population.

FIGURE 2A

These computations modify the basic natural conditions so as to produce as output a set of "conditions with plant operation."

Finally, these two sets of conditions, without and with the plant, are compared; the output of these comparisons is the goal of the whole procedure: a set of percentage values which describe the impact of plant operation.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of	)	Docket No. 50-247
New York, Inc.	)	
(Indian Point Station, Unit 2)	)	

Testimony of
John P. Lawler, Ph.D.
Quirk, Lawler & Matusky Engineers
on the
Effect of Entrainment and Impingement at Indian Point on the Population of the Hudson River Striped Bass

Modifications and Additions to Testimony of April 5, 1972

October 30, 1972

II. DEVELOPMENT OF THE MATHEMATICAL MODEL

INTRODUCTION

This chapter summarizes the methodology used to develop the Hudson River striped bass transport model. A previously developed river transport model, which describes the movement of either naturally occurring or introduced materials, and knowledge of the striped bass life cycle in the river were integrated to develop the final model, the use of which is described in Chapter V.

This chapter is theoretical: it addresses itself to the determination of the dominating mechanisms involved. Further details of the system parameters, their numerical values, and mathematical analysis are given in Chapter III.

A. THE COMPLETELY MIXED MODEL

Our testimony of April 5, 1972 divided the first year of life of the striped bass into five stages (eggs, larvae, juvenile I, II, III). The density of each stage varied with time but was assumed, at any point in time, to be the same everywhere within the total volume of the river reach in which these stages are known to appear.

This assumption of equal density everywhere in the river was explained physically by presuming that the river was so well mixed that all of the fish, regardless of where they were first spawned, upon spawning immediately became uniformly distributed throughout the river.

This assumption is a common one in making a first estimate of the manner in which a body of water will behave when subjected to some external influence. It is made because it renders the mathematical description of the physical phenomena substantially more tractable, i.e., amenable to solution, than it would otherwise be. This approach is usually justified as a first step before more complex refinements are attempted.

In the case of Indian Point and the Hudson River striped bass, it was justified as yielding a conservative estimate of the population reduction, because:

- It granted each organism in the river an equal chance of being entrained.
- It subjected these organisms to entrainment during each moment of a 52.5-day period of growth, from the moment of spawning to a point where, because of their size (2 inches ±), they were no longer subject to entrainment.

Stated in another way, it assumed that each young striped bass in the river appeared in the vicinity of Indian Point for the entire first 52.5 days of its life.

Offsetting this obvious conservatism are the facts that:

- The volume used to describe this "vicinity of Indian Point" was actually the total river volume over which organisms in this age bracket were known to exist.
- At some stages during this period of growth, the actual concentration at Indian Point is higher than the average concentration of that life stage in the river.
- Impingement losses were not accounted for.

The foregoing notion of uniform distribution, with its limited combination of conservative and liberal elements, is the *sine qua non* of the "completely mixed" model.

B. THE TRANSPORT NOTION

Based upon its geometry and hydrodynamic characteristics, an estuary can be segmented by selecting appropriate boundaries for each segment. In general, if we know the freshwater flow, dispersion, and channel geometry at the boundaries of each segment, we can predict the transport of a particular substance, that is, how it will move within each segment and from segment to segment.

The Indian Point plant operates on a limited reach of the Hudson River. At any given point in time, the Carlson & McCann report [2] shows that concentrations in this reach may not be representative of the various life stage concentrations occurring in other limited reaches throughout the estuary. Consequently, the Hudson River "transport model," which is representative of variations in river geometry, flow, and mixing as they occur along the entire reach of interest from Coxsackie to Croton Point, was based upon a segmentation which can consider variations in organism behavior from segment to segment.

Other transport models of estuaries have been constructed by numerous investigators over the last two decades. The reader is referred to References [4], [5], [6], and [7], all of which take some form of the basic equations of mass, momentum, and energy transport [8] and utilize these equations to develop mathematical descriptions of estuarine hydraulics (momentum transport), the transport of physical, chemical, and biological water quality parameters (mass transport), and the transport of heat (energy transport).

Transport models of the Hudson River have been developed by QL&M [9, 10, 11, 12, 13, 14] and by others [15, 16] to describe the movement of salt and dissolved oxygen, and of introduced materials including organic waste discharges and heat. References [11] and [12] appear as Appendices J and K of Supplement No. 1 to Con Edison's Environmental Report on Indian Point Unit 2, September 9, 1971 [17], which appears in evidence in this hearing.

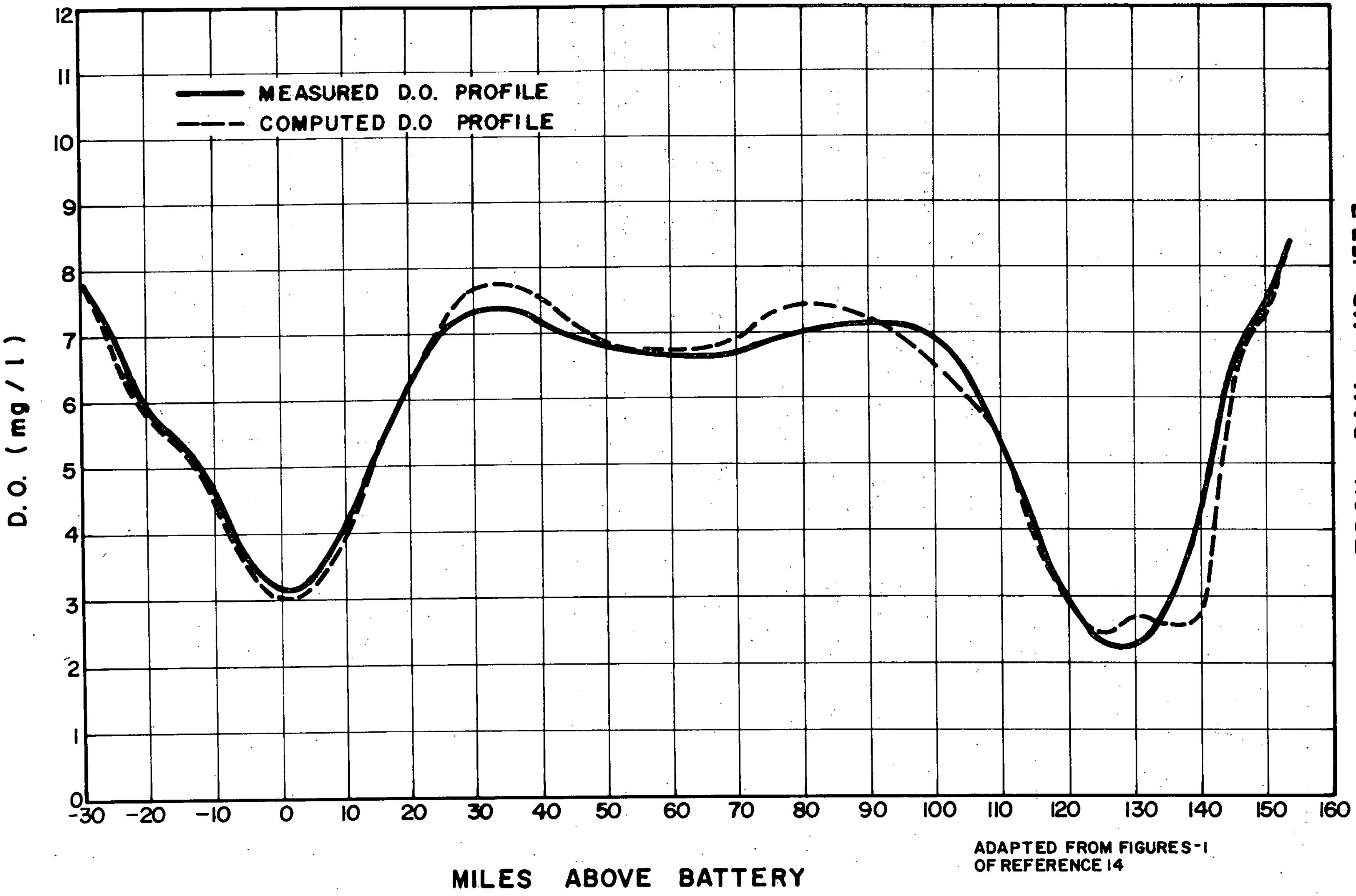
The transport model employed in this present study is basically an unsteady state, one-dimensional, longitudinally segmented model, in which the basic mechanisms of transport are advection, or net downstream movement by freshwater flow, and longitudinal dispersion, or the net additional mixing and dilution of materials due primarily to tidal oscillation and salinity-induced density currents.

Each river segment is capable of receiving as input time-variable flows, mixing coefficients, loading, and growth and/or decay rate functions. As will be demonstrated later, loading and growth/decay rate functions as used in the fish life cycle model are represented by fish spawning behavior, life stage durations, and stage survival percentages.

Model response is a time-variable concentration profile for each segment, resulting in a distribution of the sought-after concentration variable (in this case, each life stage's population density) in both time (days, weeks, and seasons from year to year) and space (river milepoint from Coxsackie to Croton Point) as well as a discrete age-group distribution of the stage concentration.

The success of any model is measured in terms of its ability to reproduce observed behavior, when the measured external conditions thought to be responsible for that behavior are introduced as model inputs. Figure 3

FINAL VERIFICATION – SEPTEMBER 1967 SURVEY



ADAPTED FROM FIGURES-1
OF REFERENCE 14

FIGURE 3

shows the excellent agreement obtained between the measured behavior of dissolved oxygen in the Hudson River and the basic transport model's prediction of that behavior. It was this known ability of the basic Hudson River transport model to reproduce the real river's behavior that suggested its use in this project.

C. THE FISH LIFE CYCLE

The basic life cycle for striped bass in the Hudson River and time periods associated with all of the early life stages are described in the April 5, 1972 testimony [1] and are shown here in Figures 4 and 5. For any individual organism, the egg stage lasts about 1.5 days, the larval stage about 28 days, and the juvenile I stage about 30 days.

A large percentage of the vast numbers of eggs represented by the top circle in Figure 4 never survive, being subjected to natural mortality via settlement into bottom muds, lack of fertilization, predation, etc. These losses are depicted on Figure 4 by the double arrow directed outward from the cycle at the egg stage.

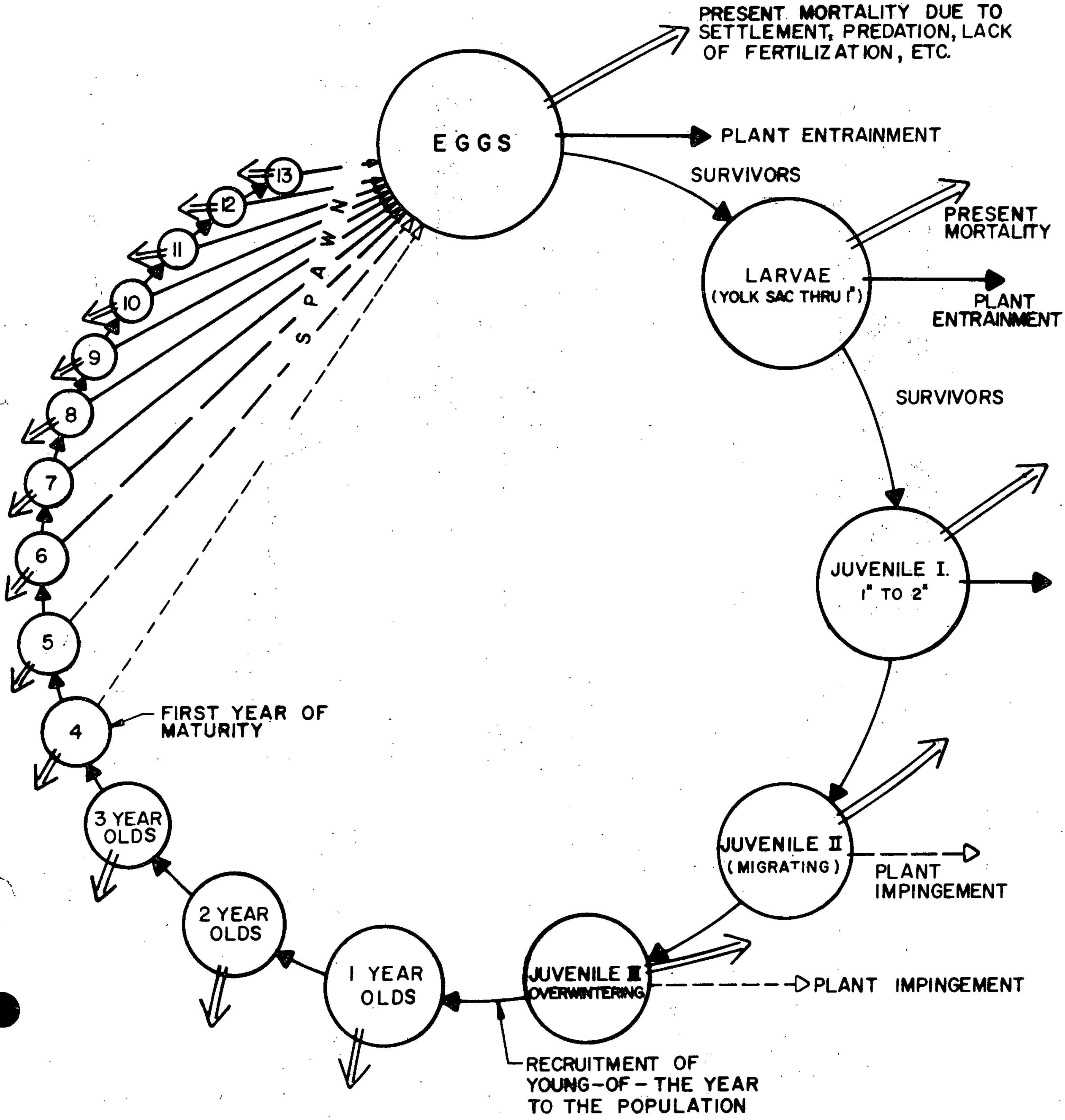
The term "present mortality" has been employed in this and successive stages to represent mortality that now takes place in the river, whether due to natural or artificial causes such as existing power plant operation.

This first stage is also subject to entrainment and some presumed resultant mortality, when within the influence of plant intakes. This effect is depicted by a single bold arrow, also directed outward from the cycle at the egg stage.

Those eggs which survive are represented on Figure 4 as being transferred into the larval or next stage of the cycle.

FIGURE 4

SCHEMATIC LIFE CYCLE FOR STRIPED BASS IN THE HUDSON RIVER



STRIPED BASS DEVELOPMENT FROM FERTILIZED EGG TO ONE YEAR OF AGE

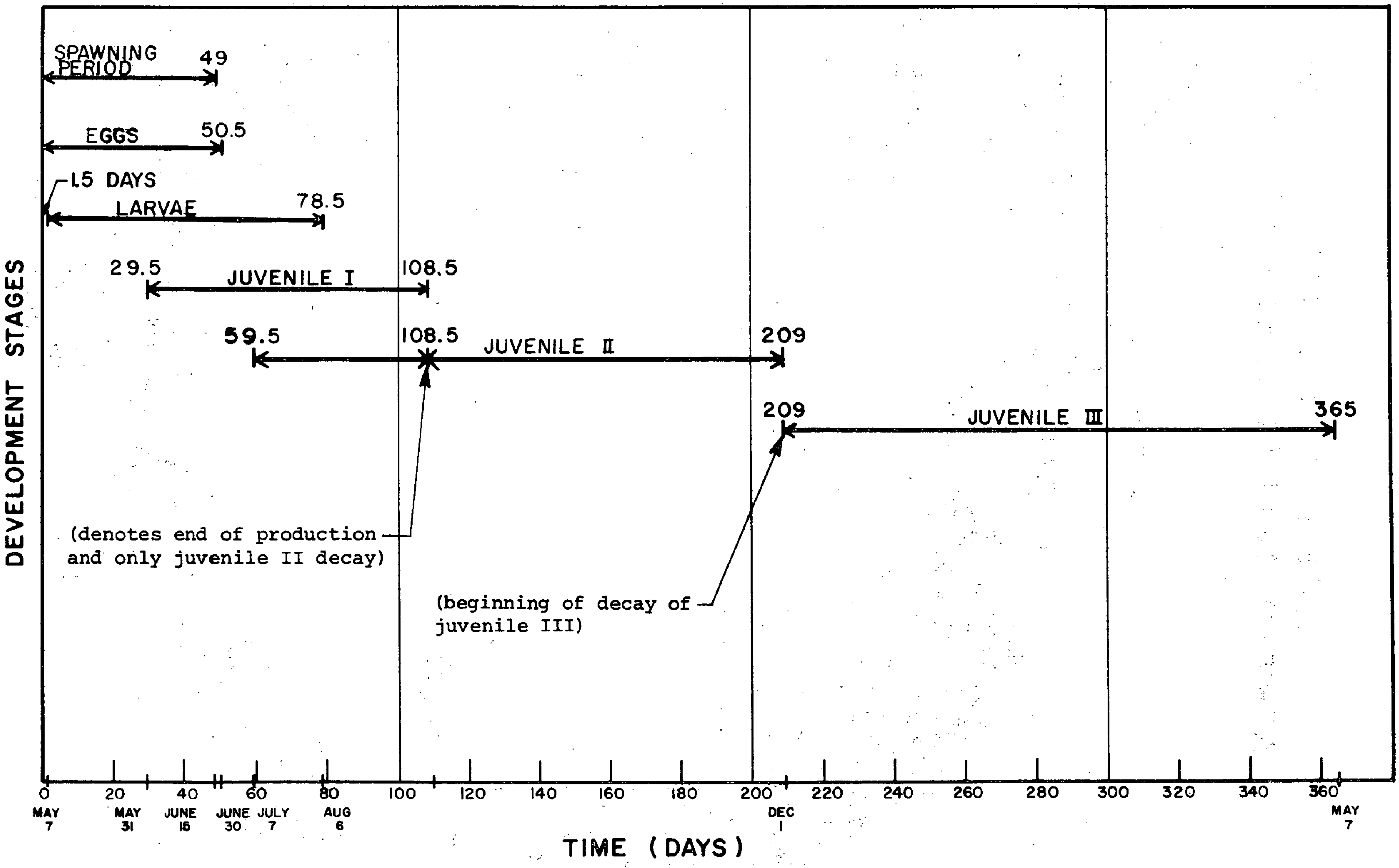


FIGURE 5

Similar behavior of present and plant-induced mortality as well as survival and passage into the next stage are shown in the larval and juvenile stages. Plant-induced mortality is shown to include impingement on fish screens as well as entrainment into the circulating water system.

Three consecutive sub-stages of the juvenile stage are recognized, as shown in Figure 4. These are:

1. The juvenile I stage, J_I, or so-called non-screenable juveniles. This stage begins at the end of the 28-day larval stage and continues for one month (30 days). This has been chosen as the length of time during which juveniles are still entrainable, or non-screenable. At the end of the 58-day post-egg development stage, the young juveniles have reached approximately 1.5 to 2 inches in length and at that point are no longer considered entrainable.

2. The juvenile II stage, J_{II}, beginning at the end of the J_I stage and lasting through November 30th. These are termed screenable juveniles, migrating mode, and represent the young of the year which appear in nursery areas along the river between Coxsackie and Croton Point from mid- to late summer and then in the fall begin to move downriver toward Haverstraw Bay.

3. The juvenile III stage, J_{III}, overwintering in the river, probably primarily in the region of Haverstraw Bay, between December 1st and May 9th.

It is realized that, biologically, the juvenile stage lasts until the attainment of sexual maturity. For the striped bass, the first significant female maturity is believed to occur in the four-year-old fish. The term "juvenile" as used in this testimony, however, represents only that stage of the life cycle between the larval stage and the completion of the first year of life. These "juveniles" are potentially subject to damage by the plant.

After reaching the age of one year, the fish are no longer subject to entrainment nor, for the most part, impingement. Therefore, the population of these immature fish has been lumped together with the mature adult population, and the abbreviated term "adult population" employed to represent all fish one year old or more. These two groups, taken together, represent the bass population that, although not directly subject to damage by the plant, may yet feel the impact of direct damage to early stages.

Some four-year-old females are sexually mature and so, from that point on, adults are shown in Figure 4 to be contributing to the egg complement, thus completing the cycle.

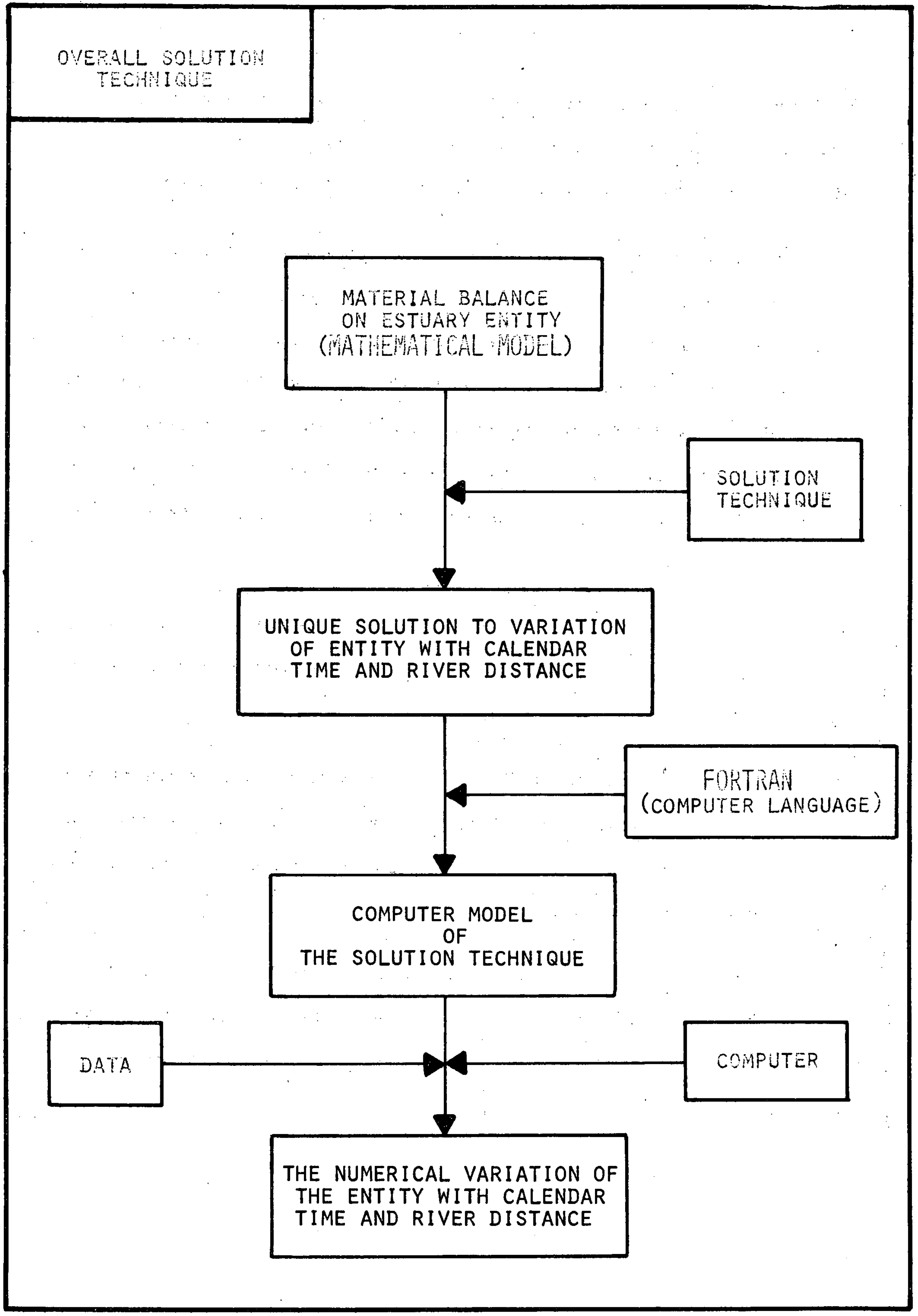
A more detailed description of these two figures is given on pages 7 through 10 and pages 30 through 33 of our April 5, 1972 testimony [1].

D. INTEGRATION OF TRANSPORT NOTION AND FISH LIFE CYCLE

The overall approach to modeling the Hudson River is depicted in Figure 6. This figure and a detailed development of the basic transport model including a description of the mathematics employed are given in Chapter V of Reference [14].

The work presented in Reference [14] was done for the Pure Waters Division of the New York State Department of Health (now a division of the New York State Department of Environmental Conservation). The NYSDEC model

FIGURE 6


OVERALL SOLUTION TECHNIQUE
MATERIAL BALANCE ON ESTUARY ENTITY (MATHEMATICAL MODEL)
SOLUTION TECHNIQUE
UNIQUE SOLUTION TO VARIATION OF ENTITY WITH CALENDAR TIME AND RIVER DISTANCE
FORTRAN (COMPUTER LANGUAGE)
COMPUTER MODEL OF THE SOLUTION TECHNIQUE
DATA
COMPUTER
THE NUMERICAL VARIATION OF THE ENTITY WITH CALENDAR TIME AND RIVER DISTANCE

delineates the river response in terms of BOD concentrations, via its transport mechanisms, to industrial and municipal organic waste loads, and yields the resulting impact on the river's dissolved oxygen profile.

In particular, the derivation delineated in Reference [14] is generalized to apply to mass or energy transport, and in its general form includes terms that describe dispersion, advection, production, and decay within the segment volume (whether chemical, biochemical, biological, or physical in nature, and whether dependent on the constituent concentration in question or on another). Also included are terms relating to production and decay at the river surface and bottom, and gain or loss of matter or energy with time.

This work was the point of departure for the construction of our present Hudson River striped bass transport model which integrates the transport notion with the fish life cycle.

Figure 7 is a continuation of Figure 6 and depicts the parameters of each input system. The system of fish life cycle parameters and the system of mass transport parameters have been combined to develop the input required for the striped bass transport model.

Figure 8 delineates the various steps involved in modeling the striped bass behavior. A brief description of these steps and of physical complexities in the striped bass behavior is given in the remaining sections of this chapter.

FIGURE 7

HUDSON RIVER STRIPED BASS TRANSPORT MODEL PARAMETERS

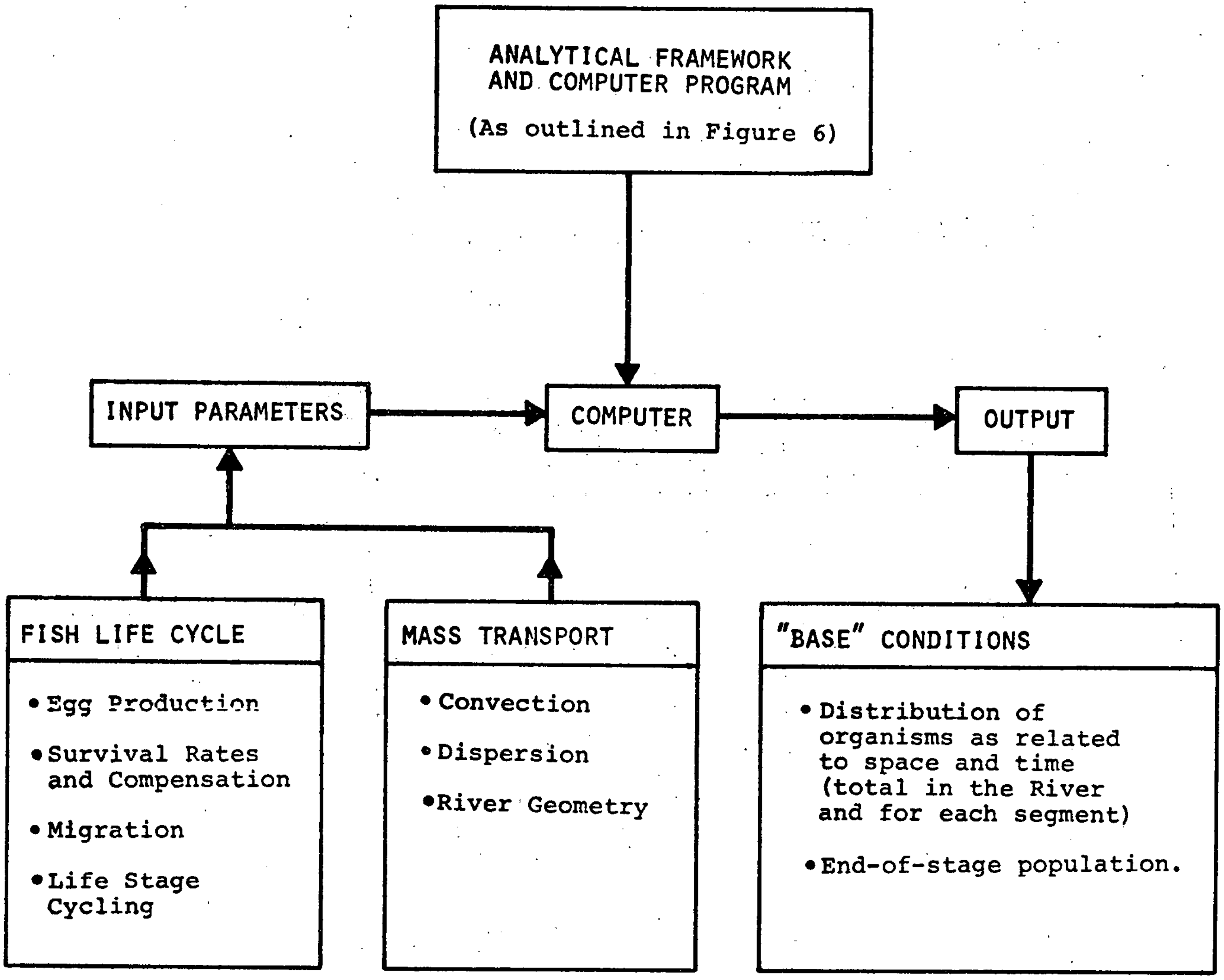


FIGURE 8. SYSTEM FLOW OF STRIPED BASS TRANSPORT MODEL

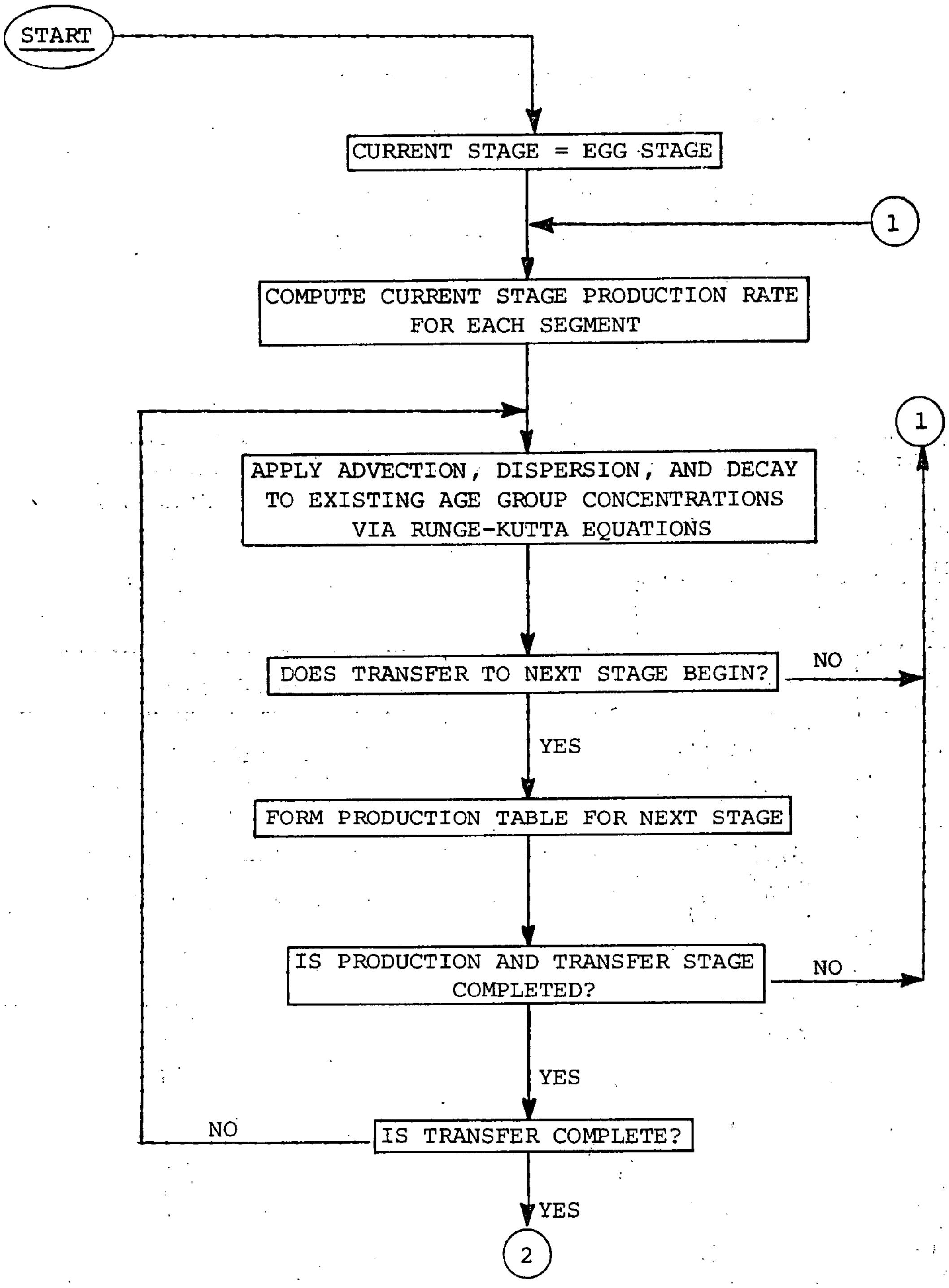
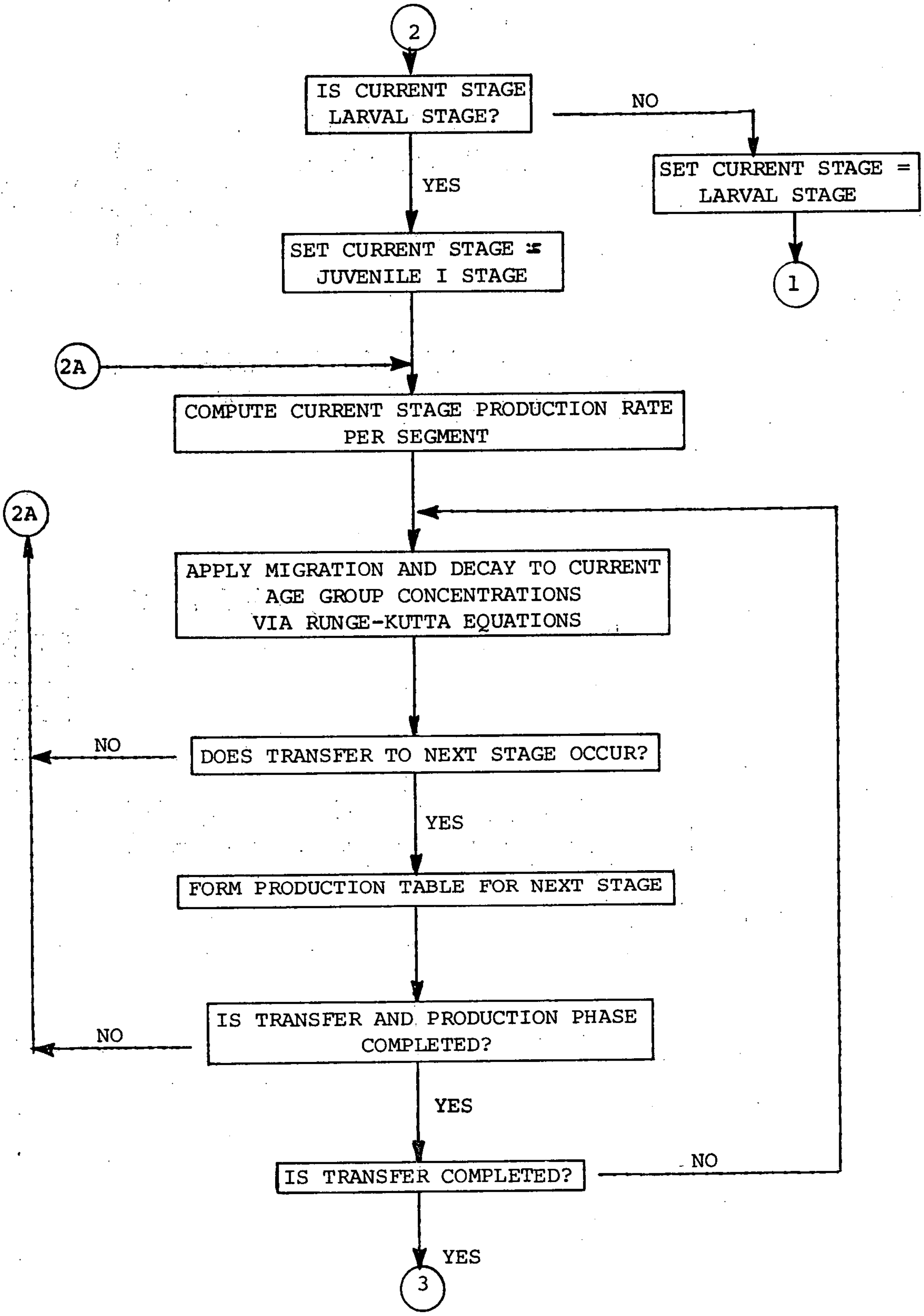


FIGURE 8 (continued)



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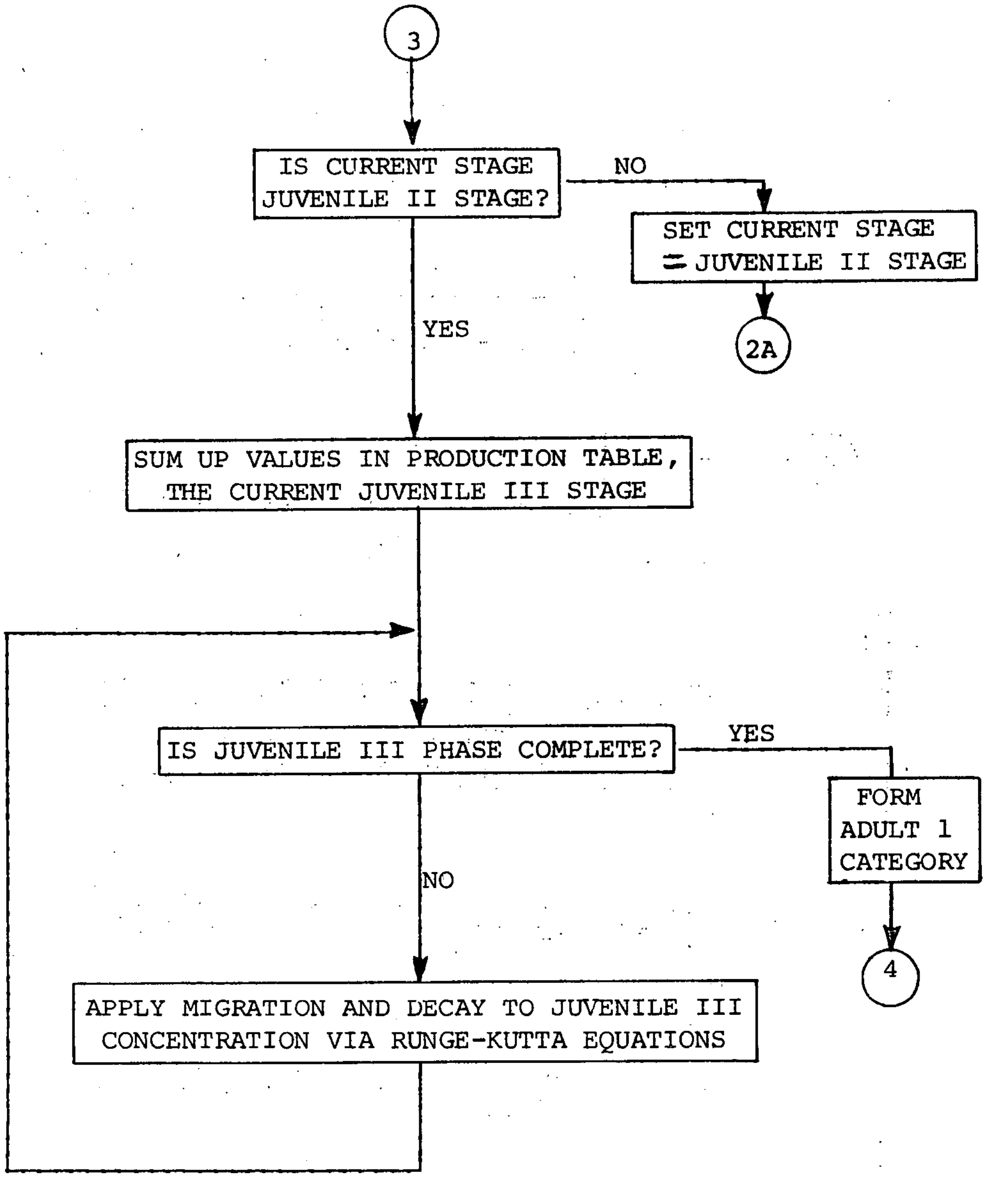

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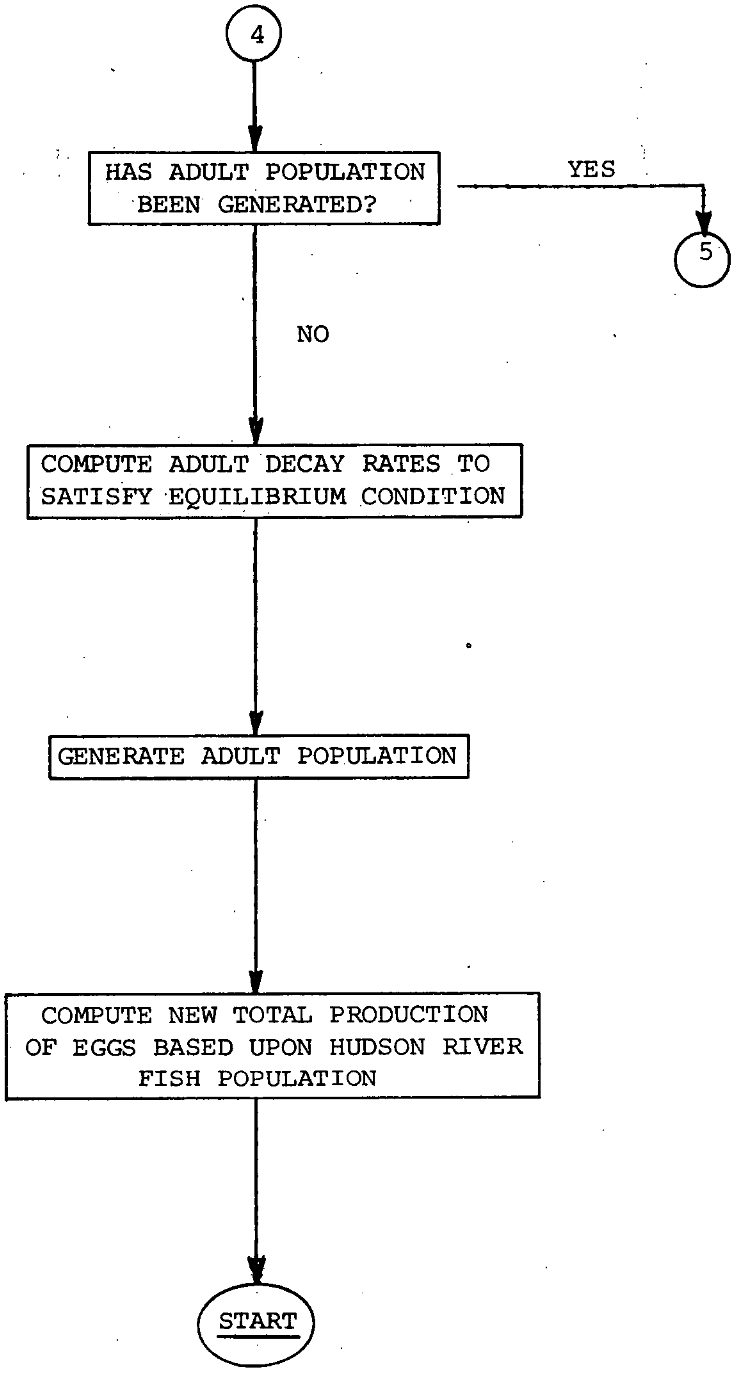

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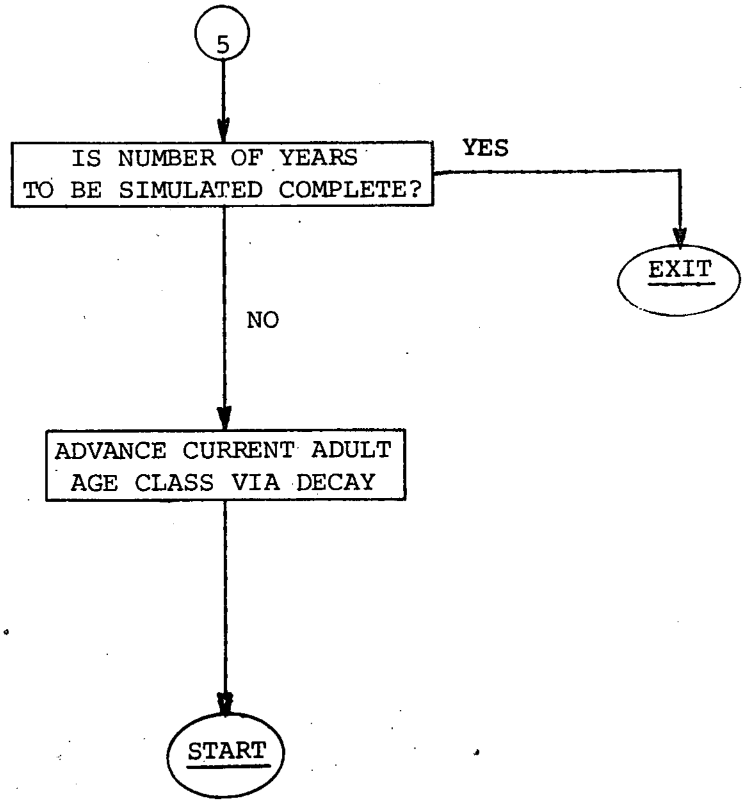

E. TRANSPORT MODEL MODIFICATIONS

Modeling striped bass behavior in the Hudson River involved substantial modifications to the basic model presented in Reference [14]. Some of these modifications were improvements in solution and computer programming techniques. The model also had to recognize certain complicating physical factors in striped bass behavior, for which there was no analogue in any of the previous Hudson River modeling efforts. These included:

1. The fact that the fate of any day's egg complement could not be simply considered as following a continuous decay function; instead, the eggs remaining after a 1.5-day period of life had to be considered as survivors and were then transferred to a larval stage. Similar statements hold for the larval and each of the juvenile stages considered.

2. The fact that, with each successive day of life, the young fish becomes more and more the master of its own fate and less and less inclined to respond passively to the river transport mechanisms.

3. The fact that compensatory mechanisms always involve non-linear or density-dependent behavior.

4. The fact that a feedback system was involved, i.e., the adult striped bass, the result of prior years of spawning, eventually mature and reproduce. This completes the life cycle.

The manner in which each of these complicating factors was accommodated in the model is briefly discussed below.

1. Transfer of Survivors to the Next Stage — The Age Distribution Notion

The treatment of passage of survivors from one stage into the next was relatively easy in the completely mixed model described in our April 5, 1972 testimony [1] because the water body was completely mixed and the kinetics were linear since no compensation was involved. In the transport model, however, it is necessary to know where the egg, larva, or juvenile is when it is ready to be identified as entering the next stage of life. At any point in calendar time, and in any river segment, we must be able to identify the relative numbers of eggs of different age groups. Similar statements hold true for each successive stage.

In particular, in order to provide the proper transfer rates in the proper segments at the proper time, it was necessary to divide the egg stage into a discrete set of age groups (15 in all were chosen) and to compute the distribution in time and space of each age group, using the basic set of equations of mass transport for the estuary.

The same analysis was applied to the larval stage except that age groups were divided into 0.5-day intervals for a total of 56 age groups.

2. Modeling of Juvenile Migration

In modeling the juvenile I stage (30-day period extending from day 30 of life to day 60 of life), the mechanisms of advection and dispersion were replaced by the notion of migration. At this stage of post-larval/early-juvenile development, the fish are capable of self-movement and can either remain stationary in moving water or migrate to other areas (i.e., segments) in the system. In modeling the migration, it was assumed that juvenile I's migrate to given areas of the Hudson. This distribution can be represented by giving a migration preference to each segment. This is simply the relative fraction of juvenile I's which exist in each segment during the latter part of their existence, i.e., prior to their classification as juvenile II's. Computation of migration preferences is given in Section A-3 of Chapter III.

Since the juvenile I and II stages overlap in time, it was decided to utilize actual (sampled) distributions of juvenile I's near the end of their "last appearance" during the year to represent that distribution which all juvenile I's tend to seek, even though the "first appearing" juvenile I's would transfer to juvenile II before this time. This was done to simplify the mathematics and programming.

The juvenile II and III stages were handled in a similar manner except that migration was used as an alternative mechanism, i.e., their stages may either migrate or remain stationary in the same segments.

3. Compensation Mechanism

The notion of compensation has been introduced in our early testimony [1] wherein it is shown that, rather than simply being a possibility, compensation must occur in the type of biological system under consideration in this study.

Use of non-compensatory survival kinetics would result in either unbounded growth or unbounded decay when the random nature of the real system is modeled. Furthermore, it was shown that the introduction into the model of any perturbation or external influence, however small, that tends to reduce the population will drive the population to extinction if the model employs only non-compensatory survival kinetics.

The reader is referred to References [18] through [23] in which the notion of compensation and mechanisms similar to the one used herein are discussed. Nicolson [18]* writes:

> "However, abundant evidence is provided by both field and laboratory studies showing that the populations of many different kinds of animals possess the ability to adjust themselves to great changes in their environments....this ability is possessed by all persistent populations....An inherent difficulty with field studies is that the observable events in natural populations consist largely of end results, and the situation in the field is generally so complex that it is difficult to identify with certainty the underlying causes of many of the observed events."

and concludes:

> "In brief, it is the innate ability of animals to produce a surplus of offspring which enables populations to persist in spite of adverse environmental factors which cause heavy mortality, or which seriously interfere with reproduction, provided these are not so severe that they cause the number of mature offspring to be less than the number of parents, when averaged over a long period. When adverse factors are less

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*Similar statements appear in [21] on pages 306-307, in [22] on page 332, in [19] on pages 28-29, 59, in [20] on pages 655-657, and in [23] on pages 275-278. We have selected these since it succintly propounds the notion of compensation.

> severe than this a population will tend to increase progressively, but increasing density induces adverse effects which oppose population growth with progressively greater severity, so preventing further growth when the intensity of this induced opposition, combined with that of the inherent environmental resistance, just counteracts the innate ability of the animals to multiply. Consequently any species automatically adjusts its density in different places, and in the same place at different times, in relation to the prevailing environmental conditions; and it maintains a state of stability under all conditions which are not inherently intolerable. This mechanism may enable populations to remain in being in spite of great changes in the environment, without any necessity for the development of new adaptations."

In the early modeling effort, the mathematical expression chosen to account for the natural mortality of fish in each stage of life was the so-called "first order" or "exponential" decay function. This simply states that the unit rate of decay is directly proportional, i.e., proportional to the first power of the remaining concentration of material. In our case, the unit rate of decay is the rate of death of fish per thousand cubic feet of Hudson River water. The "remaining concentration of material" is the surviving population of fish, again on the basis of a unit volume of Hudson River water.

First order kinetics is very commonly assumed to describe both growth and decay in many physical, chemical, and biological systems [24 through 26] because, over the range of populations of organisms or concentrations of substances being studied, the data on rate changes in these populations often can be fitted well to a first order function.

This does not mean, however, that first order kinetics describes what is actually taking place within the system. Most authors in the references cited (see, for example, page 329 of Reference [24], page 47 of Reference [25], and pages 28-39 of Reference [26]) are careful to point out that first order behavior is simply an empirical overview of what in reality is usually a far more complex phenomenon. The literature on enzyme kinetics, for example, beginning with the original kinetic expressions of Michaelis and Menten [27] and continuing to the present day, shows clearly that the more accurate description of kinetic behavior over the whole range of enzyme and substrate concentrations involves expressions that reduce to first order behavior for certain limited ranges only.

Quantitative accounting for compensation in biological systems is simply a recognition that, as in other physical systems, first order kinetics cannot be employed to describe survival kinetics over the whole range of population. This recognition requires that rather than using the simple first order decay function exclusively to describe natural survival behavior, a more complex expression must be employed.

This expression should reduce to the first order function over the range of populations where such is appropriate, but should also recognize the tendency of the system to compensate itself when driven substantially beyond this range in either the direction of increased populations or in the direction of decreased populations. This is the concept of homeostasis or 'biofeedback', that is, that a living system tends to be self-stabilizing.

The first order decay expression is written:

$$\text{Rate of mortality, fish/unit volume/day} = -K_E N$$

in which:

N = number of fish per unit volume of water

K_E = unit first order decay rate, a constant having the units of days^{-1}.

This expression was used in the early modeling to describe the natural mortality behavior in any life stage. The numerical value of K_E is obtained when the duration of the stage in days and the percent survival for that stage are known.

The kinetic expression employed in the transport model was developed by employing the first order form, in which a general rate coefficient K, rather than the constant K_E, is introduced and is allowed to vary with fish concentration.

For any stage, K is varied with the prevailing concentration so that the rate of mortality in that stage increases with increasing concentration (due to crowding, less food per unit number of fish, more food [fish] for predators, etc.) and decreases with decreasing concentration for the converse reasons. Thus, the concept of homeostasis is preserved in the model.

The functional form chosen for variation of K is:

$$K = K_E + (K_E - K_o)\left(\frac{N-N_s}{N_s}\right)^3 \quad \text{..........(1)}$$

in which:

K = generalized unit mortality rate, day^{-1}

K_E = conventional first order or "equilibrium" rate, day^{-1}

K_o = minimum unit mortality rate consistent with system biology, day^{-1}

N_s = "saturation" or equilibrium population level, fish per unit volume

N = actual fish concentration at any point in time (week and year) and space (river location)

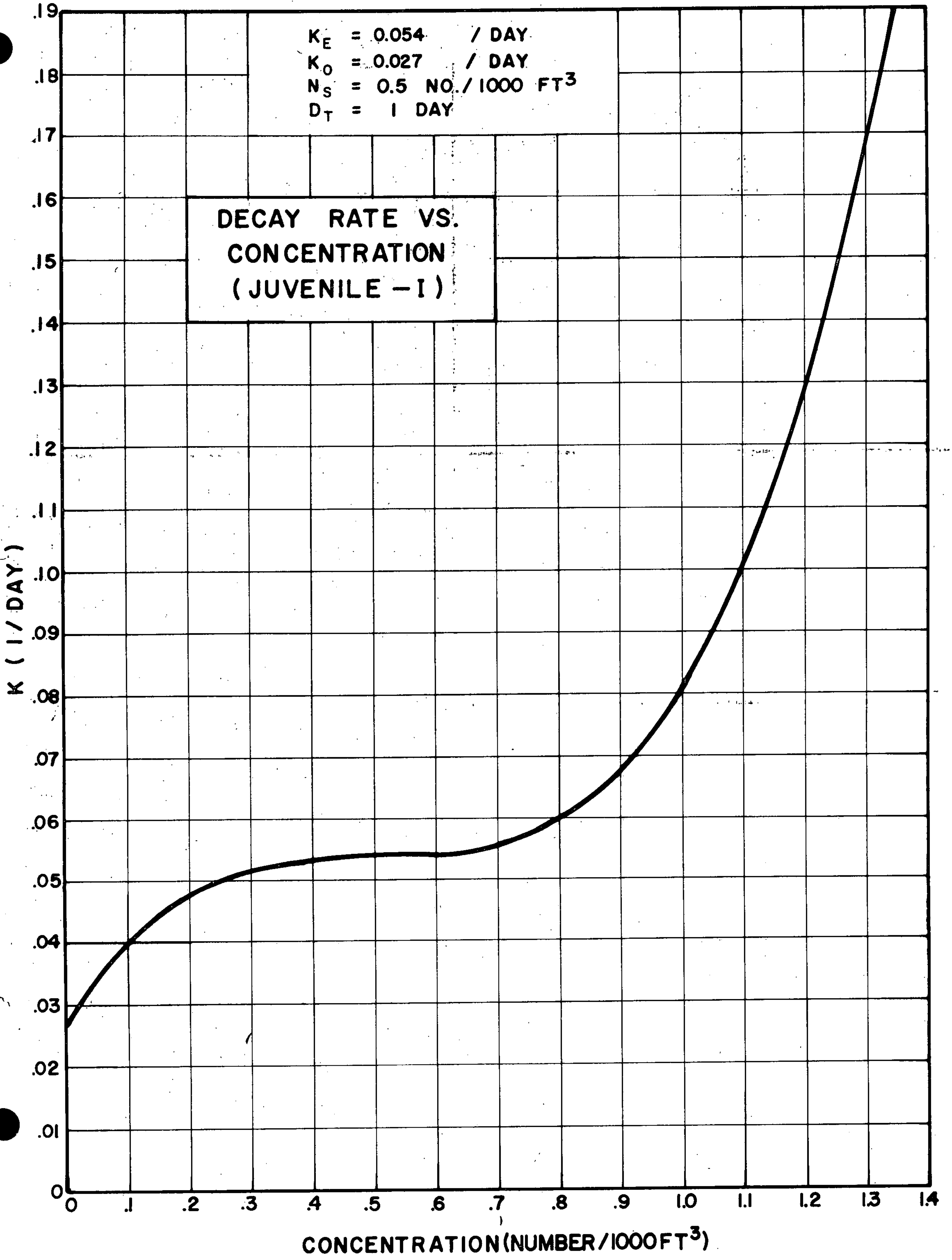
This kinetic model has been developed after extensive review of population dynamics literature [18 through 23]. Many of the concepts described herein are presented in these earlier references in a largely qualitative fashion; they have been quantified here. A brief description of early stage and adult compensation mechanisms is given below.

a. Compensation in the Early Stages

Figure 9 which is a graphical representation of the behavior of Equation 1 for a given set of rate constants (K_E, K_o, N_S) shows how the generalized rate coefficient, K, varies with population density. Explanation of the behavior of Equation 1 and Figure 9 follows.

Consideration of Equation 1 shows that when the actual population, N, is equal to the "saturation" population, the K rate reduces to the constant K_E, signifying normal first order behavior.

What we are saying is that, on a long-term basis, exclusive of the plant's effect, we are considering the estuary juvenile striped bass population to have reached some "saturation" or "equilibrium" level. This does not imply that the estuary can never support more life — it simply says that for the existing set of background conditions, i.e., conditions both natural and man-made that exist prior to the operation


K_E = 0.054 / DAY
K_O = 0.027 / DAY
N_S = 0.5 NO. / 1000 FT^3
D_T = 1 DAY
DECAY RATE VS. CONCENTRATION (JUVENILE – I)
K (1 / DAY)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
CONCENTRATION (NUMBER / 1000 FT^3)

of the plant, the river is "in balance" or is supporting that level of life which it is capable of supporting, considering all the external factors, both good and bad, that presently exist.

These include, for example, the possibility that railroad construction before the turn of the century on both sides of the river may have cut off some natural nursery areas, that the Sacandaga and Indian Lake Reservoirs in the Adirondack Mountains near the headwaters of the Hudson are probably posing a different freshwater regime than once existed, etc.

Whether we are close or far from the theoretical ultimate saturation that might be reached under the best of conditions is beside the point. We are only interested in saying that before a specific new influence enters the river, the river is probably not in a state in which significant departure from a balanced population exists.

The mathematics chosen represent this notion quite well. The plateau shown in Figure 9, extending over a concentration range of .42/TCF cubic feet to .68/TCF cubic feet of juvenile I's, and in an approximate sense over an even broader range, corresponds to the saturation level. The decay rate is constant at .0536 day^{-1}, the chosen value of K_E. Note that this corresponds to 20% survival over 30 days of life of any juvenile I complement. The kinetics over this relatively broad range are essentially first order, the system is in relative balance or at relative equilibrium, and there is little active compensation. The important point is that this numerically apparent non-compensatory behavior is occurring over a relatively broad range centered about "existing" conditions in the river.

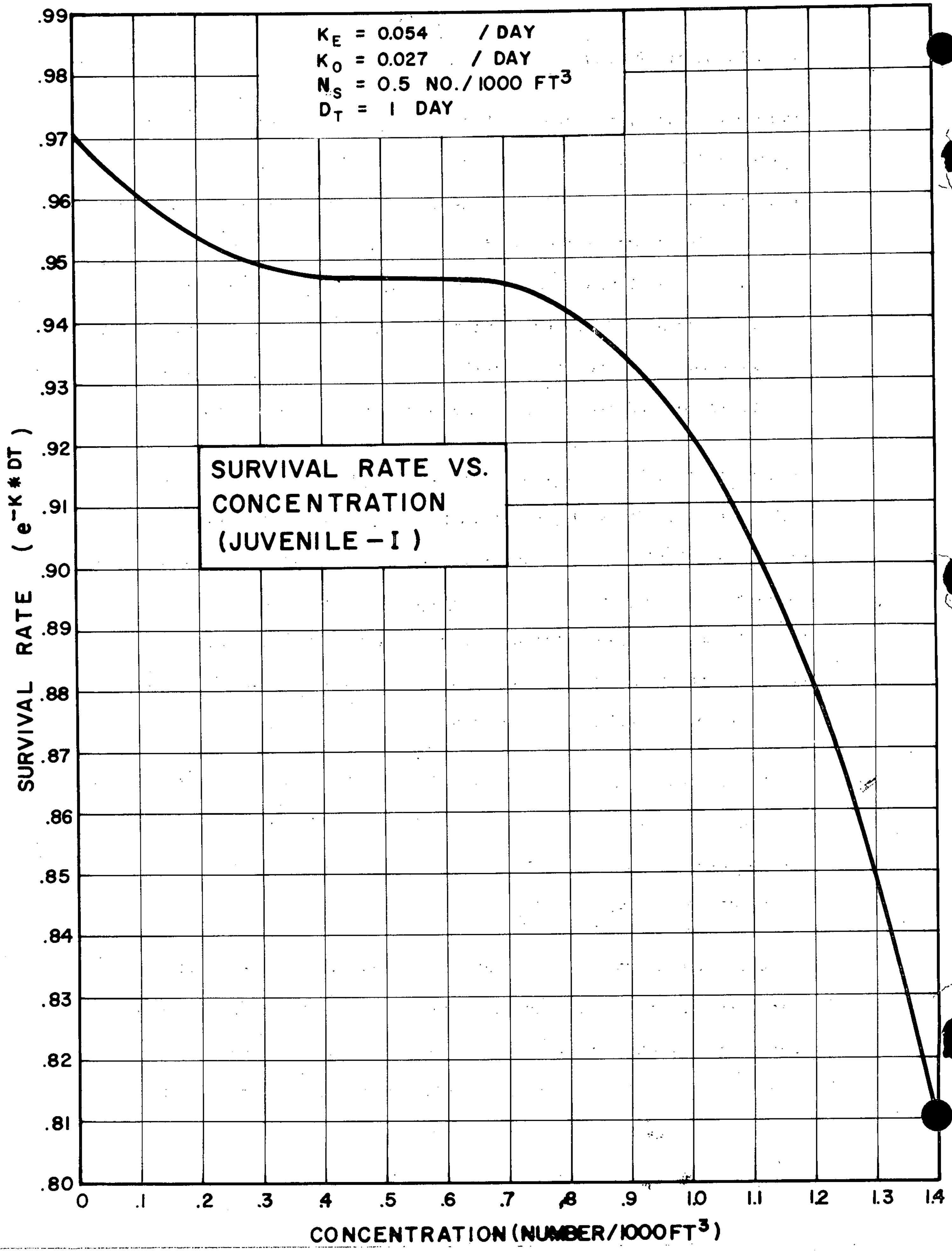
This notion is shown again in Figure 10 where survival rate versus concentration is plotted. The daily survival rate at which relative equilibrium is attained for this stage is .948. Note that the carrying capacity concentration satisfying this plateau is in the range .42 to .68 per one thousand cubic feet for given values. On either side of this plateau, we observe either an increase or decrease in survival of existing concentration. Survival increases to compensate for lower concentration and decreases to compensate for higher concentration.

Now, Equation 1 also indicates that as the fish concentration drops off, because of induced population-draining effects, the rate of mortality, K, continues to decrease until a minimum rate of mortality, K_o, is reached. K approaches K_o as the population decreases toward zero. Thus, K_o may be interpreted as the minimum rate of mortality that will exist in the system when population influences on mortality (competition for food, availability to predators, etc.) are eliminated.

In this sense, K_o has the same system interpretation as does K_E and N_S, i.e., it is representative of the "now" condition in the estuary, taking into account all positive and negative, natural and man-made influences on the system.

Equation 1, therefore, shows that, as concentrations are reduced by plant effects, the mortality rate due to other effects will decrease, thereby compensating partially for the smaller numbers by allowing a larger fraction of the fish that remain to advance to the next stage.

FIGURE 10



K_E = 0.054 / DAY
K_O = 0.027 / DAY
N_S = 0.5 NO./1000 FT^3
D_T = 1 DAY
SURVIVAL RATE VS. CONCENTRATION (JUVENILE – I)
SURVIVAL RATE (e^{-K*DT})
.99
.98
.97
.96
.95
.94
.93
.92
.91
.90
.89
.88
.87
.86
.85
.84
.83
.82
.81
.80
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
CONCENTRATION (NUMBER/1000 FT^3)

This will only partially offset the effects of the plant, since each early stage is subjected to either entrainment or impingement by the plant.

Note that in the presence of a factor which will tend to increase population, such as a year in which "everything is right,", the mortality rate, K, will exceed K_E and the tendency to increase the population will be controlled. Thus, compensation can be seen to be the mechanism which keeps a fluctuating population under control. The fate of a fluctuating, non-compensating feed back system is discussed in detail in the early testimony.

In summary, then, Equation 1 was chosen to represent background or existing survival kinetics in the model because it operates in a normal first order fashion about existing concentrations and will permit partial compensation if significant departures from existing levels occur upon introduction of new influences. Selection of the specific rate coefficient to be used in each life stage is discussed in Section A-2 of Chapter III.

b. Adult Compensation

The plant does not affect adults directly via impingement or entrainment. To offset a lower zero-year class recruitment, compensation may occur, over several years, in the adult classes. The reduced number of adults may be balanced by greater survival among the remaining adults, an earlier onset of maturity, increased fecundity in certain year classes, and possibly a change in the sex ratio to yield a higher ratio of females to males, giving a more fecund population per adult class.

To date, adult compensation generally has not been applied in our use of the transport model. However, we have incorporated in the model an ability to compensate in the adult stages, for possible future use. The mechanism chosen to compensate for adult reductions is a variation of the previous compensation mechanism. Without compensation, adult mortality is modeled as a first order reaction such that the fraction of year class i that survives is:

$$\exp^{-K_i \Delta t} = \exp^{-K_i\, 365} ,$$

in which K_i equals the first order removal rate for that age group.

Since behavior of the adults within the year is not of concern in the cycling model, any expression for survival could have been used which would reduce to the estimated age group survival.

Adult compensation is quantified in the model by modifying the first order K once at the beginning of the year, based on the initial number (N_{AB_i}) of adult fish in year class i, i.e.:

$$K_A = K_{E_{A_i}} + (K_{E_{A_i}} - K_{O_{A_i}}) \left(\frac{N_{AB_i} - N_{SA_i}}{N_{SA_i}} \right)^3 \quad \ldots (2)$$

in which:

N_{AB_i} = number of adults in year class i at start of year.

N_{SA_i} = the characteristic saturation or carrying capacity constant for that age group. This is equal to the population of that year class at the beginning of the year when the plant is not operating.

$K_{O_{A_i}}$, $K_{E_{A_i}}$ = the unit mortality rates at $N_{AB_i}=0$ and N_{SA_i}, respectively.

K_A = the overall adult mortality rate during the ith year.

Since, over the full year, K is equal to the K_i (above) for adult age group i, this amounts to varying the overall yearly survival ($e^{-K_A 365}$) with the recruits to the year class (N_{AB_i}). This differs from early stage compensation in that the instantaneous daily survival rate is continually modified as a function of the current stage concentation.

The adult compensation mechanism was applied to the first three year groups only. The remaining nine age group (4-12) survivals were assumed to remain constant.

c. Life Stage Cycling

Figures 11 and 12 show the 1967 predicted estuary average between Coxsackie and Croton Point and a typical predicted segment average (Peekskill). These depict the occurrence of early life stages of striped bass development from the spawning of eggs to adulthood in the estuary. The curves exhibited are based upon predictions generated by the computer runs of the transport mathematical model from the workup of actual data contained in the Carlson & McCann report. Each curve represents a different stage of development. Note there are five curves predicting the egg, larvae, and juvenile I through III distributions in time.

Between egg and larvae, larvae and juvenile I, juvenile I and juvenile II, there is an overlap of curves due to the duration of these life stages. These overlaps can best be understood by reference to Figure 5.

1967 PREDICTED ESTUARY AVERAGE

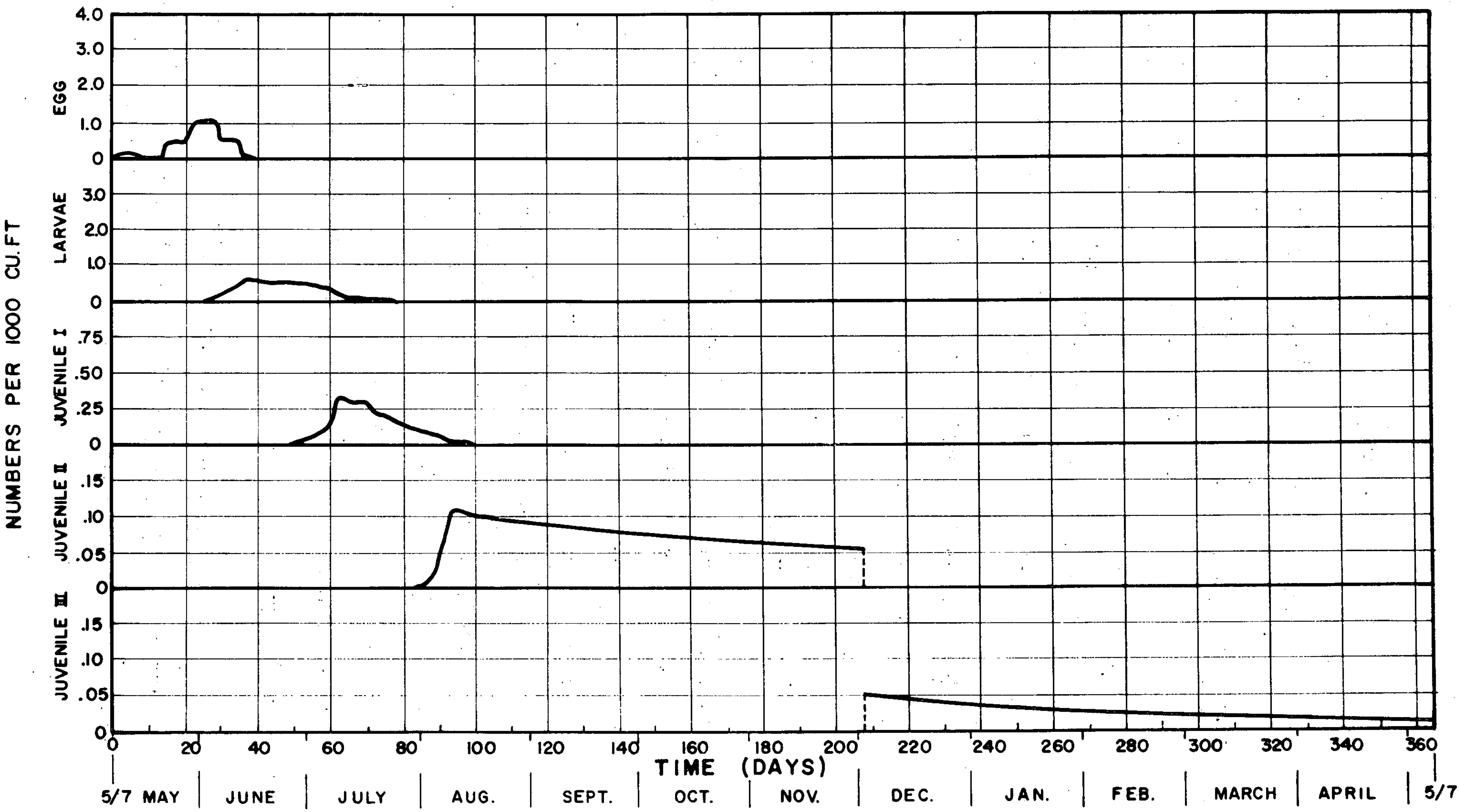


FIGURE 11

1967 PEEKSKILL PREDICTED SEGMENT AVERAGE

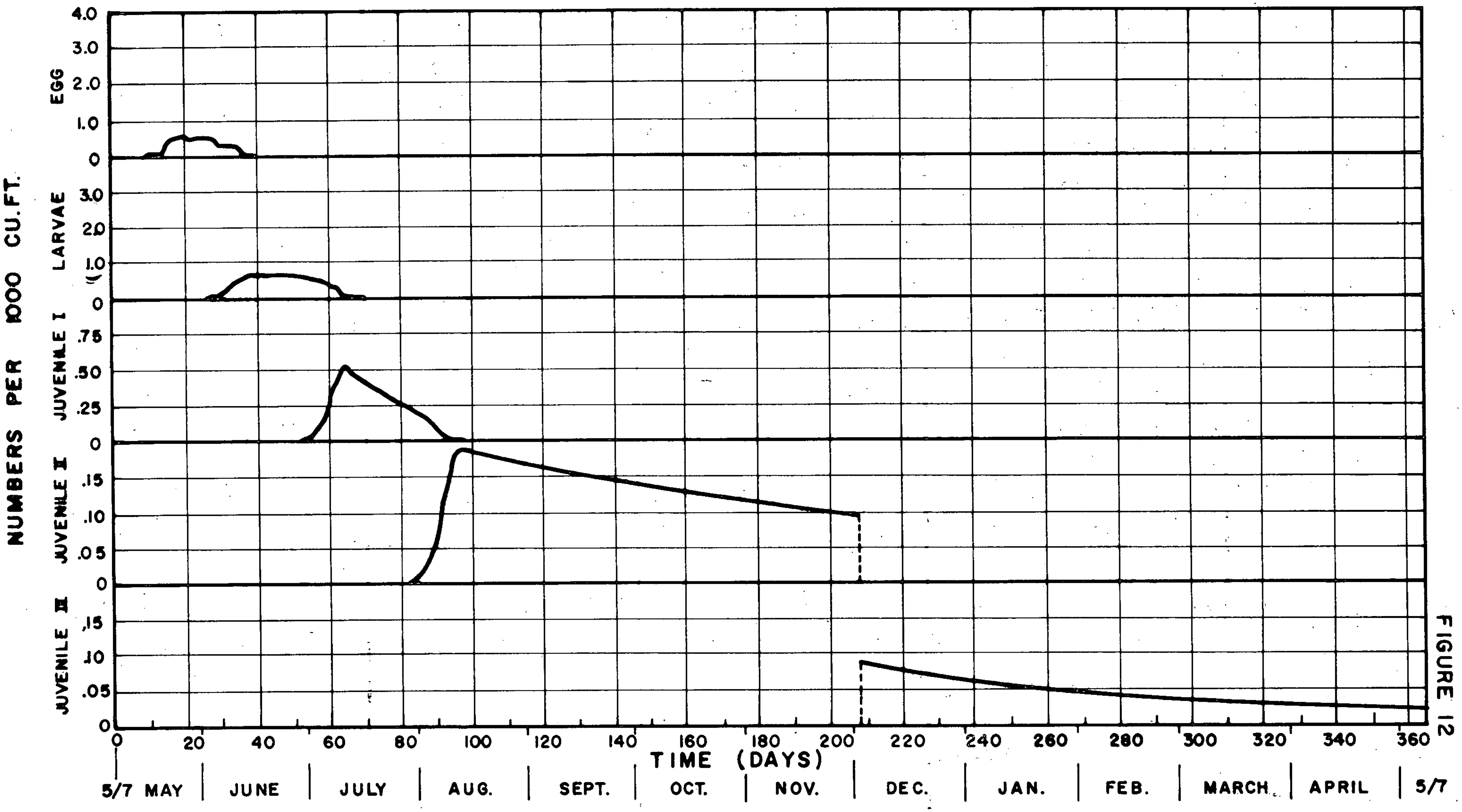


FIGURE 12

For example, if eggs are spawned in a 49-day period and exist in this stage for 1.5 days before transferring to the next life stage (larvae), eggs will be present for approximately 50.5 days, following which there will be no further egg stage.

Larvae should appear on day 1.5 and will be in the estuary a minimum of 29.5 days (from time 0) before transferring to the juvenile I stage.

At 78.5 days (from time 0), all larvae will have transferred to the juvenile I stage. Similarly, juvenile II's will begin to appear on day 59.5 if the duration of juvenile I is 30 days. The last juvenile I's will transfer to juvenile II's on day 108.5.

On day 209 (December), all juvenile II's are reclassified as juvenile III's since it is assumed that they begin an overwintering mode and are subject to different mortality. At the end of the cycle, day 365, they represent recruits to the adult population, age group 1.

After the concept of compensation is introduced, the program is ready to cope with the cycling of the newly-generated eggs through juvenile and early adult stages. This cycling is the method by which the growth of the organisms from eggs through adults is modeled. Figure 8 illustrates stage progression and cycling as these steps occur in the transport model.

The transport model generates recruits to age group 1 (one year old) of the adult striped bass contingent. If an adult population does not currently exist, the value generated coupled with survival rates obtained from the equilibrium condition is used to generate an adult population, age groups 2-13. If a population does exist, adult groups 1 through 12 are decayed to their respective succeeding adult classes and the age group 1 generated by the transport model is updated.

Given an existing adult striped bass population, if we know the ratio of females to the total and their average fecundity and maturation within each age group, we can predict the total number of eggs that will be produced by this population. We can then recycle this total number through the transport model to generate a new one year old group.

F. INTRODUCTION OF PLANT AND IMPACT PARAMETERS

The model as outlined above produces as output a description of the "base conditions" of the river. But the goal is a description of conditions in the river with the plant in operation. These conditions are obtained by adding as further inputs the parameters of plant operation and impact, and are illustrated in Figure 13, which is an expanded version of Figure 7 and includes the plant and impact parameters. It also shows a third set of model output parameters which delineate the impact of plant operation. Figure 13, therefore, shows all of the interrelationships among the various dominating mechanisms this chapter has described.

The dominating mechanisms of plant impact are entrainment and impingement. "Entrainment" applies to the egg, larval, and early juvenile stages, in which the fish can pass the 3/8-inch mesh traveling screens and be subjected to mechanical, pressure, and temperature stresses as they pass through the pump and condenser. "Impingement" applies to the later juvenile stages, in which the fish cannot pass the traveling screens, but are

HUDSON RIVER STRIPED BASS TRANSPORT MODEL PARAMETERS

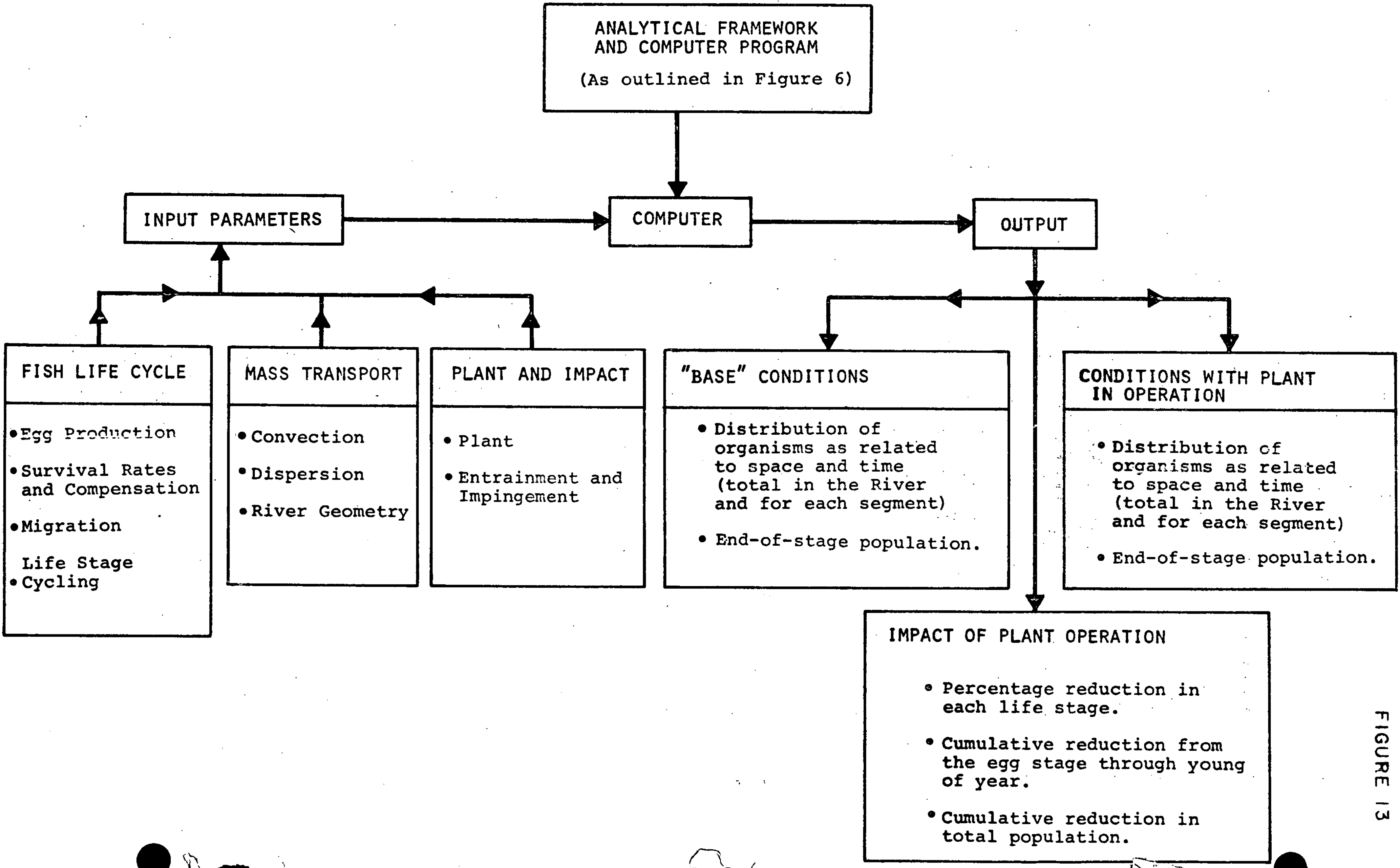


FIGURE 13

caught on them. The following analysis applies, in general, to either case, and therefore is applicable to all five early (zero-year) stages.

Movement of any stage into the intake is defined as the number of organisms entering the intake (passing the bar racks) per day. Let the concentration (numbers per unit water volume) of any stage, i, in the water moving into the intake be given $\tilde{N}_i$. Then the movement of organisms into the plant intake is given as:

$$\text{intake movement, stage i} = Q_p \cdot \tilde{N}_i$$

in which:

Q_p = plant flow, in thousand cubic feet/day (TCFD)

$\tilde{N}_i$ = concentration of stage i in intake flow, number/thousand cubic feet (#/TCF)

The reduction of the population of any stage by entrainment or impingement is defined as the number/day flowing into the intake that are actually cropped as a result of that movement. This can be expressed in terms of the number entering the intake as follows:

$$\text{number cropped per day} = f_{c_i} Q_p \cdot \tilde{N}_i$$

in which:

f_{c_i} = cropped fraction of the $i^{\underline{th}}$ stage. The parameter "f_c" is determined by sampling the intake and discharge and then comparing intake and discharge survival percentages.

The concentration "$\tilde{N}_i$" may be related to the river concentration, N_i, but cannot be set equal to it for the following reasons:

1. The river concentration is not uniform. The non-uniform distribution is due in part to the reported vertical diurnal movements of the young striped bass.
2. The plant draws the major percentage of its water from that portion of the river in the immediate vicinity of the intake.

3. The river concentration in the immediate vicinity of the intake may contain members with an inherent ability and tendency to avoid the intake.

4. Organism population in the near vicinity of the intake may not be replaced, once it is removed by the plant.

The transport model predicts the so-called "area-average, tidal-smoothed" concentration at any time (calendar date or days from commencement of spawning) and at any section along the river's longitudinal axis. "$\tilde{N}_i$" is evaluated by relating it to the area-average concentration $\bar{N}_i(x,t)$ as follows:

$$\tilde{N}_i = f_{1_i} \cdot f_{2_i} \cdot f_{3_i} \bar{N}_i \;\ldots\ldots\ldots\ldots\ldots (3)$$

in which:

f_{1_i} = ratio of the daily average river concentration of stage i in the general vicinity of the intake (east bank, upper layer), to $\bar{N}_i$.

f_{2_i} = ratio of the actual intake concentration to $f_{1_i} \cdot \bar{N}_i$, under existing conditions of operation.

f_{3_i} = $f_{3_i}(Q_p)$. A factor which recognizes population depletion in the immediate vicinity of the intake may not be immediately replenished.

Depletion of the area-average river concentration at Indian Point, $\bar{N}_i$, causes the dispersion mechanism to transport more of the depleted stage into the Peekskill segment toward the Indian Point section. This presumes that the stage undergoing removal at Indian Point is subject to the same dispersion mechanisms as are soluble river substances such as salt. This assumption is considered to be quite conservative, particularly in the later stages when the fish are not planktonic. Recognition of this conservatism is treated, at least conceptually, by the introduction of the factor "f_{3_i}."

Evaluation of these "f_{j_i}" factors for the case of operation of Indian Point Unit 2 is discussed in the next section. Substitution of Equation 11 in the expression for removal yields:

$$\text{Rate of stage cropping due to plant operation} = f_{1_i} \cdot f_{2_i} \cdot f_{3_i} \cdot f_{c_i} Q_p \bar{N}_i$$

This expression is incorporated into the material balance statement for transport in and out of the Peekskill segment. The model is then run for the case of Indian Point operating by assigning the selected (non-zero) numerical values to each "f" factor for each stage.

Operation of the transport model with Indian Point "on line" then yields end-of-stage population estimates. These are compared to the base case of operation of the model without Indian Point in order to compute percentage reduction in each stage and cumulative reduction from the egg stage through each successive stage.

III. SELECTION AND DESCRIPTION OF SYSTEM PARAMETERS

INTRODUCTION

Chapter III complements Chapter II. The theoretical description of the development of the striped bass transport model presented in Chapter II is here amplified with detailed descriptions and numerical values of all the parameters introduced into the model. As Figure 2A in Chapter I illustrates, these are of three basic types: fish life cycle parameters, mass transport parameters, and plant and impact parameters. Each type is discussed in sequence in this chapter. Section A on fish life cycle parameters is further subdivided into four classes of parameters for individual discussion. Section D, the final section, deals separately with the determination of the impact parameters called "f" factors, which were initially described in the last section of Chapter II. The numerical values are presented largely in table form throughout the chapter.

A. FISH LIFE CYCLE PARAMETERS

For convenience, the fish life cycle parameters are grouped as shown below and in Figure 11 in Chapter II:

1. Egg production parameters consisting of total egg production in the river, spawning initiation date, distribution of eggs in time and space, and duration of spawning period.
2. Age distribution. Methodology employed in all stages is described using the egg stage as typical.
3. Survival rates, and stage duration parameters. Comparisons are made to values employed in the previous testimony.
4. Compensation parameters. Compensation parameters include minimum unit mortality rates and "equilibrium" population levels for eggs, larvae, and juveniles.

5. Migration parameters including time at which autumn juveniles are reclassified to account for the overwintering mode and fractional distribution of juveniles in river segments.

6. Life stage cycling parameters including fecundity of females, percentage of mature females, and sex ratio, i.e., fraction of females to total within an adult age class.

Numerical values and descriptions corresponding to these parameters are given below.

1. Egg Production Parameters

The first step in obtaining the rate of spawning, or production of eggs, is the selection of the defining differential equation for the spawning, mortality, and hatching of eggs in each segment of the river. This is written:

$$\frac{d\,N_{E_i}}{dt} = P_i'(t) - K_{E_i}\,N_{E_i} - [P_i'(t - \Delta t_E)]\,\exp\,(-K_E \cdot \Delta t_E) \quad ....(4)$$

in which:

N_{E_i} = spatial average egg concentration in the $i^{\underline{th}}$ segment. Carlson & McCann egg concentration data in each segment were used to evaluate (N_{E_i}).

$P_i'(t)$ = spawning rate in the $i^{\underline{th}}$ segment, expressed as eggs spawned per day per thousand cubic feet. Equation 4 is to be solved for this parameter.

K_{E_i} = first order mortality rate for eggs. This is selected as constant for the eight sections. The value selected is 1.53 day^{-1} and corresponds to an egg survival of 10% in 1.5 days.

Δt_E = the egg life stage. A value of 1.5 days was selected.

The methodology involved in the construction of Equation 4 is presented in the testimony of April 5, 1972 [1]. Equation 4 presumes that no eggs enter or leave the segment during the incremental period of 1.5 days. The average value of $P'(t)$ over a selected time interval

(Δt) can be obtained by writing the integral form of Equation 4 as follows:

$$[\bar{P}'(t)]\ \Delta t = \int_t^{t+\Delta t} P'(t)\ dt = \underbrace{N_{E_{t+\Delta t}} - N_{E_t}}_{term\ (1)} + \underbrace{K_E \int_t^{t+\Delta t} N_E(t)\ dt}_{term\ (2)}$$

$$+ \underbrace{\exp(-K_E \Delta t_E) \int_t^{t+\Delta t} P'(t-\Delta t_E)\ dt}_{term\ (3)} \qquad \text{............} \quad (5)$$

in which:

term (1) = measured concentration difference between time (t) and time (t+Δt)

term (2) = mortality occurring over the time interval (Δt)

term (3) = hatching of live eggs occurring over the time interval (Δt)

Graphical-numerical computational procedures were employed, using the actual 1967 Carlson & McCann egg data (their Appendix 3-1). For the weekly values reported in Carlson & McCann's Appendix 3-1, an egg gestation period of 1.5 days and an egg survival of 10%, a total river egg production of 1.9 billion eggs was obtained, along with the fractional distribution of this production in time and space.

Tables 2 and 3 give the fractional time and space distribution of the egg production to account for each segment and each week of spawning between May 3rd and June 24th. These fractional values are multiplied as shown at the bottom of

TABLE 2

FRACTIONAL DISTRIBUTION OF EGG PRODUCTION
(FROM 1967 HUDSON RIVER STRIPED BASS DATA)

TIME DISTRIBUTION OF TOTAL ESTUARY EGG PRODUCTION

Week	Calendar Time	Fraction of Total Egg Production, F_E	Starting Time, t_s (Days)	Ending Time, t_e (Days)
1	May 7 - May 13	.0536	0	7
2	May 14 - May 20	.0243	7	14
3	May 21 - May 27	.2361	14	21
4	May 28 - June 3	.4482	21	28
5	June 4 - June 10	.2365	28	35
6	June 11 - June 17	.0000	35	42
7	June 18 - June 24	.0013	42	49
	Total	1.0000		

TABLE 3

FRACTIONAL DISTRIBUTION OF EGG PRODUCTION
(FROM 1967 HUDSON RIVER STRIPED BASS DATA)

WEEKLY SPATIAL DISTRIBUTION (BY RIVER SEGMENT)

	Fraction (fs_i) of Each Week's Production Assigned to Each Segment								
Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall	Peekskill	Croton Point	Total
1	.0	.7681	.0086	.1886	.0307	.0040	.0	.0	1.0000
2	.0	.0	.0	.8190	.0	.1237	.0573	.0	1.0000
3	.0	.6407	.0360	.0392	.0	.1178	.1663	.0	1.0000
4	.0	.4300	.0455	.2587	.0517	.1521	.0620	.0	1.0000
5	.0	.0	.0302	.4902	.1763	.2882	.0151	.0	1.0000
6	.125	.125	.125	.125	.125	.125	.125	.125	1.0000
7	.0	.0	.0	.0	.0	1.0	.0	.0	1.0000

Daily Egg Production Rate
Introduced to Transport Model Segment i $= 2.1 \times 10^9 \left(\frac{F_E}{t_e - t_s}\right) fs_i$

Table 3 to obtain the egg production rate in eggs/segment/day. This result is input to the egg stage of the transport model to initiate transport model calculations.

Table 3 shows that a value of 2.1 billion total eggs was used as total production instead of the 1.9 billion originally calculated. The total egg production was adjusted to the value of 2.1 billion eggs to permit a better fit in later use of the transport model. This adjustment simply reflects the neglect of transport in Equations 4 and 5, as well as the fact that later comparisons are made against Carlson & McCann's Figure 8, which itself represents a smoothing of the data in their Appendix 3-1.

The spawn time was extended from 37.5 days to 49 days to account for the slight additional spawning in the last two weeks. The egg complement was increased from the 1.8 billion value used in the earlier testimony to 2.1 billion to provide better agreement with Carlson & McCann survey data on egg concentration in conjunction with the assumed 10% egg survival.

2. Age Distribution

Chapter II (item 3b, Age Distribution) described the necessity for breaking population of each stage into a sequence of ages to permit proper tracking of the movement of each fish along the river as it ages. The procedure employed, and selection of age increments, are described below for the egg stage. Age distribution treatment for the other stages was similar.

In the April 5, 1972 testimony, the fate of each individual day's egg complement was evaluated first, and it was then shown that the total number of egg survivors, i.e., hatched larvae, could be obtained simply by knowing the egg survival rate and the egg production rate over the period of the spawn (Equations 5 through 7, pages 20 through 22, Reference [1]). Similar statements were shown to be true for subsequent stages.

It was noted, however, that "additional complexity in computing survival is to be expected when compensatory, i.e., density-dependent or non-linear, rate mechanisms are employed."

Consequently, for the present model the river was divided into eight segments between Coxsackie and Croton Point as defined in Section B of this chapter. The approximate midpoints of these segments correspond to the eight sampling locations described in the Carlson & McCann report.

In general, the survivors of each successive egg complement may have a different distribution at the time of passage to the next stage because flows and mixing mechanisms vary as time moves on from May through June.

Thus, rather than being able to characterize the egg behavior in each segment simply in terms of a single time-variable egg production function (P(t) in Reference [1]) and a single life stage duration and survival percentage, it becomes necessary to keep track of the age distribution of eggs at any time in any reach.

The 1.5 day egg stage was first divided into 15 age groups, each of which has a life of 0.1 days. Then the rate of spawning was computed and intorduced into each segment. The transport equations were then applied to each age group 1 (0 to 0.1 day) in each segment for each separate egg drop.

Age groups 2 to 14 were handled in a similar manner except that the generation term in the transport equation for each new age group was the number of survivors from the previous age group which survived a 0.1-day time interval, i.e., the production term for age group 1 is the egg production rate, and the transfer term to age group 2 is the number of survivors, each survivor appearing in its appropriate segment.

The production term in the transport equation for age group 15 (1.4 to 1.5 days old) is the transfer term of age group 14. Finally, the transfer term of age group 15 is the larval production term because it represents those survivors of age group 15 or those survivors of 1.5 days of age. These survivors have been traced properly in distance and in time so that the larval generation has been properly distributed among the estuary segments.

3. Survival Rates and Stage Durations

Previous testimony presented stage lengths and survival percentages. Chapter II of this testimony restates the stage durations and illustrates them in Figure 5. Several relatively minor changes are made in these parameters. A comparison of values selected in April to the present values is given in Table 4.

Stage lengths were chosen as time lengths over which comparatively constant behavior is exhibited.

Egg stage length is known to be in a 1 to 3 day range. Larval stage length is chosen to represent the period over which larvae are mainly planktonic and more or less at the mercy of their surroundings. Larval stage length used in the April 5, 1972 testimony was 21 days. However, examination of the Carlson & McCann data indicates that 28 days is a more realistic number. Therefore, it was used in the transport model, as Table 4 shows.

The differences in other stage lengths follow from the change in the larval stage length.

Juvenile I stage length is chosen to be that span of time from when self-determination (migratory swimming ability) begins to be the representative behavior to the time at which their size will prevent entrainment through a plant intake screen. Juvenile II stage length extends to early December, at which time the temperature of the surroundings begins to control behavior. From early December, the juvenile III stage extends to the young of the year recruitment into year class 1 on May 7th.

Survival percentages used are estimated to be within the range of the likely survival percentages for each stage. The literature on striped bass survival is of a more qualitative than quantitative nature. Most

TABLE 4

COMPARISON OF PRIMARY STAGE LENGTH AND SURVIVAL PERCENTAGES EMPLOYED IN TESTIMONY OF APRIL 5, 1972 AND PRESENT TESTIMONY

Parameter	April 5, 1972 (Completely Mixed)	Present (Transport Model)
Stage Length (days)		
Egg	1.5	1.5
Larval	21	28
Juvenile I	30	30
Juvenile II	134.75 (average)*	123 (average)**
Juvenile III	159	158
Survivals (%)		
Egg	1-10	10
Larval	.5-1	15 to 50
Juvenile I	20	20
Juvenile II	40-60	50
Juvenile III	18.4-40	18.98
Start of Spawn	May 9, 1967	May 7, 1967
Spawn Time (days)	37.5	49
Eggs Produced	1,830,000,000	2,157,750,000
Begin over Wintering Period	December 1	December 1

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* Minimum = 116 days, maximum = 153.5 days.

** Minimum = 98.5 days, maximum = 147.5 days.

of the estimates available in the literature discuss overall survivals rather than intra-stage survivals. An analysis of Clark's testimony [3] shows relatively good agreement in the stage lengths and the stage survival percentages chosen by ourselves and Clark.

Larval survival was changed from the original 1% estimate to numbers varying between 15 and 50% for reasons described in Chapter IV.

4. Compensation Parameters

In order to predict the effect of perturbations (plant effect) on the striped bass life cycle, it has been necessary to model the intra-stage behavior of the striped bass in its first year of life. Should perturbations alter the number of survivors of these stages significantly, they can be expected to be offset in part by compensatory mechanisms, as discussed earlier. However, quantitative data are not available on the adaptation of early stage striped bass or similar species to artificial perturbations, e.g., operation of once-through cooling systems. Therefore, an intra-stage compensation mechanism was developed to agree with qualitative descriptions of early stage and adult response characteristics, i.e., a kinetic expression was written which would increase survival (within limits) of early stages when an extra perturbation reduced their numbers.

These kinetics should be and are capable of varying survival rates within a stage under base conditions, as well as during plant operation. During any stage, any number of environmental variables is constantly changing and altering the current survival of the individuals present at any time so that operation of the basic or natural system at an "equilibrium" or "saturation" level probably does not occur.

Environmental parameters change from year to year. On a long-term basis, ecosystems continually direct themselves to adapt to changes in internal (evolutionary adaptation to competitors) and external (long-term sedimentation, changes in rainfall and runoff patterns, etc.) influences. For these reasons, the parameters, K_E, K_O, and N_S, in the compensation model given by Equation 1 can be expected to vary from year to year in a random manner.

We presume that external perturbations (plant) will not significantly alter the long-term random variation of these parameters. In order to eliminate random variations in the system's analysis, year-to-year variations of environmental variables were removed from the analysis and 1967 yearly variation was used in both the one-year and long-term predictions.

The intra-stage compensatory parameters (K_E, K_O, and N_S in Equation 1) were first developed for use in the testing or base-condition runs. These same factors were used later on when the effect of the plant was evaluated. The procedures employed in this development are described below.

The first step required selection of the survival percentage in order to compute K_E, the first order mortality rate. The survival percentages given in Table 4 were used in conjunction with stage lengths to compute K_E.

The coefficient, K_O, represents the minimum mortality rate ever present in the system and, as described earlier, can be expected to occur when concentrations are very low. Since K_o must be between 0 and K_E, values of 0.25 K_E and 0.5 K_E were used.*

N_S was chosen as a representative value of each stage concentration range which existed during 1967 sampling and was estimated using 1967 observations. This generally was equal to or close to the average concentration over the period, or at least over the peak period when substantial numbers of each stage were present.

These choices of K_E and N_S reduce to indicating that actual concentrations that exist during each stage are above and below N_S and, therefore, K has a range of $K_E + (K_E - K_o) \; [(N_{min} - N_S)/N_S]^3$ to $K_E + (K_E - K_o) \; [(N_{max} - N_S)/N_S]^3$, where N_{min} and N_{max} are the minimum and maximum values of the stage concentration. Therefore, K varies above and below K_E. This suggests that K_E can be expected to be close to the "average" K over the stage, and the use of the estimate of overall survival to compute K_E appears to be valid.

Adult (age groups 1-13) parameters were chosen to yield a year-to-year equilibrium such that the egg complement from year to year (without a plant) would be constant. This notion is discussed in detail in the earlier testimony [1].

To date, as discussed earlier, compensation has not, generally, been used in the adult stages. The procedure to be used if adult compensation is employed is given in Chapter II.

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*K_o = 0.25 K_E appears to give a slightly better agreement with larval observations.
K_o = 0.5 K_E was arbitrarily used for juvenile I, II, and III.
K_o = K_E (no compensation) was used for the egg stage.

The adult survival rates for age groups 1 through 3 are assumed as input to the transport model. Given these values, we satisfy the equilibrium condition by utilizing a Newton-Raphson technique to compute the survivals for adults 4-12. With these survivals and the number of recruits to age group 1 and no plant effect, we can compute an adult distribution based on age group 1 population.

The survivals for age groups 4 to 12 must depend largely upon external disturbances, chiefly commercial and sport fishing; the fish are considered to have already undergone a long-term process of adaptation to fishing disturbances.

Based on the equilibrium equation, these survivals are computed to be 61.4% when the age groups 1 to 3 survival is 16%. It should be noted that the survival of age groups 4 to 12 depends entirely on the assumed survivals of age groups 1 to 3. Assuming higher survivals in age groups 1 to 3 would necessitate lower survivals in age groups 4-12 and vice-versa, if the equilibrium behavior is to be preserved.

5. Migration Parameters

The approach to migration can be broken down into the following steps:

- Utilize a known estimated fractional distribution, by segment, of juvenile I's near the end of their stage to compute migration preference. A brief description of this step is given below.
- Compute the fractional distribution of juvenile I's at any time (t) using the transport model.
- Use the difference between the anytime (t) distribution and the measured end of the stage distribution to compute the number of juvenile I's which must migrate either into or out of each segment. Define the difference in time between current time and the end of juvenile I appearance as the time span over which the migration will have occurred to achieve the end of stage distribution.

- Continually update the prior step during the juvenile I stage to account for transfers to the juvenile II stage, and production and decay as well as impingement and entrainment of juvenile I's.

Migration preferences were computed by utilizing an approach similar to Clark's [3] in his calculation of relative abundances based on 1968 Carlson & McCann data [2]. The procedure employed is shown typically using this 1968 data. This is tabulated in Table 5 and explained below. Table 5 has been adapted from Clark [3].

If the number of juvenile I's per tow is known for each segment of the Hudson, the index of relative abundance, i.e., the relative number of juvenile I's in a segment, can be computed as the product of the fish per tow times the fraction of the total water volume of all segments that the water volume in a given segment represents.

The migration preference of segment 1, i.e., the fractional percentage of juvenile I's in a segment, is then equal to the index of relative abundance for segment 1 divided by the sum of all segment indices.

The migration preference is thus an index of relative abundance of juvenile I's such that the sum of migration preferences for all segments equals 1.

This procedure for computing migration preference can be used for any year's behavior, so long as information on relative abundance of juveniles is available at several points along the river. In transport model runs to date we have used the August 1967 Carlson & McCann data.

The juvenile II and III stages were handled in a similar manner except that migration was used as an alternative mechanism, i.e., their

TABLE 5

TYPICAL COMPUTATION OF INDEX OF RELATIVE ABUNDANCE OF JUVENILES

Segment Number	Location	Number of Fish/Tow(1)	Segment Volume (MI^3) x 10^2	Percent of Water Volume in Segment(2)	Index of Relative Abundance(3)	Percent of Fish in Each Segment(4)	Migration Preference(5)
1	Coxsackie	0	2.9862	5.9%	0	0	0
2	Saugerties	.2	5.1230	10.12	2	.08%	.0008
3	Kingston	.5	4.0977	8.10	4	.17	.0017
4	Hyde Park	1.7	4.8640	9.61	16	.68	.0068
5	Marlboro	4.2	6.1266	12.11	51	2.17	.0217
6	Cornwall	48.5	6.4336	12.71	616	26.15	.2615
7	Peekskill	47.4	5.9186	11.69	554	23.51	.2351
8	Croton Point	37.4	15.0654	29.76	1113	47.24	.4724
	Total		50.615	100.00%	2356	100.00%	1.0000

Notes: (1) Carlson & McCann, Table 11.
(2) Relative to volume of all segments.
(3) Column 4 times Column 5.
(4) Column 6 divided by sum of indices of relative abundance and multiplied by 100%.
(5) Column 7 divided by 100.

stages may either migrate or remain stationary (no transfer between segments).

For the juvenile II stage, migration is in accordance with the early November 1967 distribution.

For the juvenile III stage, a stationary mode was assumed, i.e., the November 1967 migration preferences were presumed to apply through the overwintering period.

Migration preferences for each of the three juvenile stages are shown in Table 5A.

6. Life Stage Cycling Parameters

Estimates of sex ratios (f_{s_i}), maturity indices (f_{m_i}), and fecundities (f_i) for adult striped bass are given in Table 6.

Reproductive parameters generally were obtained from the literature noted under Table 6. Survivals in the early stages are generally acknowledged to be very low. Survivals in the adult stages presume the inclusion of all present impacts on the river, including exploitation by sport and commercial fishing and by existing plants.

B. MASS TRANSPORT PARAMETERS

Figure 2A in Chapter I shows all input and output parameters used in the model including those adapted from the mass transport model developed previously. These parameters are discussed in detail in Reference [14] and consist of the river freshwater flow, dispersion coefficients, and the geometry of the Hudson channel.

TABLE 5A

MIGRATION PREFERENCES
1967 DATA

Segment	Migration Preference J_I	J_{II}	J_{III}
1	.04	.01	.01
2	.08	.01	.01
3	.08	.03	.03
4	.09	.04	.04
5	.17	.06	.06
6	.18	.07	.07
7	.10	.22	.22
8	.26	.56	.56

TABLE 6

SELECTED FERTILITY FACTORS

Age Group	Female Fraction*	Female Maturity**	Fecundity (Eggs/Fertile Female)***
1	.5	0	0
2	.52	0	0
3	.54	0	0
4	.56	.25	345,000
5	.58	.75	438,000
6	.6	.95	615,000
7	.62	1	752,000
8	.64	1	820,000
9	.66	1	909,000
10	.68	1	910,000
11	.7	1	964,000
12	.7	1	1,136,000
13	.7	1	908,000

*(Ref. 30) Values between age group 1 and 11 were linearly interpolated from estimates of age group 1 and 11 female fractions.

**(Refs. 31,32) Age groups 4 - 6 are computed estimates.

***(Ref. 33) Computed by weighted averages of individual measurements.

Figure 14 depicts the segment divisions with milepoint boundaries from Coxsackie to Croton Point and the types of sampling activities undertaken in each segment. The geometry of the divisions as computed from U.S. Coast Geodetic Survey charts is shown in Table 7 and includes segment lengths, average cross-sectional areas between milepoints, and water volumes.

The data used to test the model were collected in May, June and July 1967. Freshwater flow and longitudinal dispersion coefficient used to simulate Hudson River transport behavior during that period are given in Table 8.

The freshwater flow values were obtained using the U.S. Geological Survey surface water flow observations at Green Island (the most downstream gaging station) and knowledge of contribution of tributaries below Green Island and of lag time between Green Island and the lower Hudson River. A detailed description of this approach is given in References [11], [13], [14], and [28].

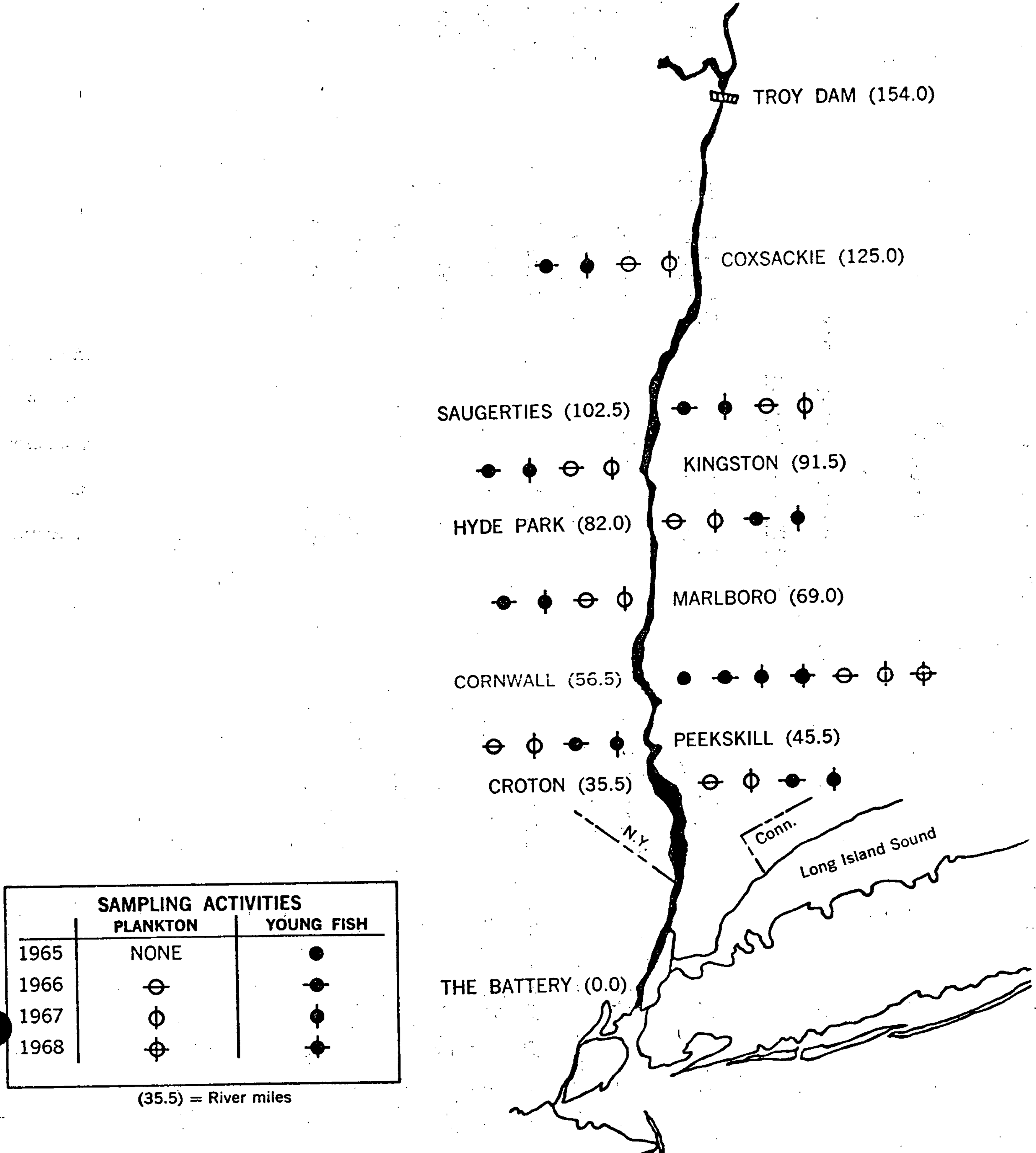
The values of the longitudinal dispersion coefficient at any point within the salt-intruded reach of the river were obtained by analysis of observed and/or estimated salinity profiles in the Hudson River. A detailed discussion of this method is given in References [11], [14], and [28]. The values of this coefficient at any point outside the salt-intruded reach were estimated using known Hudson River tidal and channel geometry characteristics as described in Reference [28].

The most upstream segment (Coxsackie) and the most downstream segment (Croton Point) were considered to possess impervious boundaries such that

FIGURE 14

PRINCIPAL STUDY LOCATIONS AND ACTIVITIES IN THE ESTUARY 1965-1968*

HUDSON RIVER ESTUARY



* Adapted from Figure 1 of

TABLE 7

HUDSON RIVER TRANSPORT MODEL

SEGMENT PARAMETERS

SEGMENT	EXTENT* (Milepoints)	LENGTH (Miles)	AVERAGE AREAS (sq. Miles)	VOLUME (Cu.Miles)
1- Coxsackie	138.4-115.9	22.5	.0013272	.029862
2- Saugerties	115.9-96.6	19.3	.0026544	.051320
3- Kingston	96.6-86.4	10.2	.0040174	.040977
4- Hyde Park	86.4-75.1	11.3	.0043044	.048640
5- Marlboro	75.1-62.9	12.2	.0050218	.061266
6- Cornwall	62.9-51.1	11.8	.0054522	.064336
7- Peekskill	51.1-40.1	11.	.0053805	.059186
8- Croton	40.1-20.1	20.	.0075327	.150654

*Milepoints from Battery.

TABLE 8

HUDSON RIVER HYDRODYNAMIC CHARACTERISTICS EMPLOYED IN THE TRANSPORT MODEL DURING THE 1967 TESTING PERIOD

Segment Number	Extent (Milepoints)	Lower Hudson Freshwater Flow, (Cubic Miles/Day) x 100			Longitudinal Dispersion Coefficient, Square Miles/Day		
		May	June	July	May	June	July
1	138.4-115.9	1.37348	0.45782	0.35218	1.0	1.0	1.0
2	115.9- 96.6	1.37348	0.45782	0.35218	1.0	1.5	1.5
3	96.6- 86.4	1.37348	0.45782	0.35218	1.0	2.0	2.0
4	86.4- 75.1	1.37348	0.45782	0.35218	1.0	2.0	2.0
5	75.1- 62.9	1.37348	0.45782	0.35218	2.0	2.0	2.0
6	62.9- 51.1	1.37348	0.45782	0.35218	2.0	6.0	6.0
7	51.1- 40.1	1.37348	0.45782	0.35218	2.0	12.0	12.0
8	40.1- 20.1	1.37348	0.45782	0.35218	14.0	12.0	12.0

eggs could not enter or leave segment 1 at its upstream boundary or segment 8 at its downstream boundary by dispersion or advection. This simply reflects the observation of the Carlson & McCann data which indicate that no such movement out of the estuary occurs.

C. PLANT AND IMPACT PARAMETERS

Plant and impact parameters are shown on Figure 2A in Chapter I. The Indian Point station is located at milepoint 43 in the Peekskill segment as shown in Figure 1.

Plant intake flow with the two units at capacity operation is 2,650 cubic feet per second.

The number of years of plant operation simulated in the striped bass transport model is described in Chapter V.

Selection of values corresponding to the plant impact parameters ("f" factors) described in Section F of Chapter II is discussed below. Entrainable stages are discussed first, followed by a discussion of impingement in the later juvenile (J_{II} and J_{III}) stages.

1. Eggs, Larvae, and Early Juveniles

Computational procedures employed for determining the "f_1" factors for each of these three stages were the same. Methodology employed for determining each of the f_2, f_3, and f_c factors was also similar for each stage; available data was sparse or non-existent for many of these latter factors so that few computations were employed here. Determination of "f_1," the ratio of intake-vicinity density to the section-average density, is discussed first for all three stages; this is followed by discussion of determination of f_2, f_3, and f_c for each of these stages.

a. Selection of f_1

Data employed in the evaluation of this factor included:

(1) 1967 Carlson & McCann striped bass egg and larval* distributions at three stations at Peekskill.

(2) 1970 (June) Raytheon striped bass egg, yolk-sac larvae, and later larvae distributions at Roa Hook (three stations), Indian Point (four stations), and Stony Point (three stations).

(3) 1971 (May through July) NYU striped bass egg, yolk-sac larvae, and later larvae distributions at seven north-south transections between Peekskill and Stony Point.

(4) 1972 (June) QL&M striped bass larvae distributions at Indian Point.

These sampling locations are identified on Figure 15.

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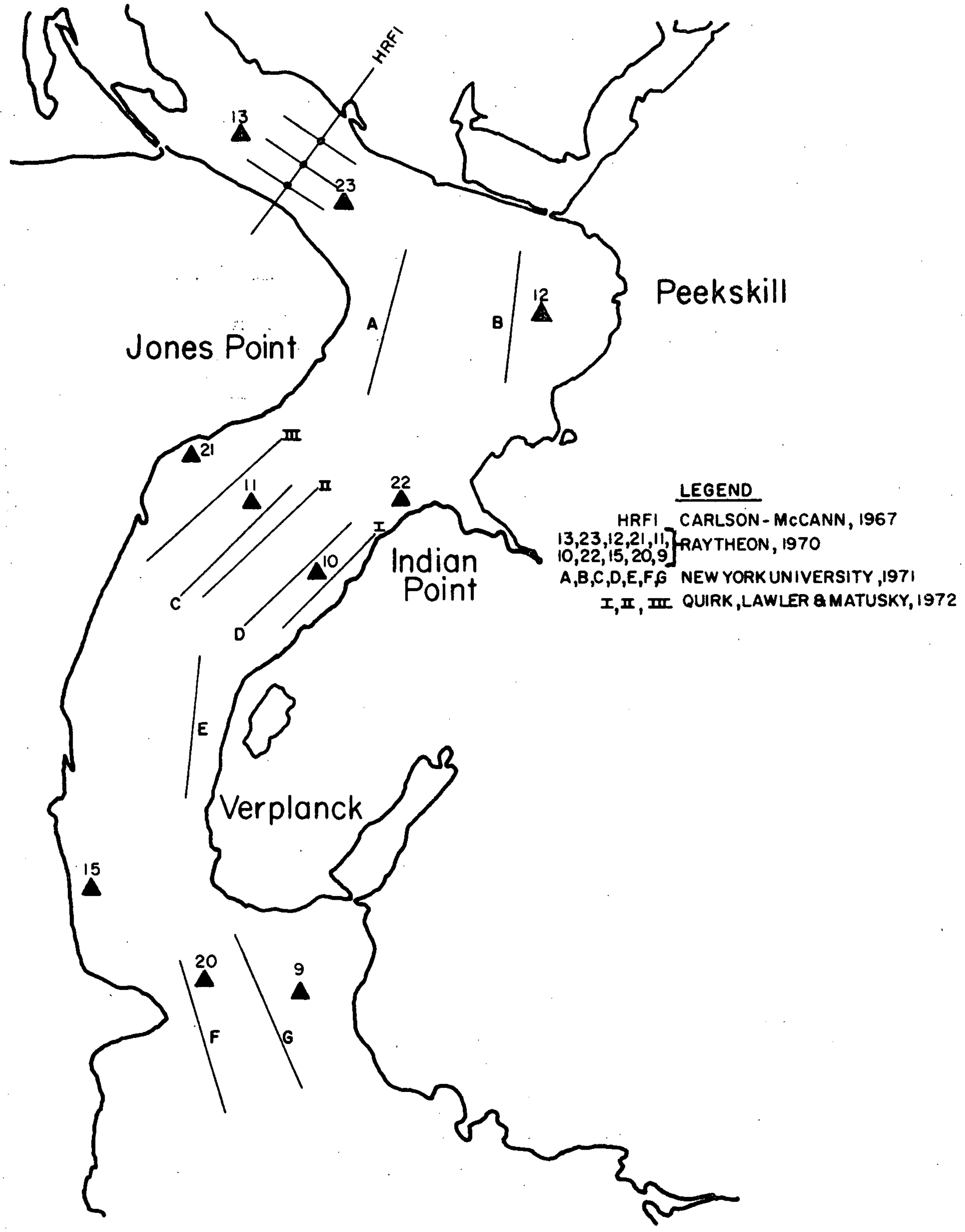
*The four data sources variously report "larvae," "yolk-sac larvae," and "later larvae." The transport model larval stage includes both yolk-sac and later larvae, while the J_I stage includes some fish which may properly be classed as later larvae. "f_1" factors for each of the three "stages" the four data sources adopt are computed first. Assignment of results to the transport model larval and early juvenile stages is presented only after all the data sources have been discussed.

FIGURE 15

LOCATION OF STRIPED BASS EGG AND LARVAE SAMPLING STATIONS IN THE INDIAN POINT AREA



The "f_1" factor was determined by dividing into four quadrants all cross-sections in the Indian Point area for which data were available, as follows:

(1) Upper west quadrant, extending from mid-channel to the west shore and from the surface to mid-depth.

(2) Lower west quadrant, extending from mid-channel to the west shore and from mid-depth to the bottom.

(3) Upper east quadrant, extending from mid-channel to the east shore and from the surface to mid-depth.

(4) Lower east quadrant, extending from mid-channel to the east shore and from mid-depth to the bottom.

The section-average concentration of organisms was computed by first determining the mean concentration for each quadrant, and then calculating the arithmetic average of these four means. The ratio of the upper east quadrant mean to the section average is "f_1."

This procedure was used to compute "f_1" because the major percentage of water passing through the Indian Point condensers comes from the upper east quadrant, in which the intake is located. Since the ratio of plant flow to net river flow is less than 0.25, this approach is considered to be conservative.

In every case, the mid-depth value was used in computing both the upper and lower quadrant means, since in most cases only surface, mid-depth, and bottom concentration values were available. Consequently, the mid-depth value received a double weight, thus avoiding bias toward either the surface or bottom values, neither of which may represent as much water as does the mid-depth value.

As Figure 15 shows, the 1971 and 1972 data (NYU and QL&M) were taken along longitudinal transects on the east and west sides of the river. For these data, quadrant means were computed using the east transect data for upper and lower east quadrant means, and west transect data for upper and lower west quadrant means.

The 1967 and 1970 data (Carlson & McCann and Raytheon) included east, mid-channel, and west stations. These data were analyzed in two ways:

(1) Method A included mid-channel data in computing both the east and west quadrant means. This gave a double weight to the mid-channel value, which tends to bias the "f" factor value to the high side since there are more fish in mid-channel.

(2) Method B divided the river into thirds, rather than an east and west half. The "f" factor was computed as the ratio of the upper east sector (one-sixth of the total) to the section average. This is considered valid since the upper east sixth still provides most of the water taken in by the plant.

Results of both methods of analysis are reported below.

The 1970 and 1971 data (Raytheon and NYU) include sections immediately in front of the plant, north of the plant (Peekskill), and south of the plant (Stony Point). Data from all three locations were employed in the determination of means for these years. This simply recognizes that water from these zones can be expected to pass Indian Point because of tidal behavior.

Results of this "f_1" factor analysis for each of the four years of data are shown in Tables 9 through 18.

Tables 9 through 11 show analysis of the 1971 NYU data. These data are considered to be the most informative of the four sets for the following reasons:

(1) All means include data taken within a tidal excursion north and south of the plant.

(2) Data are presented for each of three stages.

(3) Data distinguish between night and day.

Means must be considered as relative, since the mean for each stage is computed over the entire sampling period, May 3rd through July 30th for the daytime samples and May 11th through July 21st for the nighttime samples. Comparisons cannot be made between the day and night data, nor to the data of others, unless the means are recomputed on the basis of the actual period over which each stage appeared in the river.

This in no way abrogates the analysis for "f_1," however, since no comparison between the night and day data, nor to the data of others, is involved in the use of these data to compute the "f_1."

The daily average "f_1" is computed by weighing the results with a 0.625 factor for the day value of f_1 and 0.375 for the night value.

TABLE 9

DETERMINATION OF "f_1" FACTOR FOR STRIPED BASS EGGS

1971 NYU Data*

(East and West Transects at Peekskill, Indian Point, and Stony Point)

Day Sampling, 5/3/71 to 7/30/71

Relative Mean Concentration, #/TCM, for Sampling Period

Depth**	West		East	
Surface	0.94		0.54	
Mid-Depth	6.07		5.06	
Mean, Upper West Quadrant:		3.50	Mean, Upper East Quadrant:	2.80
Mid-Depth	6.07		5.06	
Bottom	11.23		16.98	
Mean, Lower West Quadrant:		8.65	Mean, Lower East Quadrant:	11.02
Mean, Western Half:		6.08	Mean, Eastern Half:	6.91

Section Average Concentration: 6.50

f_1, Daytime Basis = 2.80/6.50 = 0.43

Night Sampling, 5/11/71 to 7/31/71

Relative Mean Concentration, #/TCM, for Sampling Period

Depth	West		East	
Surface	1.88		1.67	
Mid-Depth	16.72		7.66	
Mean, Upper West Quadrant:		9.30	Mean, Upper East Quadrant:	4.66
Mid-Depth	16.72		7.66	
Bottom	36.38		12.30	
Mean, Lower West Quadrant:		26.55	Mean, Lower East Quadrant:	9.98
Mean, Western Half:		17.92	Mean, Eastern Half:	7.32

Section Average Concentration: 12.62

f_1, Nighttime Basis = 4.66/12.62 = 0.37

f_1, Daily Average Basis = 0.625 f_1, Day + 0.375 f_1, Night = 0.41

---

*Gear — 1/2 meter, 500 micron plankton nets.

**Depths vary between 30 and 50 feet; mid-depth samples taken between 15 and 30 feet.

TABLE 10

DETERMINATION OF "f_1" FACTOR FOR STRIPED BASS EGGS YOLK-SAC LARVAE

1971 NYU Data*

(East and West Transects at Peekskill, Indian Point, and Stony Point)

Day Sampling, 5/3/71 to 7/30/71

Relative Mean Concentration, #/TCM, for Sampling Period

Depth**	West		East	
Surface	0.0		0.06	
Mid-Depth	1.10		0.70	
Mean, Upper West Quadrant:		0.55	Mean, Upper East Quadrant:	0.38
Mid-Depth	1.10		0.70	
Bottom	5.23		5.07	
Mean, Lower West Quadrant:		3.17	Mean, Lower East Quadrant:	2.89
Mean, Western Half:		1.86	Mean, Eastern Half:	1.64

Section Average Concentration: 1.75

f_1, Daytime Basis = 0.38/1.75 = 0.22

Night Sampling, 5/11/71 to 7/31/71

Relative Mean Concentration, #/TCM, for Sampling Period

Depth	West		East	
Surface	0.72		0.60	
Mid-Depth	2.83		1.72	
Mean, Upper West Quadrant:		1.78	Mean, Upper East Quadrant:	1.16
Mid-Depth	2.83		1.72	
Bottom	1.28		3.67	
Mean, Lower West Quadrant:		2.06	Mean, Lower East Quadrant:	2.70
Mean, Western Half:		1.92	Mean, Eastern Half:	1.93

Section Average Concentration: 1.93

f_1, Nighttime Basis = 1.16/1.93 = 0.60

f_1, Daily Average Basis = 0.625 x 0.22 + 0.375 x 0.60 = 0.36

---

*Gear — 1/2 meter, 500 micron plankton nets.

**Depths vary between 30 and 50 feet; mid-depth samples taken between 15 and 30 feet.

TABLE 11

DETERMINATION OF "f_1" FACTOR FOR STRIPED BASS EGGS LATER LARVAE

1971 NYU Data*

(East and West Transects at Peekskill, Indian Point, and Stony Point)

Day Sampling, 5/3/71 to 7/30/71

Relative Mean Concentration, #/TCM, for Sampling Period

Depth**	West		East	
Surface	0.38		0.63	
Mid-Depth	54.08		32.52	
Mean, Upper West Quadrant:		27.23	Mean, Upper East Quadrant:	16.57
Mid-Depth	54.08		32.52	
Bottom	78.92		79.17	
Mean, Lower West Quadrant:		66.50	Mean, Lower East Quadrant:	55.90
Mean, Western Half:		46.87	Mean, Eastern Half:	36.24

Section Average Concentration: 41.56

f_1, Daytime Basis = 16.57/41.56 = 0.40

Night Sampling, 5/11/71 to 7/31/71

Relative Mean Concentration, #/TCM, for Sampling Period

Depth	West		East	
Surface	88.0		24.5	
Mid-Depth	46.33		20.67	
Mean, Upper West Quadrant:		9.30	Mean, Upper East Quadrant:	22.58
Mid-Depth	16.72		20.67	
Bottom	36.38		24.77	
Mean, Lower West Quadrant:		62.83	Mean, Lower East Quadrant:	22.72
Mean, Western Half:		65.00	Mean, Eastern Half:	22.65

Section Average Concentration: 43.83

f_1, Nighttime Basis = 22.58/43.83 = 0.52

f_1, Daily Average Basis = 0.625 f_1, day + 0.375 f_1, night = 0.44

---

*Gear — 1/2 meter, 500 micron plankton nets.

**Depths vary between 30 and 50 feet; mid-depth samples taken between 15 and 30 feet.

This recognizes 15 hours of daylight and 9 hours of darkness for the period May through July. The daily average "f_1" does not change during a transport model computer run because the various data employed to compute f_1 all represent the mean of several sampling days over the calendar period of stage appearance.

The 1971 NYU "f_1" factor results are summarized below:

	f_1		
Stage	Day	Night	Daily Average
Eggs	0.43	0.37	0.41
Yolk-sac larvae	0.22	0.60	0.36
Later larvae	0.40	0.52	0.44

Note that these results as well as the tabulated data show that both larval sub-stages behave as reported by numerous investigators. Nighttime concentrations of larvae tend toward a more uniform distribution throughout the water column, while the daytime concentrations are decidedly larger in the deeper water. Eggs tend to be concentrated near the bottom both day and night.

Table 12 shows analysis of the 1972 QL&M data, which was taken during two daytime periods in early and mid-June. Sampling also took place in late June and mid-July.

No striped bass were collected in the upper east quadrant during any one of these four days. Computationally, this yields a zero f_1 factor. To avoid that, a minimum of one fish per collection was assumed for this quadrant.

TABLE 12

DETERMINATION OF "f_1" FACTOR FOR STRIPED BASS EGGS YOLK-SAC LARVAE

June 1972 QL&M Data*

Day Sampling, 6/7/72, 11:30 AM to 12:00 Noon

Relative Mean Concentration, #/TCF, for Sampling Period

Depth**	West		East	
Surface	1.7		0.5***	
Mid-Depth	12.8		0.5***	
Mean, Upper West Quadrant:		7.3	Mean, Upper East Quadrant:	2.80
Mid-Depth	12.8		0.5***	
Bottom	29.3		1.1	
Mean, Lower West Quadrant:		21.1	Mean, Lower East Quadrant:	0.8
Mean, Western Half:		14.2	Mean, Eastern Half:	0.65

Section Average Concentration: 7.43

f_1, Daytime Basis = 0.5/7.43 = 0.067

Day Sampling, 6/15/72, 12:00 Noon to 1:00 PM

Relative Mean Concentration, #/TCF, for Sampling Period

Depth	West		East	
Surface	0.5***		0.5***	
Mid-Depth	1.8		0.5***	
Mean, Upper West Quadrant:		1.2	Mean, Upper East Quadrant:	4.66
Mid-Depth	1.8		0.5	
Bottom	2.9		1.6	
Mean, Lower West Quadrant:		2.4	Mean, Lower East Quadrant:	1.1
Mean, Western Half:		1.8	Mean, Eastern Half:	0.8

Section Average Concentration: 1.3

f_1, Daytime Basis = 0.5/1.3 = 0.38

f_1, Day, 1972 June Average = 0.23

---

*Gear - 1/2 meter, 500 micron plankton nets.

**Depths ranged from 25 feet on west shore to 45 feet on west and east channel

***Zero fish caught; assume one fish caught.

The late June and mid-July data are not reported in this analysis because the numbers taken in the remaining three quadrants during those periods were very small.

QL&M transects were made on the east side of the channel, about 100 yards off the east shore; on the west side of the channel in 45 to 50 feet of water; and several hundred yards off the west shore, in 25 feet of water. West means reported in Table 12 are the average of samples collected along both westerly transects.

Virtually all larvae taken on June 7th were between 5 and 6 mm long, placing the catch in the later days of the yolk-sac stage. Mean length of 71 specimens measured was 5.2 mm. Although only a few specimens of the June 15th catch have been measured, these also appear to be yolk-sac larvae.

Daylight samples only were taken. For later purposes of averaging data, the mean f_1 factor of 0.22 was scaled in proportion to the 1971 NYU results to obtain a daily average value of 0.38.

Table 13 shows analysis of the 1970 Raytheon data, done in accordance with Method A, described previously on page 52. This method causes the mid-channel values to carry extra weight.

The individual station data were taken directly from Table 6-8 of the final Raytheon report, Reference [29]. These data were not separately classified by stage. Observation of Raytheon Figures 6-10 through 6-18, however, suggests that these are primarily yolk-sac larvae, and they have been so interpreted in this analysis.

TABLE 13

DETERMINATION OF "f_1" FACTOR FOR LARVAL STRIPED BASS

June 1970 Raytheon Data
(Data from Table 6-8, Page 6-19, Reference 29)

Basis for Analysis - Method A (Double Weight Applied to Mid-Channel Values)

All Data at Each Station and Depth Are Monthly Averages and Include Day and Night Sampling

Computation of East and West Surface and Mid-Depth Means for Transects North, South and Opposite Indian Point

	Surface		
Transect	West	Mid Channel	East
Stony Point	351	111	24
Indian Point	90	59	91
Indian Point	-	-	76
Roa Hook	265	182	34
Average	235	117	56

West-Mid Channel Surface Average *176*

East-Mid Channel Surface Average *86*

	Mid-Depth		
Transect	West	Mid Channel	East
Stony Point	107	295	-
Indian Point	-	73	55
Indian Point	-	-	46
Roa Hook	45	70	-
Average	76	146	50

West-Mid Channel Mid-Depth Average *111*

East-Mid Channel Mid-Depth Average *98*

Computation of East & West Bottom Means for Transects North, South & Opposite Indian Point

Transect	West	Mid Channel	East
Stony Point	176	95	10
Indian Point	161	426	36
Indian Point	-	-	58
Roa Hook	377	855	8
Average	238	459	28

West-Mid Channel Bottom Average *349*

East-Mid Channel Bottom Average *244*

"f_1" Factor Computation

Depth	West	East
Surface	176	86
Mid-Depth	111	98

Mean, Upper West Quadrant: 144 Mean, Upper East Quadrant: 92

Depth	West	East
Mid-Depth	111	98
Bottom	349	244

Mean, Lower West Quadrant: 230 Mean, Lower East Quadrant: 171

Mean, Western Half: 187 Mean, Eastern Half: 132

Section Average Concentration: 160

f_1, Average Daily Basis = 92/160 = 0.57

These data do not distinguish between day and night sampling. Raytheon reports that day sampling was on a weekly basis and night sampling on a biweekly basis. This should yield a day/night weight factor on the order of 0.67/0.33, close enough to the accepted value of 0.625/0.375 to accept the composite results as representative daily averages.

Analysis of the Raytheon data via Method B is shown in Table 14. This method does not provide an extra weight to the mid-channel data, and thus is considered to yield a more representative value of "f_1."

These analyses of the Raytheon data yielded the following results for yolk-sac larvae:

	f_1		
	Mid-Channel		
Stage	Weighted	Unweighted	Average
Yolk-sac	0.57	0.33	0.45

Tables 15, 16, 17, and 18 show analysis of the 1967 Carlson & McCann data, as given in Tables 3 and 4 of that report [2]. Data are given for west, center, and east channel stations, so both methods of incorporating the mid-channel data into the analysis are presented in each table.

Since egg data are nonexistent at the center and east stations until the 45-foot depth is reached, this value is selected as the lower boundary (mid-depth value) of the upper half of the east and center sections in the egg analysis.

TABLE 14

DETERMINATION OF "f_1" FACTOR FOR LARVAL STRIPED BASS

June 1970 Raytheon Data*
(Station Mean Data From Table 13, This Testimony)

Basis for Analysis - Method B (Uniform Lateral Weighting)

Depth	Means* of Roa Hook, Indian Point and Stony Point Stations		
	West	Mid-Channel	East
Surface	235	117	56
Mid-Depth	76	146	50
Mean, Upper Sector	156	132	53
Mid-Depth	76	146	50
Bottom	238	459	28
Mean, Lower Sector	156	217	46

Section Average Concentration: 140

f_1, Average Daily Basis = 46/140 = 0.33

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* Concentration in numbers of larvae per thousand cubic meters.

TABLE 15

DETERMINATION OF "f_1" FOR STRIPED BASS EGGS

1967 Carlson & McCann Data*

Peekskill Transect

(data from HRFI (Reference 2), Table 3, page 21)

Day and Night Sampling, May & June 1967

Basis for Analysis

	West	Center	East
Upper Half:	0 - 30'	0 - 45'	0 - 45'
Lower Half:	30 - 60'	45 - 110'	45 - 90'

Method A - Double Weight Applied to Mid-Channel Values

Depth Means*	West Quadrant		East Quadrant		
Upper West	0.15		Upper East	0.06	
Upper Center	0.05		Upper Center	0.05	
Mean, Upper West Quadrant:		0.10	Mean, Upper East Quadrant:		0.05
Lower West	0.20		Lower East	0.56	
Lower Center	0.26		Lower Center	0.26	
Mean, Lower West Quadrant:		0.23	Mean, Lower East Quadrant:		0.41
Mean, Western Half :		0.17	Mean, Eastern Half :		0.23

Section Average Concentration: 0.20

f_1, Average Daily Basis = 0.05/0.20 = 0.25

Method B - Uniform Lateral Weighting

Depth Means*	West	Center	East
Upper	0.15	0.05	0.06
Lower	0.20	0.26	0.56
			0.31
Station Average	0.18	0.16	

Section Average Concentration: 0.22

f_1, Average Daily Basis = 0.06/0.22 = 0.27

* Concentration in numbers of eggs per thousand cubic feet.

TABLE 16

DETERMINATION OF "f_1" FOR STRIPED BASS LARVAE

1967 Carlson & McCann Data*

Peekskill Transect

(data from HRFI (Reference 2), Table 4, page 22)

Day and Night Sampling, May through July 1967

Basis for Analysis

	West	Center	East
Upper Half:	0 - 30'	0 - 30'	0 - 30'
Lower Half:	30 - 60'	30 -110'	30 - 90'

Method A - Double Weight Applied to Mid-Channel Values

Depth Means*	West Quadrant		East Quadrant		
Upper West	1.33		Upper East	0.29	
Upper Center	0.15		Upper Center	0.15	
Mean, Upper West Quadrant:		0.74	Mean, Upper East Quadrant:		0.22
Lower West	1.21		Lower East	0.59	
Lower Center	0.64		Lower Center	0.64	
Mean, Lower West Quadrant:		0.93	Mean, Lower East Quadrant:		0.62
Mean, Western Half :		0.83	Mean, Eastern Half :		0.42

Section Average Concentration: 0.63

f_1, Average Daily Basis = 0.22/0.63 = 0.35

Method B - Uniform Lateral Weighting

Depth Means*	West	Center	East
Upper	1.33	0.15	0.29
Lower	1.21	0.64	0.59
Station Average	1.27	0.40	0.44

Section Average Concentration: 0.70

f_1, Average Daily Basis = 0.29/0.70 = 0.41

*Concentration in numbers of larvae per thousand cubic feet.

Table 15 shows that either method yields essentially the same result, an f_1 factor for eggs of 0.26. Note that this result must be considered as quite conservative, since it is unlikely that eggs at 45 feet of depth would appear in the plant intake. Analysis of these data at a more realistic maximum depth value for plant withdrawal would yield a zero value for f_1.

Tables 16 through 18 show analysis of the Carlson & McCann data using various definitions of mid-depth. These data were collected to 60 feet, 110 feet, and 90 feet at the west, center, and east stations, respectively. Since these depths are substantially greater than those of the other years, various definitions of mid-depth were made to test the sensitivity of the analysis.

These data contain night and day samples. Sampling at Peekskill was done on a twice weekly basis day and night, so the data may be somewhat biased toward the night side. Recognizing the observed larval behavior of upward movement in darkness, such bias will generate conservative estimates of f_1.

Since Carlson & McCann do not indicate otherwise, it has been assumed that these data represent the entire larval sampling period, May through July. Evaluation of Carlson & McCann's Table 1 and Figure 8 suggests that these are primarily later stages of yolk-sac larvae and early post-larvae. The results of the analysis have been applied to both yolk-sac and later larvae stages.

The results of the analysis of Carlson & McCann's data are summarized as follows:

Table	Basis of Analysis	Mid-Channel Weighted	Mid-Channel Unweighted	Average
16	Upper layer to 30 feet, lower layer to full depth	0.35	0.41	0.38
17	Upper layer to 30 feet, lower layer to 60 feet	0.40	0.46	0.43
18	Upper layer to mid-depth, lower layer — mid-depth to bottom	0.46	0.37	0.42
	Average, all methods:		0.41	
	Range, all methods:		0.35-0.46	

The results for "f_1" determination for the four years of data are summarized below:

Stage	Range or Average Value of f_1 1967	1970	1971	1972	Average, All Years
Eggs	0.26	-	0.41	-	0.33
Yolk-sac larvae	0.35-0.46	0.33-0.57	0.36	0.38	0.40
Later larvae	0.35-0.46	-	0.44	-	0.42
Data Source:	Carlson & McCann	Raytheon	NYU	QL&M	All

For purposes of estimating plant impact on fish population, a range of "f_1" factors was chosen for use in the transport model. This included an apparent minimum, an apparent maximum, the average of all observations, and a current "best estimate." These selections are:

Stage	f_1 Selected for Transport Model Use Apparent Minimum	Apparent Maximum	Average, All Observations	Current Best Estimate
Eggs	0.2	0.5	0.33	0.41
Yolk-sac larvae	0.3	0.6	0.40	0.36
Later larvae	0.35	0.46	0.42	0.44

The apparent minimum and maximum values for the egg and yolk-sac larvae stages are the rounded values of the minimum and maximum observed values. The current best estimate reflects the 1971 NYU data. These data, as discussed previously, appear to be the most complete and informative of all and, therefore, have been selected as yielding the best estimate of f_1 on the basis of the information available.

Several comments are in order. In general, the deepest sections of the river were not sampled. All data on all stages certainly indicate that the concentration of each stage increases with depth. This suggests strongly that more representative sampling of the entire cross-section would yield lower "f_1" values and therefore lower estimates of plant impact.

The eggs are known to remain in deep water throughout the day. Furthermore, hatchery observations indicate that those which appear on the surface are unfertilized and die [34]. The 1967 data showed no eggs above a 45-foot depth, and this depth had to be included in the upper layer to yield a non-zero "f_1" factor. These facts suggest that the true "f_1" factor for eggs is probably very close to zero.

The stage selections for the transport model include a 28-day larval stage and a 30-day early juvenile stage. The foregoing data on yolk-sac larvae are estimated to consist primarily of larvae between 10 and 15 days old. It is difficult to assess the exact age range of the late larvae without length data but, based on the dates of appearance, it is certain that these include fish through the first 28 days of life.

Since the yolk larvae are more abundant than those in later stages of life, we have computed the f_1 factor for the 28-day transport model larval stage by applying weights of 0.67 and 0.33 to the yolk-sac and late larvae data, respectively. Although this may appear to be somewhat arbitrary, the close agreement between f_1 factors for the two larval stages permits breadth in the selection of such weights.

The early juvenile stage (J_I in the transport model) appears in the river between mid-June and mid-August. Based on dates of appearance and lengths, some of these fish (most probably the younger ones, of 30 to 40 days of life) are included in the later larvae catches. We have used the later larvae f_1 factors for this stage.

Final selection of "f_1" factors for use in the first three stages in the transport model are:

	f_1 Used in Transport Model Operation			
Transport Model Stage	Apparent Minimum	Apparent Maximum	Average, All Observations	Current Best Estimate
Eggs	0.20	0.50	0.33	0.41
Larvae	0.32	0.55	0.40	0.39
J_I	0.35	0.46	0.42	0.44

b. Determination of f_2, f_3, f_c

The factor "f_2" recognizes that all fish within the vicinity of the intake, although potentially part of the water flow to the plant, do not necessarily move into the intake. This is based on the fact that, as they grow older, the fish have the swimming ability to avoid transport by currents such as those induced by the plant, and the

TABLE 17

DETERMINATION OF "f_1" FOR STRIPED BASS LARVAE

1967 Carlson & McCann Data*

Peekskill Transect

(data from HRFI (Reference 2), Table 4, page 22)

Day and Night Sampling, May & July 1967

Basis for Analysis

Upper Half: 0 to 30 ft deep

Lower Half: 30 to 60 ft deep

Method A - Double Weight Applied to Mid-Channel Values

Depth Means*	West Quadrant		East Quadrant		
Upper West	1.33		Upper East	0.29	
Upper Center	0.15		Upper Center	0.15	
Mean, Upper West Quadrant:		0.74	Mean, Upper East Quadrant:		0.22
Lower West	1.21		Lower East	0.29	
Lower Center	0.46		Lower Center	0.46	
Mean, Lower West Quadrant:		0.84	Mean, Lower East Quadrant:		0.38
Mean, Western Half :		0.79	Mean, Eastern Half :		0.30

Section Average Concentration: 0.55

f_1, Average Daily Basis = 0.22/0.55 = 0.40

Method B - Uniform Lateral Weighting

Depth Means*	West	Center	East
Upper	1.33	0.15	0.29
Lower	1.21	0.46	0.29
Station Average	1.27	0.30	0.29

Section Average Concentration: 0.63

f_1, Average Daily Basis = 0.29/0.63 = 0.46

* Concentration in numbers of larvae per thousand cubic feet.

TABLE 18

DETERMINATION OF "f_1" FOR STRIPED BASS LARVAE

1967 Carlson & McCann Data*

Peekskill Transect

(data from HRFI (Reference 2), Table 4, page 22)

Day and Night Sampling, May through July 1967

Basis for Analysis

	West	Center	East
Upper Half:	0 - 30'	0 - 60'	0 - 45'
Lower Half:	30 - 60'	60 -110'	45 - 90'

Method A - Double Weight Applied to Mid-Channel Values

Depth Means*	West Quadrant		East Quadrant	
Upper West	1.33		Upper East	0.27
Upper Center	0.39		Upper Center	0.39
Mean, Upper West Quadrant:		0.86	Mean, Upper East Quadrant:	0.33
Lower West	1.21		Lower East	0.68
Lower Center	0.68		Lower Center:	0.68
Mean, Lower West Quadrant:		0.95	Mean, Lower East Quadrant:	0.68
Mean, Western Half :		0.91	Mean, Eastern Half :	0.52

Section Average Concentration: 0.72

f_1, Average Daily Basis = 0.33/0.72 = 0.46

Method B - Uniform Lateral Weighting

Depth Means*	West	Center	East
Upper	1.33	0.39	0.27
Lower	1.21	0.68	0.68
Station Average	1.27	0.54	0.42

Section Average Concentration: 0.74

f_1, Average Daily Basis = 0.27/0.74 = 0.37

*Concentration in numbers of larvae per thousand cubic feet.

supposition that, having such ability, they may make use of it to avoid the intake.

The eggs have no such ability so that f_2 for eggs is chosen as 1.0. This states that the intake will see whatever concentration appears in the near vicinity of the intake, i.e., in the upper east quadrant.

The yolk-sac larvae are feeble swimmers at best, and move primarily vertically, so they are not expected to possess any "avoidance" mechanism beyond that already implicit in "f_1." Thus f_2 for yolk-sac larvae is also chosen as 1.0.

The later larvae through age 28 days probably have some ability to avoid the intake, but in the absence of data, f_2 through the first 28 days of life has been assumed to be 1.0.

Sampling in the intake and in the general vicinity of the plant, conducted by NYU and QL&M in July 1972, establishes the presence of this mechanism. Data are reported in Table 19 in terms of total serranids (white perch and striped bass) because the number of striped bass caught was too small to perform any valid analysis.

The river sampling data suggest reasonably uniform concentrations throughout the 24-hour period. This is not unusual since the collections consisted primarily of white perch, which reportedly do not exhibit the distinct negative phototaxic behavior of the striped bass.

Some variation exists between day and night in the intake sampling. Whether this is real or an artifact of the low total numbers caught is not known. Accordingly, weighted and unweighted f_2 calculations have been made.

TABLE 19

ESTIMATION OF "f_2" FACTOR FOR EARLY JUVENILES

All Sampling Data Reported as Numbers of Total Serranids per Thousand Cubic Feet

Depth	Day Sampling		Night Sampling	
	East	East Channel	East	East Channel
0	2.26	10.94	1.34	3.01
10	3.76	4.14	5.27	8.17
20	2.96	7.95	4.03	9.93
Average	2.99	7.68	3.55	7.04
Quadrant Average	5.33		5.35	
Intake Concentration	1.41		3.77	

Calculation of f_2

Basis for Analysis	Unweighted	Day/Night Weighting
East Shore	0.74	0.67
East Quadrant	0.48	0.42

To keep the analysis consistent, since f_1 calculations involve the entire upper east quadrant, f_2 should be calculated by dividing the intake concentration by the entire upper east quadrant concentration. The calculation based on the east shore values is therefore considered to be less representative of the contribution of f_2 to the overall "f" factor effect.

Based on the known greater ability of the young striped bass by comparison to the white perch to escape the nets, it is believed the striped bass have at least as strong a tendency to avoid the intake as is shown above. The range of f_2 factors for the J_I stage then is:

	Apparent Minimum	Apparent Maximum	Average, All Observations	Current Best Estimate
f_2	0.4	0.8	0.58	0.5

No information is available at this time to compute f_3. Therefore, although it is believed it must be less than 1.0, particularly beyond the larval stage, a value of 1.0 has been selected for this parameter for all three early stages.

The cropping factor, "f_c," can also be estimated using 1972 NYU data. Total sampling covering a variety of conditions (variable plant temperature rise, etc.) yielded the following counts of white perch and striped bass.

	Number of Fish			
	Alive	Damaged	Dead	Total
Intake	327	105	225	657
Discharge	177	55	167	399

Statistical analysis of the significance of these results has not yet been performed. It is unknown, for example, whether the substantially lower total numbers of fish caught in the discharge can be explained within the statistical limits of the sampling process, or whether the difference is real.

If the latter, the explanation may lie in escapement, in which the missing numbers would be presumed alive, or in dropping to the bottom due to death, in which the missing numbers would be presumed dead.

A particularly severe interpretation would be to presume the difference in total count is made up of dead fish only. This yields a plant passage survival fraction of 177/327 or 54%. The cropping factor is (1 - 0.54) or 0.46.

The most liberal interpretation would be to presume the difference is all live fish. For this case, survival exceeds 100%. This, of course, simply suggests that if the difference is primarily made up of live fish, the plant may not be causing mortality.

If the data are accepted as samples from the same population, then the 50% intake survival and 44% discharge survival yield a survival reduction of 10% due to plant passage.

Observations by study personnel [34] indicate that survivability appears to increase with age, the young larvae being most vulnerable and the larger larvae and early juveniles showing greater ability to condition to the impact.

These data and observations suggest that, on a conservative basis, an "f_c" factor of 1.0 be selected for the larval stage, and a range between 0.1 and 0.5 be selected for the juvenile I stage.

1972 NYU data on egg survival show ability to withstand temperature rises of 15°F and more, depending on the particular stage of growth reached at the time of exposure. These data suggest clearly that the f_c factor for eggs is less than 1.0, perhaps substantially so. Until such data have been more completely analyzed, the apparently quite conservative value of 1.0 is used for this stage.

Selected cropping factor values are summarized below:

	Cropping Factor, f_c		
Stage	Apparent Minimum	Apparent Maximum	Estimate Used in Transport Model
Eggs	0±	<<1.0	1.0
Larvae	>0	<1.0	1.0
J_I	0.1±	0.5±	0.5

Note that plant recirculation has not been considered here, or elsewhere in the model. Inclusion of recirculation in the model will further reduce the computed impact of the plant on the river's bass population.

Table 20 summarizes all f factors for the first three stages of striped bass development.

2. Estimation of Impingement Factors

Estimation of individual f factors for impingement of the J_{II} and J_{III} stages (late summer through fall and overwintering juveniles) is

TABLE 20

SUMMARY OF ENTRAINMENT "f" FACTORS TO BE USED IN TRANSPORT MODEL

Stage	Apparent Minimum	Apparent Maximum	Average of Observations	Current Available Estimate
River Distribution Factor, f_1				
Eggs	0.2	0.5	0.33	0.41
Larvae	0.32	0.55	0.40	0.39
Juvenile I	0.35	0.46	0.42	0.44
Intake Avoidance Factor, f_2				
Eggs	1.0	1.0	-	1.0
Larve	<1.0	1.0	-	1.0
Juvenile I	0.4	0.8	0.58	0.5
Availability After Drawn Down Factor, f_3				
Eggs	<1.0	1.0	-	1.0
Larvae	<1.0	1.0	-	1.0
Juvenile I	≪1.0	<1.0	-	1.0
Plant Cropping Factor, f_c				
Eggs	0±	≪1.0	-	1.0
Larvae	> 0	<1.0	-	1.0
Juvenile I	0.1±	0.5±	-	0.5
Composite Factor, $f = f_1 \cdot f_2 \cdot f_3 \cdot f_c$ (For Use in Transport Model)				
Eggs	0.2*	0.5	-	0.41
Larvae	0.3	0.55	-	0.39
Juveniles	0.0	0.3**	-	0.11

---

*Larger than computed minimum

**Larger than computed maximum

virtually impossible. The overall factor, f, however, may be obtained directly on the basis of available Indian Point impingement data and of total population in the Indian Point segment.

This f factor is adjusted in the model during operation so that total impingement will yield predetermined impingement by the plant. The two unit impingement data are obtained by Unit 1 impingement observations in proportion to two-unit flow. In other words, the model is calibrated to yield this impingement value.

These values have been obtained using observations made at Unit 1 and are reported in Table 21. The computational procedure is also given in Table 21. Using this computational procedure which includes a 25% upward adjustment factor as well, the following striped bass impingement loss is obtained:

Unit	Juvenile II (July Through November)	Juvenile III (December Through May 7)
1	3,670	7,565
2	11,010	22,695
Total	14,680	30,260

In addition to the July through November computed total, the estimated 1,275 striped bass impinged between May 7th and June 30th are added to the total J_{II} impingement. This yields a rounded J_{II} impingement of 16,000. Impingement values for Unit 1 and 2 operation in the transport model are 16,000 and 30,000 for the J_{II} and J_{III} stages, respectively. As indicated in Table 21, these values are based upon operation at 60% of full flow for both units for six months of the year, and full flow otherwise.

TABLE 21

STRIPED BASS IMPINGEMENT VALUES FOR TWO UNIT OPERATION AT INDIAN POINT ASSUMING REDUCED FLOW IN OCT., NOV. & DEC. JAN., FEB., MARCH*†

Month	Unit 1 Monthly Totals		Two Unit Operation Monthly Totals
	Base	Adjusted**	
①	②	③	④
January	728	910	3,640
February	3,330	4,163	16,650
March	463	579	2,315
April	462	578	2,310
May	174	218	870
June	131	164	655
July	49	61	245
August	780	975	3,900
September	1,130	1,413	5,650
October	112	140	560
November	865	1,081	4,320
December	1,020	1,275	5,100
Totals	9,244	11,557	46,215

This table is based on the following assumptions:

1. Both units operate all days per month.
2. Fish collection at Unit 2 will be directly related to flow rate and follow a similar annual pattern of abundance.
3. Annual per cent composition will be similar at Units 1 & 2.

* Reduced flow is 60% full flow or 84,000 gpm per each main pump.

† Using annual striped bass per cent composition of 3.1.

** 25% upward adjustment to account for specimens lost.

③ = 1.25 x ②

④ = 4.0 x ③

The factors f_1, f_2 and f_c are implicit in the Unit 1 impingement data. Table 21 assumes there will be sufficient fish in the vicinity of the intake to permit impingement to continue to be simply proportional to flow. This assumes the f_3 factor, which accounts for the rate at which the drawdown population is replenished, is 1.0. This assumption is probably quite conservative because it forces the fish to continue to migrate into the Indian Point segment as the fish population in that segment is drawn down.

IV. TESTING THE TRANSPORT MODEL

This chapter tests the ability of the mathematical model to simulate Hudson River striped bass life history and to reproduce observed bass behavior. The 1967 Carlson & McCann data were employed in the comparison.

A brief description of the notion of model testing as it applies to the present model is given first. Subsequently, the details of testing the various life stages are discussed.

Results indicate that the model has been successful in simulating striped bass behavior. This conclusion is established by showing that the model can properly progress through the early life history by using a given spawning rate as a function of river location and calendar time and from this, generating egg, early larvae, and later larvae-early juvenile distributions via internal transport mechanisms. These distributions are shown to agree reasonably well with corresponding measured data.

A. THE NOTION OF MODEL TESTING

An acceptable criterion for evaluating the internal consistency of the model has been established. This criterion shows that the model provides a complete description of striped bass life history by accounting for the fate of all surviving organisms. Beginning with a particular initial egg production number, the model is able to move through the entire series of life stages, delineate in terms of absolute concentrations all stages of the history, and continue through any number of repetitions of the cycle.

Beyond self-consistency, however, it is normal procedure to test the ability of the model to reproduce observed behavior as well. Reproduction of this behavior was shown in Chapter II to be the criterion for measuring the value of the basic river transport model. However, certain important distinctions exist between the observability of a substance such as dissolved oxygen in which no intra-stage transfer occurs and, say, eggs or larvae of fish. These organisms are not distributed throughout the estuary in the continuous fashion of soluble substances such as salt or dissolved oxygen, but rather in a more random and discrete manner. Thus, any collection of samples, no matter how thoroughly and scientifically undertaken can only represent a series of uncertain and varied percentages of the total number of organisms in the river.

The apparent most comprehensive set of observations for the Hudson estuary by which the model can be tested is the Carlson & McCann data. These data reflect those inherent difficulties just described as well as additional difficulties among which are both the inability to collect eggs located very near the river bottom and/or to obtain a representative amount of yolk-sac larvae (0-2 weeks), and the avoidance of the nets by the older larvae. In the absence of this unavailable information and given the random distribution of the organisms, the data on actual behavior, unlike the mathematical behavior in the model, cannot represent precisely either absolute concentration or the entire life history of the bass in a continuous fashion.

Thus, perfect or even near perfect agreement between model and field data should not be expected. The model will reproduce behavior comparable to field observations by the careful selection of parameters and by recognition of just what portions of the life history are being observed in the field. Such selection and recognition was made in comparing the model to the 1967 Carlson & McCann data.

If the original egg production inputs, which are based upon 1967 observations, and considered to represent only a portion of the actual egg production rate, the model, presuming other parameters are correct, should produce the same relative proportion of the "true" concentration of all stages, including both those that can be sampled and those that cannot. A "test" of this kind was successfully carried out and showed that the model can reproduce observed Hudson River striped bass behavior.

The model, therefore, has been shown to have the following characteristics:

1. The ability to represent the complete life history of Hudson River striped bass.
2. The ability to produce results which are in relatively good agreement with field observations.
3. The ability to yield more information than field observations because it both describes stages that elude sampling and it generates consistent absolute values.

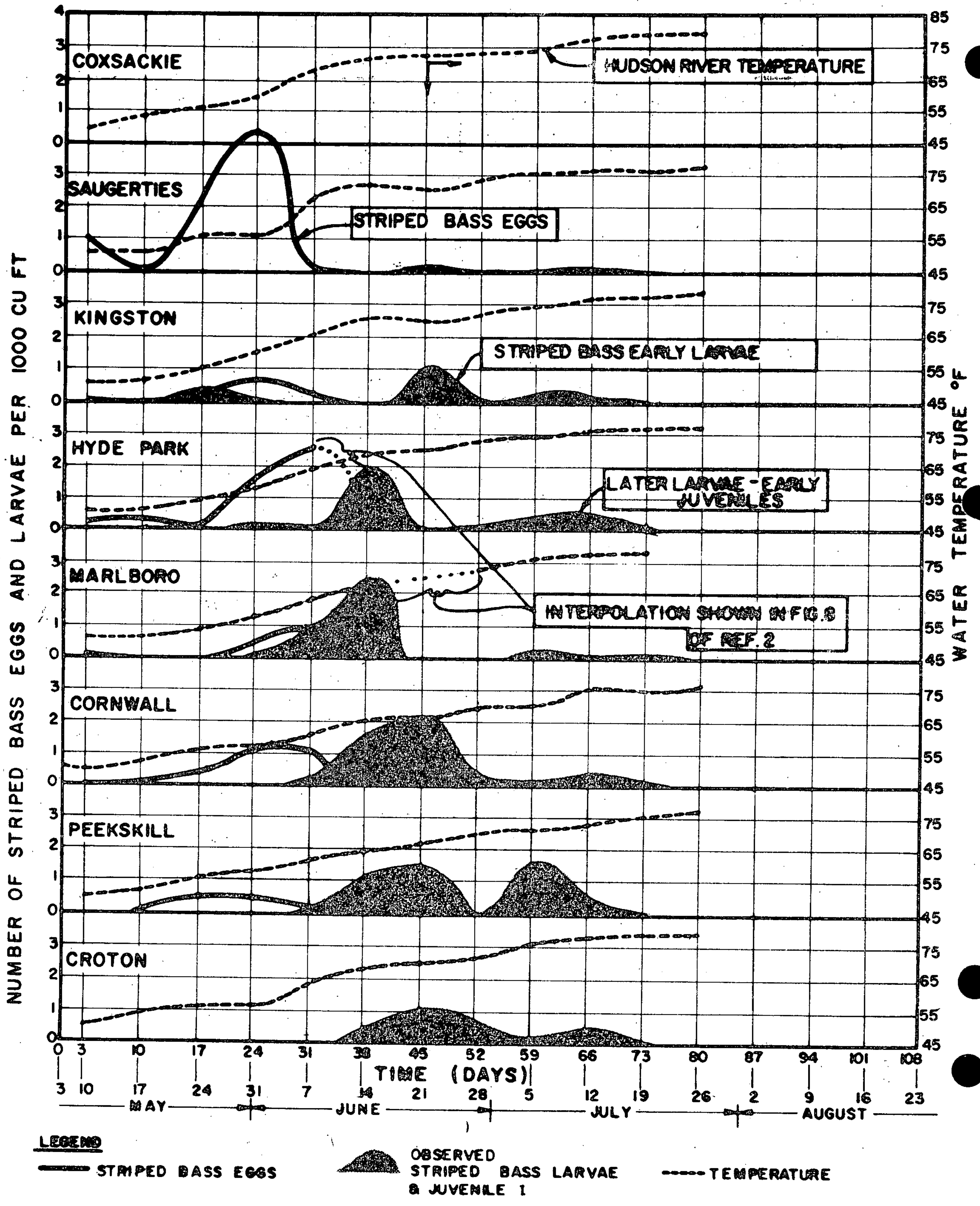
More importantly, the final objective of the model is not to produce a set of data but to predict plant impact, i.e., to compare the background population level of the bass in the river to their level when the plant is operating. Since the model describes quite thoroughly the manner in which the river works, the way fish interact with the river, and the plant action on both - that is, how all the complex factors involved are related to each other - it is capable of delineating an accurate percentage expression of expected plant impact.

B. TESTING PROCEDURE

Carlson & McCann 1967 data [2] for eggs, early larvae, and later larvae-early juveniles, used for comparison with model results, are shown in Figure 16. The following procedure was employed in testing with these data:

FIGURE 16

WEEKLY ABUNDANCE OF STRIPED BASS EGGS AND LARVAE WITH TEMPERATURE OF THE HUDSON RIVER, 1967
(REPRODUCED FROM FIG. 8 OF REFERENCE 2)



1. Using the egg data, compute the rate of spawning in terms of eggs dropped per river segment per day.

2. Insert these egg production rates into the transport model and compute the egg concentration distribution in space along the river's longitudinal axis and in time from commencement to completion of the spawning run.

3. Compare the results of step 2 with the Carlson & McCann egg distributions in Figure 16 as a first test of the transport model.

4. Obtain from the results of step 2 the rate at which eggs survive the egg life stage, hatch, and become larvae. The egg survival rate becomes the larval production or generation rate.

5. Continue running the transport model through the larval stage, using the results of step 4 as the larval input. Compute the distribution of larvae in space along the river's longitudinal axis and in time over the calendar period during which larvae are known to appear.

6. As a second test of the reproducibility of the transport model, compare the early larval distributions with the corresponding computed results in step 5. These larval distributions are represented by the first larval "hump" in Figure 16.

7. Determine the production rate of early juveniles (the J_I stage) by obtaining its equivalent which is the rate of survivors of the larval stage determined from the larval stage computations of step 5.

8. Continue running the transport model through the J_I stage, using the results of step 7 as the early juvenile input. Migration rates computed as previously described in Chapters II and III are used in this step.

   Compute the distribution in space along the river's longitudinal axis and in time over the calendar period during which early juveniles are known to appear in the river.

9. Compare the computed distribution of the juvenile I stage to the corresponding later larval-early juvenile distribution which are represented by the second "hump" in the 1967 Carlson & McCann larval curves shown in Figure 16. This is a third test of the reproducibility of the transport model.

Procedures used to generate further stages of first year development (juvenile II and II's) are given in the previous chapter. Delineation of the results obtained employing this above described procedure is given in the remaining sections of this chapter.

C. EGG STAGE

The striped bass egg distribution as a function of time from the first day of spawning and of distance along the river's longitudinal axis is generated by the transport model once the distribution of the egg production rates computed as described in the previous chapter is put into the model.
The model actually simulates real behavior in the Hudson River by moving the spawned eggs downstream in the freshwater flow (the advection term), distributing them in both directions by tidal movement (the dispersion term),

removing them by natural phenomena including predation, settling, etc. (the natural mortality term), and finally by allowing those which remain after 1.5 days of life to pass into the next larval stage (the egg survival transfer term).

Figure 17 shows clearly the excellent agreement between the measured egg concentrations and those predicted by the transport model. It should be noted, however, that this is basically a check on the internal consistency of the transport model. The egg production rate employed in the transport model was developed using the 1967 data and the same survival percentage and life stage duration that was used to compute the egg production (via Equations 4 and 5). Although Equations 4 and 5 do not permit transport of eggs from segment to segment, the life stage of 1.5 days is sufficiently short so that the relative transport in or out of the segment should not be significant in each 1.5-day time increment.

Nevertheless, the good agreement shown in Figure 17 is still clear evidence that the transport model is functioning properly and has the ability to move particles from point to point along the estuary in the proper manner. Compensation was not used in the egg stage, i.e., K_o in Equation 1 was set to equal to K_E. The concentration of eggs should not significantly affect survival. Eggs are primarily self-contained and do not compete for food sources.

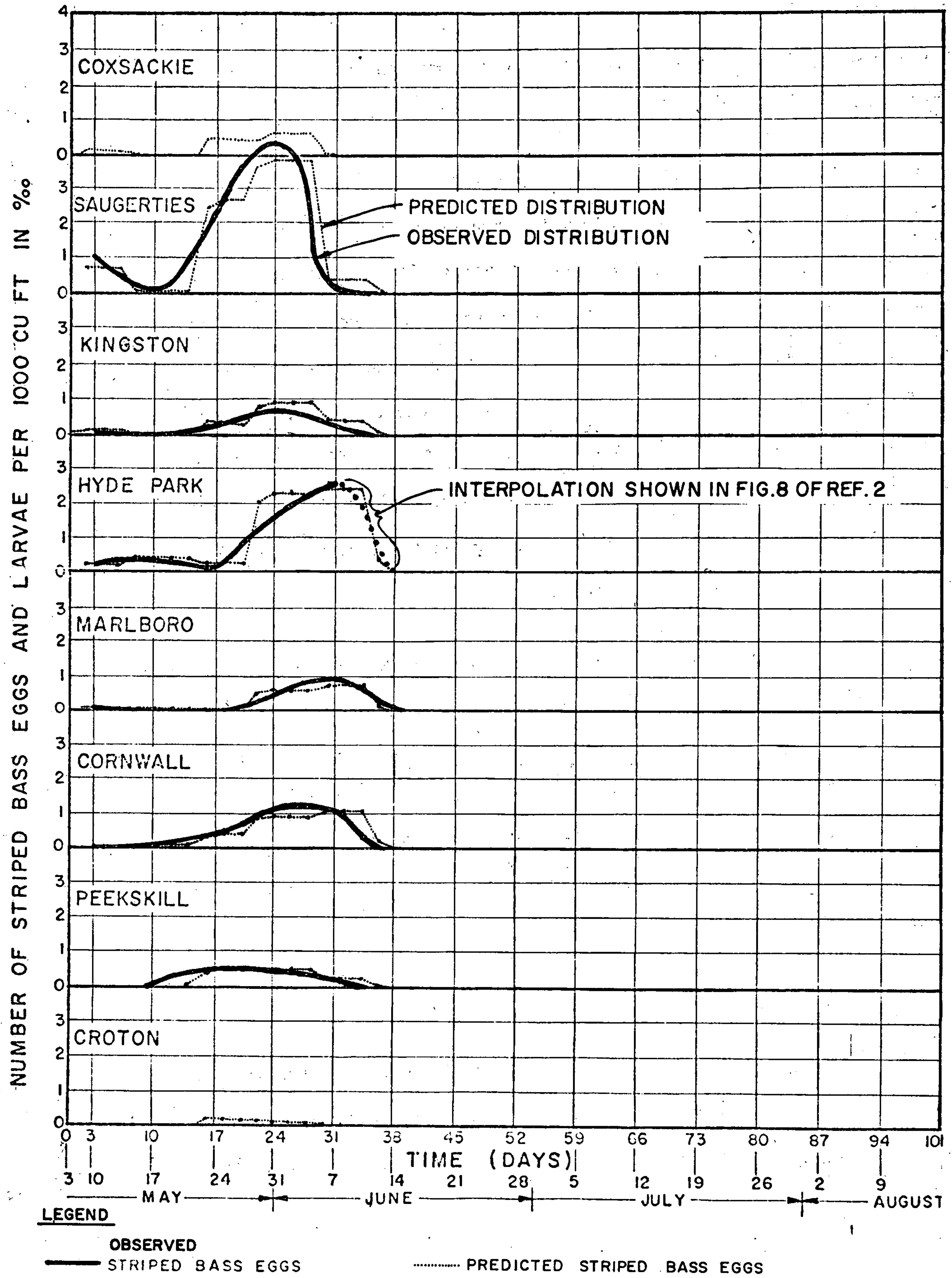
D. LARVAL STAGE

Figure 16 of this testimony and Figure 8 of the Carlson & McCann report [2] showing 1967 striped bass egg and larval behavior indicate that the collected larvae begin to appear in the Hudson River about 2 to 3 weeks after the

FIGURE 17

COMPARISON OF HUDSON RIVER STRIPED BASS EGG CONCENTRATION PREDICTED BY THE TRANSPORT MODEL TO MEASURED VALUES

DATA BASE - 1967 HRFI DATA (REF. 2)

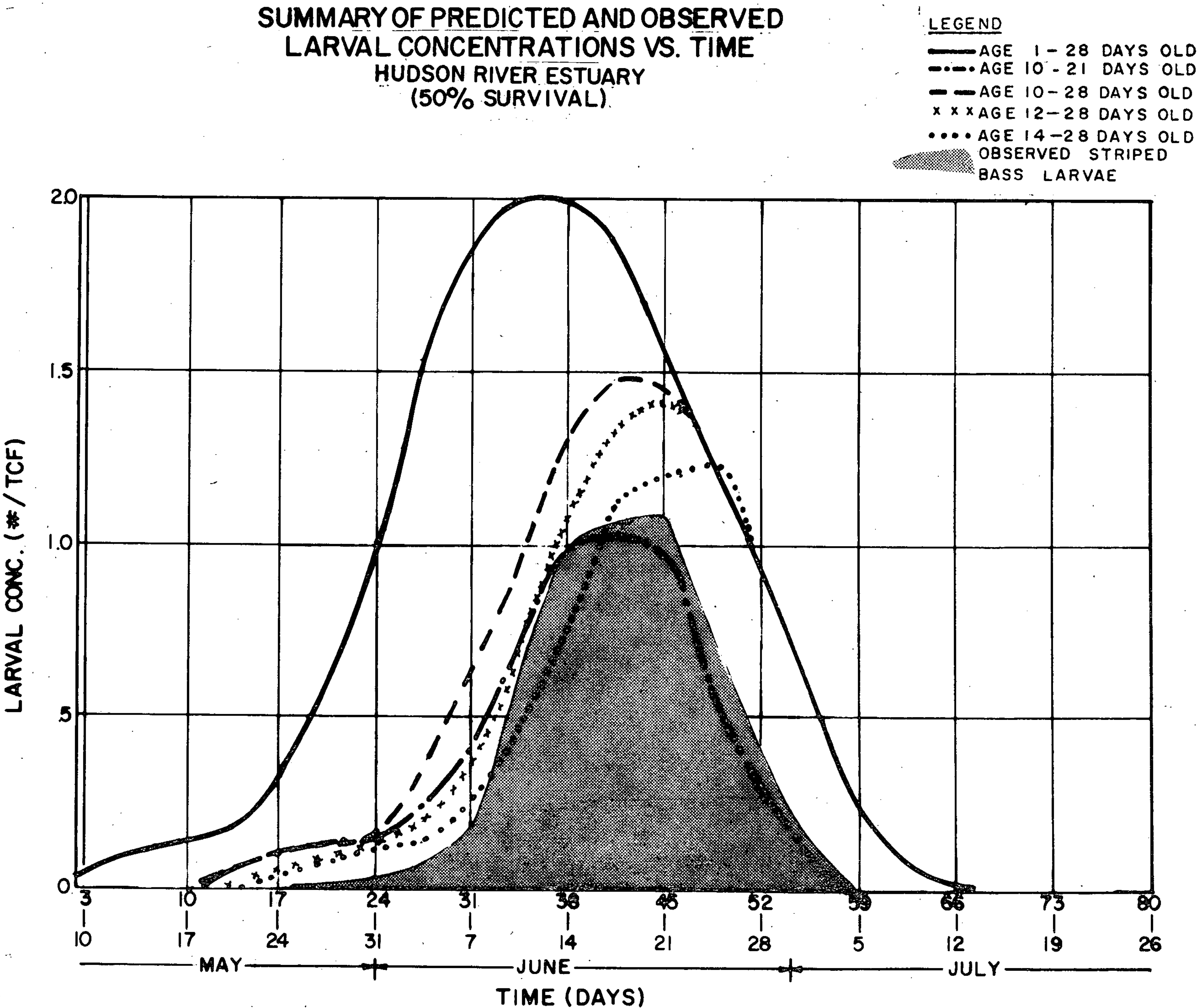


start of egg production. However, as indicated in Section A of this chapter, these larval profiles represent organisms about two to three weeks old. In other words, they neither include most of the newly hatched larvae (0 to about 2 weeks old) nor the older and more mobile larvae (3 to 4 weeks old). This finding is based upon a number of gear selectivity statements regarding mesh openings and net avoidances, made in References 2 and 3 and upon the reported mean length of these larvae of about 0.22 inches or 5 mm and associated range in length as shown in Table 1 and Figure 8 of Reference 2. This length places the catch in the later days of the yolk-sac stage. In other words, the Carlson & McCann larval observations employed in this "testing" step represent a portion of the total larval population that may have existed in 1967 and should be considered in this light.

On the other hand, the mathematical model delineates in a continuous fashion the entire life history of the striped bass and accounts for the fate of all organisms including the newly hatched and older larvae. Therefore, the 1967 larval observations should be compared with the corresponding sub-stage of the larval predictions.

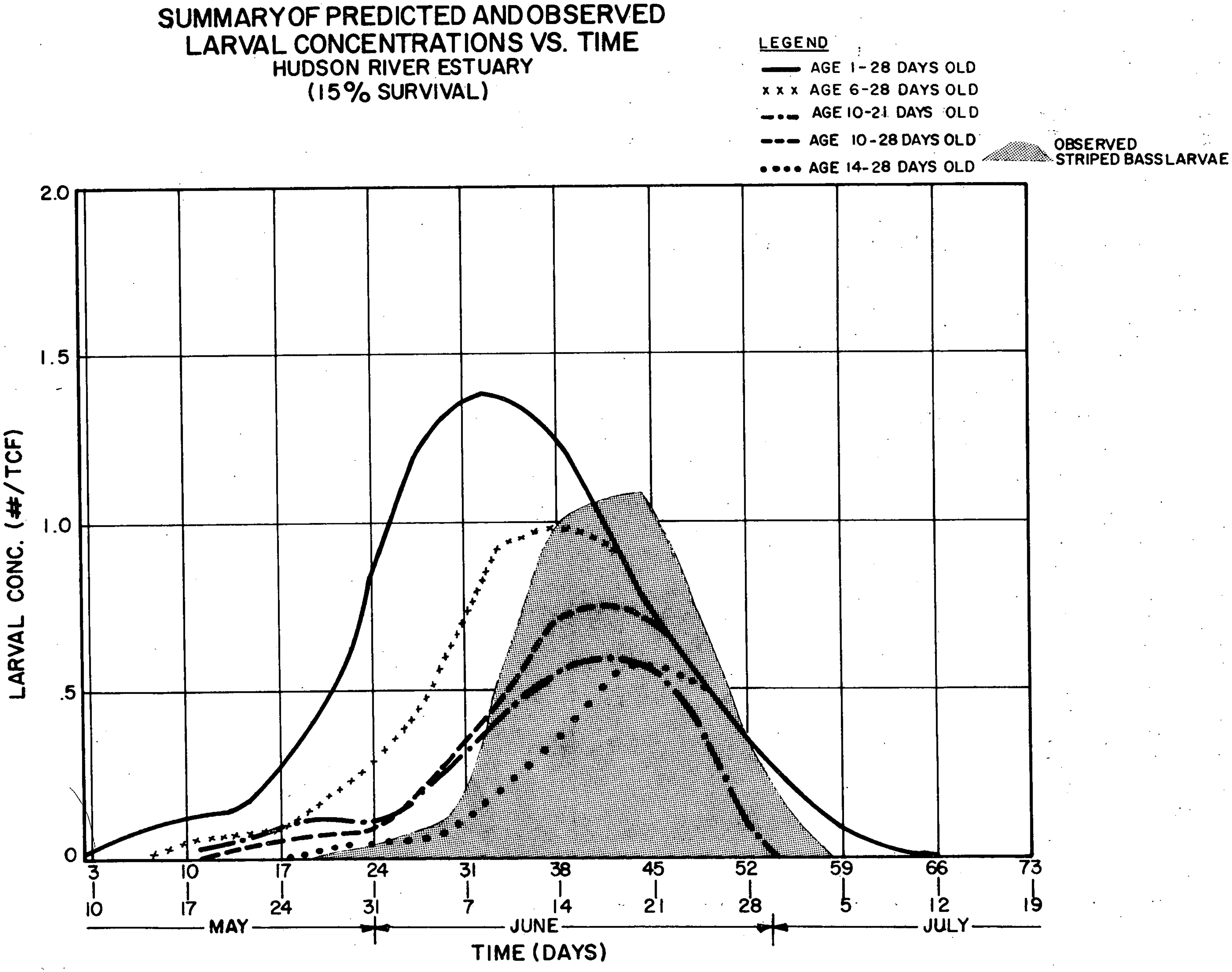
Figures 18 and 19 compare 1967 Hudson River larval observation with predictions corresponding to the entire larval stage (1-28 days old) as well as a number of larval sub-stages. Profiles corresponding to two survival rates (15% and 50%) are depicted in these figures.

Figure 18 shows that when a 50% larval survival rate is presumed, predicted Hudson River concentrations for larval ages somewhere between a minimum age of 10 to 14 days and a maximum age of 28 days compare reasonably well with



SUMMARY OF PREDICTED AND OBSERVED LARVAL CONCENTRATIONS VS. TIME
HUDSON RIVER ESTUARY
(50% SURVIVAL)

FIGURE 18



SUMMARY OF PREDICTED AND OBSERVED LARVAL CONCENTRATIONS VS. TIME
HUDSON RIVER ESTUARY
(15% SURVIVAL)

FIGURE 19

the field observations in the first half of the calendar period during which larvae appear.

During the last half of this period, the predicted values are somewhat higher than their observed counterparts. This difference is to be expected since, as in the case with the newly hatched larvae, the field observations may not be representative of the actual behavior in the river. The larvae by this time are older and more mobile and, therefore, capable of avoiding the nets. On the other hand, the mathematical model, which does not recognize field survey deficiencies, should be expected to include the mobile larvae as well as newly hatched larvae in the analysis.

Further refinement involved commanding the model to output the 10 to 21 day age group composite concentration. This is seen to exhibit rather excellent agreement with the observed data. A further sub-stage selection of 12 to 23 day age group would probably yield virtually perfect agreement with the estuary average.

These comparisons, coupled with the observations on larval length in June catches, suggest the excellent ability of the model to reproduce the Hudson River striped bass life history.

Figure 19 compares 1967 Hudson River larval observations with predictions made using a lower survival rate (15%) and the 1-28 day larval stage duration as well as a number of sub-stages. The agreement between the observations and the 6-28 day and 10-28 day sub-stage profiles is reasonable, but not as good as with the 50% survival rate and the 10 to 21 day sub-stage.

Figures 20 and 21 compare the transport model results with 1967 larval profiles for each one of the eight river segments, using survivals of 15% and 50%. For convenience, Figures 20 and 21 depict predicted profiles corresponding to both the entire larval stage (1-28 days) and selected sub-stages (10-21 days). The comparison should be made between the observations and the 10-21 day profiles with the understanding that other sub-stages, such as 12-23 days could have produced closer agreements.

In general, these figures show moderately good agreement between the "collected" larvae and corresponding sub-stage predictions. The agreement is not exact, but peaks do occur in the approximate locations of the sampling peaks and the areas under the sampling profiles, particularly on an estuary-wide basis are relatively close to the areas under the corresponding computed curves.

Trial and error testing of a variety of plausible egg production, variable survival and sub-stage duration factors and/or introduction of gear selectivity parameters could have been employed to obtain even better agreement. The notion of higher egg productions seems to be a particularly likely possibility. Although the 50% sub-stage 10-21 day olds show particularly good agreement on an estuary average, 50% seems to be high for larval stage survival. Furthermore, agreement between measured and model concentrations in individual reaches is less good, suggesting segment-variable mortality factors. Each of these considerations is worthy of further investigation.

As discussed in Section A of this chapter, the observed concentrations must be viewed as relative rather than absolute indications of the

FIGURE 20

PREDICTION OF EARLY LARVAE CONCENTRATIONS VS. OBSERVED EARLY LARVAE CONCENTRATIONS IN 1967

(50% SURVIVAL)

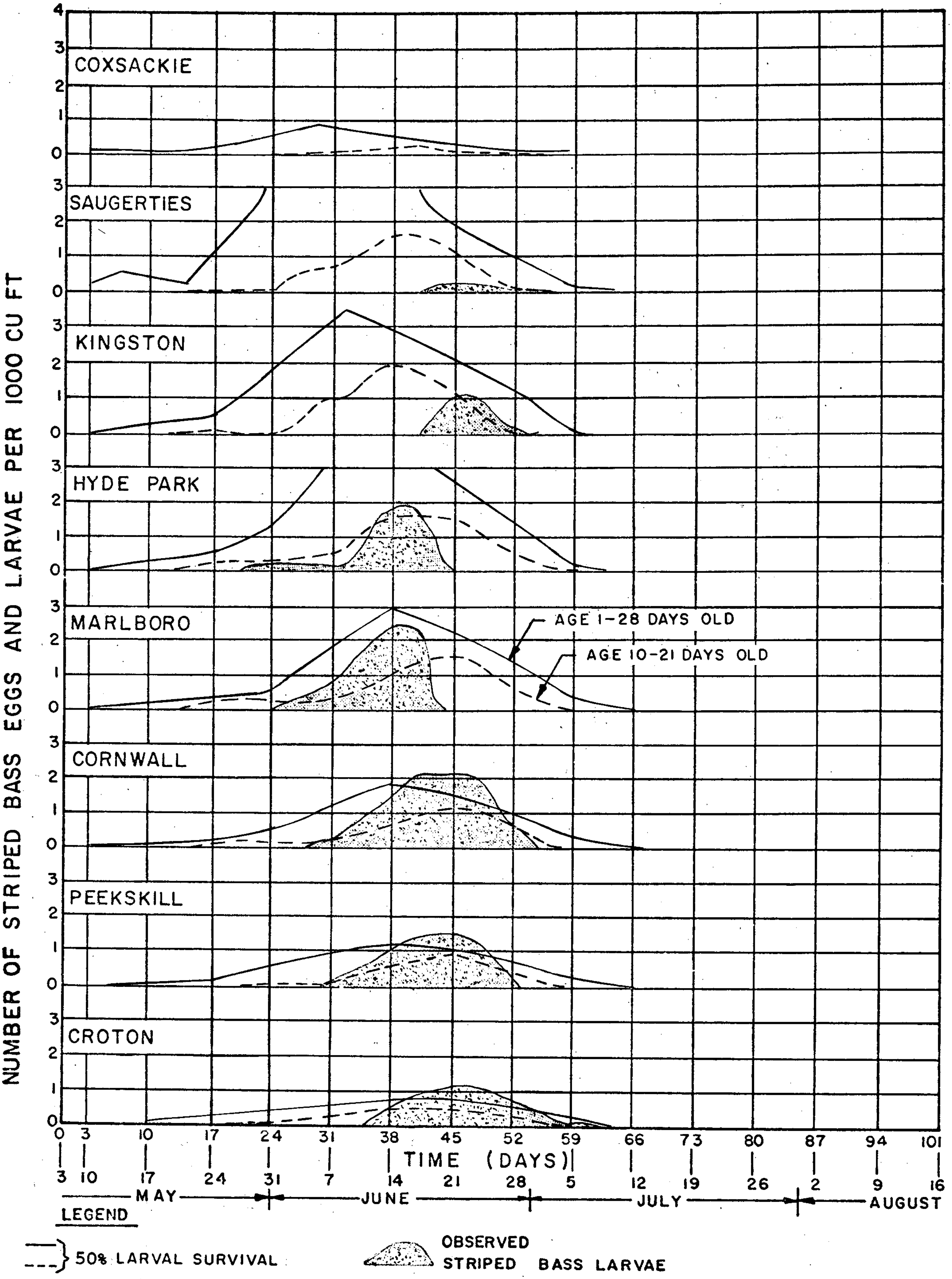
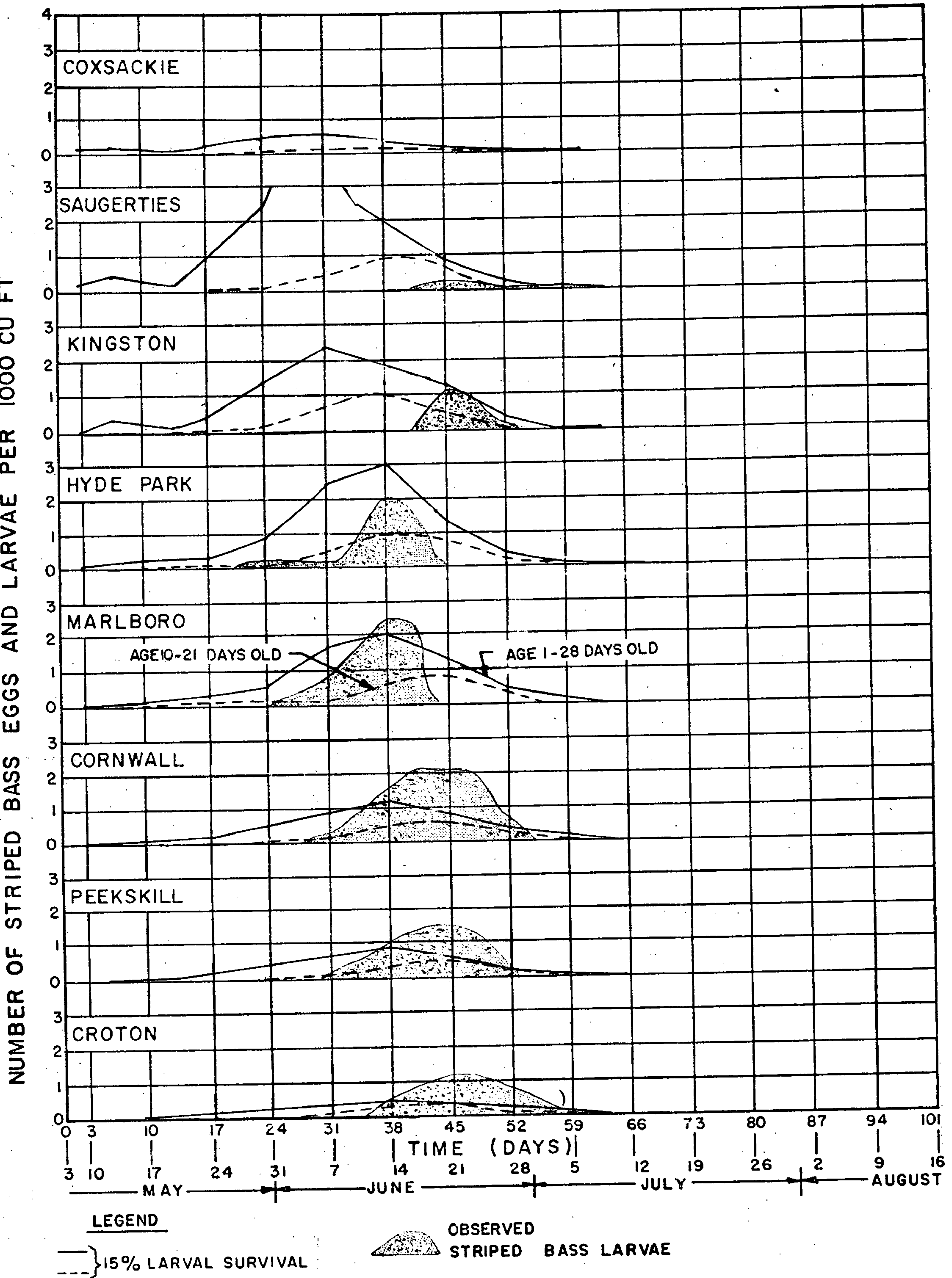


FIGURE 21

PREDICTION OF EARLY LARVAE CONCENTRATIONS VS. OBSERVED EARLY LARVAE CONCENTRATIONS IN 1967
(15% SURVIVAL)



population density of any stage. Since each observed stage density may represent a different relative proportion of the true population for that stage, there is nothing to be gained by forcing perfect agreement between model and observed results. The model sub-stage concentration predictions are equally likely to be accurate representations of the true concentrations as are the observed concentrations.

Furthermore, the model is filling in the gaps in the data on life history, due to incomplete sampling acknowledged to be incomplete.

E. LATER LARVAE-EARLY JUVENILE STAGE

The second "humps" in the Carlson & McCann data (Figure 16 in this testimony) are considered to be representative of a portion of the juvenile I stage. The juvenile I's have a stage length of 30 days and represent those larvae which survived through the 28-day early larvae stage. The juvenile I's possess swimming ability, but are still sufficiently small to be entrainable by the plant. The size of the fish at the end of the first 60 days of life (end of the juvenile I stage) ranges between 1.5 and 2 inches.

Results of the juvenile testing step are depicted in Figure 22 for the entire study reach and in Figure 23 for each of the eight river segments. The two predicted profiles shown in these figures represent predictions made using the survivors of the larval stage distributions corresponding to the 15% and 50% larval survival rates as J_I recruits.

The predicted distribution of juvenile I stage was obtained by using the computed termination of larval stage distributions to initiate activity in the juvenile I stage, and by employing the 1967 mid August data on striped bass distributions (i.e., near the end of the juvenile I stage) to direct their migration pattern.

SUMMARY OF PREDICTED AND OBSERVED LATER LARVAE-EARLY JUVENILES (J_I STAGE) VS. TIME

HUDSON RIVER ESTUARY
(15% & 50% SURVIVAL)

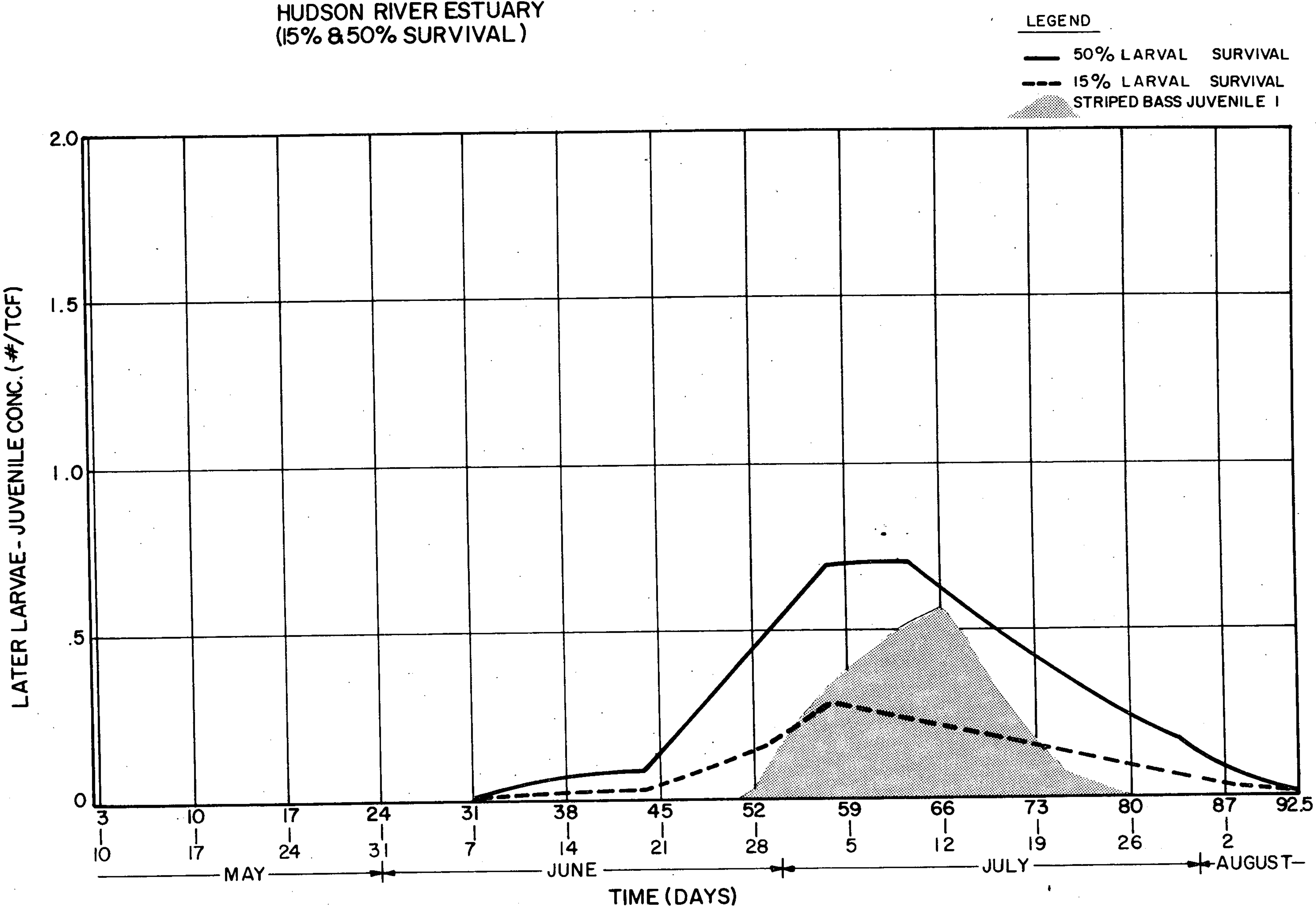
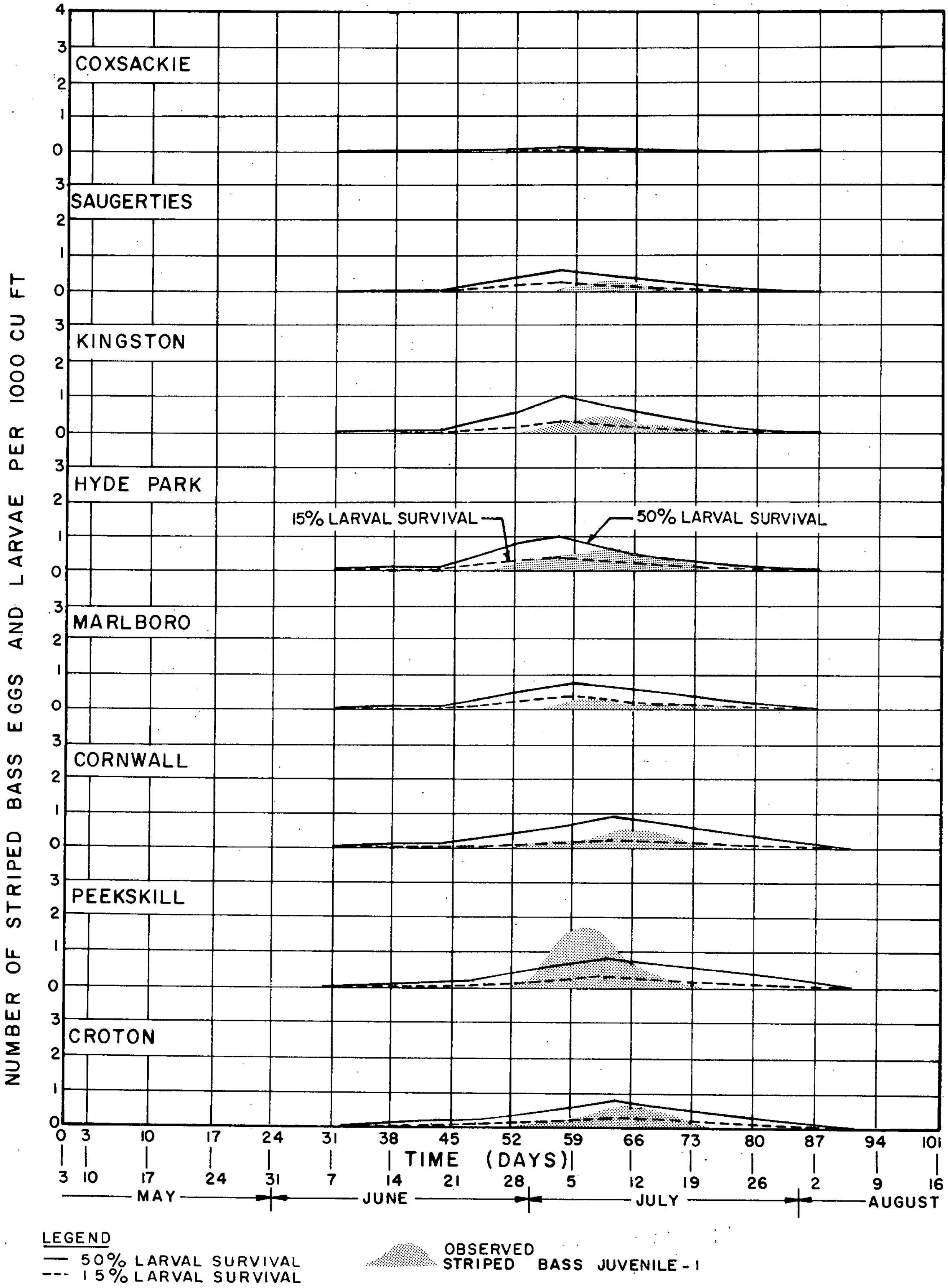


FIGURE 22

FIGURE 23

PREDICTION OF LATER LARVAE-EARLY JUVENILES (J_I STAGE) VS. OBSERVED LARVAE CONCENTRATIONS IN 1967



In general, the model produced proper order of magnitude results with peaks at the approximately correct times but having values somewhat higher using the 50% survival rate for larvae and lower, using the 15% survival rate than 1967 collections. As in the case of the larval curves, the predicted juvenile I profiles begin before and extend beyond the observations. The latter in particular should be expected since the model produces concentrations of fishes 30 to 60 days old. These older fishes are not expected to have been part of the 1967 sample.

The comparison shown in Figures 22 and 23 is not only indicative of the moderately good agreement between the transport model predictions and the measured values for the later larvae-early juvenile stage, but also the continuing good ability of the transport model to move through a whole series of stages and to characterize field limitations. In summary, the model has been shown to be successful in taking a given spawning rate as a function of river location and calendar time and via internal transport model mechanisms, generating egg, early larvae, and later larvae-early juvenile distributions, totals (eggs) or substages (larvae, juveniles) corresponding measured data. We consider this to be an indication of the model's excellent capability to simulate striped bass behavior in the Hudson River.

V. EFFECT OF PLANT OPERATION

Runs were made to evaluate the effects on the bass population of two unit operation at Indian Point. The plant impact was defined in terms of the reduction in recruitment to the one year old class, and in reduction of the total adult population (age groups 1 to 13).

The primary determinant of the reduction percentage is the "f" factor in each stage. Accordingly, runs were made for two sets of "f" factors, as follows:

1. The current best estimates of "f" in each stage.
2. The apparent maximum values of "f".

Rationale for selection of values for each category is discussed in detail in Chapter III. Values selected were:

"f" Factor Category	Egg	Larvae	J_I	J_{II}	J_{III}
Current Best Estimate	0.4	0.4	0.1	0.003	0.01
Apparent Maximum Values	0.4	0.55	0.3	0.004	0.01

"Current best estimate" signifies those values which, based on the data available, appear to be reasonable yet conservative. For example, the evidence relative to eggs suggests a value of 0.2 may well be supportable, based on buoyancy characteristics alone. Furthermore, their apparent good ability to withstand temperature and pressure changes would justify an even lower value.

"Apparent maximum values" signify those values which, again based on the data available, are considered to be rather conservative estimates of the actual effect.

Note that the impingement factors are simply those which yield a striped bass fish impingement of 46,000 fish.

Life stage, natural survival percentages and mortality rate factors are given in Tables 22 and 23 for the two categories considered.

Results of model runs for these conditions are given in Table 24. These results show clearly that the impact of the plant can to expected to be small under any set of reasonable estimates of exposure of the early stages of the striped bass to entrainment and impingement.

Table 24 shows that the reduction in the one year old population reaches an equilibrium level in about five years. The reduction in the total population tends to reach an equilibrium level in 5 to 10 years. The adult population should respond to the impact at a slower rate because the young of each year begin to feel the effect immediately after plant operation, while the total population must lose through natural attrition, all those bass living in the river at the time operation begins before equilibrium is reached.

Several additional considerations suggest that the plant's impact will be lower than that predicted above.

1. Evaluation is made in terms of Indian Point two unit operation. The basis for analysis, however, is the river condition in the late sixties and early seventies, a time when Indian Point Unit 1 was already in operation. Indian Point Unit 1 operates at approximately one third the flow of Unit 2. The impact above the base case of Unit 2

TABLE 22

FISH LIFE STAGE AND MORTALITY PARAMETERS

Run #1 - Current Best "f" Estimate

Stage	Duration (days)	Percentage Survival	First Order Mortality Rate (day^{-1})	Minimum Mortality Rate (day^{-1})	"Equilibrium" Concentration (Number/TCF)	f Factor
Eggs	1.5	10	1.5	1.5	0.0	0.4
Larvae	28	15	0.068	0.017	2.0	0.4
Juvenile I	30	20	0.054	0.027	0.5	0.1
Juvenile II	98.5 to 147.5	50	0.005	0.025	0.1	0.003
Juvenile III	158	18.98	0.01	0.005	0.075	0.01

TABLE 23

FISH LIFE STAGE AND MORTALITY PARAMETERS

Run #2 - Apparent Maximum "f" Values

Stage	Duration (days)	Percentage Survival	First Order Mortality Rate (day^{-1})	Minimum Mortality Rate (day^{-1})	"Equilibrium" Concentration (Number/TCF)	f Factor
Eggs	1.5	10	1.5	1.5	0.0	0.4
Larvae	28	15	0.068		2.0	0.55
Juvenile I	30	20	0.054	0.027	0.5	0.3
Juvenile II	98.5 to 147.5	50	0.005	0.025	0.1	0.004
Juvenile III	158	18.98	0.01	0.005	0.075	0.01

TABLE 24

EFFECT OF TWO UNIT PLANT OPERATION ON HUDSON RIVER STRIPED BASS POPULATION

Age Group	Percentage Reduction after Years of Operation 1 Year	5 Years	10 Years
Run #1 - Current Best "f" Estimates			
1 Year Olds	2.5	3	3.5
Years 1 to 13	2	3	3.5
Run # 2 - Apparent Maximum "f" Values			
1 Year olds	4	5	6
Years 1 to 13	3	5	6

operation alone is approximately 75% of that reported for two unit operation.

2. Continuing studies on entrainment mortality are expected to show that such mortality will be less than 100% in the egg and larval stages. Furthermore, the estimate of 50% mortality in the early juvenile stage may be high, particularly in view of the fact that dead and damaged fish in the samples taken so far tend to be predominantly earlier stage larvae.

This study has demonstrated the significant role, in assessing impact, of the distribution of early forms of the striped bass in the general vicinity of the plant. A study should be designed to evaluate this role in fuller detail. Such a study should include:

1. Day and night sampling at several lateral and vertical stations at river sections north, south and opposite Indian Point. Such efforts have been made in the past, but should be intensified in the spring and early summer of 1973. Particular consideration should be given to deeper sampling than has been practiced to date, to give a more representative picture of the deeper water's contribution to the section-average density.

   Sampling should take place over at least one and preferably two 24 hour periods during each week beginning in the last week of April and continuing through August. Attention should be given to proper net selection to yield representative capture of as many stages of the fish's life history as possible. In this regard, particular attention might be focused on the newly hatched larvae and on the later larvae-very early juveniles.

2. Simultaneous with item 1 above, sampling of intake and discharge to determine avoidance factors (f_2) and cropping rates (f_c). Preliminary investigations toward this end, conducted during 1972, indicate gear improvements are necessary to insure representative capture and to avoid death by sampling.

   Conduction of this study during actual operation of Unit 2 will permit evaluation of the rate at which any population drawdown is replenished (the f_3 factor).

3. Evaluation of the data developed in these two complementary study efforts by use in the transport model, and, vice-versa, continued refinement of the model to permit greater accuracy and confidence in its predictions.

   In this regard, some emphasis should be placed on evaluation of the notion of differential egg, larval and early juvenile survival rates in the various segments of the Hudson. This could be accomplished by implementing the type of program described above at other existing and planned Hudson River generating stations.

Other areas of further study should include continuation of the determination of juvenile distribution through the late spring, summer and fall months (migration preferences) and determination of up-river migration rates, female fecundity, fertilization and fertilized egg survival rates to establish the basis for progress through subsequent stages more soundly.

APPENDIX I

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APPENDIX II

LIST OF SYMBOLS

Parameter	Description
ΔtE	The egg life stage.
ΔtL	Length of larval stage.
ΔtJ	Length of juvenile stage.
f_{c_i}	Cropped fraction of the i^{th} stage. The parameter "f_c" is determined by sampling the intake and discharge and then comparing intake and discharge survival percentages.
f_{1_i}	Ratio of the daily average river concentration of stage i in the general vicinity of the intake (east bank, upper layer), to $\tilde{N}_i$.
f_{2_i}	Ratio of the actual intake concentration to $f_{1_i} \cdot \tilde{N}_i$ under existing conditions of operation.
f_{3_i}	A factor which recognizes population depletion in the immediate vicinity of the intake may not be immediately replenished.
K	Generalized unit mortality rate.
K_c	The overall mortality rate during the i^{th} year.
K_E	Conventional first order or "equilibrium" rate, day^{-1}.
K_{E_i}	First order mortality rate for eggs. This is selected as constant for the eight sections. The value selected is 1.53 day^{-1} and corresponds to an egg survival of 10% in 1.5 days.
K_i	The first order removal rate for that year class.
K_o	Minimum unit mortality rate consistent with system biology.
K_{oA_i} K_{EA_i}	The unit mortality rates at $N_{BA_i} = 0$ and N_{SA_i}, respectively.
N	Actual fish concentration at any point in time (week and year) and space (river location).

Parameter	Description
$N_{A_{B_i}}$	Number of adults in year class i at start of year.
N_{E_i}	Spatial average egg concentration in the i^{th} segment. Carlson & McCann egg concentration data in each segment were used to evaluate (N_{E_i}).
N_S	"Saturation" or equilibrium population level, fish per unit volume.
$N_{S_{A_i}}$	The characteristic saturation or carrying capacity constant for that year class. This is equal to the population of that year class when the plant is not operating.
$P_i'(t)$	Spawning rate in the i^{th} segment, expressed as eggs spawned per day per thousand cubic feet.
TCF	Thousand cubic feet.
TCM	Thousand cubic meter.

Appendix E

COMMENTS ON STATEMENTS ON ENTRAINMENT AS PRESENTED BY THE AEC STAFF IN DRAFT DETAILED STATEMENT ON THE ENVIRONMENTAL CONSIDERATIONS RELATED TO THE PROPOSED ISSUANCE OF AN OPERATING LICENSE TO THE CONSOLIDATED EDISON COMPANY OF NEW YORK FOR THE INDIAN POINT UNIT NO. 2 NUCLEAR GENERATING PLANT

DOCKET NO. 50-247

MAY 14, 1972

QUIRK, LAWLER & MATUSKY ENGINEERS
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The AEC Staff, in the Draft Detailed Statement of April 13, 1972, has addressed itself to the question of entrainment of fish eggs and larvae at Indian Point. Detailed analysis of the possible effects of such entrainment have been presented. Conclusions to these analyses appear in a number of locations. Pertinent quotations are as follows:

1. <u>In Summary and Conclusions, page ii</u>

   In Unit No. 2, aquatic biota impinged on the intake structure or entrained in the cooling water will be exposed to severe mechanical, chemical (chlorine), and thermal conditions; as a consequence, up to 25% of the average number of eggs and larvae of certain species of fish that annually pass by the Plant may be killed; under the most adverse conditions, up to 100% of some of the entrained planktonic species may be killed; and fish kills of a magnitude two or three times greater than those caused by Unit No. 1 may occur.

2. <u>In the Summary of Conclusions, page iv</u>

   From review and evaluation of the applicant's Environmental Report and Supplements thereto, and from independent observations and analyses discussed in this Statement, the regulatory staff has reached the following conclusions concerning the environmental impact of the Plant's operation:

   a. *The operations of Units Nos. 1 and 2 with the present once-through cooling system has the potential for long-term environmental impact on the aquatic biota inhabiting the Hudson River which could result in permanent damage to the fish population in the Hudson River, Long Island Sound, the adjacent New Jersey coast, and the New York Bight The potential impact is due to possible damage to aquatic biota (including fish eggs, larvae, and plankton) from entrainment in the cooling water system resulting in exposure of the biota to severe mechanical, chemical (chlorine) and thermal conditions and impingement on the intake structure.*

   b. *The estimate of potential environmental impact identified above and discussed in this Statement is based on inconclusive and incomplete data from the applicant. Existing information is insufficient to accurately predict the degree to which the potential damage will eventually take place during operation.*

3. In Chapter V, "Environmental Impacts of Indian Point Unit No. 2 with Unit No. 1 Operation", Section D-2-e, "Biological Impact of Station Operation of Unit Nos. 1 and 2, Sources of Potential Biological Damage, - Entrainment." page V-42

Large numbers of planktonic organisms will pass through the condensers during Plant operation, and, more importantly, a considerably large proportion of the biota will be withdrawn with the addition of Unit No. 2 (Fig. V-5). These organisms will include bacteria, planktonic algae, many invertebrate species, fish eggs and larvae. Table V-6 lists the fish species in the area whose eggs and larvae are known to be vulnerable to entrainment. During their passage through the Plant, these organisms will be exposed to mechanical, thermal and chemical damage. High mortality may result, especially for fragile species or during periods of chlorination. The methods used to determine the fraction of organisms entrained are presented in Appendix V-1. The monthly average probability of randomly distributed plankton moving downstream to be withdrawn varies from a low of about 6% in April to a high of 31% in August, although during drought conditions withdrawal may exceed 45%. Plankton that migrate via density flows to maintain their position in the river will be the most susceptible to entrainment, since they may remain in the area for several weeks.

4. In Chapter V, "Environmental Impact of Indian Point Unit No. 2 with Unit No. 1 Operation," Section D-3-a, "Biological Impact of Station Operation of Units No. 1 and 2, - Probable Biological Effects, - Direct Effects of Plant and Station Operation on Biota." page V-52

The striped bass is the best-studied species in the area that appears to be vulnerable to population changes and will be used to illustrate possible Station impact. Adult striped bass migrate upstream in the spring and spawn upstream from Indian Point. The eggs and larvae drift with the currents in a net downstream direction; large numbers pass the Plant. Several studies have indicated that the principal nursery area for the species is below Indian Point in Haverstraw Bay but that there are some less extensive nursery areas upstream. High entrainment mortality of larvae and eggs as they drift past Indian Point Units Nos. 1 and 2 could result in a loss of 25% or more of the larvae and eggs that pass the Plant en route to their nursery area (see Appendix V-II). Based on the sizes and numbers of the young of the year in the estuary in late July and August, it appears that 75% to 90% of the surviving portion of the total yearly reproduction is below Indian Point. If we assume: (1) that all those fish migrated past the Plant during a life stage which was susceptible to entrainment; (2) that density-independent

> *factors are responsible for mortality in the populations; and (3) that entrainment mortality is 100%, then the operation of Indian Point Units Nos. 1 and 2 will effectively reduce recruitment resulting from reproduction by about 19% to 22%. This is a maximum estimated loss of recruitment which would result from entrainment of 25% of the striped bass eggs and larvae that pass the Plant and would not likely be reached. However, losses of the young of the year and 1-year age classes from impingement on the intake screens will add to the actual entrainment mortality and could offset the increases in survival during entrainment, so that the total yearly recruitment loss for each subsequent year class in the population may be as high as 15% to 20% from direct effects of Plant operation. Sustained reproductive losses of this magnitude over a long period of time would result in substantial reductions of the striped bass populations that spawn in the Hudson, including those of both the Hudson itself and the area from the south New Jersey coast to Long Island Sound.*

This statement is followed by a discussion of numerous factors that may partially offset the estimates given above. The section is then concluded:

> *These same arguments apply to other species that spawn in the area and may cause important losses of recruitment to local populations of the alewife, blueback herring, bay anchovy, tomcod, smelt, and Atlantic silversides, as well as striped bass.*

5. Chapter VII, "Adverse Environmental Effects which cannot be Avoided," Section A, "Factors Responsible for Adverse Effects, page VII-1.

> *Several factors associated with the operation of Indian Point Units Nos. 1 and 2 are capable of producing adverse effects. The more important of these factors in the order of their importance include:*
>
> 1. *Entrainment of large numbers of planktonic organism in the once-through system.....*

6. Chapter VII, "Adverse Environmental Effects which cannot be Avoided,"Section B-4, "Probable Adverse Effects - Biological Impact," page VII-6.

The entrainment of planktonic organisms appear to be the most serious threat to the aquatic community. Entrained organisms will be exposed to mechanical, thermal, and chemical damage. Most species of the aquatic organisms in the area will be subject to entrainment at some life stage. These include phytoplankton, planktonic crustaceans, and larval stages of benthic invertegrates and of many of the estuarine fishes which use the area for spawning. The species of fish which appear most likely to be affected include the striped bass, alewife, blueback herring, tomcod, smelt and white perch.

7. Chapter VIII, "The Relationship Between Local Short Term Usage on Man's Environment and Maintenance and Enhancement of Long Term Productivity," Section B-2, "Uses of Adverse to Productivity - Water Uses," Page VIII-4.

In consideration of the impacts and alternatives discussed in detail in Chapters IV, V, VI, VII, X and XI, the staff has concluded that the only effect of the operation possibly inimical to the objectives of NEPA with respect to productivity is the potential for further degradation of the Hudson River estuary, which is used as the spawning and nursery area in the life cycle of many marine aquatic organisms that spend much of their adult life in the coastal areas of northern New Jersey, New York and Long Island. Such degradation would, indeed, over the long-term diminish the productivity of the area to an extent that cannot be stated in precise terms at present. Only the yearly cost of replacing the estimated number of fish that might be killed has been calculated (see Chapter XI). The ultimate impact on commercial and sport fishing has not been estimated, since the decline of the Hudson River fishery is problematical at this time.

8. Chapter IX, "Irreversible and Irretrievable Commitments of Resources," Section B, "Water and Air Resources," page IX-4

The proposed action when taken has a potential of affecting the aquatic organisms essential to maintaining a fish population of the Hudson River as well as that along the Long Island Sound,

> *New Jersey coast and the New York Bight so that the population could deteriorate beyond the point of rehabilitation. In this event, operation of the Plant could entail an irreversible commitment of the river as a resource.*

9. Chapter XI, "Alternatives to Proposed Action and Cost Benefit Analysis of Environmental Effects," Section B, "Summary of Alternatives," page XI-12.

> *The important areas of disagreement between the applicant's analysis and that of the staff are the following:*
>
> *(2) Environmental effects from operation of the intake-discharge structure have a potential for long-term significant biological damage to aquatic bioto not only in the localized area in the vicinity of Indian Point Unit No. 2, but also in the Hudson River estuary, New Jersey coast and New York Bight. (see Chapter V.D. 3)*
>
> *There are other areas of difference which are relatively minor. The staff feels that there are insufficient data available to make a reasonably accurate estimate on long-term effects on biota. Of the major differences between the staff and the applicant in the analysis and evaluation of available information, the entrainment of nonscreenable fish eggs, larval, and fingerlings and the impingement of fish on the intake structure appear to be the major impacts on the aquatic ecosystem. Although the staff does not feel that the impacts can be quantified at this time, the staff does not agree with the small impact of about 2-3% damage to eggs larval made by the applicant. Details of the staff's disagreements are given in Chapters V.D., and Appendices II-1, V-2, and XI-1.*

10. Appendix V-2, "Entrainment," page A-69

> *Thus, the probability that a larval striped bass migrating downstream would be entrained is about 25%. Comparison of the freshwater inflows used in these calculations with inflows during the period from 1944 to 1964 indicates that these values were similar to the median conditions.*

A discussion of various offsetting factors then follows: The Staff then concludes:

> *Consequently, the Staff believes that the total average probability of withdrawal of larval striped bass migration downstream past the Station is approximated by the 25% figure, and that this fraction is the best estimate than can be made using available information.*

> *In conclusion, based on these considerations, about 25% of the larval striped bass may be entrained as they migrate downstream past the Indian Point site.*

The Staff supposition of damage to the Hudson River fishery and to the population in the offshore waters thus appears to be primarily based on its calculation that some 25% of the planktonic forms of many of the various fishes using the estuary will be entrained and presumably destroyed.

Our approach in these comments is directed first at a critical evaluation of the procedures employed by the Staff to obtain the 25% factor, and then will address the numerous non-quantitative statements made by the Staff regarding possible offsetting mechanisms.

The critique to follow will include the following items:

1. A demonstration that the Staff calculation of available dilution flow at Indian Point, as given by Equations 1 and 2 and Figure A-II-6, in Appendix II-1, entitled "Characteristics of Hudson River Circulation at Indian Point, in Relation to Dilution," employs an inaccurate and theoretically unsupportable methodology, and in the Hudson seriously underestimates available dilution flow at Indian Point.

2. Modification of the probability model given by Equations 1 through 12, Appendix V-2. This probability model was employed by the Staff to compute entrainment loss. The modification includes the quantification of the influence of vertical diurnal movement and estuary density flow on entrainment.

   The Staff's calculation of a 25% entrainment loss is then revised, employing a theoretically and experimentally supportable means of estimating dilution flow in the Hudson River, and the modifications made on the probability model.

1. Criticism of Staff Calculations of Available Dilution Flow at Indian Point

Pages A-4 through A-7 state clearly the Staff's belief that the flow available for dilution in an estuary is given by:

$$Q_T = \frac{Q_F}{1-S/S_0} \qquad \ldots(1)$$

in which:

Q_T = total dilution flow at point in the estuary

Q_F = net freshwater discharge

S = the section average salt concentration at a given point along the estuary's longitudinal axis

S_0 = the ocean salt concentration

Equation (1) above is identical to Equation (2) (Page A-4), provided that the salinity of the freshwater is zero, and that volume is replaced by volume per unit time, or flow rate (Q). The assumption of zero salinity in the freshwater discharge is quite valid for the Hudson River. The staff replaces volume by flow in constructing Figure A-II-6.

Freshwater flow and salinity data taken from the applicant's Environmental Report Supplement are then reproduced in Figure A-II-5. These data are then employed in conjunction with Staff Equation (2) to obtain the relationship between freshwater flow and dilution flow at Indian Point in Figure A-II-6.

We submit that this procedure is generally invalid in predicting estuary dilution flows. We will show that this method of predicting estuary dilution flow defies analytical development, and has been discounted by most investigators shortly after its appearance in the literature in the early 1950^s.

The Staff's reference for their Equations (1) and (2) is a paper by Ketchum, entitled "Eutrophication of Estuaries", which appeared in 1969 in the proceedings of a symposium on eutrophication.[1] Pertinent excerpts from this reference follow:

> *I will mention a few of the essential characteristics of estuarine circulation as they relate to the distribution of pollutants. I will not go into detail because this is covered by Carpenter, Pritchard and Whaley in this volume (page 210). The estuary offers advantages not offered by the river in its ability to dilute and disperse added contaminants.*
>
> *In the river itself, the volume of water available to dilute a pollutant is furnished simply by the river flow, which carries the contaminant downstream at a rate determined solely by the river flow and the geometry of the river bed. In the estuary, the circulation is more complex, although the net seaward flow is also determined by the rate of river flow. If no mixing were involved, this fresh river water would merely flow seaward as a layer on top of undiluted seawater. Mixing is involved, however, and salinity gradually increases down the estuary as river water mixes with more and more seawater. Seawater must flow into the estuary to provide the salt needed to balance the system. In a steady-state condition, the volume of seawater entering the estuary in a given unit of time equals the volume flowing out; there is no augmentation of the net seaward flow. The seawater thus entrained with the freshwater does, however, increase the diluting capacity of the mixed water that is escaping from the estuary. This effect can be evaluated by using the distribution of salt water and freshwater in the estuary.*

---

[1] Ketchum, B.H. "Eutrophication of Estuaries". Eutrophication: Causes, Consequences, Correctives. National Academy of Sciences, Washington, 1969. p. 197

> *The amount of freshwater contained in any given sample of brackish water can be calculated from the salinity, since*
>
> $$F = 1 - \frac{S}{\sigma}$$
>
> *in which F is the fraction of freshwater in the sample, S is the salinity of the sample, and σ is the salinity of the "source" seawater. If the average freshwater content of a complete cross section is known, the volume available for the dilution of the pollutant at that location can be approximated. To obtain the fraction of freshwater in a complete cross section of the estuary, it is necessary to integrate the values from top to bottom and from bank to bank. The volume available for the dilution of the pollutant in a given period is determined approximately by dividing the rate of river flow by the fraction of freshwater in the cross section.* If the section is 50 percent freshwater, two volumes must move seaward to move one volume of river water seaward. Closer to the mouth of the estuary, where the amount of freshwater has been reduced to 10 percent, ten volumes must move seaward to remove the river water. A more precise determination of the diluting volume requires detailed knowledge of the circulation. But this simple calculation shows that the total volume available for dilution increases in the seaward direction.*

The underlined statements show clearly that Ketchum's estimate of dilution flow is given by Equation (1) above, or Equation (2) in Appendix A-2 of the AEC Draft Detailed Statement. Note that the last section of the excerpt suggests that Ketchum himself could be viewing this calculation as merely an indication of a trend toward increased dilution as one moves seaward in an estuary, rather than a hard and fast quantitative estimate of dilution flow.

This last statement is made recognizing that Ketchum introduced this method of computation of dilution flow in the early 1950s.[2]

Note: Underlining added for purposes of this reviewer.

*This statement, combined with Ketchum's expression for the fraction of freshwater, is precisely equivalent to Equation (1) above.

[2] Ketchum, B.H. "The Flushing of Tidal Estuaries". Sewage and Industrial Wastes, Vol. 23, No. 2, February 1951. pp. 198-209

Before presenting various comments from the literature on this computation procedure for estimating dilution flow in an estuary, a few statements on the calculation are in order.

The calculation of the fraction of freshwater flow at any point in the estuary, given by Ketchum's definition of "F", above, or by the denominator of Equation (1), above, is generally accepted as correct. This merely states that at any point in the estuary a certain percentage of the water there is of freshwater origin, and the remainder is of ocean origin. This split can be obtained by recognizing that the total volume is the sum of the volume of ocean water origin, containing salt of ocean concentration, and the volume of freshwater origin, containing no salt.

The problem arises when one attempts to show that this percentage split can be employed, along with the freshwater flow, to calculate movement or dilution flow. Ketchum, for example, in the excerpt given above, simply states;

> The volume available for the dilution of the pollutant in a given period is determined approximately be dividing the rate of river flow by the fraction of freshwater in the cross section.

After presentation of the literature comments on Ketchum's work, we shall show the problems which arise when one tries to demonstrate the validity of Ketchum's procedure analytically.

In 1953, Stommel, a coworker of Ketchum's at the Woods Hole Oceanographic Institute, presented a paper[3] in which his intent was to provide a method of estuary pollution analysis that would avoid the difficulties that had been observed in employing Ketchum's methods since its introduction in 1950. It should be noted at this point, that Ketchum's major contribution was not the computational procedure given above, but rather a modification of the "Tidal Prism" concept, a procedure that had been employed to estimate dilution flow, but which was shown by Ketchum to overestimate that flow very grossly. Ketchum merely employed the computational procedure discussed above as a means of verifying his prediction, via the modified tidal prism, of dilution flow. Stommel's introductory remarks are excerpted below:

> *Papers recently published by Ketchum (1) and Arons and Stomel (2) have presumed to give a theoretical account of the distribution of freshwater in an estuary. Pritchard (3), however, justly has pointed out that these treatments are at best applicable only to estuaries so intensely tidally mixed that they exhibit no vertical stratification. In such cases the salt is carried upstream against the main river flow by turbulence. Ketchum proposed a mixing process, which he called "exchange ratio", and was able to compute the salinity distribution in the Raritan. Using the published data (4) on the Severn estuary, the author and Harlow G. Farmer found that the method of the "exchange ratio" gave a grossly incorrect salinity distribution. Inasmuch as the Severn is unstratified, and appear to fit all the requirements of Ketchum's analysis, it is quite clear that the method of the exchange ratio is not nearly so general as was proposed.*

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[3] Stommel, Henry. "Computation of Pollution in a Vertically Mixed Estuary". Contribution #640 from the Woods Hole Oceanographic Institution. *Sewage and Industrial Wastes*, Vol. 25, No. 9, September 1953. pp. 1065-1071.

Pritchard[4,5,6] has discussed, on a number of occasions, the various procedures employed by Ketchum. Reference 4 is a written discussion of a paper by Todd and Lau, in which Pritchard disagrees strongly with the manner in which these authors' propose that estuarine salinity profiles be employed to estimate freshwater flow. The proposed method employs an approach similar to Ketchum's. Excerpts from this discussion follow:

> *The estuary offers many interesting and important problems to the physical hydrographer, and it is encouraging to find that hydrologists are extending their work into this intermediate zone between the river and the ocean. It is unfortunate, however, that this paper by Todd and Lau exhibits a lack of understanding of the mechanisms of circulation and mixing in a tidal estuary.*
>
> *To a casual reader the concepts presented by these authors are disarmingly clear and simple. Unfortunately, they have not used the basic hydrodynamic concept of continuity in its complete form which has led them to misinterpret the equations they develop, particularly their Equ. (1). The error results from the assumption that sea water on the one hand and freshwater on the other can be considered as the two species involved in the mixing processes in an estuary, when in fact, the two separate species which are involved are the salt and the water. The processes of turbulent diffusion, or 'mixing', can lead to a net upstream transport of salt without a net upstream transport of water....*

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[4] Pritchard, D.W. "Discussion of 'On Estimating Stream Flow into Tidal Estuaries," by David K. Todd and Leung-Ku Lau." which appears in Transactions, American Geophysical Union, Vol. 37, 1956, pp. 468-473. Pritchard's discussion appeared in Vol. 38, No. 4, August 1957. pp. 581-584.

[5] Pritchard, D.W. "The Equation of Mass Continuity and Salt Continuity in Estuaries". Journal of Marine Research, Vol. 17, 1958. pp. 412-423

[6] Pritchard, D.W.. "Estuarine Hydrography". Recent Advances in Geophysics, Vol. 1, 1952.

> *...The error results from an incomplete use of continuity concepts which presents a continuity argument for fresh water only. Actually there are two species to which the continuity concepts apply in the estuary: the water (actually mass) and the salt. Other investigators have made this same error. An apparent reasonable argument is frequently presented along lines something like the following: A certain amount of fresh water flows into the estuary from the river. In order to maintain continuity an equal amount of fresh water must be carried through each section, and since, as one proceeds down the estuary, the salt content increases, it is evident (?) that only a portion of the volume can be fresh water, and so the seaward directed flow must increase in proportion to the decreasing fraction of fresh water. The correct application of continuity concepts recognizes that it is the mass of water on the one hand, and the salt on the other that is conserved over one or more tidal cycles, not the 'fresh water'....*
>
> *...It might be appropriate to point out that Ketchum (1950) made the same questionable assumption that Todd and Lau did when he defined a non-tidal drift (NTD) as* $NTD = R/F \times \bar{A}$. *Ketchum's arguments parallel the disarmingly simple but erroneous presentation given earlier in this critique.*

We interpret the authors (Todd and Lau) closure to Pritchard's discussion, as a circumlocution of Pritchard's arguments, rather than a direct statement of disagreement, suggesting their recognition of the accuracy of Pritchard's analysis.

The following statement appears in a very extensive analysis of the effect of pollution on the Thames Estuary.[7]

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[7] "Effects of Polluting Discharges on the Thames Estuary". Department of Scientific and Industrial Research, Water Pollution Research. Technical Paper No. 11, Chapter 14, 'Tidal Mixing', under Section entitled" 'Theories of Estuarine Mixing', 1964. p. 392

KETCHUM'S THEORY

Ketchum[4–6] divides an estuary into segments such that the length of each is equal to the average excursion of a particle of water on the flood tide. The position of the landward boundary of the first segment is determined by the river flow and the cross-sectional areas at high and low water. In one paper[4] he considers the mixing process may be represented by assuming that, during each tidal cycle, the water is completely mixed within each segment at high water, and that there is an exchange of water between adjacent segments during the ebb—the amount of water removed from a segment being given by the ratio of the difference between the volumes of the segment at high and low water to the volume at high water.

The final equations express the proportion of fresh water in each segment solely in terms of the river flow and the volumes of the segments at high and low water. However, these equations do not follow rigidly from the theoretical model and, although the method has the very considerable merit of simplicity, this concept of tidal mixing is undoubtedly over-simplified, and it is evident that the theory is unlikely to be applicable to all estuaries even though it has been used successfully in particular cases. It is sufficient here to indicate that it cannot be used in the case of the Thames Estuary. Ketchum found that his method did not apply to the Delaware Estuary, and he was not surprised to learn that it did not apply to the Thames[7].

In Fig. 220 the continuous curve shows the approximate observed equilibrium distribution of salinity for a flow at Teddington of 1500 m.g.d. (derived from several years' records of the London County Council), and the broken curve is the distribution calculated (for average tidal conditions) by means of Ketchum's theory. There is a similar disparity between the observed and calculated distributions for flows of 500 and 3000 m.g.d.

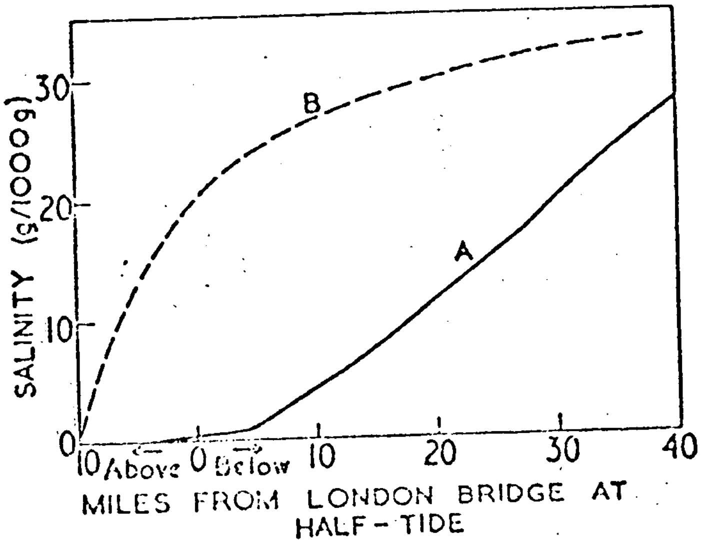

FIG. 220. Equilibrium distribution of salinity in Thames Estuary when flow at Teddington is 1500 m.g.d.

(A) Observed

(B) Calculated using Ketchum's representation of mixing

Ketchum references taken from Reference 7

4. KETCHUM, B. H. *J. mar. Res.*, 1951, 10, 18.
5. KETCHUM, B. H. *The Exchanges of Fresh and Salt Waters in Tidal Estuaries.* Woods Hole Oceanographic Institution, Colloquium on Flushing of Estuaries, 1950, p. 1.
6. KETCHUM, B. H. *Sewage industr. Wastes*, 1951, 23, 198.
7. KETCHUM, B. H. Personal communication, 1957.

Thus, it is clear that the methodology employed by the Staff to estimate estuary dilution flow has not met with general acceptance by the field, and, in general, has been discarded in favor of models which recognize more details of observed physical behavior in estuaries, particularly that of salinity-induced circulation.

Before going on to a theoretical presentation as to why the Staff method is unacceptable, and while on this topic of behavior in the Thames River, it should be noted that several investigators including Bowden[8], Preddy & Webber[9] and Inglis & Allen[10] have concluded that the Thames River, like the Hudson, falls into the class of partially stratified estuaries. Similarity between the Thames and Hudson River circulation patterns and mixing characteristics is supported by field observations which established existence of density induced circulation in the Thames[10] and the Hudson[11], relatively high dispersion coefficients (33.8×10^5 cm^2/sec or about 10 square miles per day in the salt intruded reaches of both estuaries) and comparable circulation and mixing classification criteria, such as the ratio of tidal amplitude to freshwater used by Bowden[8], the ratio of the flood tide to freshwater volumes used by Pritchard, or the vertical stratification factor (VSF) employed by QL&M[11].

[8] Bowden, K.F. "Circulation and Diffusion." Estuaries, Publication #83, American Assoc. for the Advancement of Science, Wash., D.C. 1967. p. 20

[9] Preddy, W.S. and B. Weber. "The calculation of Pollution of the Thames Estuary by a Theory of Quantized Mixing," International Conference on Water Pollution, Paper No. 42, September 1962.

[10] Inglis, Sir Claude and F.H. Allen. "The Regimen of the Thames Estuary." Porc. Inst. Civil Engineers (London), 7:827-868. 1957

[11] Quirk, Lawler & Matusky Engineers. "Environmental Effects of Bowline Generating Station on the Hudson River". Vol. 1-4, QL&M Project No. 169-1, March 1971.

Rejection of the Staff's methodology via theoretical reasoning follows.

Transport phenomenon such as the volume rate of flow available for dilution in an estuary, should always be derivable by application of one or more of the equations of mass, momentum and energy to the system in question. When the system is viewed macroscopically, a conventional means of applying these basic and quantitative laws of physics is control volume analysis. In this method, a finite and typical volume segment of the system is drawn, and rates at which mass momentum or energy flow through, and are produced and or consumed within the segment, are written down. Each entry is then assigned its proper position in an inventory or "balance" equation and a result obtained.

This procedure is applied below to illustrate the development of the two layer estuary model, and then employed to demonstrate the difficulty in deriving the intuitive formulation of estuary dilution flow employed by the Staff.

Consider the typical estuary segment shown below. Freshwater flows into the segment at a rate Q_F. In an attempt to recognize its dilution by salt water, as evidenced by a continually increasing salinity concentration as one moves seaward in the estuary, ocean water is assumed to flow into the estuary, predominantly along the bottom half of the estuary, due to its greater density.

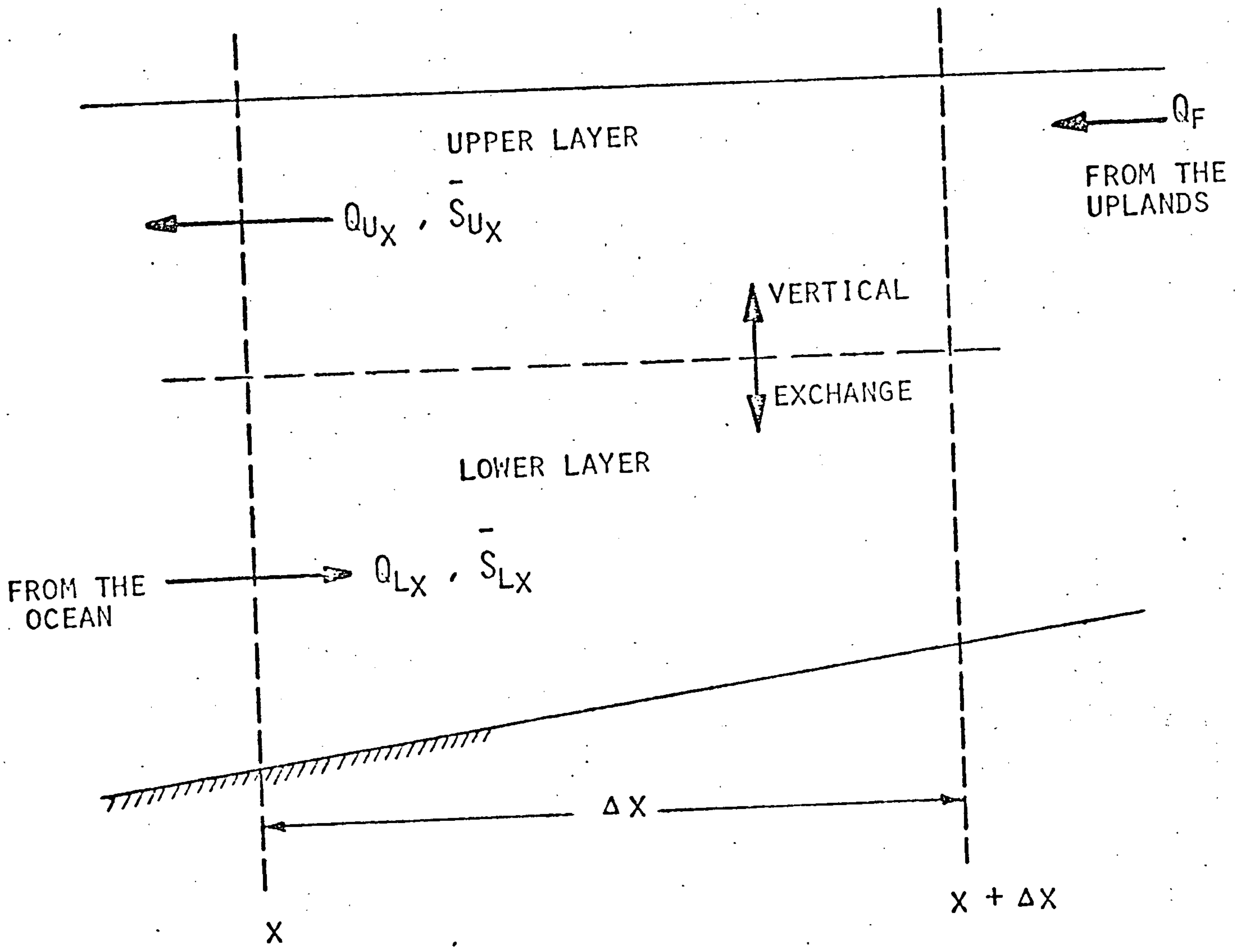

FIGURE 1 - Two Layer Exchange of Water in an Estuary

A steady-state condition is assigned, so that there can be no net transport of salt either into or out of the estuary. In the real world, tidal average behavior approaches this steady condition when external factors controlling movement in the estuary, such as ocean tide, winds, etc., and in particular, river freshwater discharge, remain constant, or nearly so, for extended periods.

Note that the long term condition is a quasi-steady condition. Freshwater discharge undergoes a yearly cycle of high and low water flows, preventing any long term net landward flux of salt. The estuaries salt profile oscillates about some mean position, just as a freshwater discharge oscillates throughout the year about a yearly average runoff value. Since there is no net flux of salt, a mechanism must be provided for returning the salt introduced to the estuary in the landward directed underflow, shown by Q_L in Figure 1. To provide such a return mechanism, water is assumed to be mixed vertically by some means and then returned to the ocean by a seaward movement which takes place predominantly in the upper layer.

Note that a physical rationale is available to explain the postulated movement. This rationale includes the notion of density current development occuring in a system in which waters of different density are brought in contact with each other, and the notion of vertical mixing via tide-induced turbulence.

The notion of vertical mixing is necessary to permit continuous transfer of the heavier seawater up into the layer in which the lighter freshwater is presumed to be moving. Without this, only shear at the salt water-freshwater interface would be available to affect the transfer. This would result in only a fraction of the transfer which can be expected in the presence of tidal turbulence, and in fact describes the stratified, or "salt wedge" type of estuary.

At this point, we have succeeded in developing a conceptual model of estuary water movement. Note that since a macroscopic view is the objective, details of the mixing and transfer process are not required at this point. We are simply attempting to structure an overall view of the estuary, with the objective of writing a statement to describe in a quantitative fashion, the observation that freshwater discharge is diluted by ocean water as it moves down the estuary.

The Law of Conservation of Mass is applied to both the water and the salt in the estuary. This is done by writing a material balance over the volume segments shown in Figure 1.

Since there is no loss or gain of either salt or water within the segment, due to generation or decay processes, and since we are dealing with a steady condition, so that no accumulation of either material can occur over time within the segment, the required balance can be struck across any cross-section of the segment to describe the behavior at that section. This is done first, before striking a balance over the whole volume segment.

Consider Section X in Figure 1. Since there is no net flux of salt, the salt moving into the estuary across the lower portion of the section must balance that moving out of the estuary across the upper half. This is written:

$$Q_U \cdot \overline{S}_U\}_X = Q_L \cdot \overline{S}_L\}_X$$

...(2)

in which:

Q_U, Q_L = the total upper and lower layer flows, respectively

$\overline{S}_U$, $\overline{S}_L$ = the average upper and lower layer salt concentrations, respectively

Since the net overall movement is out of the estuary (seaward), and is given simply by Q_F, the freshwater flow, the upper layer flow, Q_U, must exceed the lower layer flow, Q_L, by this amount. This is written:

$$Q_U - Q_L = Q_F$$

...(3)

Substitution of Equation (3) into Equation (2) yields:

$$Q_U = \frac{Q_F\overline{S}_L}{\overline{S}_L - \overline{S}_U}$$

...(4)

Subscript "X" has been dropped since the section location was arbitrary and Equation(4) is the so-called "salt budget" equation and is described by a number of authors. (see, for example, Reference 8.)

A material balance may now be struck over the whole volume segment. Upper and lower layer flows are entering and leaving the segment at sections X and X + ΔX. The general inventory equation for mass is written:

$$\text{Rate of Mass Input} - \text{Rate of Mass Output} + \text{Rate of Production of Mass} - \text{Rate of Loss of Mass}$$
$$= \text{Rate of Accumulation of Mass} \quad \ldots (5)$$

In applying Equation (5) to the system in Figure 1, the last three terms are all zero, for both water and salt. There is no production or loss of either water or salt within the segment, and, since the system is at steady-state, no accumulation of either material occurs.

Application of Equation (5) to salt movement through the segment ΔX yields:

$$\text{Input} \quad - \quad \text{Output} \quad = \quad 0$$

$$Q_U \cdot \bar{S}_U\}_{X+\Delta X} + Q_L \cdot \bar{S}_L\}_X - Q_U \cdot \bar{S}_U\}_X - Q_L \cdot \bar{S}_L\}_{X+\Delta X} = 0 \quad \ldots (6)$$

Rearrangement and division by ΔX yields:

$$\left[\frac{Q_U \cdot \bar{S}_U\}_{X+\Delta X} - Q_U \bar{S}_U\}_X}{\Delta X}\right] - \left[\frac{Q_L \cdot \bar{S}_L\}_{X+\Delta X} - Q_L \bar{S}_L\}_X}{\Delta X}\right] = 0$$

The limit of this Equation as ΔX → 0 yields:

$$\frac{d(Q_u \cdot \overline{S}_u - Q_L \cdot \overline{S}_L)}{dX} = 0 \qquad \ldots(7)$$

Integration yields:

$$Q_u \cdot \overline{S}_u - Q_L \cdot \overline{S}_L = \text{Constant}$$

Consideration of the no net salt flux condition requires that the integration constant be zero. The result is identical to Equation (2).

Application of Equation (5) to water movement through the segment ΔX yields:

$$\text{Input} - \text{Output} = 0$$

$$Q_u\}_{X+\Delta X} + Q_L\}_X - Q_U\}_X - Q_L\}_{X+\Delta X} = 0$$

Rearrangement, division by ΔX and taking the limit as ΔX → 0 yields:

$$\frac{d[Q_U - Q_L]}{dX} = 0 \qquad \ldots(8)$$

Integration yields:

$$Q_U - Q_L = \text{Constant}$$

Consideration of the fact that the net overall movement across any section in the segment is given by Q_F, the freshwater flow requires that this integration constant be given by Q_F. The result is identical to Equation 3.

Thus, by use of material balances with salt and water across either an arbitrary cross-section or volume segment of the estuary, we have succeeded in establishing an overall quantitative relation between freshwater flow, estuary dilution flow and observed salt concentration. This relationship is given by Equation (4), in which Q_U, the upper layer flow, is the estuary dilution flow.

Equation (4) suggests that the estuary dilution flow can be calculated, provided one knows the location of the interface between the upper and lower layer and has accurate vertical salt profiles. QL&M has shown that, for for the Hudson, vertical salt profiles tend to follow an "S" shaped distribution with the inflection point near the half depth.[11]

This inflection point can be used to estimate the location of the upper-layer - lower layer interface as follows. The equation of continuity in two dimensions is written:

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0 \qquad \ldots(9)$$

in which:

U = horizontal water velocity at the point X,Y

V = vertical water velocity at the point X,Y

In the two layer system, the vertical distribution of horizontal velocity moves through zero at the upper layer-lower layer interface. Thus, since the interface is roughly horizontal, at the interface , $\partial U/\partial X = 0$. From Equation 9 the vertical velocity is seen to be a maximum at the interface.

The rate of vertical salt transport by vertical turbulence is proportional to the vertical velocity, and should be a maximum at the interface. This vertical salt flux can also be shown to be essentially proportional to the vertical salinity gradient, so that the point at which this gradient is a maximum can be used to estimate the location in the interface. In an "S"-shaped vertical salt profile, such as those observed on the Hudson, the vertical salinity gradient is a maximum at the inflection point.

This is just one means of estimating the location of the interface in using Equation (4) to estimate estuary dilution flow. Knowledge of the velocity distribution is another. In any event, the whole thrust of the work referred to in Reference 11, is directed at a valid estimate of the dilution flow, in which the role vertical salinity gradients play in this estimating process is discussed in detail. It should be noted that this reference is Reference 4, page III-61, to Chapter III in the AEC Draft Detailed Statement.

The use of Equation 4 and vertical salinity profiles to estimat density flow is recognized by the Staff in Chapter III, pages III-22 to III-27. In this regard, the Staff concludes on III-27:

> *The presence of a net nontidal seaward flow in the salt-intrusion zone of the Hudson is clearly established by means of (1) observed vertical salinity gradients, (2) direct velocity measurements, (3) high computed values for the longitudinal dispersion coefficient. Of these three means of detection, it is thought that only method 1 may be reliably used to obtain a reasonably accurate direct determination.*

The foregoing shows clearly that a model of estuary dilution flow can be developed by application of the Equation of Continuity (Law of Conservation of Mass) to the estuary. To do this, recognition is given to the fact that a vertical density difference exists in any section in the estuary.

No such similar analysis appears to exist which will generate the formulation used by the Staff to estimate estuary dilution flow (Equation (1) above, or Equation (2), page A-4 in the Draft Detailed Statement).

To show this, refer to Figure 1. Since the ultimate formulation (Equation (1)) contains only $\overline{S}$, the area-averaged salt concentration and S_0, the ocean salt concentration, we presume that mixing across the section is assumed for whatever derivation technique one can conceive of. Actually, no such assumption has to be made; the major point is that since the final expression contains only $\overline{S}$ to represent section salinity behavior, the deriver must use this, and only this value in developing his model.

Due to the observed dilution of Q_F, a seaward flow is assumed to exist and to be larger than Q_F. Use the notation Q_u to define the total seaward flow. Define a landward flow Q_L. Q_L is the makeup flow necessary to permit the existence of Q_u and still maintain a net water flux of Q_F.

Application of a material balance on water across the section X shows that Equation (3) still holds; i.e., that:

$$Q_U = Q_L + Q_F$$

Write a salt balance across section X. Since no attempt is made to define vertical variation of salinity and the investigator is apparently working only with $\overline{S}$, the area-averaged salt concentration, this balance yields:

$$Q_U\overline{S} - Q_L\overline{S} = \text{net section salt flux}$$

The net section salt flux must be zero at steady-state. However, substitution of the preceeding equation for Q_U yields:

$$Q_F\overline{S} = \text{net section salt flux}$$

This is clearly a contradiction and arises because the investigator has not distinguished between the concentrations of salt being carried landward by Q_L and seaward by Q_u. The presumption of landward and seaward flows is clearly necessary if one is to explain dilution of Q_L. This fact is acknowledged by many investigators. Care must be taken, however, to recognize that the actual points within the estuary section at which such flows are crossing, must see flow going in one direction or the other. No one point can see two way flow at the same time. Since this must be the case, one must also realize that the concentrations of salt seen by each flow may (and in fact, must) be different. Therefore, application of $\bar{S}$ to all flows is incorrect.

Proliferation of this error over the years seems to be associated with the assumption of the sectionally homogemeous estuary. Ketchum, for example, ignored vertical variation, assuming complete and immediate mixing with each of his segments. In using salinity, therefore, to "verify" his model, only section average salinities were used.

In discussing Todd and Lau's paper, Pritchard[4] states:

> *The authors have stated certain limitations on their development. A fundemental requirement is that the estuary be sectionally homogeneous, that is, it shall have no vertical or lateral salinity gradients. This is an unfortunate restriction to place on estuarine studies, since the majority of estuaries do exhibit some degree of vertical or lateral stratification, with accompanying circulation patterns related to the mass distribution.*

> *The characteristic circulation patterns in the various types of coastal plain estuaries have been discussed by Stommel (1953) and by Pritchard (1952, 1955). However, an adequate study of even this most simple of estuarine types would be welcome so that one should not be unduly critical of this aspect.*

Pritchard's point in the discussion, as described previously, is that if the assumption of vertical homogeneity is going to be made, presumably for the purposes of simplifying a complex system, then it should be done with great care, recognizing that the existence of vertical salinity variation is part and parcel of what makes the estuary "go".

Witness, for example, his comment in Reference 5, as he introduces the one-dimensional analysis of an estuary:

> *The Case of One Spatial Dimension. Because of the complexity of the general three-dimensional equations, and even of the more restricted two-dimensional equations given above, many investigators have attempted to reduce kinematic and dynamic problems in estuaries to a single spatial dimension. It is in these treatments that the most frequent misuse of continuity concepts has occurred.*

That the assumption of vertical homogeneity is an idealization is again suggested by Pritchard[12] in a discussion of estuary classification:

> *It is, in fact, quite possible that the vertically homogeneous estuary does not exist. Our observational methods may not be sufficiently sophisticated to show the slight degree of vertical stratification which might, on the average, exist in such systems. Only a small vertical stratification would be required to remove some of the anomalous factors mentioned above which are associated with this class of estuary.*

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[12] Contribution No. 64 of Chesapeake Bay Institute and the Department of Oceanography, The John Hopkins University, Reproduced by permission from The Sea, vol. 2, Interscience Publishers, 1963.

Bowden suggests that density-induced circulation must exist, even in cases where vertical mixing is intense and the tendency would be simply to assume vertical homogeneity.[13] A pertinent except from this reference follows:

> *Where the tidal currents are most effective, there is an increase in the intensity of vertical turbulent mixing, which is an exchange process, mixing the fresher water downwards as well as the salter water upwards. In this type of estuary, with moderate mixing, a state of dynamic equilibrium is set up, with a two-layer flow and the salinity along a given vertical increasing with depth. The volume of water involved in the density current flow may be many times the river discharge, e.g., the seaward flow in the upper layer may be 40 times the river flow while the upstream flow below it is 39 times the river flow. With very strong tidal currents, the vertical mixing predominates and a third type of estuary has been described, which is so intensely mixed that there is no vertical variation in salinity and the density current flow is no longer present. It would seem, however, that a tendency to differential flow must persist, even under these extreme conditions, since the primary driving force, the longitudinal density gradient, is still present.*

Comparison of Equations (1) and (4) show that estuary dilution flow calculated by each, will be the same when:

$$\frac{\overline{S}}{S_0} = \frac{\overline{S}_U}{\overline{S}_L}$$

These ratios will approach each other close to the true mouth of the estuary, as all values approach the ocean salt concentration. However, the validity of either equation is questionable at this point. Ketchum recognizes this in

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[13] Bowden, K.F. "The Mixing Process in a Tidal Estuary." presented at the International Conference on Water Pollution Research, Paper No. 33, of Section 3. September 3-7, 1962. Pergamon Press.

Reference 2 above, and the two-layer model presented previously is an idealization of actual estuary circulation. The simple idealization given tends to be inaccurate as one approaches the estuary mouth.

The foregoing literature review and analysis demonstrate clearly that the staff method of estimating estuary dilution flow, for use in its evaluation of entrainment, is highly questionable, if not categorically in error. We submit that a far more accurate estimate of estuary dilution flow in the Hudson River is that given in Reference 11 (Reference 4, Chapter III, draft detailed Statement.

As noted previously, the staff does recognize the existence of density flow in the Hudson in its Chapter III, Section E-1d entitled "The Hudson River Estuary and its Cooling Capacity." The salt budget equation, identical to Equation 4 above, is presented (Equation 1, page III-22) and the Staff goes on to state:

> *The mixing flow calculated in Equation (1) is the upper layer flow in the downstream direction. This should not be confused with what is called dilution flow in Appendix II-1 and Appendix V-2. (This dilution flow is defined by Equation (1) in Appendix II-1). These two appendices deal with the ecological effects of the Hudson River which are better described by the dilution flow concept mentioned above.*

However, no indication is given at this point or in either Appendix as to why "ecological effects......are better described" by the Staff concept of dilution flow, as given by Equation 1, page 8 of these comments.

2. COMMENTS ON THE STAFF'S CALCULATION OF ENTRAINMENT LOSS

On pages A-62 through A-64, the Staff presents a model of entrainment loss. On pages A-68 and A-69, this model is used to calculate the percentage of larval striped bass entrained by Units 1 and 2 at Indian Point.

This model presents a very conservative view of entrainment in the river. A number of factors are ignored, the consideration of each one of which will result in reduced estimate of the percentage entrained. These considerations include:

1. The role of density induced circulation.
2. The role of vertical diurnal movement of the organisms.
3. Susceptibility to entrainment

These comments are directed toward showing how the factors of density flow and vertical diurnal movement can be introduced to the Staff's model, and how the notions of planktonic movement and uniform distribution make the entrainment models employed by the staff quite conservative.

The Staff's model is based on the concept of the probability of capture of an organism as it passes Indian Point in the flow. The probability of capture per pass is given as Q_C/Q_T, the ratio of the station cooling water flow to the average tidal flow. The oscillating motion of the tide is recognized so the number of passes, or possible times capture can occur, is greater than once. The number of passes is shown to be given by Q_T/Q_D, the ratio of the average tidal flow to the estuary dilution flow.

Very simply, but approximately stated, the total probability of capture is given by the product of the probability of capture on a single pass times the total number of passes, or

$$P_T = \frac{Q_C}{Q_T} \times \frac{Q_T}{Q_D} = \frac{Q_C}{Q_D} \qquad \text{......(10)}$$

Equation 10 is only close to being accurate when the probability of capture on a single pass is low. Otherwise, recognition must be given to the fact that after each pass, a certain number of organisms has been removed from the system, reducing the number of the original batch, and therefore the number available for capture on the next pass.

The Staff model recognizes this and presents a careful treatment of the probability notion. The probability of withdrawal per pass is shown to be very small and the Staff concludes that an appropriate expression, given by their Equation 12, is:

$$P_T \approx \frac{Q_C}{Q_D} \left(1-\nu\right)\left[1-1/2\ (1-\nu)\ \frac{Q_C}{Q_D}\right] \qquad \text{...(11)}$$

in which: ν = the fraction of particles which have passed the condenser and are re-exposed due to recirculation.

The cooling water recirculation ratio, ν, is obtained using model and prototype data as a tracer and is estimated to be on the order of 14%. Q_C/Q_D is also relatively small, and for ease of explanation in this section, we will use the simple Q_C/Q_D as the staff's estimator of entrainment, recognizing that in the actual case, their actual model will give somewhat lower value since the recirculation and higher order probability terms are not dropped.

Note the Staff's statement after presentation of Equation 12.

> *Equation 12 shows that the total probability of being withdrawn is proportional mainly to the ratio of cooling water flow to the river freshwater flow. It is almost independent of the tidal characteristics, although these characteristics are important in that they provide the mixing and dilution which must be met in order for this model to be accurate.*

We disagree with the last sentence of this statement. When higher order terms are neglected, the model the Staff presents can be obtained just as readily by assuming a plug flow non-tidal river moving at the rate Q_E. From this standpoint is virtually "independent of the tidal characteristics." It is true that the tidal characteristics are important and important from the viewpoint of mixing and dilution, but this mixing and dilution is not recognized by the Staff. No attempt has been made to include estuary flushing or exchange characteristics, the real means by which an estuary mixes and dilutes, other than the previously demonstrated erroneous estimate of estuary dilution flow.

Consider first the role of diurnal migration of the organisms. The Staff addresses itself to this on page A-69, saying:

> *These values are based on area-average susceptibility. However, it is known that the larval striped bass make vertical diurnal migrations in the water column and are most concentrated from mid-depth to the surface at night but from mid-depth to the bottom during the day. These distributional patterns are important since the cooling water is taken from mid-depth to the surface. Thus, there would a significant difference in the day vs. nighttime susceptibility of the larvae, i.e., lower during the day and higher at night. Since the length of day and night are not equal at this time of year, these organisms may be slightly less susceptible to entrainment than predicted using this technique, provided that the deeper water is moving seaward.*

We object to the use of the word "slightly" in the last sentence of the above statement, as well as to the statement that the organisms "are most concentrated from mid-depth to the surface at night."

A more accurate description would be to say that the organisms are known to move up from the bottom during the night, and tend to spread out into a relatively uniform distribution throughout the water column during the night, as opposed to being concentrated in the bottom during the day.

An estimate of the reduced impact of entrainment, due to recognizition of this diurnal movement, can be obtained by computing the average probability of capture throughout the day. During the period of the year when this activity occurs, (± 3 weeks about June 21), daylight hours represent roughly two-thirds of the day and darkness roughly one-third of the day.

Assume that the upper layer larval concentration is zero during the daylight hours, and at night that the concentration of larval organisms is uniform throughout the water column. Actually, there will probably be some organisms in the upper layer during the day but this should be offset by only a tendency to approach uniformity from the bottom up. The longer daylight period will allow a greater period of time over which the organisms are "programmed" to seek the deeper layers. This suggests that the description of concentration below mid-depth during daylight hours is the more stable condition, and that the diurnal upward movement, since it has less time in which to equilibrate, is stable for a shorter percentage of its total period.

Since the cooling water "is taken from mid-depth to the surface," the probability of withdrawal of organisms during the day is zero, and at night is Q_C/Q_T, as before. Thus, the average probability of capture per pass is 1/3 (Q_C/Q_T).

The total number of passes is still given approximately by Q_T/Q_D, so that the fraction entrained is now given by $1/3(Q_C/Q_D)$, or one-third the original estimate, hardly worthy of the statement "slightly less susceptible to entrainment."

The Staff suggests, however, that this technique is only valid "provided that the deeper water is moving seaward."

In the next paragraph on page A-69, the Staff goes on to say:

> *However, if the density flow is well developed, then these diurnal migrations will cause them to occupy an inland-moving zone during the day and a seaward moving zone at night. Since their occupancy within the water mass moving inland would be of longer duration than within the water mass moving seaward on the surface, the length of time which they are susceptible to entrainment may be much longer than predicted in the above calculations. This is an important consideration in that the probability that they will be withdrawn is related to the number of exposures. A single week of exposure would increase the likelihood of withdrawal to about 34% and 10 days would result in about 45% of the larvae being entrained (assuming random distribution in the water column). These time periods do not seem unrealistic based on the behavior of larval striped bass and the high probability for the occurrence of density flows at Indian Point. As a consequence, the staff believes that the 25% estimate derived by the above calculations is probably somewhat low. However, the increased residence time within the volume of water which passes back and forth in front of Indian Point may be partly offset by a reduction in the average probability of withdrawal per pass, which results from the non-random distribution within the water column. Consequently, the staff believes that the total average probability of withdrawal of larval striped bass migrating downstream past the Station is approximated by the 25% figure, and that this fraction is the best estimate that can be made using avaialble information.*

We disagree with the Staff's analysis of the influence of the density flow on entrainment. As presented previously in the two layer flow model, the upper layer flow, Q_U, exceeds the lower layer flow, Q_L, by an amount equal to the freshwater runoff. In Reference (11), QL&M shows that the upper layer flow corresponding to freshwater runoff of 7500 cfs (used by the Staff in their analysis on page A-68) is 35,000 cfs. The corresponding lower layer flow is 28,000 cfs.

More careful analysis of this shows that if the daylight-darkness factor is taken into account, there will be a substantial net transfer in the landward direction rather than seaward. This suggests that if the organisms were subject to the density flows in the manner in which the Staff suggests they are, then the net movement of all organisms will be upstream, and for some (that portion which remains in the lower layer during the night-time hours) this will be the only movement.

Note that, in the model used by the Staff, entrainment only occurs during actual passage past the plant. The influence of density flows as suggested by the Staff would therefore expose only organisms whose origin is below the plant to potential capture by the plant. What we are saying here is that the staff is using a Lagrangian form of reference; i.e., is following the motion of a typical sample of organisms as they move back and forth in the general vicinity of the plant. Simultaneous superposition of the density flow and organism diurnal movement on the Staff's probability model results in a net upstream motion of the organism. Therefore, only those whose origin is below the plant will have an opportunity for capture.*

Simplify the analysis by recognizing that the net effect of the tide is to yield a total probability of capture equal to approximately Q_C/Q_D, when density flow and diurnal movements are not present. By analogy, for a two layer density flow tidal system, in which, for the moment, vertical diurnal movement is neglected, the fraction of entrained organisms is given by Q_C/Q_U, the ratio of the plant flow to the upper layer flow. Recognize also that in this case this capture applies only to those organisms appearing in the upper layer.

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* When tidal motion is included, this statement should be modified to include those organisms whose origin is with a tidal excursion above the plant.

Now introduce diurnal movement and recognize that, just as in the tidal analysis, the alternating seaward-landward movement will expose some of the organisms to more than one pass by the plant. Those that will be exposed will be those whose origin is below the plant, and which move up into the upper layer after they have moved landward in the lower layer, past the plant, and then prior to the end of darkness, will move back in the seaward direction past the plant.

The probability of capture per pass, recognizing that roughly half of the organisms reach the upper layer during the darkness hours, will be given by $Q_p/2Q_U$. The number of passes is equal to the number of times the organisms introduced into the seaward directed upper layer pass the plant between the time the particle of water in the lower landward directed layer first reaches the plant from below to the time it finally reaches a point above the plant, at which point the seaward return remains above the plant. This is given as follows:

$$\text{Number of passes past the plant in the upper layer} = \frac{Q_u \cdot T}{Q_L \cdot 2T - Q_u \cdot T} = \frac{Q_u}{2Q_L - Q_u}$$

T is the period of darkness and 2T the daylight period. The denominator $[Q_L \cdot 2T - Q_u \cdot T]$ is simply the net upstream movement that takes place each 24 hour day.

To derive the numerator, consider a particle in the lower layer, just $Q_L \cdot 2T$ distance seaward of the plant, at the onset of daylight. On a net, or daily cyclic basis, it must move upstream this distance, less one net translation $(Q_L \cdot 2T - Q_u \cdot T)$ before it can be said to have reached a point such that its organisms, during their sojourn in the return flow, will still be above the plant, and therefore no longer susceptible to entrainment. This net distance is equal to $\{[Q_L \cdot 2T] - [Q_L \cdot 2T - Q_u \cdot T]\}$ or $Q_u \cdot T$, the numerator of the above expression. The ratio of this net upstream movement required to push the particle out of the entrainment zone to the net translation each day, yields the number of passes to which the organisms in the particle are subject.

Following the Staff's probability notation, the formula for entrainment for this case is given:

$$P_T = 1 - (1 - P_e)^n$$

in which: P_T = total fraction entrained

P_e = entrainment per pass, $= \frac{Q_c}{2Q_u}(1 - \nu)$

n = number of passes, $= \frac{Q_u}{2Q_L - Q_u}$

For the case of density flow corresponding to a runoff of 7500 cfs, we have:

$Q_c = 2,500$ cfs

$Q_u = 35,500$ cfs

$Q_L = 28,000$ cfs

$\nu = 0.14$ (page A-64)

$P_e = 0.03$

$P_T = 0.05$ or 5% entrainment loss

Summarizing, we believe that three cases may be viewed as possible:

Condition	Percentage Loss by Entrainment
1. Density flow only	3%
2. Diurnal movement only	8%
3. Density flow with diurnal movement	5%

These estimates have been computed employing the Staff model for entrainment loss, modified for either density flow, diurnal movement or both. They show clearly that the Staff opinion that these two mechanisms offset each other is in error, and that the Staff estimate of 25% entrainment loss is not "the best estimate that can be made using available information."

Actually, we believe that all of these models yield conservative estimates of the actual effect. As shown above, the model in which diurnal movement and density flow is introduced, applies essentially to larval organisms originating seaward of the plant. Using the Staff's notion of the interaction between these two mechanisms, it is seen that all organisms originating above a point between $Q_u \cdot T$ and a tidal excursion above the plant, will not be exposed to entrainment during the planktonic stage.

The foregoing has been presented primarily to indicate that relatively simple models, of the type presented by the Staff in the draft detailed statement, must be interpreted extremely carefully. These models are clearly very conservative and note of this fact should be made. Statements such as:

> *"In conclusion, based on these considerations, about 25% of the larval striped bass may be entrained as they migrate downstream past the Indian Point site". (Reference A-69, Draft Detailed Statement)*

are misleading, when care is not taken to demonstrate, in a similar quantitative fashion, how known river and biological behavior can alter these conclusions.

In its discussion of probable biological effects in Chapter V, "Environmental Impact of Indian Point Unit #2 Operation with Unit #1 Operation", the Staff, on pages V-52 through V-55, discusses the probable impact of its conclusion that 25% of the larval striped bass may be entrained by the plant.

The statement is made that:

> *"The eggs and larvae drift with the currents in a net downstream direction; large numbers pass the plant."*

The Staff then states that data show that 75 to 90% of the young juveniles are below Indian Point by late July and August and then go on to state:

> *"If we assume: (1) that all these fish migrated past the plant during the life stage which is susceptible to to entrainment; (2) that density independent factors are responsible for mortality in the population; and (3) that entrainment mortality is 100%, then the operation of Indian Point Units #1 & will effectively reduce recruitment resulting from reproduction by about 19% to 22%,"*

We take strong exception to the thrust of these statements. First of all, it is not at all clear just how the eggs and larvae drift with the currents and for how long. The analysis above shows that if purely planktonic behavior, other than diurnal vertical movement is assumed, then only a small portion of the estuaries larval population is even susceptibel to entrainment (those below or just above the plant).

None of the immature stages are purely planktonic. Even the eggs have a density different than water and tend to settle in the absence of any current. Furthermore, the eggs only exist on the order of two days, before hatching; only those eggs spawned in close proximity to the plant could be susceptible to entrainment by the plant as eggs.

The larvae are sometimes described as planktonic, but by as early as the sixth or seventh day of their existence, are reported to absorb the yolk sac and begin diurnal movement. From this time forward their swimming ability increases, suggesting that the description of drifting with the current is not accurate. Furthermore, the presumption that susceptibility to entrainment is controlled by flow ratio is also highly questionable, since the swimmers may very well avoid the intake.

Studies do show that by September, most of the young striped bass have reached Haverstraw Bay. To assume that this means they are susceptible to entrainment as they pass Indian Point in the manner assumed in the draft detailed statement is misleading. It is true that their passage through the river section bordered on the east by Indian Point probably occurs when they are less than 3 inches long, and in many cases less than 2 inches long, and that fish of 2 inch size or less may be entrained. This does not mean, however, that the entire population passing is planktonic, is subject to tidal and other current drift, is distributed uniformly across the cross-section and, therefore, is subject to 25% entrainment.

These young striped bass are known to seek the bottom as well as shallows and shoal areas, none of which describes the source of the major volume of water passing the Indian Point intake.

In conclusion, we state that the assumptions of uniform distribution across the section, and of downstream drift and planktonic behavior of all entrainable forms are not supportable by the known behavior of the immature fish at many stages of their development. Therefore, the percentage entrainment should be substantially less than the values given above in the modified entrainment model (3 to 8%) and in no way even close to the 25% estimate given by the AEC.

CHAIRMAN JENSCH: Has the Applicant presented copies of those to the reporter for incorporation?

MR. TROSTEN: We have them and will present them.

CHAIRMAN JENSCH: Proceed.

MR. TROSTEN: Having previously identified the following documents by stipulation among the parties, I ask that these be received in evidence as the testimony of Dr. James T. McFadden of the University of Michigan, and Mr. Carl Newman of Con Edison, and Dr. Edward C. Raney of Ichthyological Associates as if these gentlement were present and had sworn to them as indicated.

CHAIRMAN JENSCH: Any objection to that offer? By the Hudson River Fishermen's Association?

MR. MACBETH: Only the same objection.

CHAIRMAN JENSCH: Very well. New York State Atomic Energy counsel?

MR. MARTIN: No objection.

MR. KARMAN: No objection.

CHAIRMAN JENSCH: The objections of the Hudson River Fishermen's Association are overruled and pursuant to the stipulation among the parties in reference to the form of the presentation, the proposed statements by Witnesses Raney, McFadden and Newman are accepted as evidence and may be received into evidence, and the statements may be physically incorporated within the transcript as if read, upon the understanding that sufficient copies are furnished to the reporter.

(The documents follow.)

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of)
)
Consolidated Edison Company) Docket No. 50-247
of New York, Inc.)
(Indian Point Station, Unit No. 2))

Testimony of
Carl L. Newman,
Vice President, Consolidated Edison Company
of New York, Inc.
On
Alternative Closed-Cycle Cooling
Systems At Indian Point 2

October 30, 1972

I. Introduction

In its Final Environmental Statement issued on September 28, 1972 the Regulatory Staff of the Atomic Energy Commission recommended that Consolidated Edison be required to operate its Indian Point 2 facility with a closed-cycle cooling system after January 1, 1978. This determination is based on certain inaccuracies, included among them, the time necessary for implementation of an alternative closed-cycle cooling system at Indian Point 2 and the cost for such implementation. A clarification of the schedule and cost is presented in this testimony.

II. Schedule for Implementing a Closed-Cycle Cooling System at Indian Point 2

The schedule recommended by the Regulatory Staff in its Final Environmental Statement for Indian Point 2 fails to allow adequate time for the completion of necessary environmental studies and evaluations; for appropriate governmental reviews and approvals; for detailed design of the approved system; for procurement of components and construction of the system. The Regulatory Staff has recommended that Consolidated Edison be required to submit an evaluation of the economic and environmental impacts of alternative closed-cycle cooling systems for review no later than July 1, 1973 in order to provide adequate time for appropriate approvals, design, construction and operation of a required closed-cycle cooling system by January 1, 1978. Then, after approval of the alternative system, Consolidated Edison would be required to design, construct and operate the approved closed-cycle cooling system no later than January 1, 1978.

Rather than five years as recommended by the Regulatory Staff, implementation of an alternative closed-cycle cooling system at Indian Point 2 would take approximately eight years to complete. The schedule presented herein would permit a sufficient reassessment of the environmental impact of alternative cooling systems as well as an adequate time for the design and construction of an optimum system.

A. Evaluation of Environmental Impact

In order to present the Commission with an evaluation upon which it can issue a considered approval, an environmental program encompassing one and one-half years is required. This program will include approximately three months for preparation, one year for acquisition of field data and surveys and three months for review and development of conclusions. Preliminary investigations have indicated that a natural draft closed-cycle wet cooling tower system would be the most advantageous closed-cycle system at Indian Point; therefore, the evaluation which will be conducted will consider primarily the environmental impact of this particular system. Consolidated Edison, however, will modify its program, where feasible, to include the collection of additional information on mechanical draft closed-cycle wet cooling tower and closed-cycle spray pond systems. In addition, Consolidated Edison will continue to consider and evaluate the literature published on alternative closed-cycle systems as well as operating experience obtained in the United States and abroad.

The evaluation of the natural draft closed-cycle wet cooling tower system will include not only a detailed environmental evaluation of this particular system, but will also include an evaluation of the optimum location for such a system. Preliminary studies by Consolidated Edison considered a natural draft closed-cycle wet cooling tower system utilizing two hyperbolic towers located south of the Indian Point 2 complex at an elevation of approximately 100 feet and approximately 2,000 feet from the containment building of Indian Point 2. See Figure 1 attached hereto. Detailed studies will now consider additional locations and designs including a natural draft wet cooling-tower system utilizing a one-tower concept at a location 200 feet north of the Indian Point 2 complex at an elevation of approximately eight feet. See Figure 2 attached hereto. Natural draft systems will be evaluated assuming the present once-through cooling system at Indian Point 1 so that cooling water flow from Indian Point 1 could be used for dilution of both radwaste discharges and cooling tower blowdown.

The environmental evaluation, preparations for which are already underway, will build on the information derived from preliminary studies. The focal point of the detailed evaluation will be the on-site studies and measurements to determine the specific impact of the alternatives at Indian Point 2 and to compare conditions and impacts at Indian Point 2 with those reported in literature and operating experiences for existing facilities. Specifically, the program will include studies of meteorology, salt deposition, acoustical emissions and blowdown as well as consideration of the impact on land, air and the community.

The meteorological studies will assess quantitatively if fogging and icing will occur at Indian Point 2 and its environs due to operation of the closed-cycle system. These studies will include among other things a determination of the possible effects of the plume on roads, highways and airports in the vicinity of Indian Point 2. It is estimated that the erection of meteorological instruments on a tower and the collection of meteorological data will take at least one year. The salt deposition studies will evaluate the effect of the drift releases on the vegetation in the vicinity of Indian Point.

Consideration of estimated acoustical emissions from the alternative systems includes an evaluation of the nature of the terrain at the Indian Point site and the ultimate impact of operation of the alternative systems on the residents in the vicinity of the facility. Studies will be conducted to determine the effect of untreated chemical and thermal blowdowns resulting from operation of cooling towers at Indian Point 2 on the Hudson River environment. In addition, the aesthetic impact of the structures will be considered during this period. The impact on ambient air quality resulting from the additional power generation by fossil fuel plants as a result of necessary operational and peak deratings will also be analyzed concurrently with the program outlined above.

Placement, construction and operation of an alternative closed-cycle cooling system may also have radiological safety implications which must be considered prior to the selection of a particular system. Consolidated Edison during the period of the environmental evaluation will consider the interface of radiological factors on the design of an alternative closed-cycle cooling system. This analysis of radiological factors may have a significant impact on the cost of an alternative closed-cycle cooling system.

Consolidated Edison and the Regulatory Staff agree that additional environmental investigation is necessary prior to the final selection of a specific alternative. Although preparations for environmental studies have begun, Consolidated Edison estimates that the program will take approximately one and one-half years to complete.

If the Board adopts the Regulatory Staff's recommendation for the submittal of an environmental evaluation by July 1, 1973, Consolidated Edison would be in the position of recommending for review and approval a system at Indian Point 2 for which the environmental effects at the Indian Point site have not been sufficiently analyzed. This would be a radical departure from the course Consolidated Edison has followed throughout the design and review of its Indian Point facility. Consolidated Edison submits such a departure would be irresponsible and inconsistent with the objectives of NEPA.

B. Governmental Approvals and Detailed Design

Subsequent to the completion of the environmental evaluation of alternative closed-cycle cooling systems at Indian Point 2, a particular alternative system will be proposed by Consolidated Edison. Appropriate governmental review and approval followed by the preparation of a detailed design of the selected alternative by Consolidated Edison will follow. Consolidated Edison estimates that governmental review and approval and preparation of a detailed design could take approximately two to two and one-half years to complete.

During the governmental review which includes both the Atomic Energy Commission and the New York State Department of Environmental Conservation, the alternative selected by Consolidated Edison will be analyzed and approved or modified as appropriate. It should be noted that these governmental reviews might be conducted consecutively. Based upon the conclusions of these agencies, Consolidated Edison will proceed with the detailed design of the alternative closed-cycle cooling system. Although preliminary designs for a natural draft closed-cycle wet cooling tower system have been prepared, a final design including specifications for components, layouts, excavation design, borings, site investigations, erection specifications and foundation design for even a natural draft system must await final governmental approval. The precise period for approval and final design cannot be determined until the particular proposal by Consolidated Edison is presented and the extent of the modifications resulting from the governmental review is known.

C. Construction

Construction of the selected alternative cooling system* is estimated to require four years. This schedule includes an initial period for the issuance of specifications, for the receipt of bids and for the finalization of the choice of vendors. Actual work in the field is estimated to require 36 months.

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*Preliminary studies by Consolidated Edison, as well as the Regulatory Staff in its Final Detailed Statement, have indicated that a natural draft closed-cycle wet cooling tower system would have the minimal water impact at Indian Point 2; therefore, the construction schedule presented herein is based on the construction of a natural draft system. A construction schedule for other alternative closed-cycle cooling systems at Indian Point 2, however, would approximate that for a natural draft system.

Early phases of construction would include clearing and grading the Indian Point property for the construction of the modified cooling system. As work proceeded an additional circulating water pumphouse would be erected and interfaced with the existing once-through condenser cooling system. Portions of the cooling system would be erected in sequences optimized to enable efficient use of labor and to account for seasonal factors. In the final stages of field effort Indian Point 2 would be shut down to permit interties with the altered circulating water system and to segregate the new system from existing Hudson River intakes and the Indian Point 1 discharge canal. These final stages of interfacing are expected to require approximately seven months during which Indian Point 2 could not operate. A chart setting forth an approximate schedule for implementation of an alternative closed-cycle cooling system at Indian Point 2 is attached hereto as Table A.

D. Interim Program for Implementation of a Closed-Cycle Cooling System

At the same time that the evaluation and review period preparatory to construction of an alternative closed-cycle cooling system is underway, Consolidated Edison will develop a detailed conservative design for a natural draft closed-cycle wet cooling tower system. This design will be based upon the preliminary studies undertaken by Consolidated Edison, but will not be the optimum design which will result from appropriate environmental studies as recommended by Consolidated Edison. If at any time during operation of Indian Point 2 with the once-through cooling system the environmental monitoring program indicates that irreversible biological injury might be done to the Hudson River as a result of long-term operation of the plant, Consolidated Edison would be prepared to commence construction of a closed-cycle cooling system expeditiously following receipt of governmental approvals. By preparing this design Consolidated Edison believes that an appropriately considered closed-cycle cooling system as suggested herein could be implemented at its Indian Point 2 facility without concern that the necessary studies and reviews might cause a delay which would irreversibly damage the biological species in the Indian Point environment.

III. Economic Costs of an Alternative Closed-Cycle Cooling System

The Regulatory Staff in its Final Environmental Statement presented incomplete economic costs for the implementation of an alternative closed-cycle cooling system at Indian Point 2. Not only did the Regulatory Staff neglect to compute properly the incremental generating costs for closed-cycle cooling systems at Indian Point 2, but also erroneously omitted the outage cost in determining the total cost for a closed-cycle cooling system.

A. Incremental Generating Costs

In its Final Environmental Statement the Regulatory Staff estimated the economic cost of implementing alternative closed-cycle cooling systems by presenting those figures estimated by Consolidated Edison in its Indian Point 2 Environmental Report, Supplement No. 3, filed with the Commission on February 15, 1972 tempered only by an 8.75% discount factor rather than the 8% discount factor used by Consolidated Edison. The preliminary figures presented by Consolidated Edison in Supplement No. 3, however, estimated the economic cost of constructing alternative closed-cycle cooling systems in 1972 for operation in January, 1975. The Regulatory Staff's conclusion, therefore, is based on figures computed for operation in January, 1975, rather than for operation as recommended by the Regulatory Staff in January, 1978.

Table B attached hereto sets forth the correct incremental generating costs for the implementation of a natural draft closed-cycle wet cooling tower system* for Indian Point 2 utilizing the two-tower concept. These costs are computed on the basis of operation in January, 1978. Table C attached hereto sets forth the preliminary cost study for a natural draft closed-cycle wet cooling tower system utilizing the one-tower concept described on pages 3-4 above. These costs are also computed on the basis of operation in January, 1978.

B. Outage Cost

In addition to the inadequate incremental generating costs, the economic cost estimates reflected in the Final Environmental Statement are deficient in that the cost of outage or downtime for that period during which necessary modifications for the implementation of a closed-cycle cooling system will be made is not included. The modifications to the intake structure and the discharge tunnel which must

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*For the reasons stated in the footnote at page 8 the detailed costs for a natural draft closed-cycle wet cooling tower system are presented herein; however, a detailed cost analysis would correspondingly alter the cost of all alternative closed-cycle cooling systems.

be made include:

(1) Completion of channels from the existing cooling system to the new alternative closed-cycle cooling system;

(2) Installation of pilings in front of the existing intake structure;

(3) Completion of service water by-pass;

(4) Segregation of Indian Point 2 discharge from that of Indian Point 1; and

(5) Completion of a new booster pump structure.

While the exact period of outage depends on the alternative system selected and approved, Consolidated Edison estimates that downtime for the implementation of a natural draft closed-cycle wet cooling tower system at Indian Point 2 would be approximately seven months.* The present worth cost of this outage is estimated at 20.3 million dollars. At this time it is not known whether modifications at Indian Point 2 would require an outage at Indian Point 1.

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*The requisite construction outage may overlap the annual two-month maintenance outage at Indian Point 2, thus limiting the construction outage to five months. For this reason the construction outage for the purpose of determining the total cost of implementing an alternative closed-cycle cooling system at Indian Point 2 has been estimated at five months.

The cost of the Indian Point 2 outage would be added to the incremental generating cost of an alternative natural draft closed-cycle wet cooling tower system whether it be the one-tower or two-tower concept. The present worth value of the incremental generating cost including outage cost for a natural draft cooling system utilizing the two-tower concept is estimated at 182,257 million dollars; for a natural draft cooling system utilizing the one-tower concept at 138,025 million dollars.

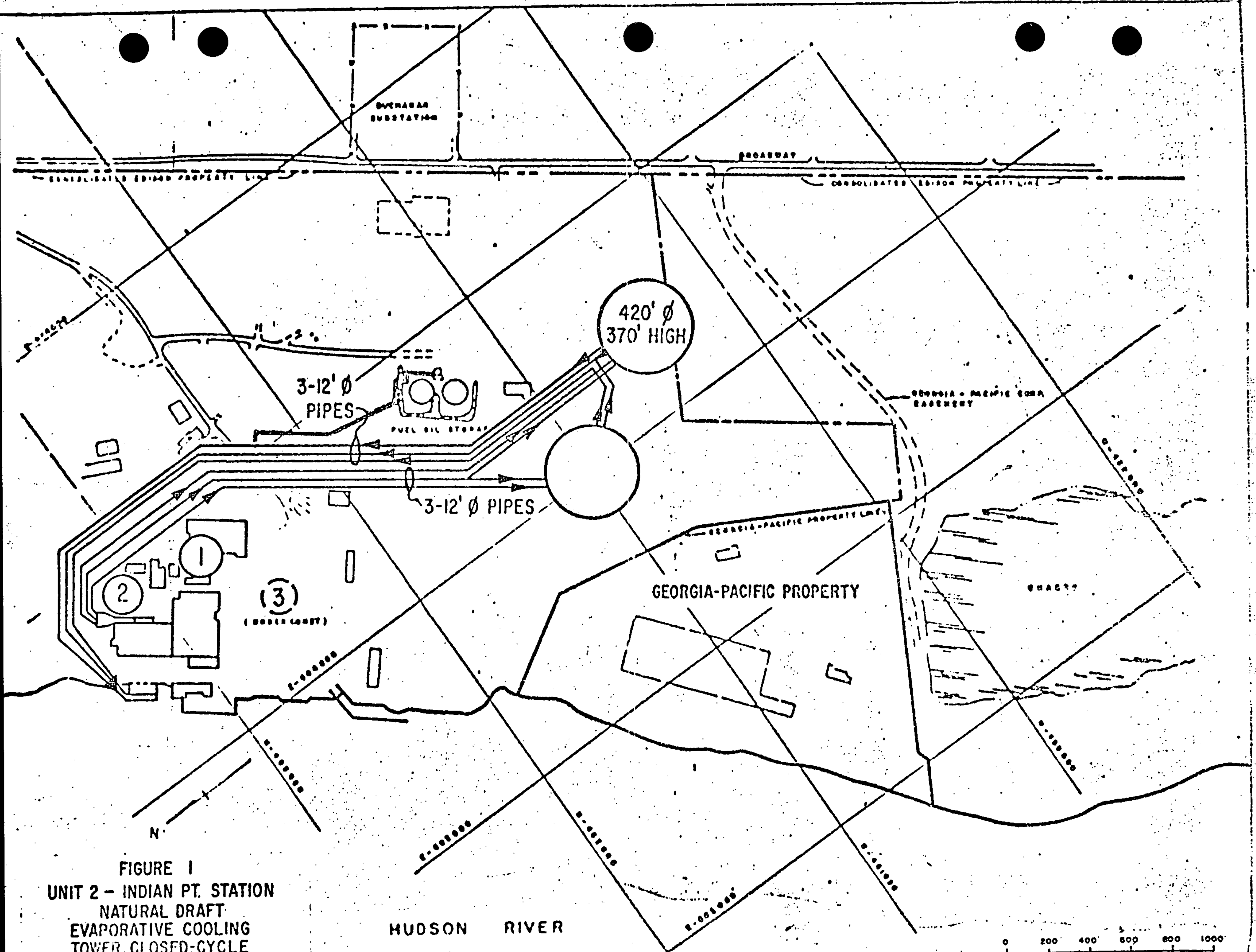
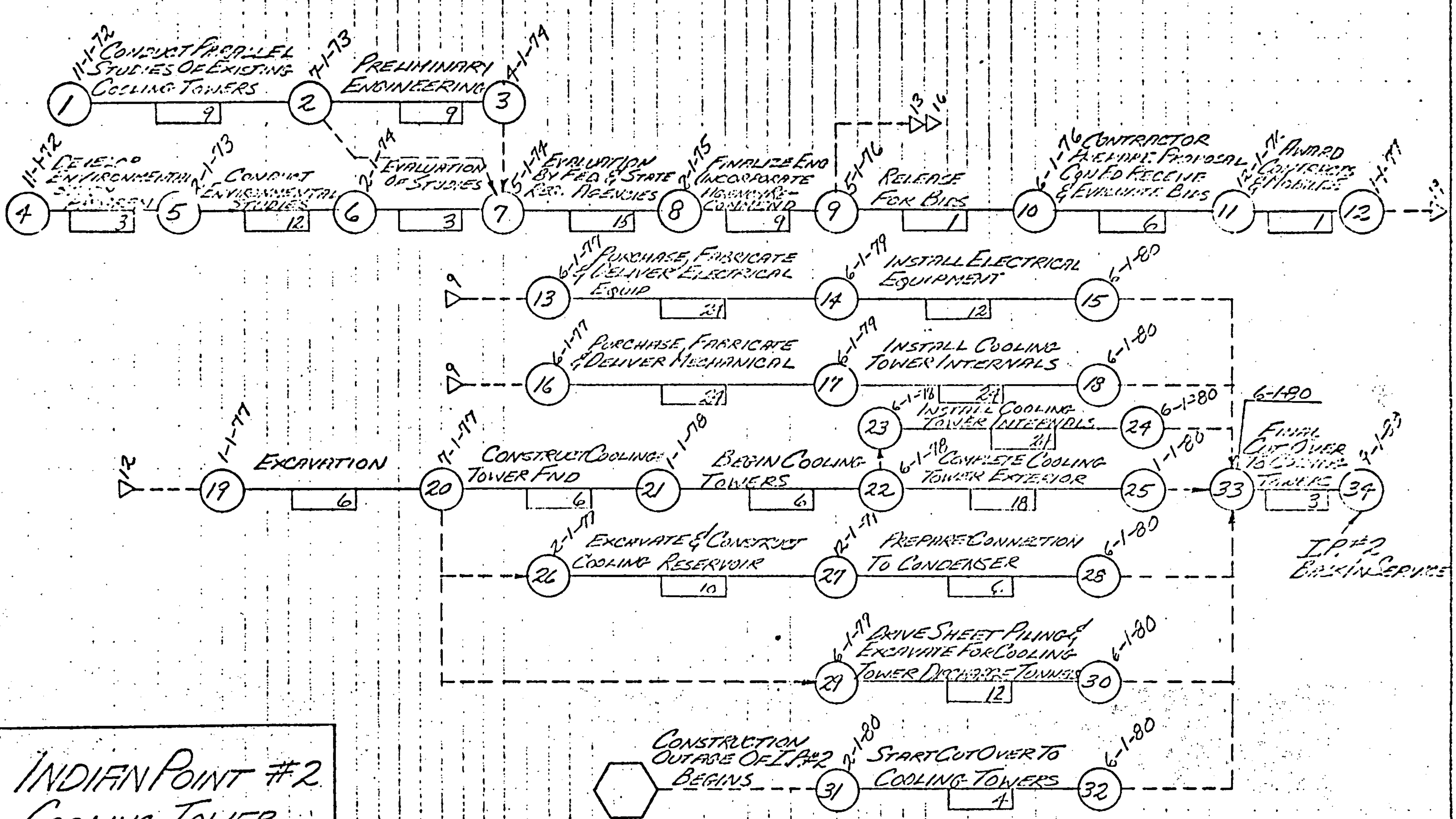


FIGURE I
UNIT 2 – INDIAN PT. STATION
NATURAL DRAFT
EVAPORATIVE COOLING
TOWER CLOSED-CYCLE



INDIAN POINT #2
COOLING TOWER

TABLE A

DURATION IN MONTHS

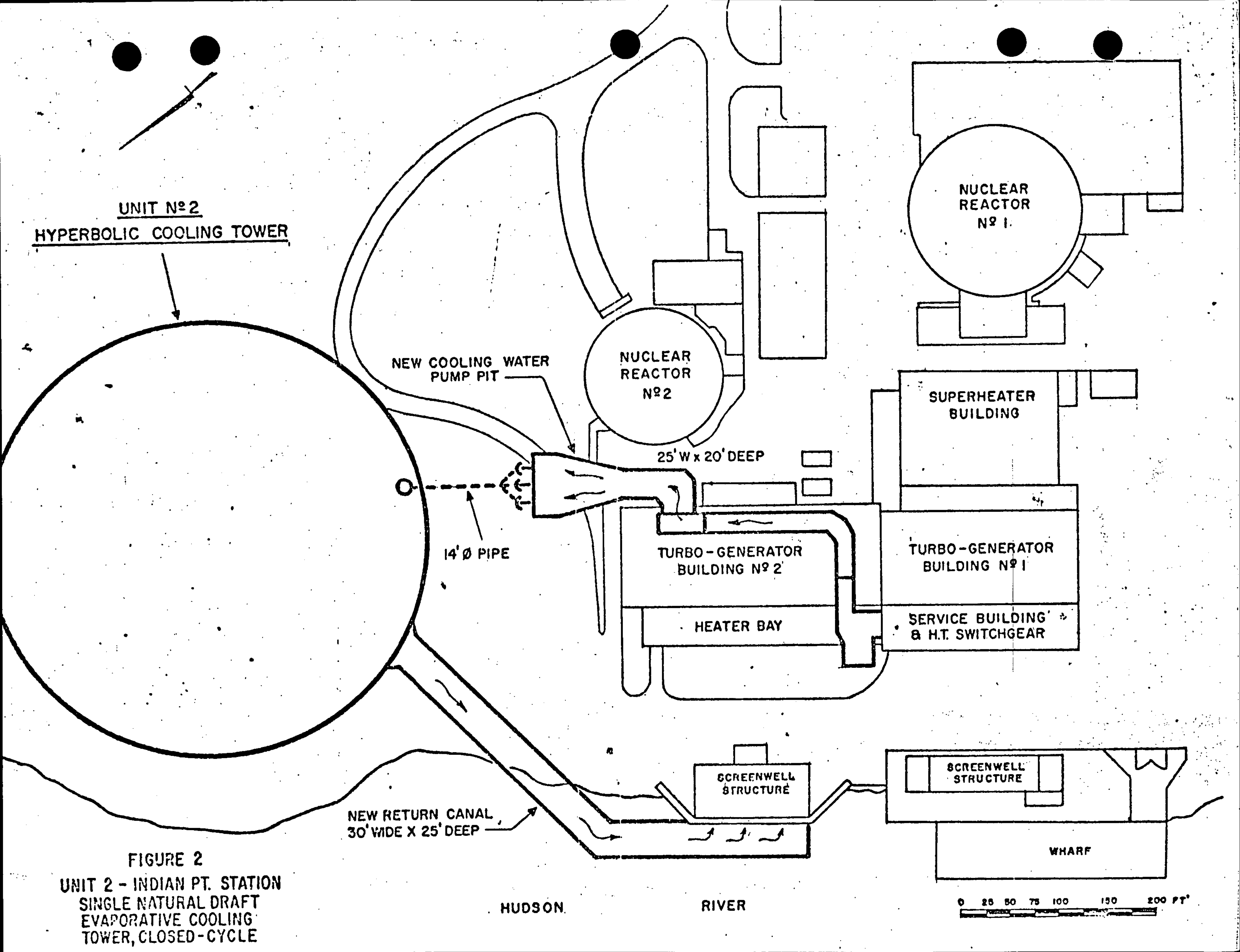


FIGURE 2

UNIT 2 - INDIAN PT. STATION
SINGLE NATURAL DRAFT
EVAPORATIVE COOLING
TOWER, CLOSED-CYCLE

Table B

Cost of Generation with a Two Tower Natural Draft Closed-Cycle Wet Cooling Tower System

1.	Additional Capital Expenditure - $1,000		$ 119,741
2.	Present worth of incremental generating costs above "Base Plant" - $1,000		
	a.	Maintenance and other operating expenses	3,228
	b.	Charges on additional capital for alternative (at a carrying charge of 13.9%)	120,578
	c.	Cost of purchasing deficient power	23,249
	d.	Charges on additional capital for replacement turbine capability (at a carrying charge of 14.3%)	14,959
	e.	Replacement power for plant downtime	20,243
	f.	Total cost of alternative	$ 182,257
3.	Generation deratings - MWe		
	a.	Annual overall	37
	b.	At peak ambient temperature	82

NOTE: Above present worth estimates are based on AEC prescribed 8.75% discount rate.

Table C

Cost of Generation with a

One Tower Natural Draft Closed-Cycle Wet Cooling Tower System

1.	Additional capital expenditure - $1,000		$ 68,905
2.	Present worth of incremental generating costs above "Base Plant" - $1,000		
	a.	Maintenance and other operating expenses	1,614
	b.	Charges on additional capital for alternative (at a carrying charge of 13.9%)	69,389
	c.	Cost of purchasing deficient power	28,902
	d.	Charges on additional capital for replacement turbine capability (at a carrying charge of 14.3%)	17,877
	e.	Replacement power for plant downtime	20,243
	f.	Total cost of alternative	$ 138,025
3.	Generating deratings - MWe		
	a.	Annual overall	46
	b.	At peak ambient temperature	98

NOTE: Above present worth estimates are based on AEC prescribed 8.75% discount rate.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2)	)))))	Docket No. 50-247

Testimony of
Edward C. Raney, Ph.D.
Ichthyological Associates
301 Forest Drive
Ithaca, New York 14850

on

The Striped Bass, *Morone saxatilis*, of the Atlantic Coast of the United States with Particular Reference to the Population Found in the Hudson River

October 30, 1972

CONTENTS

STUDIES OF THE STRIPED BASS AND OTHER FISHES

BY DR. EDWARD C. RANEY

Raney began his professional career after the completion of his doctorate at Cornell in 1938 as a member of the Cornell faculty where he did research and taught until his retirement August 31, 1971 as Professor of Zoology Emeritus. His intensive studies of the striped bass were begun in 1948. His field and laboratory studies have concentrated on the ecology, distribution, behavior and systematics of fishes. His studies have resulted in the publication of more than 100 papers in scientific journals and hundreds of reports and popular articles on fishes.

Intensive studies of the striped bass began in 1948 and led to his paper "The Life History of the Striped Bass" published in 1952. With Donald P. de Sylva, he discovered the racial status of the Hudson River striped bass in 1953. See the attached list of papers having to do with striped bass and other fishes found in the Hudson River which were authored by Raney.

These early studies rekindled an interest in the investigation of the striped bass which had been first stimulated by the classic papers of Merriman (1937 and 1941).

As a result of the renewed interest in study of striped bass, Raney organized a coordinated study of the species and from 1953 to 1957, on a part-time basis, served as the Coordinator of the Atlantic States Cooperative Striped Bass Program of the Atlantic States Marine Fisheries Commission during which he was employed as a Fishery Biologist by the United States Fish and Wildlife Service. Activities during this period stimulated intensive study of the species by numerous biologists of various state and federal agencies as well as private laboratories which have resulted in the extensive series of papers listed in the bibliography of this testimony. Many of the authors of the papers cited in this testimony were students of Raney or consulted with him during the course of their studies.

Raney first became familiar with and was active in field studies of the striped bass during the summer of 1938 and he was employed as a biologist by the State of New York Conservation Department during its biological survey of the waters of Long Island. He was personally involved in the collection and study of Hudson River striped bass from 1949 to 1954. In recent years, and particularly during the past four years, he has been involved with studies of the striped bass done for Consolidated Edison Company, by Raytheon Corporation and others. For four years he has served on the Fish Advisory Board for Consolidated Edison. Other more recent studies of striped bass and other marine and estuarine fishes include intensive studies of the Connecticut River during the past seven years by a group working out of Essex Marine Laboratory in connection with the Connecticut Yankee Atomic Power Station located at Eash Haddam, Conn. This before and after study of effects of the introduction of considerable heated water into the Connecticut has provided insight into the problems faced on the Hudson and other eastern rivers.

Because of the need for expertise and intensive study Raney in 1966 organized Ichthyological Associates which now numbers more than 150 aquatic biologists and other specialists who are dedicated to studies of the aquatic and terrestrial environment, and in particular, those near nuclear plants in operation or under construction. These include sites in the ocean off New Jersey.

The ocean, bay and Mullica River populations of striped bass have been investigated and will continue to be for many years to come. The Delaware River which is a source of a separate race of striped bass (see de Sylva, 1961) has been studied intensively since 1968 at river mile 50 in connection with the construction of the Salem Nuclear Generating Station. Our studies here have resulted in a report by William H. Bason "Ecology and Early Life History of Striped Bass, *Morone saxatilis*, in the Delaware Estuary", October 1971, Ichthyological Associates Bulletin No. 4. This study showed that the Chesapeake and Delaware Canal is an important spawning area for striped bass. Studies of the effect of silt on striped bass eggs were carried out.

Other studies on the lower Susquehanna River and the upper Chesapeake Bay have been under way in regard to striped bass and other anadromous fish populations since 1963.

Papers by Edward C. Raney on the striped bass and other fishes which are found in the Hudson River.

1952 The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull. Bingham Oceanographic Coll. 14(1): 5-97.

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1957 Special study of the striped bass problem. State of N.Y. Legislative Doc. (1957) No. 11. Rept. Jt. Leg. Comm. on the Revision of Conserv. Law, pp. 31-39.

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1959 Some young (of) fresh-water fishes of New York. N.Y.S. Conservationist 14(1):22-28.

1959 Fishery resources of the marine district. State of N.Y. Legis. (1959) Doc. No. 11. Rept. Jt. Leg. Comm. on the Revision of Conserv. Law, pp. 25-55.

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CONCLUSION

In arriving at this conclusion and recommendation to the Atomic Energy Commission, I speak as an environmentalist who has dedicated his life to the study of aquatic life and environments. As a result of my intensive field and experimental studies which have been undertaken since 1939, and which continue to date, and which have involved the population of striped bass and other fishes in the Hudson River and other rivers of eastern United States; and on the further basis of (a) my knowledge of the studies which have been and are being made of the fishes and other biota of the Hudson River for Consolidated Edison Company, and (b) my knowledge of the present design of the once-through cooling system and of steps which are being taken to study, design and install a more effective cooling water screening system,

I am confident in predicting the following with respect to the operation of Indian Point Units 1 and 2 with the present once-through cooling system over the next eight years:

1) There will be no irreparable or irreversible damage to the striped bass population which is native to the Hudson River (Hudson River race) or those which occasionally overwinter in the Hudson River (Chesapeake Bay or Delaware Bay race) over a period of the next eight years.

2) There will be no irreparable or irreversible damage to the striped bass populations which frequent the western quarter of Long Island Sound, the New York bays or the adjacent limited coastal area in northern New Jersey or southwestern Long Island.

3) There will be no effect on the major Atlantic Coast populations which are spawned in the south (mostly in Chesapeake Bay tributaries) and which generally have been on the increase along the New Jersey shore and south shore of Long Island as well as New England since the large year-class of 1934 in Chesapeake Bay.

Moreover, I have reached the following conclusions with respect to the A.E.C. Staff's Final Environmental Statement:

a) The Staff inference that passive drifting of eggs and larvae of striped bass would permit from 70 to 90% of the surviving portion of the total annual production in the Hudson River to pass the Indian Point Plant by early August is not true. Such a conclusion by the Staff was reached because of limited investigation and inprecise knowledge of the distribution and movement of young striped bass in the Hudson. Probably too much emphasis was placed upon studies which were done for other purposes and which did not accurately reflect the substantial annual production to the striped bass population from the upper sections of the river.

b) The Staff estimate of the great impact of entrainment and impingement at Indian Point Plants 1 and 2 on the middle Atlantic fishery is inaccurate and greatly exaggerated. The bulk of the middle Atlantic fishery for striped bass (outside of the Hudson River, the western quarter of Long Island sound and the New York Bay area) is supported by striped bass production in areas to the south of New Jersey, and mainly by the Chesapeake and Delaware bays.

c) The skepticism expressed in the Staff report with regard to the ability of the Chesapeake Bay to supply the large numbers of striped bass found in the spring and fall off the middle Atlantic coast is understandable in view of their lack of field experience. Those who have not personally viewed the hoards of migrating striped bass in spring and fall often have difficulty in reconcilling the tremendous numbers which actually leave the Chesapeake Bay, which is the area of maximum production, with reports of the tag returns.

The wise and economical use of the tremendous natural resources of the Hudson River, including water, for man demands the rational approach of testing through intensive study the questionable hypothesis of irreversible harm advanced in the Final Environmental Statement.

Other witnesses reinforce the conclusion by supplying the results of studies of the effects of entrainment (Dr. Lauer), of population dynamics (Dr. McFadden) and distribution of larvae and their probable entrainment and impingement utilizing field and model studies (Dr. Lawler). My testimony will emphasize the racial aspects, migratory behavior and distribution of various populations of striped bass with emphasis on that found in or near the Hudson River.

GENERAL SUMMARY REGARDING STRIPED BASS

The following inferences can be supported from the vast amount of work done over the last 35 years:

1) The tributaries of the Chesapeake Bay are the major spawning

and nursery areas for the striped bass. The production in the Chesapeake Bay area is very large compared with the usual production found elsewhere.

2) A study of meristic characters indicates that there are at least three recognizable sub-races of striped bass in the Chesapeake Bay area. See Raney and de Sylva (1953), Raney (1957) and Massmen and Pacheo (1961).

3) Very large populations of two-year and older striped bass are present in the Chesapeake Bay and its tributaries. Some of these which are primarily two years and older undertake non-spawning coastal migrations northward in the spring and returned to the Chesapeake Bay or its vicinity following coastal routes in the fall of the year.

4) Some of these coastal migrants may enter and winter-over in northern coastal rivers such as the Connecticut, the lower Hudson, the Mullica and the Delaware. However, observations indicate clearly that this over-wintering population in the north is a very small population of the total migrating hoards of striped bass.

The Hudson and the Delaware rivers support spawning populations of striped bass. The Chesapeake and Delaware Canal is an important source. The contribution of the Delaware River and the Hudson River to the total Atlantic coastal stock is almost certainly relatively small.

There is no spawning population in the Connecticut River as determined by intensive studies of the fish fauna for the past seven years. Indeed, it is unlikely that any river north of the Hudson makes a major contribution to the major Atlantic coastal stock.

Generally-speaking, larger striped bass move much further on the average than do small specimens.

Relatively little is known of the possible contribution of striped bass which are produced south of the Chesapeake Bay region. From tagging results, it appears that the area contributes little to the migratory Atlantic Coast population. However, some larger specimens of the migratory Atlantic stock may over-winter off North Carolina waters at times.

There is a substantial population of spawning striped bass in the Roanoke River and its estuary, but it makes little contribution to the migratory stock along the Atlantic Coast.

The Hudson River striped bass are a separate race based on the analysis of meristic characters. Their contribution to the Atlantic Coast fishery is restricted and limited (see additional discussions below).

It has been shown conclusively that the striped bass populations may vary greatly in number in all rivers where they have been studied.

Such variations are known as year-class fluctuations. The best documented example is the production from a very small number of adults in Chesapeake Bay in 1934 of a tremendous year-class which entered the fishery offshore in 1936-37 and subsequent years. A series of other strong year-classes in the Chesapeake Bay and possibly elsewhere have increased greatly since 1934.

STRIPED BASS

The striped bass is a tolerant and wide-spread species which is distributed along the Atlantic coast from the St. Lawrence River to the St. Johns River in northern Florida and in the Gulf of Mexico from western Florida to Louisiana. From Delaware southward it is commonly known as rock or rockfish. Its adaptability is attested by its successful introduction, in the last quarter of the 19th Century, into waters of San Francisco Bay. (See Raney, 1952, for a general discussion of the life history). It is an important sport fish in that vicinity at present, has spread and is now distributed from southern California to the Columbia River.

On the Atlantic coast, adults are found in salt, brackish and freshwater, but in salt water they are coastwise in distribution and few are known to have been taken more than ten miles from shore. Freshwater groups usually consist of stragglers or of spawning groups which are usually found near the mouths of rivers just above brackish waters. However, in some cases they may move far upstream to spawn and at times may even be found as much as 200 miles from salt water. Occasionally striped bass move upstream through locks into strictly freshwater situations such as the Mohawk River, New York or the Santee-Cooper Reservoir, South Carolina (Stevens, 1957). Striped bass also have been stocked in small freshwater ponds where they may be of local importance as a fishery but where there is, as yet, no evidence of spawning.

Most stocks of striped bass make two types of migration. One is an upstream or anadromous migration into fresh river waters. Probably most of this type of migration takes place in the spring, although it is probable that some schools which have moved upstream to over-winter in the Hudson and elsewhere may remain to spawn. The actual time of the spring migration for spawning purposes may range from early April in Alabama to early July in New Brunswick. On the mid-Atlantic coast spawning occurs mostly in April and May.

Heavy fishing pressure on the spawning grounds does not necessarily result in depletion of stocks since the reproductive potential is high. The Roanoke Rapids near Weldon, North Carolina has been a famous fishing grounds during the striped bass spawning run for many years. After spawning, some adult stripers may remain in the rivers but most apparently drift down to salt water where they are usually the subject of an intense fishery along the shore.

Another type of migration which is by far the most spectacular apparently involves striped bass two years and older that travel in huge schools. This migration which is apparently not associated with spawning activity occurs in the spring. Some of the bass move out of wintering areas, such as Chesapeake and Delaware bays (and to a lesser extent New Jersey and Long Island bays and the Hudson River), and travel northward. These bass are the object of an intense fishery as they hit off southeastern Long Island (Montauk Point), eastern Connecticut, Rhode Island, Massachusetts, New Hampshire and Maine. From tagging studies based first on the very successful 1934 year class it is obvious that most of these migrating striped bass originated in tributaries of Chesapeake Bay, or other southern areas. It is probable, however, that only a small percentage of the total number of Chesapeake Bay striped bass is involved in such migrations. Nevertheless it is obvious that a very successful spawning and survival of young in the Chesapeake Bay area have a pronounced effect on the number of striped bass present at distant northern localities along the coast.

Apparently, no such extensive coastwise migration occurs on the California Coast although recent study indicates a fall migration into the freshwater Sacramento-San Joaquin Delta area where they remain during winter. In the spring they disperse out over the delta and into tributary rivers to spawn, after which they return to San Francisco Bay and adjacent salt and brackish waters for the summer.

On the Atlantic coast, there is a reverse movement in fall, during October and November, as the bass move southward to their overwintering grounds. Although the bulk go to Chesapeake and Delaware bays, some segments break off and winter in southern New Jersey and occasionally even farther north. For example, during January to March, 1938, bass were known in Shinnecock and Moriches bays, Long Island. Apparently some go as far south as Albemarle and Pamlico sounds, North Carolina. The data on the migration of the Chesapeake-Delaware race are from the excellent studies of Merriman (1937 and 1941) and Raney, et al (1954). These migratory routes as well as summer and winter occurrence are shown on maps in Merriman (1952).

Some segment of this southward moving mass of striped bass overwinter in the lower Hudson River, especially in the vicinity of Haverstraw. Studies by Raney, et al (1954), Rathgen and Miller (1957) and Clark (1968) have shown that the Hudson River is an important spawning area for striped bass and the stock of bass produced therein is of importance to the fishery, especially the sport fishery, in and about New York Harbor and in the western end of Long Island Sound. The evidence comes from a study by Raney and de Sylva (1953) of counts of fin rays made on young striped bass from the Hudson and from the Delaware and Chesapeake bays and a knowledge of migration of bass into the Hudson obtained from a study of tag returns. Counts of the number of soft fin rays of the dorsal, anal and pectoral fins of young striped bass, especially for the 1949 and 1953 year classes has shown that is possible to separate a high percentage (70-80) of bass which originated in the Hudson River from those which were reared in the several tributaries of Chesapeake Bay. This pronounced difference in number of fin rays indicates that the Hudson River striped bass do not freely mingle and spawn with the Chesapeake-Delaware segment of the population which on occasion may be present in the Hudson. Limited data on fin ray counts of adult striped bass indicate that the two races come in contact at other times, especially during the spring and fall migrations.

The striped bass has fluctuated considerably in abundance over the years. It is a species that is subject to the so-called "dominant year-class" where an age-group may dominate the population -- and catch -- for several years. For example, the stock in the Chesapeake Bay area was at a very low level in 1934 but due to a combination of favorable factors influencing spawning and survival the 1934 year-class was the largest to be produced in the preceding half century and produced good fishing in 1936 and 1937. A series of good year classes, such as those produced in the Chesapeake region in 1940, '42 and '43 have followed and produced. See Schaefer 1968 for additional information. Thus, a knowledge of successful spawning in Maryland or Virginia in any year may be of great interest to a striped bass fisherman of Montauk Point. Also, the success of a year class in the Hudson River may have an important bearing on the quality of fishing in western Connecticut and northern New Jersey.

SPAWNING GROUNDS IN THE HUDSON

Spawning grounds of the striped bass in the Hudson includes the freshwater section downstream from the Troy Dam, except where pollution is severe.

The number of eggs produced varies with the size of the female; some 14,000 are laid by a three pound female, as many as 250,000 by a five-pounder and nearly 5,000,000 are produced by a fifty pound specimen. Some females reach maturity at four years of age; virtually all are mature at six. Most males are mature at two and all are mature at three.

The eggs are known to be deposited near the surface during the splashing which accompanies the so-called "rock fights" where a single large female may be surrounded by a few or as many as fifty males. The eggs which are spherical, non-adhesive and slightly heavier than fresh water;

During the first summer the young congregate in small schools and feed on freshwater shrimp, insect larvae, small worms, an occasional small fish and similar small organisms. Young may be observed in the Hudson River at such places as Coxsackie and Haverstraw beaches where they seem to prefer sand bottom and some current. The schools numbering usually up to 15 or 20 individuals do not usually mix with other species such as shad, river herring, killifish, or white perch which are often present in the area. That young may be relatively widespread in the Hudson River is known from the work of the Biological Survey which actually took young striped bass at 67 localities during 1936. A survey of young present in the Hudson River made by the author in 1949, 1953 and 1954 indicate a goodly supply from a successful spawning.

In 1954 Edward C. Raney and Associates collected young (in their first summer) from the Hudson River during the period from 20 July to 4 November. These young were seined along shore in order to get sufficient specimens to make counts and measurements for racial studies. No attempt was made to get quantative data. During the period specimens were taken from the stations chosen for ease in collecting from Coxsackie (upstream) to Palisades State Park. Other than these sites young were taken at Middleground Island, Alsen, Mills State Park, Newberg, Denning, Roa Hook, Green Cove, Stony Point, Haverstraw, Harmon, Croton, Nyack and Piermont. Numerous young were taken the same summer by Rathjen and Miller (1957).

The success of spawning and survival will as it is known to do elsewhere vary from year to year and place to place in the summer. No data taken to date have been secured to adequately estimate quantitatively the production of various sections of the river which produce striped bass. These include the data taken for special purposes such as those reported by Rathjen and Miller (1957) which was a general survey of the river for eggs, larvae and young of year and Carlson and McCann (1969) which was to attempt to evaluate the effects of the proposed pumped storage project at Cornwall.

At the end of the first summer the young are from two to five inches in total length. In succeeding years the juveniles still tend to school and gradually switch to a diet of fishes and large invertebrates. Many kinds of fishes are eaten but the silversides, menhaden, killifishes, anchovy, spot and croaker are favorite foods. Apparently the members of schools feed periodically and at about the same time.

The intensive Biological Survey carried out during 1938 showed the streams and bays of Long Island are not important for spawning or as nursery grounds for young striped bass. Indeed, young bass are rarely found there.

The following sections give the results of the major studies on striped bass in reference to New York and serve as confirmation for the generalizations given above.

STUDIES OF THE MIGRATIONS OF THE HUDSON RIVER RACE OF STRIPED BASS

(Raney, Woolcott and Mehring, 1954)

From 1948 to 1952 a total of 9,320 striped bass were tagged along the Atlantic Coast from Massachusetts to Chesapeake Bay. About two-thirds were tagged in the western quarter of Long Island Sound in the vicinity of Greenwich, Connecticut. The fork length of 95% of those tagged was 16 inches or less and was usually 9 to 15 inches.

Some 792 (8.5 per cent of those tagged) were returned, of which 764 had usable data. Of these 92 percent were recovered within a year. Tags were usually returned within 5 to 9 months and only a few were out more than 20 months. The best rate of return came early in the program.

Western Long Island Sound. The tagging results are significant mostly in relation to the stock fished in the western quarter of Long Island Sound during spring, summer, and fall. Fin ray counts of specimens of the 1949 year class obtained from Cos Cob, Connecticut, indicate this stock to be largely of the Hudson race. Several thousand bass were tagged in this area and 555 were recovered; of these 372 (67 percent) were retaken in the Hudson River, mostly in the spring fishery; 156 (28 per cent) were recaptured in the western quarter of Long Island Sound (seldom east of Fairfield, Connecticut, or Northport, Long Island) and only 27 (5 per cent) were recaptured from elsewhere. Of the latter, five were retaken off Connecticut and Rhode Island from the mouth of the Connecticut River and eastward; eight were caught on the eastern and southeastern end of Long Island; six were taken in New Jersey at Great Bay (2), Toms River (1), Maurice River (1), Barnegat Bay (1) and Mullica River (1); and four were taken in both Delaware Bay and Chesapeake Bay.

More tags were recovered of those attached in 1950 than for any other single year. Of those tagged at Greenwich, Connecticut, and nearby localities such as Cos Cob, 234 were recovered. For those for which precise date of tagging is available the data are as follows: May (8), June (14), July (53), August (59), September (58) and October (16). Of the 234 recovered 76.3 per cent were taken in the Hudson River drainage. Most of these (164 bass) were captured in the Hudson River during the spring fishery in April and May. Eight per cent were recaptured at Greenwich or Cos Cob within several miles of the place where they were tagged, the same summer or fall (8 specimens), the following summer and winter (9 specimens) or the summer of 1952 (2 specimens). By-month recoveries were May (4), June (2), July (6), August (1), September (3), October (2) and January (1). An additional 7.2 per cent were captured in the western quarter of Long Island Sound in nearby areas. These were captured in April (1), June (1), July (4), August (7), September (3), and October (1), and except for one recaptured in 1952 were about evenly divided between 1950 and 1951. This indicates a summer population which does not move far from the western quarter of Long Island Sound. These presumably are joined from time to time and in varying, but usually small numbers, of Chesapeake stock which find their way westward in the Sound rather than following the usual migratory path northward to Massachusetts. This assumption is based on the results of tagging in 1950 which show that only 3 per cent migrated as far as Delaware and Chesapeake Bays and only 1.6 per cent were recovered as far away as eastern Long Island and New Jersey.

The 146 returns from those tagged at Greenwich and Cos Cob, Connecticut, in 1951 gave a similar picture but with fewer returns from the south; the Hudson River produced 68 per cent, mostly during the spring following tagging. From the locality of tagging (Greenwich) 18 per cent were recaptured and 12 per cent retaken in nearby areas in the western quarter of Long Island Sound. Only 2 per cent were taken as far as western Connecticut and New Jersey.

Six bass 9 to 10 inches long tagged at Greenwich, Connecticut, on August 25 and September 6-10, 1952, were recaptured nearby below the Cos Cob, Connecticut, power dam on January 20, 1953. Fishermen with a thorough knowledge of local conditions report that for the past 20 years bass have been taken from time to time in the winter in the power plant plume.

Bass tagged at other localities in the western quarter of Long Island Sound also show the same general pattern of movement, the vast majority being captured in the Hudson River or at areas close to the point where tagged.

Hudson River and New York bays. At the Narrows which separate Lower from Upper New York Bay numerous bass were tagged, mostly from September 9 to November 18 in 1950 and 1951; 92 were recovered. During the following two spring seasons and in the fall of 1952, 89 (96.7 per cent of those recovered) were recaptured in the Hudson River and its tributary, the Hackensack River. Most recoveries were made in the spring; 43 in 1951 and 31 in 1952 compared with fall recaptures of 12 in 1951 and none in 1952. All recoveries were made during the first spring or in the fall one year after they were tagged which apparently is due to a lack of permanency of the tags rather than an indication of the natural mortality of the stock. Virtually all tags were returned from the fishermen engaged in the spring shad fishing, without whose fine cooperation little data would have accumulated. However, it is known that many tags were recovered and not made available. The sparsity of returns from sport anglers seems to indicate a paucity of the latter in the geographic area of concern rather than a shortage of striped bass.

One striped bass tagged in April, 1952, was recovered later that spring in the Hudson River at Edgewater, New Jersey. Two others tagged at the Narrows on July 5 and 6, 1952, were recaptured between Palisades and Hastings-on-Hudson in the spring of 1953. Three specimens (3.3 per cent of those recovered) were taken elsewhere and were recaptured in New Jersey within 50 miles of The Narrows where they were tagged. One tagged October 29, 1950, was recaptured in the river at Highlands, New Jersey, near the Highland River bridge on April 3, 1951; another marked November 10, 1951, was taken on February 6, 1952, in Shark River, New Jersey; the third was tagged November 18, 1950, and was taken in the Toms River area during the week of February 10, 1952.

The same type of upstream movement of striped bass was noted from 34 recaptures in the Hudson River originally tagged in 1948 (6 specimens), 1950 (12 specimens), and 1951 (16 specimens) in Upper New York Bay. Five of these were first tagged during the period July 3 to August 22 and the remainder were marked from September 17 to November 17. All 34 recaptures were from the Hudson and 29 were made in the spring during the period March to June; five were taken in the period September to December. With five recoveries no more precise data on locality of recapture are available than Hudson River. The other 29 recoveries were as follows: Peekskill (1), Stony Point (5), Ossining (1), Nyack (7), Piermont (6), between Palisades and Hastings-on-Hudson (5), mouth of Harlem River (1), and Edgewater (3). Five recoveries were made during the same fall in which they were originally tagged which gives further evidence of a movement upstream into the Hudson River, perhaps for overwintering purposes.

Another series of striped bass was originally tagged at Gravesend Bay and Hoffman Island (Lower New York Bay). Five were recaptured in the Hudson River during October and November, 1951. One marked at Hoffman Island on October 14 was retaken at Stony Point on November 11, 1951. Single specimens were recovered in May to June from Hyde Park, Verplanck, Alpine, and Hackensack River.

A summary of 133 recoveries of striped bass originally tagged in Lower New York Bay, the Narrows and Upper New York Bay reveals that all but three (2.3 per cent) were retaken in the Hudson River upstream from the point of tagging. Only two (recaptured at Toms River and Shark River, New Jersey) actually moved any considerable distance outside the area since the third was recaptured at Highland, New Jersey, which is located at the southernmost point of Lower New York Bay.

It is inferred from the above data that there is a large movement up the Hudson River either in the fall of the year or early in the spring. When viewed in the light of our knowledge of the existence of an upstream Hudson River race, this movement seems to be, at least in part, a spawning migration. It also appears that the Hudson River race and a relatively small proportion of the Chesapeake race also winter in the Hudson River. The possibility seems remote that any considerable number which pass downstream through the Narrows go any considerable distance either north or south.

Twelve were recaptured in the Hudson River which originally were tagged in the Hudson in the stretch from 96th Street, New York City, to the Albany-Troy dam. None tagged in the Hudson were recaptured outside the Hudson. The only known upstream migrant was tagged at Englewood, New Jersey, on May 4, 1952, and was recaptured at Piermont, New York, in late May. Three moved downstream; one tagged at the Albany-Troy dam June 2, 1951, was retaken at Stony Point October 29, 1951; a second tagged at Stony Point on September 16, 1951, was recaptured at Upper Nyack, New York, in late October 1951; and a third marked off Haverstraw in September 1951 was taken in October at Upper Nyack. Six striped bass originally tagged off Stony Point in 1951 were recaptured at or close to the area of release. For these, the dates of tagging followed by the date of recovery (in parentheses) are July 26 (August 20), September 16 (October 29), September 30 (October 29), October 3 (October 7), September 19 (September 30), and September 19 (November 11). There is an indication here of a wintering population near Stony Point. This was a well known fact to commercial fishermen who formerly fished the area near Stony Point and Haverstraw in the fall.

Southwestern Long Island. Data on the recaptures of 32 striped bass originally tagged in 1949, '50 and '51 along the southwest shore of Long Island from Coney Island to Jones Beach are available. Tags were originally affixed from April 3 to November 20; two thirds were tagged in the fall after September 1. Six (18.8 per cent) were taken in April, June and November, in the same area where they were tagged. Sixteen (50 per cent) were taken in the Hudson River from Verplanck to Yonkers. Of these, 3 were taken in August and September.

A single specimen tagged at Jones Beach, April 18, 1951, had moved to Port Jefferson on the north shore of Long Island by July 9, 1951. Another tagged on July 21, 1951, in Swift Creek, Freeport, was one of an overwintering group taken at the Cos Cob, Connecticut, power dam on January 20, 1953. One tagged at Far Rockaway May 6, 1951, was recaptured on July 20, 1951, in Great South Bay, Long Island.

Only 6 specimens or 19.3 per cent of all recaptures were recovered any considerable distance from the release area. One tagged at Jones Beach, April 28, 1951, was found at Westport, Massachusetts, on June 12, 1951. Two tagged on September 30, 1949, and October 22, 1950, were retaken at New Jersey at Avon-by-the-Sea on November 24, 1949, and at Shark River on July 20, 1951. Two tagged on November 1, 1950, and July 10, 1951, were recaptured in Delaware at Indian River Inlet on December 6, 1951, and near Makon on January 10, 1951. Another tagged on August 28, 1950, was retaken on March 1, 1951, at Swan Point, Chesapeake Bay.

Although these data on migration are sparse they are in line with findings regarding the existence of two races which seasonally mingle in the Coney Island to Jones Beach area. Some are apparently of the Hudson River stock and relatively fewer are of the Chesapeake-Delaware type, the migratory path of which was worked out by Merriman (1941).

New Jersey. Of the bass originally tagged in the fall (September 17 to November 30, 1950, '51 and '53) along the northeast New Jersey coast from Sandy Hook to Manasquan, 15 were subsequently recovered to the southward either in known overwintering areas such as Toms River, Barnegat Bay or Great Bay or had moved southward to Delaware Bay (3 specimens) or Chesapeake Bay (4 specimens).

Six bass 14 to 16 inches long of a group originally tagged in northeast New Jersey (Asbury Park, 5 specimens, and mouth of Shark River, 1 specimen) during the period October 26-November 25, 1948 and 1950, were recaptured the following spring in the Hudson River from the area between Nyack and Piermont, New York. These may have overwintered in the Hudson River or have been part of a breeding migration.

Four were also tagged and recovered in summer (July 11-August 12, 1951) along the northeast coast of New Jersey. Those tagged at Deal (1 specimen) and Bradley Beach were recovered later that summer or early fall (August 6 to September 15, 1951) at nearby Asbury Park, Elberon, and Shark River. Another specimen tagged at Barnegat Jetty in late August, 1950, was recaptured at a short distance to the northward, Bay Head Canal, October 19, 1950. The inference from the small sample is that a proportion of New Jersey stripers remain in the same or a nearby area through the summer.

Delaware Bay. Ten returns are available from striped bass 9 to 12 inches long tagged originally in Delaware Bay, at Salem Cove, Salem, New Jersey. Six tagged from September 6 through November 1, 1950, 1951 and 1952 were recovered from Delaware Bay during the period January 14 to March 18. The captures occurred the winter or early spring following the release in each case. The returns were from Delaware Bay off the region between Little Creek and Bowers, Delaware, and were probably taken in the short winter fishery which has long been known in Delaware Bay. Three returns originally tagged at Salem were from the Chesapeake Bay. One tagged at Salem Cove June 4, 1951, was recaptured on October 14, 1951, in upper Elk River, which is near the western end of the Chesapeake and Delaware Canal. Another return from Millers

Island in upper Chesapeake Bay recaptured on April 1, 1952 (originally tagged Salem Cove, October 27, 1951) also might have used the Canal. The third return first tagged at Salem Cove September 17, 1951, was recaptured in Chesapeake Bay off Matapeake on February 10, 1952.

Chesapeake Bay. Twenty recoveries in Chesapeake Bay and tributaries of stripers mostly 8 to 10 inches long marked in the spring (3), summer (3) and fall (14), 1949, were all made from within Chesapeake Bay or one of its tributaries and none marked in Chesapeake Bay were recovered from outside the Bay.

Massachusetts. Five recoveries of bass originally tagged in Massachusetts (September 18 to October 13) were all made south of the area and although the data are sparse, confirm the previous findings of Merriman (1941). Recoveries were made in Delaware Bay (January 25); Toms River, New Jersey (February 10); East Hampton (November 2) and Patchogue (November 12), Long Island; and one tag was recovered from the fish market, Stamford, Connecticut.

Two other Massachusetts returns are available. One 21-inch specimen tagged at Plum Island River, Newburyport, Massachusetts, on May 23, 1952, was retaken in the Merrimac River on June 16, 1952. Another 14-inch specimen, tagged on May 6, 1951, at Wareham, Massachusetts, was retaken on March 30, 1952, at Salt Pond, Rhode Island.

CONCLUSIONS AND SUMMARY OF THE 1954 STUDY

The presence of one race, such as the Hudson race, located in the center of the migratory range of another race such as the Chesapeake, with a segment of the latter regularly migrating north to Rhode Island, Massachusetts, and perhaps farther, requires explanation. A study of tag returns indicates that in the late spring the Hudson race, or a portion thereof, regularly moves to the western end of Long Island Sound. This Hudson stock seldom goes eastward beyond Fairport, Connecticut, or Northport, Long Island. Some also migrate out of the mouth of the Hudson River but do not often go farther east along the south shore of Long Island than Jones Beach. In the fall there is a reverse movement into the Hudson River where the striped bass is found in numbers as far upstream as Stony Point. <u>Actually it is this latter or upstream migration which is proven beyond doubt by tag returns</u>.

Merriman (1937 and 1941) showed that striped bass of the Chesapeake race apparently migrate independently and strike off the New Jersey shore, the south and southeast shore of Long Island where concentrations are known at points such as Montauk. From there they move almost directly north to such well-known bass areas as Niantic River, Point Judith, Rhode Island, and northward. During the fall southern migration, it seems that a relatively <u>few individuals of the Chesapeake race get into the western end of Long Island Sound and a few enter the mouth of the Hudson River</u>. Most make their way southward to the New Jersey coast and the Delaware and Chesapeake Bays.

In the present study the returns from bass tagged in Massachusetts generally confirm the findings of Merriman (1941) of a southward coastwise migration in the fall.

Racial studies using fin ray counts confirm previous findings, Raney and de Sylva (1953), of an upstream race which is found in the Hudson at Haverstraw and northward. The lower Hudson, south of Haverstraw, has a population of young which at least in some years are derived from Chesapeake stock or bass with similar characters. It seems improbable that the upstream stocks in the Hudson River are a result of modification due to different external physical conditions. On the basis of the character index the Hudson race is separated 70 per cent from the Chesapeake race. The dorsal fin count gives the best separation of any single character; the count is 11 more often than 12 in the Hudson race and the reverse in the Chesapeake race.

STRIPED BASS OF GREAT SOUTH BAY LONG ISLAND

(Alperin, 1966 a and b)

This paper summarizes years of experience by Alperin with the striped bass on the south shore of Long Island. In his paper he reports that 1,917 fish were seined and tagged in Great South Bay from 1956 to 1961, mostly during May and June of 1960 and 1961. They were predominantly ages II, III and IV, and few year classes were represented. None were young-of-the-year. Of 281 recoveries, 63.0 per cent were from New York, 11.0 per cent were from New England and 26.0 per cent from areas south of New York. In New York, more came from eastern than from western Long Island waters, and only 2.1 percent were recovered from the Hudson River. Evidence is presented indicating that the irregular presence of large numbers of striped bass in Great South Bay is related to the appearance of fish from dominant year classes originating outside the State, probably in the Delaware Bay-Chesapeake Bay region. When emigration from the south does not occur to any extent, the principal source of the bay stock may be striped bass of Hudson River origin. The data indicate that striped bass are present in Great South Bay primarily during May and June. On such occasions, small fish predominate and, at time, about half may have reached legal size of 16 inches. In all years between 1954 and 1963 the reported yearly commercial catch of the striped bass varied from 350 to 9,334 pounds.

The geographic distribution of the recovered striped bass is shown in the following table.

SEASONAL AND GEOGRAPHIC DISTRIBUTION OF RECOVERIES (281) OF STRIPED BASS TAGGED IN GREAT SOUTH BAY (from Alperin, 1966)

	Season				
Recovery Location	Winter	Spring	Summer	Fall	Total
Tagged in 1956					
New York:					
Long Island			4	1	5
Hudson River		1			1
Total		1	4	1	6
Tagged in 1959 (Number tagged 34)					
Maine		1			1
Massachusetts			1		1
Rhode Island		1	1		2
New York:					
Long Island		7	10	1	18
Hudson River	1	2		1	4
New Jersey	1			2	3
Total	2	11	12	4	29
Tagged in 1960 (Number tagged 69)					
Massachusetts		1	3	2	6
Rhode Island		4			4
Connecticut			1		1
New York:					
Long Island		40	18	9	69**
Hudson River*		3		1	4
New Jersey	5	10	3	2	20
Delaware		1			1
Maryland	3			1	4
Virginia				1	1
Total	8	59	25	16	110**
Tagged in 1961 (Number tagged 1,814)					
Maine		1	1		2
Massachusetts		2		1	3
Rhode Island		3	2	2	7
Connecticut			4		4
New York:					
Long Island		22	25	24	71
Hudson River*		1	2	2	5
New Jersey	14	15	1	7	37
Delaware		3			3
Maryland		2			2
Virginia	2				2
Total	16	49	35	36	136

* Includes all New York Harbor, Jamaica Bay and western Long Island Sound.
**The season taken was unknown for two records from Long Island.

ORIGINS

The origins of the striped bass that frequent Great South Bay are not readily descernible from the information collected during Alperin's investigation. Returns from the fish tagged in 1960 and 1961 do not, however, suggest a Hudson River origin, although this river contains the nearest important spawning grounds. Of the 149 tag returns from within New York waters, only three (2.0 per cent) came from the main body of the Hudson. Even when all adjacent areas were included (i.e., Jamaica Bay, Upper and Lower New York Bays, Staten Island and western Long Island Sound) the returns totalled only 11 (7.4 per cent). In contrast, much higher rates of recovery in the Hudson River resulted from the small samples tagged in 1956 and 1959. Of the six returns for fish tagged in 1956, all in New York waters, one (16.6 per cent) was taken in the lower Hudson River in 1958. For the fish tagged in 1959, recoveries from the Hudson River totalled four (18.1 per cent) of the 22 from State waters.

These meager data (summarized in following table) may indicate that the fish marked in 1956 and 1959 may have originated in the Hudson River. Those marked in 1960 and 1961, which appeared in great numbers, probably originated elsewhere. In the years when migrants from the south are not abundant in Great South Bay, fish of Hudson River origin may be the principal (albeit meager) source of supply. Raney *et al*, (1954), after examining 792 tag returns from 9,320 striped bass marked in the years 1948 through 1952, concluded that Hudson River stock did "not often go further east along the south shore of Long Island than Jones Beach". However, since the fishing for striped bass in Great South Bay *was negligible*, tag returns

RELATION OF RETURNS FROM HUDSON RIVER TO TOTAL RETURNS FROM NEW YORK FOR STRIPED BASS TAGGED IN GREAT SOUTH BAY

			Returns from New York	
				From Hudson River
Year	Number tagged	Total returns	Total	Number
1956	34	6	6	1
1959	69	29	22	4
1960-1961	1,814	246	149	3
1960-1961	1,814	246	149	11*

*Includes all New York Harbor, Jamaica Bay and western Long Island Sound.

were unlikely. During the Alperin study considerable numbers of striped bass from Great South Bay were captured, either in the year of tagging or subsequent years, in the bay area behind the barrier beach on which Jones Beach State Park is located (causeway area) which is a 3-mile-wide sector of bay channels and salt marsh islands bounded by two long causeways and their supporting bridges which connect the mainland of Long Island to Jones Beach. It lies 20 to 25 miles west of the tagging sites in Great South Bay. It may be speculative (says Alperin) to attribute to Hudson River origins that portion of the striped bass population of Great South Bay that moved westward to the causeway area, but such a separation of stock of mixed origin is entirely possible.

All available tagging records for the Hudson River were reviewed by Alperin. There was <u>no evidence that the river stock reaches the south shore of Long Island to any appreciable extent, except in the vicinity of New York City</u>. Neville (1940) reported that a few striped bass tagged off South Nyack were recovered near the George Washington Bridge within 4 days after release. Subsequent returns from the 200 bass tagged that year (1940) <u>did not include any recoveries from outside the Hudson River or its downstream New York Harbor terminus</u>. These and other data for the 504 striped bass tagged in the Hudson River in the years between 1940 and 1956 are summarized in the following table. The number tagged in any one year was small, and the tagging was sporadic. Also, most of the fish were sub-legal (less than 12 inches) in size at the time of tagging. It is well established that small striped bass, particularly those less than 2 years old, are relatively non-migratory. Vladykov and Wallace (1938, 1952), Merriman (1941), Raney (1952, 1957), Mansueti (1961), and Massmann and Pacheo (1961) have all commented on the non-migratory behavior of small

SUMMARY (BY ALPERIN, 1966) OF RECORDS FOR STRIPED BASS TAGGED IN THE HUDSON RIVER, 1940-1956

Year	Season and location	Fish Tagged*&					Recoveries	
		Size (inches)			Legal Size			
		Number	Range	Mean	Number	Per Cent	Number	Per Cent
1940	April 9-17	200	7-16				72/	36.0
	South Nyack	(100)						
	Piermont	(100)						
1942	July 22	20	5-12		0	0	0	0.0
	Haverstraw	(20)						
Sub-total		220	5-16				72	32.7
1954	June 11 - November 1	108	6-20	8.6	1	0.9	0	0.0
	Stockport	(96)						
	Croton	(10)						
	Coxsackie	(1)						
	Newburg	(1)						
1955	March 1 - September 21	28	5.75-29	15.1	12	42.9	1‡	3.6
	Croton	(15)						
	Stockport	(7)						
	Mill State Park	(6)						
1956	April 26 - October 23	148	8-37	15.9	44	29.7	9#	6.1
	Croton	(148)						
Sub-Total		248	5.75-37		57	20.1	10	4.0
Total		504	5-37				82	16.2

* In 1940, 1954 and 1956 the fish tagged were taken by seining; in 1942 by angling; in 1955 by trap netting.

& Of the fish marked in 1954, 45 were tagged with Petersen disc tage, 57 with jaw tags and 6 were doubled tagged; the figures were 20, 4 and 4, respectively, in 1955; and 136, 12 and 0 in 1956.

/ From Hudson River, one or two south to New York Harbor.

‡ From Hudson River at Englewood (N.J.) boat basin.

\# From Hudson River (7), New York Harbor (1) and Jamaica Bay (1).

striped bass and their tendency to remain in or near restricted river systems. The latter two investigators reported that as high as 98 per cent of recaptures were within the river system in which they were tagged. Of 82 returns (16.2 per cent) from the 504 tagged bass, none came from beyond New York Harbor and adjacent Jamaica Bay.

In an earlier report, Raney et al (1954) analyzed returns from angler-tagged striped bass and reported that none of those released in the Hudson River was recaptured outside its waters. Further, of 133 recoveries of bass tagged at the Narrows and in Upper and Lower New York Bays, all but three (2.3 per cent) were from the Hudson River. These were small fish (but not young-of-the-year). Some 95 per cent were 16 inches or less in length, and most were between 9 and 15 inches. Alperin suggests that further work with substantial numbers of mature fish will be required to describe the range, migrations and population dynamics of striped bass that frequent the Hudson River.

If, however, most of the striped bass in Great South Bay did not originate from Hudson River stock, what was their probable origin? The relative paucity of returns from Chesapeake Bay, the center of striped bass abundance on the East Coast, and the only slightly greater number from Delaware Bay make it difficult to assign these areas as points of origin. Vladykov and Wallace (1938, 1952) showed that only very small numbers of striped bass tagged in Chesapeake Bay were recaptured outside the bay. Only 28 (1.5 per cent) of 1,869 fish tagged in the Middle Chesapeake area were recaptured along the Atlantic Coast north of Chesapeake Bay. They believed that this low recapture rate was partially due to the intensive fisheries which reduced the number of tagged fish before they started to leave Chesapeake Bay, and they estimated that migrants amounted to about 30 fish out of 1,000. Nevertheless, Tiller (1950) presented evidence that striped bass of the dominant 1940 year class, taken at Montauk and Great South Bay in 1942, were of Chesapeake Bay origin. He based his conclusions on an analysis of growth, comparing body lengths and calculated lengths at age 1 of fish from two locations in Chesapeake Bay with those of the northern specimens. Recent studies involving numbers of striped bass tagged at several different locations in Chesapeake Bay have contributed little to our knowledge of coastwise migrants. Mansueti (1961) reported that less than 1 per cent of 418 tag returns, from 1,103 striped bass released in Maryland's portion of Chesapeake Bay and its tributaries, were recovered outside the bay. Massmann and Pacheco (1961) found a somewhat higher proportion (4.2 per cent) of recoveries outside the bay from fish tagged in Virginia's Chesapeake Bay tributaries. On the other hand, if only large striped bass (6 pounds or heavier) are considered, Chapoton and Sykes (1961) reported that 14 of 27 recaptures, from 206 fish tagged in Chesapeake Bay, were taken along the coast north of the bay. It is probably true, as Mansueti (1961) has stated, that "tagging studies up to now have not yet shown the true relationship between the available population and the migratory segment".

Even less is known about the migratory behavioral patterns of the Delaware Bay populations of striped bass. The species is known to spawn in the Delaware and Maurice Rivers. A number of authors, including Raney and deSylva (1953), Lewis (1957), Lund (1957), Murawski (1958) and deSylva (1961), have made meristic and morphometric studies of Delaware Bay fish and have concluded that these striped bass are a separate population. But the size of the population and its contribution to striped bass stocks elsewhere on the Atlantic coast are unknown. Maltezos (1960) concluded, on the basis of meristic counts, that part of the population of striped bass of the Connecticut and Niantic Rivers was derived from Delaware Bay stock. Some fish tagged in Connecticut were recovered along the south shore of Long Island as well as southward to Delaware and Chesapeake Bays.

The following explanation is offered by Alperin as an hypothesis to explain why additional returns were not received from Chesapeake Bay, the probable source of the majority of the striped bass of Great South Bay. Most of the bass in Great South Bay were small. Their length-frequency distribution shows that at least 70 per cent were less than 17 inches (432 millimeters) in fork length and almost 80 per cent were less than 18 inches (457 millimeters). If they were also predominantly females, most would have been immature. Merriman (1941) found that about 25 per cent of the female striped bass he examined from Connecticut waters first spawned just as they were becoming 4 years old (mean length 17.7 inches), that about 75 per cent were mature as they reached 5 years of age (20.9 inches) and that 95 per cent had attained maturity by the time they were 6 years old (24.0 inches). Vladykov and Wallace (1952) reported that no female less than 17 inches long was mature among their Chesapeake Bay collections, and only 25 per cent between 17 and 18 inches had reached maturity. Two reports are available on the sex ratio of striped bass in the vicinity of New York. Merriman (1941) determined that only 9.7 per cent of 676 specimens from Long Island and southern New England were males, and Alperin (1965) found 14.2 per cent to be males among

775 collected along the outer beaches of Long Island. Therefore, since most of the striped bass in Great South Bay were less than 17 inches long, and assuming that they were preponderantly females, this population could be described as basically immature. These fish, then, would not necessarily be involved in spawning runs in the spring after tagging and perhaps not for several years. In the intervening time many would be recaptured, some would lose their tags, and a large percentage (estimated by Sykes et al (1961) to be as high or higher than known fishing mortality rates of 40 to 45 per cent per year) would die before they could return to their "home" grounds in tributaries of Chesapeake Bay.

This idea was advanced by Merriman (1941) to account for the spring coastal migration of striped bass. He correlated it with size (age) and sexual maturity and commented on the appearance of a vanguard of immature females in April and May followed by postspawning mature females. Merriman presented several kinds of evidence to support his contention that the myriad small bass present on the coast north of Chesapeake Bay in 1936 and 1937 were derived from the dominant 1934 year class which originated in Chesapeake Bay. The data of Chapoton and Sykes (1961) on the recapture of large post-spawning striped bass along the mid-Atlantic and New England coasts lends support to the latter part of Merriman's supposition.

SEASONAL DISTRIBUTION

The seasonal distribution of striped bass in Great South Bay is quite compatable with that described for the Northeast by other authors (Merriman, 1941; Raney, 1952; Raney et al, 1954). Striped bass are known to winter, at times in numbers, from Long Island north to Massachusetts. Most of the records, however, of wintering fish in New York refer to the Hudson River and the bays along the north shore of Long Island (Neville et al, 1939; Neville, 1940; Raney, 1952), but commercial catches have been made in midwinter in the south shore bays as well. There are very local wintertime recreational fisheries in both north and south shore bays, and at least one operates within the area where tagging was done in Great South Bay. Nevertheless, there is little evidence that the tagged fish wintered north of New Jersey. There was but one winter record from the Hudson River and most of the others were from New Jersey, the greatest number were from Barnegat Inlet south to Delaware Bay. Other wintering fish were recovered in Maryland and Virginia, but the number was small.

Most of the spring records were from New Jersey and Long Island, the fish moving progressively northward with the season, and there was evidence of early migration into New England waters (as far north as central coastal Maine) during this period. With the advent of summer, returns were concentrated at Long Island with a number of recaptures from New England, again including Maine. At this season, records from south of New York were neglible - a few from New Jersey and none from the Delaware or Chesapeake Bay areas. During the fall the tagged fish exhibited a broad coastal distribution, with evident movement from north to south as the season progressed. Most of the records were from Long Island waters and along the New Jersey coast but the total area involved extended from Massachusetts to Virginia.

This distributional pattern was repeated in each year in which recoveries were made, and, although the numbers taken at either end of the range were few, it is evident that the coastal movement was similar to that described for striped bass tagged in Connecticut and eastern Long Island by Merriman (1941) and others. Without citing the individual recoveries, it is possible to outline the seasonal distribution and migration. In the winter (December 22-March 21) the fish were present from Barnegat Inlet (New Jersey) to Chesapeake Bay. In the spring (March 22-June 21) they moved northward to northern New Jersey, Long Island (but not into Long Island Sound) and New England. They summered principally in Long Island and New England waters. In the fall (September 23-December 21) they were found from Massachusetts to as far south as Virginia, but most of those recaptured were taken in Long Island and northern New Jersey waters. As winter approached the fish were again found mainly along the coast from central and southern New Jersey. A few were taken in the Hudson River (one record in winter, five in spring and one in fall).

DISPERSAL FROM GREAT SOUTH BAY

The movements of striped bass tagged in Great South Bay, during the period immediately after tagging, appear to have been random. There were many instances of dispersal over a wide geographic area of fish that had originally been taken from a single school or, at least, at the same time.

For example, a successful haul at Hyde's Canal at West Islip on May 11, 1960 resulted in the tagging of 362 striped bass, 22 of which were recaptured during 1960. In the same month in which they were tagged, recoveries were made as far apart as Sakonnet Point (Rhode Island) and Sandy Hook (New Jersey). Others were taken at this time at several locations in Great South Bay within a few miles of the tagging site and at Amagansett and Napeague to the east and Jones beach and the causeway area to the west of Great South Bay, as well as at Ossining on the lower Hudson River. In June the fish were widely distributed and returns ranged from Narragansett Bay and Charleston in Rhode Island to Barnegat Inlet in New Jersey. In Long Island waters they were taken at various points along the south shore from Montauk Point to Rockaway Inlet.

Similar random dispersal was noted for fish tagged in 1961. Within two months after a group were tagged near Bayport on June 13, recoveries were made at Newburyport (Massachusetts), Narragansett Bay (Rhode Island), Southampton and Moriches Inlet (eastern Long Island), the causeway area and Jamaica Bay (western Long Island), as well as in the vicinity of the tagging site and at Fire Island Inlet.

The generalization can be made concerning this dispersal is that fish tagged in May were more frequently recovered in New England than those tagged in June. More of the latter were recaptured in Long Island waters during the first weeks after tagging. This could be interpreted to mean that the earliest arrivals in Great South Bay have more of a tendency to migrate farther to the eastward and northward.

DISTRIBUTION OF TAG RETURNS FROM NEW YORK WATERS

Since almost all the marine waters of Long Island and souther New York contain striped bass at one season or another, it is pertinent , with respect to the State's striped bass fishery, to correlate the tag returns with the various areas involved. Although the intensity of sport and commercial striped bass fishing pressure for any particular area is largely unmeasured, except for the surf area between Jones and Shinnecock Inlets (Briggs, 1965), some measure of it, as it applies to fish that disperse from Great South Bay, may be found in the distribution of the specimens recovered.

There were 149 recoveries of tagged fish from New York waters. All but one of these were used to plot an east-west distribution related to geographically selected fishing areas known to harbor striped bass. Waters west of the Nassau-Suffolk County boundary, on both the north and south shores of Long Island and including all of New York Harbor, Staten Island and the Hudson River, were designated the western sector. All waters east of this boundary were designated the eastern sector. Although this divided the Marine District unequally, a lack of recoveries between South Oyster Bay and the Captree area of Great South Bay provided a convenient region of separation. Combined tag returns from the commercial and sport fisheries totaled 84 (56.8 per cent) from the eastern sector and 64 (43.2 per cent) from the western sector. Within these broad designations some subareas produced many more returns than others in proportion to the known fishable waters.

Outstanding in the western sector was the causeway area which produced 29 (19.6 per cent) of the returns for the State. This area which is comprised essentially of East Bay and Jones Bay (inside Jones Inlet) is a mere 3 to 3½ square miles in size. Farther west the more extensive area from the western side of Jones Inlet to Jamaica Bay (essentially all of Hempstead Bay) produced 24 (16.2 percent) of the recoveries. This area includes about 21 miles of ocean beachfront for surf and troll fishing and 84 square miles of bay environment. In contrast, the remainder of the sector furnished but 11 (7.4 per cent) of the tag returns although it includes more than 300 square miles of striped bass environment.

In the western sector it appears that the relatively narrow confines of East Bay, where fishing pressure was heavy under the Jones Beach causeway bridges and in the adjacent boat channels (all within 20 to 25 miles of the tagging sites), produced a disproportionately large number of returns from the striped bass that were tagged in Great South Bay in May and June of 1960 and 1961. Whether these fish first entered Great South Bay via Jones Inlet or Fire Island Inlet is unknown. In the former case they may merely have returned, either through the bay complex or along the outer beaches, to a more favorable deep-water environment under the causeway bridges after a brief seasonal exploration of the more shallow expanses of Great South Bay. Some bass, as shown by scattered tag returns and recoveries by project seining, remained in Great South Bay, but either their numbers were not substantial or they were hard to locate. Also, numbers of bass moved westward to the causeway area (and beyond), and some were recaptured there within days after tagging and throughout the ensuing summer and fall. Additional recoveries were made there two or more years later. The causeway area produced 2.4 tag returns per square mile, the area from Point Lookout (Jones Inlet) to Rockaway Point (entrance to Jamaica Bay) 0.3 per square mile, Jamaica Bay 0.1 per square mile, New York Harbor and environs 0.02 per square mile, and the Hudson River and western Long Island Sound 0.05 per linear mile.

No such concentration of recoveries as that at East Bay occurred in the more extensive eastern sector even though it included the tagging areas. From Great South Bay (including the Suffolk County portion of South Oyster Bay) there were 19 (12.8 per cent) scattered returns. An additional 17 recaptures resulted from project seining, mostly within a short period after the tagging but several in subsequent years, bringing the total recovery rate to 24.3 per cent. The rate of return was only 0.1 per square mile from the Suffolk County boundary to Smith Point, representing a total area of about 140 square miles plus an additional 31 miles of barrier beach.

The most easterly section of Long Island is famous for its striped bass fishing both from the beaches and by trolling. It is also most intensively fished by commercial interests and is the center of the surf haul seine fishery. But the area is vast, including about 59 miles of ocean beach frontage and 78 square miles of bay environment from Smith Point to Montauk Point together with an additional 180 square miles of bay involving the Gardiners Bay-Peconic Bays complex. Moriches Inlet, Shinnecock Inlet and the extreme eastern portion of this area are most intensively fished, and, although returns were scattered throughout this region, the eastern end was the most productive. There were 48 (32.4 per cent) of the total tag returns for the State from this area (including one from Fisher's Island about 16 miles farther east). Even though the area has about twice the amount of bay and estuarine environment and of ocean frontage, the recovery rate of 0.2 per square mile was double that for Great South Bay. This area lies directly along the route of all striped bass traveling northward to summer in New England waters, and any fish from Great South Bay must pass through, either by way of the bays or along the outer beaches. In either case, they are subject to intensive fishing pressure. This probably accounts for the fact that on the whole more striped bass were recovered from the eastern than from the western parts of this sector.

CONCLUSIONS (ALPERIN, 1966)

In years when the population of striped bass in Great South Bay is low, a substantial proportion of those present may be of Hudson River origin. But when the species is abundant, it seems probable that most of the fish come from the Delaware Bay-Chesapeake Bay region and represent dominant year classes spawned there. On such occasions, young fish predominate and, at times, about half may have reached legal size. Furthermore, they are present primarily during May and June, after which they disperse widely.

MIGRATION OF STRIPED BASS TAGGED IN THE SURF WATERS OF SOUTH CENTRAL LONG ISLAND

Richard H. Schaefer (1968)

This study was done by Schaefer because of the lack of information concerning the dispersal of striped bass from surf environments and the migration of large fish along the Atlantic coast of the United States. It includes results of three separate projects conducted by the New York Conservation Department over an 11-year period (1954 through 1964). The intent of the work was to augment previous tagging investigations on striped bass in New York (Neville, 1940; Merriman, 1941; Raney et al., 1954; Alperin, 1966) and, further, to complement the research of Chapoton and Sykes (1961).

DESCRIPTION OF TAGGING SITES

Two similar ocean surf localities, both situated on the south shore outer barrier beach of Long Island were used as tagging sites.

Westhampton Beach is located approximately 75 miles east of New York City. It extends for a distance of about 6 miles westward from the vicinity of the village of Westhampton Beach and is separated from the mainland by Moriches Bay. To the south is the open Atlantic.

The other tagging site was located west of Moriches Inlet, along a 7-mile stretch of Great South Beach (commonly known as Fire Island) extending approximately 3.5 miles east and 3.5 miles west of Smith Point County Park. Great South Beach is fully exposed to the open Atlantic to the south and is isolated from the mainland by Great South, Bellport, Narrow and Moriches Bays to the north, and extends from Fire Island Inlet approximately 32 miles eastward to Moriches Inlet.

Westhampton Beach, 1954 to 1956

Between November 9 and 17 in 1954, between October 27 and November 25, 1955, and on May 24, 1956 striped bass were tagged and released in the ocean surf at Westhampton Beach. The fish were obtained from commercial fishermen operating in the area which, at that time, supported an extensive haul seine fishery for striped bass.

Great South Beach, 1961 to 1963

Striped bass were tagged at the Great South Beach site between June 27 and November 30 in 1961, between May 8 and October 25, 1962, and between May 6 and November 22 in 1963. The collecting gear was a modified 1,300 by 12½-foot commercial nylon beach seine.

Tag Returns From Those Tagged From 1954 to 1956

Of the 178 striped bass tagged during these years at Westhampton Beach, 50, or 28.1 per cent, were recaptured. Only 10 per cent of the recovered fish were taken in New England waters, more than 50 per cent were recaptured in New York waters and 34 per cent were taken from waters to the south of New York. Of all fish recovered in New York, more than half came from the Hudson River.

Nearly 70 per cent of the fish were taken by commercial fishing, while the remainder were taken by anglers.

The geographical distribution of these recoveries by season suggest that most striped bass tagged at Westhampton Beach wintered well to the south of New York, especially in the vicinity of Delaware Bay and Chesapeake Bay. Spring recoveries indicated that, of 25 fish recaptured during this season, 18 (72 per cent) were recovered from the Hudson River. Only one spring recovery was made north of New York, while six were made to the south.

Summer recoveries were few, but all (except for one unknown) came from New York and northward, while fall recovery areas extended from New York south to Maryland.

Tag Returns From Those Tagged From 1961 to 1963

Data for the small fish tagged in 1961 were analyzed separately from those for the larger fish tagged during 1961 and the following two years.

Small Fish

A total of 332 striped bass less than 6 pounds in weight or 600 millimeters in fork length was tagged at Great South Beach in 1961. Of these, 33 were recovered, representing a return of 9.9 per cent. Most of the specimens (45.4 per cent) were taken by sport fishing, 36.4 per cent were taken by the commercial fishery and more than 18 per cent were discovered in a dead or dying condition.

Recaptures were made from as far north as Maine and as far south as Virginia. More than 75 per cent of the returns came from New York. However, six of the 25 recoveries from New York were fish that had apparently sustained fatal injuries during tagging. Only two returns (6.1 per cent) were from New England waters, and only six returns (18.1 per cent) came from the area to the south of New York. Four of the latter were from New Jersey.

Although winter and spring recoveries were few (7) and constituted only about 20 per cent of all tag returns, all winter recoveries were from Delaware Bay, while spring recovery locations were distributed from the mouth of Chesapeake Bay northward to the south shore of Long Island. Nearly all summer and fall recoveries, which respectively comprised 33 per cent and 45 per cent of all tag returns, were made at various locations along the south shore of Long Island. Ten of 11 summer returns and 13 of 15 fall returns came from New York; the others were from Maine, Massachusetts and New Jersey. No tagged fish were recaptured from the Hudson River.

Large Fish

A total of 580 striped bass 6 pounds or more in weight or 600 millimeters or more in fork length were tagged at Great South Beach during this period: 75 in 1961, 134 in 1962 and 371 in 1963. Of these, 67 specimens (11.6 per cent) were recaptured. More than 60 per cent of the recaptured fish were taken by sport fishing. The remainder were taken by the commercial fishery (29.8 per cent) or were found dead or dying (7.5 per cent).

Returns from 1961 to 1963 came from Maine to Virginia, but most recoveries (52.2 per cent) were made in New York waters. With the exception of one from the Hudson River, all returns from New York represented fish taken along the south shore of Long Island. Of all those recaptured, 14 (20.9 per cent) were taken from New England waters, of which seven were from Massachusetts and four from Rhode Island. A total of 18 returns (26.9 per cent) were received from areas south of New York. Of these, 11 (16.4 per cent) were from New Jersey.

Only seven recoveries (10.4 per cent) were made during the winter. All of these were from waters to the south of New York. Four were from the ocean off New Jersey. Spring recoveries totaled 19 and constituted approximately 28 per cent of all returns, were reported from Chesapeake Bay in Virginia to Cape Cod in Massachusetts. Most of the large fish recaptured (28 or 41.8 per cent) were taken during the summer, and most of these (19) came from the south shore of Long Island. With the exception of one from Maryland, summer tag returns were from the area from New York northward to Maine. There were 13 tag returns (19.4 per cent) during the fall; 11 from Long Island and 2 from New Jersey.

Year Class Dominance and Origin of the 1958 and 1961 Year Classes

The monthly and annual age-frequency distributions of all specimens collected at Great South Beach from 1961 to 1963 reveal that the striped bass population was dominated at the time by fish from the 1958 and 1961 year classes. More than half the fish recorded in 1962 were 4 year olds, while 2-year-old and 5-year-old specimens together constituted nearly 75 per cent of the catch in 1963. Because all specimens captured in July of 1961 and all but a few collected in August of the same year were tagged, the age-composition data for these fish are also representative of the total catches during those months; these data indicate that nearly 50 per cent of the July catch and 85 per cent of the August catch were comprised of 3-year-old fish.

Raney (1952), in his review of the life history of the striped bass, noted that this fish is one species "subject to the so-called 'dominant year-class' phenomenon" whereby from time to time a large number of offspring are produced and survive from a not necessarily large spawning population. The 1958 year class was a very dominant one, and its influence on the Atlantic coastal population of striped bass has been reported. Shearer et al. (1962), Frisbie and Ritchie (1963) and Mansueti and Hollis (1963), for example, observed a greatly increased catch rate for striped bass in the sport fishery of Chesapeake Bay during 1960 and attributed the "excellent" fishing to the abundance of the dominant 1958 year class. Similarly, Briggs (1962, 1965) also arrived at the same conclusion as an explanation, in part at least, for the increased catch and catch rate for striped bass in several of the sport fisheries along the south shore of Long Island between 1960 and 1963. Moreover, Alperin (1966) suggested it was the 1958 year class which comprised the major portion of striped bass collected and tagged in Great South Bay during 1960 and 1961. While both the latter authors based their assumptions largely on the sizes of fish in the catch, the results of the present study would seem to substantiate them since ages were determined from actual counts of scale annuli.

Because of the obvious importance of the dominant 1958 and, to a lesser degree, 1961 year classes to the striped bass population in Long Island waters, it is of considerable interest to speculate on their origin. It has been demonstrated from past tagging studies (Vladykov and Wallace, 1938, 1952; Chapoton and Sykes, 1961; Mansueti, 1961; Massmann and Pacheco, 1961; Nichols and Miller, 1967) that at least a small percentage of striped bass two years of age and older migrate out of Chesapeake Bay and northward along the Atlantic coast. While small, this percentage led Nichols and Miller to conclude that "the Potomac River is a significant contributor to the striped bass stocks along the northeast Atlantic coast". Moreover, certain investigators (Merriman, 1937, 1941; Vladykov and Wallace, 1938, 1952; Neville et al., 1939; Neville 1940; Wallace and Neville, 1942; Tiller, 1950) have observed the strong influence of dominant year classes on stocks of striped bass in northern waters (primarily New York and southern New England) two and more years following good production of young-of-the-year fish in Chesapeake Bay. Based on the evidence at hand, a similar relationship is indicated for the 1958 and 1961 year classes. Mansueti and Hollis (1963), for example, stated that "exceptionally good striped bass production from spawning was found in 1950, 1954, 1956, 1958, 1961 and 1962" in Chesapeake Bay. This statement, when related to the subsequent observations of Shearer et al. (1962), Frisbie and Ritchie (1963), Briggs (1962, 1965) and Alperin (1966) and the results of the present study, seem to suggest strongly that Chesapeake Bay was the major geographical source of the 1958 and 1961 year classes. Similarly, both Briggs and Alperin concluded that Chesapeake Bay was the most probable major location from which the 1958 year class originated.

Contribution of the Hudson River

The geographical distribution of tag recoveries by season from all fish tagged during the present study suggests an annual migratory pattern highly reminiscent of that already well documented for the Atlantic coast of the United States (Vladykov and Wallace, 1938, 1952; Merriman, 1937, 1941; Wallace and Neville, 1942; Raney, 1952; Raney et al., 1954). A general northward movement in the spring from southern wintering areas and an opposite return movement in the fall are indicated. The data demonstrate that major wintering areas extended from Virginia to New Jersey as evidenced by the fact that 17 of 19 winter tag returns were received from these states. Of the remaining two winter recoveries, one was taken in New York Harbor and the other somewhere offshore in the North Atlantic. More specifically, the data for tag returns reveal that Delaware Bay and the ocean between 1 and 5 miles offshore along the southern New Jersey coast were probably the most "important" wintering grounds, since nine and four, respectively, of the 17 winter recoveries from south of New York came from these localities. Only two winter returns came from Chesapeake Bay.

The extensive distribution (Virginia to Massachusetts) of the tag recoveries made during the spring suggests that some striped bass vacated the southern wintering areas and began a general coastal movement to the north. It is apparent, however, that the northward migration was essentially completed by summer, since only one of a total of 44 tag recoveries during this season occurred to the south (Maryland). Moreover, a general southward migration in the fall can be predicted from the locations of the recoveries made during this season; only one of 39 tagged fish was retaken north (Massachusetts) in the area extending from New York south to Maryland.

While such a general migratory pattern can be inferred from the combined recovery data, obvious dissimilarities are also evident when the data for the individual tagging operations (i.e., 1954-1956 and 1961 small specimens; 1961-1963, large specimens) are considered separately. The number of recoveries from the Hudson River for fish tagged during the 1954-1956 period, for example, is striking when compared with that from the same location for fish tagged between 1961 and 1963. For fish tagged during the earlier period 14 (28.0 per cent) of the 50 recoveries came from the Hudson River, but only one of the 100 recoveries for both small and large fish tagged during the later period came from this river. A t test indicated a highly significant difference (.01 probability level) between the two proportions (t = 100, d.f. = 148). Of the 14 Hudson River returns for fish tagged during the 1954-1956 period, 12 represented spring recoveries of which 11 were taken by commercial gill netting in the Haverstraw-Nyack area and one was caught by a sport fisherman on hook and line in New York Harbor. The other two were caught by hook and line in New York Harbor (one in the early fall, October 7, and the other in late winter, March 6).

Despite the general absence of winter recoveries from the Hudson River for fish tagged at Westhampton Beach between 1954 and 1956, it seems probable from the observations of earlier investigators (Neville, 1940; Vladykov and Wallace, 1952; Raney, 1952; Raney et al., 1954) that the striped bass recaptured in the Hudson River during the spring also overwintered there, in the vicinity of New York Harbor, or in adjacent ocean areas. The paucity of winter recoveries from the Hudson River is not surprising because commercial fishing for striped bass is prohibited in the Hudson River between the southern end of Manhattan Island and the dam at Troy from December 1 to March 15. At the same time, although not prohibited, sport fishing is greatly reduced because of generally cold and inclement weather conditions.

On the basis of two of 31 recoveries outside Chesapeake Bay, Vladykov and Wallace (1952) concluded that the Hudson River might be a wintering ground for some migrants from Chesapeake Bay. Similarly, Raney (1952) suggested that certain groups of the main migratory body of striped bass defect during the southward fall movement and enter coastal estuaries and rivers such as the Hudson where they spend the winter. In a later study concerning the Hudson River stock, Raney et al. (1954) further concluded that striped bass which move out of the Hudson in late spring and summer along both the north and south shores of Long Island, reverse direction in the fall and re-enter the river. This pattern is similar to that hypothesized by Neville (1940).

It is also possible that more of the striped bass of all sizes that were tagged at Great South Beach between 1961 and 1963 overwintered in the Hudson River and may have participated in the spring spawning known to occur there (Curran and Ries, 1937; Greeley, 1937; Neville, 1940; Raney, 1952; Raney et al., 1954, Rathjen and Miller, 1957). Indeed, it seems unlikely that many of these fish would have been captured even if present in the river during winter or spring, because the commercial fishing effort for the species (and the number caught) has declined sharply over the last several years, especially between 1962 and 1965.

It seems less likely that the striped bass recaptured in the Hudson River during the spring may have moved there immediately after an extensive early northward migration from southern wintering grounds (e.g., Chesapeake Bay and Delaware Bay). Merriman (1941), for example, reported that one fish tagged in North Carolina "on November 15, 1937, was caught in New Jersey on January 16, 1938, showing that some fish migrate north before the spring months". Moreover, Vladykov and Wallace (1952) indicated that, of 31 recoveries made from outside Chesapeake Bay for fish tagged there during October of 1936 and 1937 and in Croatan Sound (N.C.) during November of 1937, one specimen was recaptured after only 67 days at liberty (December 18) in New York Harbor near Bayonne, New Jersey. Two additional recoveries were made in New Jersey during the following winter (February 1 and 25) after being free for only 110 and 122 days, while 16 fish were recaptured in coastal areas from Maryland to Massachusetts during the following spring (March 22 to June 14). Nichols and Miller (1967) noted that, of 43 striped bass tagged in the Potomac River during the winter (November through March) and subsequently recovered outside Chesapeake Bay, 26 were recaptured within 117 days from coastal waters as far north as Maine. Of these, one was caught in southern New Jersey (Great Egg Harbor) during March after only 8 days at liberty, and a second was recovered from New York Harbor in April after only 17 days. These latter recoveries suggest some northward movement in winter and early spring.

The results of the present study are similar to those presented by Alperin (1966) for striped bass tagged in Great South Bay between 1956 and 1961. He reported that 16.6 per cent and 18.1 per cent, respectively, of the recoveries for fish tagged during 1956 and 1959 came from the Hudson River, but that only 2.0 per cent of those for fish tagged during 1960 and 1961 came from that location. He suggested that the fish marked in 1956 and 1959 were of more local nature and may have originated in the Hudson River, while those bass marked in 1960 and 1961, which appeared in great numbers, probably originated to the south. In the years when migrants from the south are not abundant in Great South Bay, fish of Hudson River origin may be the principal source of supply. Although it may seem contradictory that both Raney et al. (1954) and Alperin (1966) suggested that striped bass of Hudson River stock seldom go farther east along the south shore of Long Island than Jones Beach, it should be noted that this conclusion is based solely on recovery data from fish tagged in the Hudson River which were mostly specimens of sublegal (less than 16 inches in fork length) size. It has been demonstrated by several investigators (Vladykov and Wallace, 1938, 1952; Merriman, 1941; Raney, 1952, 1957; Mansueti, 1961; Massmann and Pacheco, 1961; Nichols and Miller, 1967) that small striped bass, especially those less than 2 years old, are, for the most part, non-migratory. Thus, the hypothesis of Alperin (1966) concerning the origins of the Great South Bay population seems plausible. It is suggested that a rather sizeable portion of the fish tagged at Westhampton Beach between 1954 and 1956, and possibly some of those tagged at Great South Beach between 1961 and 1963, may have been of Hudson River origin.

Migratory Behavior of Large Fish

While the emphasis of the present study was to describe the migratory behavior of large striped bass tagged in Long Island waters, few differences were noted between the distribution of recoveries for small fish tagged in 1961 and large fish tagged between 1961 and 1963 at Great South Beach. Recaptures for both groups were made from Maine to Virginia, although the percentage from waters outside New York was greater for the large fish. These observations suggest that both size groups, but especially the larger specimens, were highly migratory. Chapoton and Sykes (1961) noted from tag recovery data that large striped bass, which were marked during the winter on the North Carolina coast, were subsequently recaptured in Chesapeake Bay during the spawning season (spring) and north along the Atlantic coast to New England after the spawning season. While no tags were returned from North Carolina for large fish marked during the present study, there is some evidence from winter recoveries in the coastal areas of Delaware, Maryland and Virginia and spring recoveries in Chesapeake Bay that the large specimens tagged at Great South Beach were of essentially the same stock as those marked by Chapoton and Sykes (1961) in North Carolina. The complete migratory cycle suggested by the latter authors for large striped bass along the Atlantic coast, i.e., North Carolina to New England in the spring with a return movement in the fall, seems to be supported by the results of the present investigation.

Because the striped bass is generally considered to be an inhabitant of "inshore" waters, it is of particular interest to note the number of tag returns for large specimens recaptured between 0.5 and 5 miles offshore in the ocean. Eight (11.9 per cent) of the 67 recoveries for large fish were taken there, while only one of the small striped bass tagged at Westhampton Beach between 1954 and 1956 and one of the small individuals tagged at Great South Beach in 1961 were recaptured from this habitat. Tests of these differences in the proportion of tag returns from offshore waters revealed that the number of recoveries for large fish was significantly higher (.01 probability level) than that for small specimens for bass tagged at either Westhampton Beach (t = 40.0, d.f. = 115) or at Great South Beach (t = 46.2, d.f. = 98). From these observations, it would appear that the large striped bass tagged during the present study possessed a greater affinity for the oceanic habitat than the smaller specimens. Moreover, six of the eight oceanic recoveries of large fish were made 1 to 5 miles offshore along the coast of southern New Jersey (Seaside Park to Brigantine) between late November and early February during the years 1962 to 1965, while none was recaptured from the inshore waters of New Jersey during the same time period. This further suggests that the ocean area immediately off the coast of southern New Jersey served as an important wintering ground for large striped bass.

Importance of the Sport Fishery

Raney (1952) reported that, while catch statistics for the commercial fishery were available, there were no reliable figures for catch of striped bass by the sport fishery along the Atlantic coast of the United States. Although the evidence is sketchy, some data are available which suggest that until recently most of the striped bass harvested along the east coast were landed by commercial fishermen. Vladykov and Wallace (1952), for example, reported that, of 24 striped bass tagged in 1936 and 1937 and recovered by known methods outside Chesapeake Bay between 1937 and 1939, only four (16.7 per cent) were taken on hook and line. It is interesting that many of the states in which these recoveries were made have since enacted legislation prohibiting commercial netting of the species and/or establishing a minimum size limit. Moreover, while no specific data are presented, Merriman (1941) indicated that large quantities of striped bass tagged in Connecticut and Long Island waters in the late

1930's were recaptured by pound nets and haul seines. These types of gear, especially those operated in the ocean, have sharply declined in number during recent times apparently for economic reasons.

The data now indicate that sport fishing accounted for a substantially greater percentage of the recoveries for striped bass of all sizes tagged between 1961 and 1963 at Great South Beach than it did for those tagged at Westhampton Beach between 1954 and 1956. While only 32 per cent of the recoveries from fish tagged at Westhampton Beach were harvested by sport fishing, 45 per cent of the small specimens and more than 60 per cent of the large specimens tagged at Great South Beach were taken in this manner. Moreover, Alperin (1966) reported that nearly 65 per cent of the striped bass tagged in Great South Bay between 1956 and 1961 were recovered by sport fishing, while Chapoton and Sykes (1961) indicated that returns for large fish tagged in North Carolina and recovered north of Chesapeake Bay subsequent to the spawning season were taken by sport fishermen. These observations suggest that sport fishing, which has grown enormously in recent years, is rapidly supplanting commercial fishing as the major method of harvesting striped bass along the Atlantic coast north of Chesapeake Bay. This conclusion is further supported by Clark (1960) who estimated that 9,272,000 striped bass having an aggregate weight in excess of 37,000,000 pounds were landed by salt-water sport fishermen during 1960 in that Atlantic coastal region extending from Maine to Cape Hatteras, North Carolina. During the same year, the striped bass landings for the commercial fisheries from Maine to North Carolina was 8,550,000 pounds (Source: Fishery Statistics of the United States, 1960. U. S. Dept. Interior), or approximately one-fourth the estimated sport catch. Moreover, for all of Chesapeake Bay during 1962, Elser (1965) estimated that 9,340,000 pounds (approximately 5,000,000 specimens) were harvested by the sport fishery while, for the same area and year, the commercial fishery landed only 3,910,000 pounds or less than half the sport catch. That sport fishing will have an even greater impact on the harvest of striped bass in the future is suggested by the fact that the number of salt-water anglers on the Atlantic coast has expanded from 3,383,000 in 1960 to 4,178,000 in 1965, an increase of nearly 25 per cent over the 5-year period (Source: National Survey of Hunting and Fishing, 1960. U. S. Dept. Interior).

Since the majority of striped bass tagged during the present investigation were recovered from New York, it is of interest to note the growth of marine sport fishing in this State in recent years and to project this growth into the near future. Based on an average annual rate of increase of 6.7 per cent (Stroud, 1963) and census data compiled by Crossley, S-D Surveys, Inc. (1956), Alperin (1966) estimated that the number of salt-water anglers in New York nearly doubled (from 608,000 to 1,163,000) over the 10-year period between 1955 and 1956. Using the same data to extrapolate further, it is estimated that by 1970 the total number of salt-water anglers in New York will be more than 1,500,000.

CONCLUSION

It would appear that, for the most part, the abundance of striped bass inhabiting the south shore surf areas of Long Island is directly dependent upon the contribution of stocks produced in more southern waters, most probably Chesapeake Bay. Apparently only in years when this contribution is low does the influence of Hudson River stock on the south shore population become evident.

Table 1. Seasonal and geographic distribution of recoveries of striped bass tagged at Westhampton Beach, 1954-1956.

Location	Season				Total	
	Winter	Spring	Summer	Fall	Number	Per cent
North of New York						
North Atlantic	1	-	-	-	1	2.0
Massachusetts	-	1	2	-	3	6.0
Rhode Island	-	-	1	-	1	2.0
Sub-total	1	1	3	-	5	10.0
New York						
Long Island	-	5	1	5	11	22.0
Hudson River*	1	12	-	1	14	28.0
Unknown	-	1	-	1	2	4.0
Sub-total	1	18	1	7	27	54.0
South of New York						
New Jersey	2	4	-	2	8	16.0
Delaware	3	1	-	1	5	10.0
Maryland	1	1	-	1	3	6.0
Virginia	1	-	-	-	1	2.0
Sub-total	7	6	-	4	17	34.0
Unknown	-	-	1	-	1	2.0
Total						
Number	9	25	5	11	50	100.0
Per cent	18.0	50.0	10.0	22.0	100.0	xxx

* Includes all of New York Harbor.

Table 2. Seasonal and geographic distribution of recoveries of large* striped bass tagged at Great South Beach, 1961-1963.

Location	Season				Total	
	Winter	Spring	Summer	Fall	Number	Per cent
North of New York						
Maine	-	-	1	-	1	1.5
Massachusetts	-	4	3	-	7	10.4
Rhode Island	-	1	3	-	4	6.0
Connecticut	-	1	1	-	2	3.0
Sub-total	-	6	8	-	14	20.9
New York						
Long Island	-	4	19	11	34	50.7
Hudson River	-	1	-	-	1	1.5
Sub-total	-	5	19	11	35	52.2
South of New York						
New Jersey	4	5	-	2	11	16.4
Delaware	1	-	-	-	1	1.5
Maryland	1	2	1	-	4	6.0
Virginia	1	1	-	-	2	3.0
Sub-total	7	8	1	2	18	26.9
Total						
Number	7	19	28	13	67	100.0
Per cent	10.4	28.4	41.8	19.4	100.0	xxx

* Fish 6 pounds or 600 millimeters or larger.

SEASONAL MOVEMENTS OF STRIPED BASS CONTINGENTS OF LONG ISLAND SOUND AND THE NEW YORK BIGHT

(John Clark, 1968)

This documents reports on the recovery of striped bass tagged along the northeast Atlantic coast in 1959 to 1963 and gave data on seasonal movements. It confirms and extends the findings reported by Raney, Woolcott and Mehring (1954). He noted that various groups which he called "contingents" occupied the Hudson-West Long Island Sound area, the Hudson Estuary, and the Hudson and nearby Atlantic. He assumes that the above three contingents had their origin in the Hudson River. The origin of what he terms a Long Island Sound contingent was not to him evident. In the light of Raney's, et al, 1954 findings and the lack of spawning in Connecticut and Massachusetts rivers, it is probable that this group is of Hudson origin. He also showed that what he called other contingents of southern or undetermined origin also appeared in the area from spring to fall. This confirmed the findings of Merriman (1941) and Raney, et al (1954).

His findings are discussed with particular reference to the Hudson River. His Hudson River-West Long Island Sound contingent behaves like a section of the Hudson River race which was described by Raney, et al, 1954. It moves from the Western Long Island Sound in fall into the Hudson River where it spawns. It then returns to the Sound by way of the Harlem River, East River or around Manhattan Island and up the East River to the Sound. It does not take the oceanic pathway around Long Island.

What he calls the Hudson Estuary contingent is included in Raney's Hudson River race. This is basically a resident group which moves within the Hudson and some spill out found along the northeastern coast of New Jersey and the southwest area of Jamaica Bay. This is noted by Raney and by Alperin (1966). At times segments of this race may reach eastward on southern Long Island as far as Great South Bay.

Clark's Hudson-Atlantic contingent was also reported by Merriman (1941) and Raney (1952) and Raney, et al (1954) and represents fishes which may or may not have wintered in the Hudson and presumably in the lower Hudson (Haverstraw Bay area) and on some occasions, these fishes of southern origin (Chesapeake or Delaware Bay) may spawn.

Raney, et al (1954) reported as follows: "Several year-classes from the Hudson River suggest that the Hudson race is an upstream form which apparently is limited to the vicinity of Haverstraw and northward, while a quite different stock with fin ray counts similar to the James River population of the Chesapeake Bay race exists in the lower part of the river south of Haverstraw. More detailed studies are necessary to determine the precise status of these sub-races." Such studies were not done. However the over-wintering or other visitation of the lower Hudson by bass of presumed southern origin, as judged from tagging returns and as noted by Merriman (1941), Raney (1952) and Raney, et al (1954), as well as Clark (1968), needs further investigation.

This point is particularly important in regard to the Indian Point plant inasmuch as these are downriver fishes which may contribute substantially to what Clark calls the Hudson-Atlantic contingent.

Clark also recognizes a Long Island Sound contingent. His contingent represents part of Raney, et al (1954) Hudson River race which were found by the latter to occupy the Hudson. As noted by Raney, occasionally a specimen of striped bass from the Chesapeake Bay race is found in the Long Island Sound. These are mostly limited to east or north shore tributaries such as the Connecticut River and Thames. The poor record of returns from the Hudson River may be attributable to lack of fishing in the Hudson River or lack of cooperation by commercial fishermen who, in Raney's experience, are suspicious of the motives of the Long Island League of Saltwater Sportsmen who supported the tagging program reported by Clark. Their obvious concern was that their cooperation might put them out of business within the Hudson River. Clark pointed out (1968: 340) that during the period of his study there was no winter commercial fishing in the Hudson. The gill net fishery for striped bass was closed by law on 30 November and opened again on 15 March. However, fishing normally did not begin until early April when the drift ice was out of the river. Clark succinctly points out "There is little sport fishing for striped bass in the Hudson at any time of the year and it is virtually non-existent in the winter."

MIGRATIONS OF STRIPED BASS TAGGED OR RECOVERED IN THE NEW YORK AREA

from 1967-1971

(Edward C. Raney, 1972)

The American Littoral Society has conducted a tagging program on Atlantic Coast striped bass since 1967. Lists of the recaptured fish have been published in Underwater Naturalist (Vol. 4, No. 2; Vol. 5, No. 2; Vol. 6, No. 1; Vol. 6, No. 2; Vol. 6, No. 3; Vol. 6, No. 4; Vol. 7, No. 1; Vol. 7, No. 2; and Vol. 7, No. 3). An analysis was made of the movement of the 309 fish which were either tagged or recaptured in New York waters and for which complete information was available. The results are in accord with many studies of Atlantic Coast striped bass which have been published since Merriman's (1941) study.

SPATIAL DISTRIBUTION OF STRIPED BASS (Table 2)

1. The 20 fish tagged in New Jersey were recaptured near Staten Island, Brooklyn and Queens, and along the southern shore of Long Island (south Nassau and south Suffolk). Only two were found on the northeastern tip of Long Island, and only two were found in the Hudson River, one in August and one in March. Generally, the fish seemed to migrate northward in the spring. All those tagged in New Jersey in the spring (12 out of a total of 20) were found farther north by the time of their recapture in early summer. Of the eight remaining fish, only one was tagged in July; it was recaptured in the same area that month. The rest were tagged in late summer, August or September. These fish were probably already on their southward migration. Six of these seven fish were recaptured early the following season at more northerly points, probably during the spring migration. Only one fish did not adhere to this pattern. It was tagged in August in Middlesex, New Jersey and was recaptured in November of the same year on the southeastern tip of Long Island.

2. The 33 fish tagged in the vicinity of Staten Island were recaptured as far south as Virginia, Maryland and Delaware and as far north as Massachusetts. They were also recaptured in the Hudson River, in New York Bay and Jamaica Bay and along the southern shore of Long Island. The 7 fish recaptured in Virginia, Maryland and Delaware were recaptured in the winter and early spring. Most (7) of those recaptured in New Jersey were caught in the spring or fall. Only two fish recaptured along the New Jersey coast were caught in mid-summer. Of the 5 fish recaptured in the New York

area and along the southern shore of Long Island, most were caught in the spring or fall. Their occurrence in these areas in the summer was infrequent. Generally, the fish tagged in Staten Island seemed to be of the same migratory stock as those tagged in New Jersey. They move northward in the spring along the southern shore of Long Island towards Massachusetts, skirting Long Island Sound and the north shore of Long Island. Only one fish of the 33 tagged in Staten Island was caught along the Connecticut coast, but it was caught at the most northerly county, New London. Furthermore, not one fish tagged in the vicinity of Staten Island was caught along the northern shore of Long Island.

3. The 22 fish tagged in Brooklyn and Queens (the New York Bay and Jamaica Bay areas) were of the same migratory stock as those mentioned above. They were recaptured from Virginia to Massachusetts, but most were recaptured in the same area in which they were tagged or along the south shore of Long Island. None of these fish were recaptured in Long Island Sound.

4. The fish tagged along the south shore of Nassau and Suffolk Counties were recaptured as far south as North Carolina, Maryland and Delaware. These fish were recaptured in the winter and early spring. The most northerly point of recapture was in the fall near Washington, Rhode Island. Only two of the 17 fish tagged along the south shore of Long Island were recaptured in Long Island Sound. Both of these were recaptured along the Connecticut coast. One had strayed as far west as Fairfield, Connecticut, but the other was caught at the most easterly county, New London.

5. The fish tagged off the northeast and southeast end of Long Island (east of Riverhead) were, again, of the migratory stock which travels up north and down south along the coast. These fish were recaptured from North Carolina and Virginia along the New Jersey coast to Rhode Island. Of the 44 fish tagged in this area only one was caught on the north shore of Long Island in Nassau County.

6. Most of the fish tagged in the western part of Long Island Sound along the north shore of Nassau County and along the Fairfield, Connecticut coast were recaptured in Long Island Sound. Only 17 of the 85 tagged in these areas were caught out of the Sound. One of these was caught as far north as Newport, Rhode Island, but the remaining 16 were caught off Long Island. The fish tagged off New Haven, Connecticut and New London, Connecticut were also recaptured in Long Island Sound.

7. Of the 42 fish tagged along the north shore of Suffolk County, six were part of the migratory stock. Four of these were caught in the southern states, Virginia, Maryland and Delaware; one was caught off Washington, Rhode Island, and one was caught along the New Jersey coast. An additional six were caught along the south shore of Long Island. Most of the fish tagged in north Suffolk County, however, remained in Long Island Sound. The migratory stock apparently mixes occasionally with the Long Island population while along the north Suffolk shore.

8. The 5 fish tagged near the Bronx were all recaptured in the New York areas, in Long Island Sound and along the south shore.

9. The 2 fish tagged off Manhattan were part of the migratory stock which come into New York Bay; one was recaptured near Ocean, New Jersey and the other was recaptured in Maryland.

10. The fish tagged in the Hudson River were generally recaptured near either the western end of Long Island Sound (Fairfield, Connecticut) or in the New York Bay area. Of the 13 fish tagged in the Hudson River, five were recaptured off Fairfield, Connecticut, and one was caught off Nassau County. Four of the remaining fish were caught in the New York Bay area, two off Brooklyn, one off Staten Island, and one off Monmouth, New Jersey. Only two fish were found out of these two general areas; one off the south shore of Suffolk County and one off Plymouth, Massachusetts. One fish was recaptured in the Hudson River.

Of the five fish which were recaptured in the Hudson River, three were tagged off Staten Island and one was tagged off Monmouth, New Jersey. One was tagged as far south as Ocean, New Jersey.

Since 1967, 19 striped bass have been either tagged or recaptured in the Hudson River. Fifteen of these fish were in the Hudson River in the spring, 6 in April and 9 in May. One was caught in the summer (August). Only two fish were caught in the winter (one in February and one in March), and only one was caught in the fall (November).

SEASONAL DISTRIBUTION (Table 4)

1. Striped bass were found in the extreme southern sectors (North Carolina, Virginia, Maryland and Delaware) in the winter, early spring and fall. None were recaptured there in mid-summer.

2. Striped bass occurred in New Jersey from February to December. In the southern areas, as far north as Ocean, New Jersey, they were more generally found in the spring and fall. North of Monmouth, New Jersey, however, they were more abundant in the summer.

3. The striped bass occurring in Richmond, Kings and Queens were found from April to November. They were most abundant in the spring and summer.

4. The striped bass caught in the western end of Long Island Sound (Nassau County and Fairfield, Connecticut) were caught in the spring, summer and early fall.

5. The striped bass caught along the north shore of Suffolk County were most abundant in the spring and fall.

6. Along the south shore of Long Island, south Nassau County and south Suffolk County, striped bass were most abundant in the spring and fall.

7. East of Riverhead, on the northeast arm of Long Island, striped bass were most abundant in the fall but were also found in the spring and summer. On the southeast arm of Long Island, striped bass were found primarily in the fall.

8. The one fish which was tagged along the Westchester County coast was recaptured in Virginia. It therefore seems to be of the migratory stock described above.

9. The two fish tagged in Rhode Island were recaptured off the extreme eastern end and along the south shore of Long Island.

10. Of the six fish tagged in Massachusetts, two were found in Long Island Sound along the north Nassau County shore. The rest were caught at the extreme eastern end and along the south shore of Long Island.

11. The six fish tagged in Maine were part of the migratory stock. They were recaptured along the eastern end of Long Island, along the south shore of Long Island and in Jamaica Bay.

12. The striped bass in the Hudson River were recovered mainly in the early spring.

13. North of Washington, Rhode Island, most of the striped bass were caught in the summer.

The overall trend was for fish to be caught in the late fall, winter and early spring in the southern states; in the summer in the extreme northern states (New England); and in the late spring and early fall in the New York-New Jersey region.

DISCUSSION

The Atlantic Coast migratory stock originating in the southern sectors move north in the spring and south in the fall. They go as far north as Maine. Only four of these fish originated as far south as North Carolina, which confirms Merriman's (1941) contention that areas as far south as North Carolina contribute little to the Atlantic Coast fishery.

The Hudson River contingents described by Clark (1968) were largely confirmed in this study. There was little evidence of an overwintering striped bass population in the Hudson; only one fish was caught there in the winter. This is probably a reflection of the lack of a winter sport or commercial fishery in this area.

The Hudson-Estuary contingent was evidenced in the New York Bay area. The bays off Monmouth, New Jersey and off Richmond, Kings and Queens seemed to support summer populations of striped bass. Many of these were of the Atlantic Coast migratory stock, but many had either been tagged or were recaptured in the same areas or in the Hudson River.

The existence of the Hudson-West Sound contingent was also confirmed. Five of the thirteen fish tagged in the Hudson were recaptured in the Sound.

The Long Island Sound contingent remained fairly stationary, and contrary to Clark's observations, there was little migration along the New England coast. Only one of the 85 fish tagged in this area was caught as far north as Rhode Island.

The existence of a Hudson-Atlantic contingent could neither be proven nor disproven in this study. One of the 13 striped bass tagged in the Hudson River was caught off Plymouth, Massachusetts (Table 5). Whether or not a portion of the Hudson River population is contributed to the Atlantic Coast stock is an important question for further research.

It remains clear that the Hudson River contributes to the fishery of the New York metropolitan area. Striped bass from the Atlantic Coast migratory stock mingle with the Hudson fish in New York Bay and along the northern New Jersey shore. Clark reported that the Atlantic Coast stock also enters the western end of Long Island Sound, but there was no evidence of this in this study. There was some mingling of the two populations off the north shore of Suffolk County.

Table 1. Zones within which striped bass were tagged or recaptured.

Zone #	
1A	North Carolina
1	Virginia
2	Maryland
3	Delaware
4	Cape May, New Jersey
5	Atlantic, New Jersey
6	Burlington, New Jersey
7	Ocean, New Jersey
8	Monmouth, New Jersey
9	Middlesex, New Jersey
10	Union, New Jersey
11	Essex, New Jersey
12	Hudson, New Jersey
13	Bergen, New Jersey
14	Richmond, New York
15	Kings, New York
16	Queens, New York
17N	North Nassau, New York
17S	South Nassau, New York
18N	North Suffolk, New York
18S	South Suffolk, New York
18NE	Northeast Suffolk, New York
18SE	Southeast Suffolk, New York
19	Manhattan, New York
20	Bronx, New York
21	Westchester, New York
22	Rockland, New York
23	Fairfield, Connecticut
24	New Haven, Connecticut
25	Middlesex, Connecticut
26	New London, Connecticut
27	Washington, Rhode Island
28	Kent, Rhode Island
29	Providence, Rhode Island
30	Bristol, Rhode Island
31	Newport, Rhode Island
32	Bristol, Massachusetts
33	Plymouth, Massachusetts
34N	North Barnstable, Massachusetts
34S	South Barnstable, Massachusetts
35	Massachusetts Bay
36	Essex, Massachusetts
37	New Hampshire
38	Maine

Table 2. Sites where striped bass were tagged or recaptured.

TAGGED		RECAPTURED	
May 69	Burlington, New Jersey	South Suffolk	May 69
April 68	Ocean, New Jersey	South Suffolk	June 68
April 68		Southeast Suffolk	August 68
April 69		Northeast Suffolk	May 69
April 69		South Suffolk	May 69
May 70		Richmond, N. Y.	June 70
April 70		South Suffolk	July 71
May 69		Hudson R. (Riverdale)	August 69
June 69		Kings, N. Y.	August 69
June 67	Monmouth, New Jersey	Northeast Suffolk	July 67
Sept. 68		Kings, N. Y.	June 69
Sept. 68		Richmond, N. Y.	May 70
June 69		Queens, N. Y.	August 69
June 70		Southeast Suffolk	Oct. 70
July 71		Monmouth, N. J.	July 71
Aug. 70		Hudson (Rock.)	March 71
Sept. 68		Kings, N. Y.	August 69
Aug. 70		Monmouth, N. J.	Oct. 70
Aug. 69	Middlesex, N. J.	Richmond, N. Y.	May 70
Aug. 70		Southeast Suffolk	Nov. 70
April 67	Richmond, N. Y.	Essex, Massachusetts	July 67
April 68		Northeast Suffolk	June 68
Oct. 68		Southeast Suffolk	Nov. 68
Oct. 68		Virginia	Nov. 68
Aug. 68		Kings, N. Y.	Sept. 68
April 69		South Suffolk	May 69
Oct. 68		Monmouth, N. J.	June 69
Oct. 68		Maryland	April 69
April 69		Richmond, N. Y.	May 70
Nov. 69		Hudson R.	April 70
May 70		South Suffolk	May 70
July 69		Delaware	March 70
April 69		Atlantic, N. J.	Feb. 70
May 69		Virginia	Feb. 70
July 69		Virginia	April 70
April 69		Monmouth, N. J.	Oct. 69
April 69		Southeast Suffolk	Aug. 69
April 70		Ocean, N. J.	Nov. 70
April 70		New London, Conn.	Dec. 70
April 70		Queens, N. Y.	July 70
May 70		Kings, N. Y.	July 70

Table 2. Sites where striped bass were tagged or recaptured. (Cont'd)

	TAGGED	RECAPTURED	
	Richmond, N. Y.		
May 70		Monmouth, N. J.	July 70
May 69		Virginia	Dec. 71
May 71		Richmond, N. Y.	Sept. 71
May 71		Monmouth, N. J.	June 71
May 70		Atlantic, N. J.	July 71
June 71		Ocean, N. J.	Oct. 71
July 69		Ocean, N. J.	Nov. 69
Aug. 70		Monmouth, N. J.	Dec. 70
Aug. 70		Kings, N. Y.	Aug. 71
Oct. 69		Hudson (Rockland)	Nov. 69
Oct. 68		Monmouth, N. J.	Oct. 69
	Kings, N. Y.		
Oct. 66		Kings, N. Y.	July 67
Sept. 66		Kings, N. Y.	July 67
Nov. 67		Virginia	Feb. 68
May 68		Kings, N. Y.	June 69
June 69		Kings, N. Y.	June 69
Oct. 67		Kings, N. Y.	June 69
Aug. 68		Richmond, N. Y.	June 69
June 70		Queens, N. Y.	July 70
	Queens, N. Y.		
Oct. 66		South Nassau	June 68
June 69		Kings, N. Y.	Aug. 69
Oct. 69		Queens, N. Y.	April 70
Sept. 69		Kings, N. Y.	May 70
June 69		South Nassau	July 69
June 69		Northeast Suffolk	Nov. 69
Sept. 70		Queens, N. Y.	Oct. 70
Sept. 68		Monmouth, N. J.	July 70
July 69		South Suffolk	Aug. 71
Sept. 70		Queens, N. Y.	June 71
Oct. 69		Essex, Massachusetts	July 71
June 71		Washington, R. I.	Oct. 71
Oct. 69		Essex, Massachusetts	July 71
July 69		South Suffolk	Aug. 71
	North Nassau		
April 71		Newport, R. I.	Aug. 71
April 71		North Nassau	April 71
Aug. 70		Northeast Suffolk	Oct. 70
May 70		Northeast Suffolk	Nov. 70
	South Nassau		
May 70		Fairfield, Conn.	June 70
Aug. 69		North Carolina	Jan. 70
June 71		Southeast Suffolk	Nov. 71
May 70		Maryland	April 71
Sept. 71		Delaware	Dec. 71
Sept. 71		South Nassau	Sept. 71

Table 2. Sites where striped bass were tagged or recaptured. (Cont'd)

TAGGED	RECAPTURED	
North Suffolk		
Oct. 67	Maryland	Feb. 68
May 68	North Suffolk	June 68
Sept. 68	North Suffolk	Oct. 68
Aug. 66	North Suffolk	Oct. 68
Oct. 67	Washington, R. I.	Sept. 68
Oct. 67	Northeast Suffolk	Sept. 68
Aug. 67	North Suffolk	July 68
June 68	Northeast Suffolk	Oct. 68
June 68	Northeast Suffolk	Sept. 68
June 68	Southeast Suffolk	July 68
Oct. 67	North Suffolk	July 68
June 68	North Suffolk	June 69
June 68	Delaware	Feb. 69
June 68	Fairfield, Conn.	May 69
May 69	South Suffolk	May 70
Sept. 68	South Suffolk	May 70
Feb. 71	Northeast Suffolk	Nov. 71
Feb. 71	North Suffolk	April 71
March 71	Fairfield, Conn.	June 71
March 71	New London, Conn.	June 71
May 68	Burlington, N. J.	Nov. 71
April 71	Middlesex, Conn.	May 71
April 71	North Suffolk	April 71
April 71	Northeast Suffolk	May 71
May 71	Bristol, Mass.	July 71
May 71	Northeast Suffolk	Nov. 71
May 71	North Suffolk	June 71
May 71	North Suffolk	June 71
May 70	South Nassau	June 71
May 71	South Nassau	June 71
Aug. 69	Maryland	Sept. 69
June 69	Virginia	Dec. 70
Aug. 71	South Suffolk	Nov. 71
Aug. 71	North Suffolk	Dec. 71
Aug. 71	Southeast Suffolk	Nov. 71
Aug. 71	Northeast Suffolk	Nov. 71
Oct. 70	Northeast Suffolk	Nov. 71
Oct. 70	Northeast Suffolk	Nov. 71
Oct. 70	Northeast Suffolk	Oct. 71
Nov. 67	South Suffolk	Oct. 70
Oct. 68	North Suffolk	Oct. 70
Oct. 70	Fairfield, Conn.	July 71

Table 2. Sites where striped bass were tagged or recaptured. (Cont'd)

TAGGED	RECAPTURED	
South Suffolk		
Nov. 66	Maryland	Feb. 67
May 68	South Suffolk	June 68
July 67	Kings, N. Y.	June 68
Sept. 68	South Suffolk	Sept. 68
Aug. 68	South Suffolk	July 69
Oct. 69	South Suffolk	May 70
April 69	Southeast Suffolk	Oct. 69
April 69	New London, Conn.	July 70
May 70	Queens, N. Y.	Nov. 70
June 71	Washington, R. I.	Oct. 71
June 71	South Nassau	Oct. 71
Northeast Suffolk		
Sept. 66	Delaware	March 67
Sept. 65	Kings, N. Y.	July 67
Sept. 67	South Suffolk	May 68
Oct. 67	Delaware	March 68
Oct. 67	Southeast Suffolk	May 68
May 68	Northeast Suffolk	May 68
Aug. 67	Burlington, N. J.	April 68
Oct. 67	Bristol, Mass.	June 68
Aug. 68	Virginia	Sept. 68
July 67	Virginia	March 69
May 67	South Suffolk	May 69
May 67	Northeast Suffolk	May 69
Sept. 68	Northeast Suffolk	June 69
May 68	Virginia	April 69
Sept. 68	Richmond, N. Y.	July 69
May 69	Washington, R. I.	July 69
Nov. 69	North Nassau	May 70
Oct. 67	Atlantic, N. J.	May 70
Nov. 69	South Suffolk	May 70
Sept. 68	Delaware	March 70
Aug. 68	North Carolina	March 70
May 69	Northeast Suffolk	May 69
June 69	Northeast Suffolk	Sept. 69
May 70	Ocean, N. J.	Nov. 70
May 70	Southeast Suffolk	Nov. 70
June 69	Northeast Suffolk	Nov. 70
May 69	South Suffolk	Nov. 71
May 70	Delaware	Feb. 71
July 69	Southeast Suffolk	Sept. 69
July 70	South Suffolk	Oct. 70
July 70	Northeast Suffolk	Sept. 70
Southeast Suffolk		
Sept. 67	Virginia	March 68
Oct. 67	North Carolina	March 68
Oct. 67	Delaware	April 68
Oct. 67	Washington, R. I.	July 68
Nov. 68	Virginia	April 69

Table 2. Sites where striped bass were tagged or recaptured. (Cont'd)

	TAGGED	RECAPTURED	
	Southeast Suffolk		
Oct. 68		Maryland	May 69
Oct. 69		North Carolina	March 70
June 69		South Nassau	July 70
July 71		Southeast Suffolk	Oct. 71
Oct. 69		Kings, N. Y.	Nov. 69
Oct. 70		Kings, N. Y.	Nov. 70
Oct. 70		Maryland	April 71
Oct. 70		Southeast Suffolk	June 71
	Bronx, N. Y.		
June 67		Westchester	Aug. 67
Sept. 68		Queens, N. Y.	Oct. 68
Sept. 68		North Suffolk	May 69
April 69		Queens, N. Y.	Aug. 69
June 70		South Suffolk	June 71
	Manhattan, N. Y.		
Sept. 68		Ocean, N. J.	April 69
Sept. 68		Maryland	March 69
	Westchester, N. Y.		
Aug. 65		Virginia	March 67
April 69		Fairfield, Conn.	June 69
April 68		Fairfield, Conn.	June 69
May 70		Kings, N. Y.	June 70
May 69		Monmouth, N. J.	July 69
May 70		Richmond, N. Y.	Nov. 70
May 70		South Suffolk	July 70
May 70		Plymouth, Mass.	Aug. 70
May 70		Fairfield, Conn.	July 70
May 71		Westchester (Hudson)	May 71
April 71		North Nassau	May 71
May 71		Fairfield, Conn.	June 71
April 69		Fairfield, Conn.	June 69
April 69		Kings, N. Y.	May 69
	Fairfield, Conn.		
Oct. 67		Hudson River	Feb. 68
Sept. 68		North Suffolk	Oct. 68
Oct. 67		North Suffolk	May 69
Sept. 68		North Suffolk	May 69
July 68		Richmond, N. Y.	June 69
Aug. 69		South Suffolk	May 70
Aug. 69		North Nassau	May 70
Oct. 69		South Suffolk	May 70
Oct. 69		Northeast Suffolk	June 70
Oct. 69		South Suffolk	April 70
July 68		South Suffolk	July 69
May 69		Northeast Suffolk	Nov. 69
June 69		Northeast Suffolk	Oct. 69
June 70		Northeast Suffolk	Nov. 70
May 70		South Suffolk	Nov. 70
May 70		South Suffolk	Nov. 70

Table 2. Sites where striped bass were tagged or recaptured. (Cont'd)

TAGGED		RECAPTURED	
May 70	Fairfield, Conn.	Southeast Suffolk	Nov. 70
June 70		North Suffolk	Oct. 70
June 70		North Suffolk	Aug. 70
June 70		North Suffolk	Oct. 70
June 70		Northeast Suffolk	Nov. 70
June 70		Kings, N. Y.	Nov. 70
June 70		Northeast Suffolk	Oct. 70
June 70		North Suffolk	Oct. 70
June 70		Southeast Suffolk	Oct. 70
June 71		Northeast Suffolk	Sept. 71
June 71		North Suffolk	Aug. 71
May 71		Northeast Suffolk	Nov. 71
April 67		North Suffolk	June 69
May 71		North Suffolk	June 71
May 70		Kings, N. Y.	June 71
June 70		South Nassau	May 71
Sept. 69		North Suffolk	Oct. 69
Sept. 67		North Suffolk	Oct. 69
Aug. 69		North Suffolk	Oct. 69
July 69		North Suffolk	Nov. 69
July 68		South Suffolk	Nov. 69
Sept. 69		Northeast Suffolk	Nov. 69
Sept. 69		Northeast Suffolk	Oct. 69
Sept. 68		Northeast Suffolk	Sept. 69
July 70		Southeast Suffolk	Nov. 70
Sept. 69		Southeast Suffolk	Nov. 70
Sept. 70		Southeast Suffolk	Oct. 70
July 70		Southeast Suffolk	Nov. 70
Aug. 70		Southeast Suffolk	Nov. 70
July 70		Northeast Suffolk	Nov. 70
July 70		Southeast Suffolk	Nov. 70
July 70		North Suffolk	Nov. 70
Aug. 70		North Suffolk	Nov. 70
July 70		North Nassau	Sept. 70
Aug. 70		Southeast Suffolk	Nov. 70
Aug. 69		Southeast Suffolk	Aug. 70
Aug. 70		North Suffolk	Nov. 70
Sept. 70		North Suffolk	Nov. 70
July 69		Northeast Suffolk	Nov. 70
July 70		North Suffolk	Oct. 70
Oct. 69		North Suffolk	Oct. 69
Oct. 69		North Suffolk	Nov. 69
Oct. 69		North Suffolk	Nov. 69
Oct. 69		North Suffolk	Nov. 70
Oct. 69		Northeast Suffolk	Oct. 70
Oct. 70		Southeast Suffolk	Nov. 71
Oct. 70		Northeast Suffolk	July 71
Nov. 69		North Suffolk	Aug. 71
July 71		South Nassau	Nov. 71

Table 2. Sites where striped bass were tagged or recaptured. (Cont'd)

	TAGGED	RECAPTURED	
	Fairfield, Conn.		
Aug. 71		North Suffolk	Nov. 71
July 71		South Suffolk	Nov. 71
Aug. 71		Northeast Suffolk	Nov. 71
July 71		Northeast Suffolk	Nov. 71
Aug. 71		North Nassau	May 71
June 71		South Nassau	Oct. 71
July 70		Northeast Suffolk	Oct. 71
July 70		Southeast Suffolk	Nov. 71
Sept. 70		Southeast Suffolk	July 71
Aug. 70		Southeast Suffolk	May 71
July 70		South Suffolk	Nov. 70
July 70		South Suffolk	Dec. 70
July 69		Southeast Suffolk	Nov. 71
Sept. 69		Northeast Suffolk	Nov. 71
July 69		North Suffolk	Nov. 70
June 69		North Suffolk	Oct. 70
Oct. 71	New Haven, Conn.	Northeast Suffolk	Nov. 71
	New London, Conn.		
June 67		North Suffolk	Aug. 68
June 70		Northeast Suffolk	Aug. 70
June 71		North Suffolk	Oct. 71
	Washington, R. I.		
Aug. 70		South Suffolk	Oct. 70
Aug. 70		Northeast Suffolk	Nov. 70
Aug. 70		Southeast Suffolk	Oct. 70
Aug. 71			
June 71		Southeast Suffolk	Nov. 71
July 71			
Aug. 70		South Nassau	June 71
Nov. 71		Southeast Suffolk	Nov. 71
May 69	Kent, R. I.	Northeast Suffolk	July 70
	Newport, R. I.		
July 68		South Suffolk	June 69
June 70		Southeast Suffolk	Nov. 70
Oct. 70	Bristol, Mass.	Southeast Suffolk	July 71
Aug. 69	Barnstable, Mass.	South Suffolk	Dec. 69
Oct. 69		North Nassau	June 70
May 67	Massachusetts Bay	North Nassau	July 67
June 69	Essex, Massachusetts	Southeast Suffolk	Nov. 69
Aug. 69		Southeast Suffolk	Nov. 69
	Maine		
July 68		South Suffolk	Nov. 68
June 69		Queens, N. Y.	Nov. 69
Aug. 70		Southeast Suffolk	Nov. 70
Aug. 69		South Suffolk	July 70
Sept. 71		South Suffolk	Nov. 71
July 69		Northeast Suffolk	July 71

Table 3. Zones where striped bass were tagged arranged by season.

	Winter			Spring			Summer			Fall			
Zone	1	2	3	4	5	6	7	8	9	10	11	12	Total
1A-North Carolina													
1 -Virginia													
2 -Maryland													
3 -Delaware													
5 -Atlantic, N.J.													
6 -Burlington, N.J.					1								1
7 -Ocean, N. J.				5	2	1							8
8 -Monmouth, N. J.						3	1	2	3				9
9 -Middlesex, N. J.								2					2
14-Richmond, N. Y.				10	8	1	4	3		6	1		33
15-Kings, N. Y.					1	2		1	1	2	1		8
16-Queens, N. Y.						4	2		4	4			14
17N-N. Nassau, N. Y.				2	1			1					4
17S-S. Nassau, N. Y.					2	1		1	2				6
18N-N. Suffolk, N. Y.		2	2	3	9	7		7	2	9	1		42
18S-S. Suffolk, N. Y.				2	2	2	1	1	1	1	1		11
18NE-NE Suffolk, N. Y.					10	2	4	3	6	4	2		31
18SE-SE Suffolk, N. Y.						1	1		1	9	1		13
19-Manhattan, N. Y.									2				2
20-Bronx, N. Y.				1		2			2				5
21-Westchester, N. Y.				5	8			1*					14
22-Rockland, N. Y.													
23-Fairfield, Conn.					7	16	21	12	12	12	1		81
24-New Haven, Conn.										1			1
25-Middlesex, Conn.													
26-New London, Conn.						3							3
27-Washington, R. I.						1		4			1		6**
28-Kent, R. I.					1								1
31-Newport, R. I.						1	1						2
32-Bristol, Mass.										1			1
33-Plymouth, Mass.													
34-N. Barnstable, Mass.								1		1			2
35-Massachusetts Bay					1								1
36-Essex, Mass.						1		1					2
38-Maine						1	2	2	1				6
TOTAL		2	2	28	53	49	37	42	37	50	9		309

* - Caught in Long Island Sound off Westchester County.

** - Two were not recaptured.

Table 4. Zones where striped bass were tagged or recaptured arranged by season.

	Winter			Spring			Summer			Fall			
Zone	1	2	3	4	5	6	7	8	9	10	11	12	Total
1A-North Carolina	1		3										4
1-Virginia		2	3	3						1	1	2	12
2-Maryland		2	1	3	1				1				8
3-Delaware		2	5	1								1	9
5-Atlantic, N. J.		1			1		1						3
6-Burlington, N. J.				1	1						1		3
7-Ocean, N. J.				6	2	1				1	3		13
8-Monmouth, N. J.						5	5	2	3	3		1	19
9-Middlesex, N. J.								2					2
14-Richmond, N. Y.				10	11	4	5	3	1	6	2		42
15-Kings, N. Y.					3	9	4	5	2	2	4		29
16-Queens, N. Y.				1		5	5	2	4	6	1		24
17N-N. Nassau, N. Y.				3	4	1	1	1	1		1		12
17S-S. Nassau, N. Y.					3	5	2	1	3	2	1		17
18N-N. Suffolk, N. Y.		2	2	5	11	13	2	11	2	23	12	1	84
18S-S. Suffolk, N. Y.				3	14	6	6	3	2	4	10	2	50
18NE-NE Suffolk, N. Y.					15	5	8	5	12	11	22		78
18SE-SE Suffolk, N. Y.					2	2	4	3	2	15	22		50
9-Manhattan, N. Y.									2				2
-Bronx, N. Y.				1		2			2				5
21-Westchester, N. Y.		1		6	9			3*					19
22-Rockland, N. Y.			1								1		2
23-Fairfield, Conn.					8	19	26	12	12	12	1		90
24-New Haven, Conn.										1			1
25-Middlesex, Conn.					1								1
26-New London, Conn.						4	1					1	6
27-Washington, R. I.						1	2	5		2	1		11
28-Kent, R. I.					1								1
31-Newport, R. I.						1	1	1					3
32-Bristol, Mass.						1	1			1			3
33-Plymouth, Mass.								1					1
34-N. Barnstable, Mass.								1		1			2
35-Massachusetts Bay					1								1
36-Essex, Mass.						1	3	1					5
38-Maine						1	2	2	1				6
TOTAL	1	10	15	43	88	86	79	64	50	91	83	8	618

* Two were caught in Long Island Sound off Westchester County.

TABLE 5. SCATTERPLOT OF THE NUMBER OF FISH TAGGED AND RECAPTURED IN EACH LOCATION

ZONE	RECOVERED																																											
	1A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	19	21	22	15	16	17S	18S	18SE	18NE	18N	17N	20	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	TOTAL
T 1A																																												
A 1																																												
G 2																																												
G 3																																												
E 4																																												
D 5																																												
6																						1																						1
7															1		1		1			3	1	1																				8
8									2						1			1	2	1			1	1																				9
9															1								1																					2
10																																												
11																																												
12																																												
13																																												
14		4	1	2		2		3	6						2		1	1	3	1		2	2	1							1										1			33
19			1					1																																				2
21		1							1						1		1		2			1				1		5										1						14
22																																												
15		1													1				5	1																								8
16									1										2	3	2	2		1								1									2			14
17S	1		1	1																	1		1					1																6
18S			1																1	1	1	4	1								1	1												11
18SE	2	2	2	1															2		1		2									1												13
18NE	1	3		4		1	1	1							1				1			5	3	7		1						1					1							31
18N		1	2	1			1														2	4	2	10	12			3		1	1	1					1							42
17N																								2		1										1								4
20																	1			2		1			1																			5
23															1		1		2		3	10	15	19	27	3																		81
24																								1																				1
25																																												
26																								1	2																			3
27																					1	1	3	1																				6
28																								1																				1
29																																												
30																																												
31																						1	1																					2
32																							1																					1
33																																												
34																						1				1																		2
35																										1																		1
36																							2																					2
37																																												
38																				1		3	1	1																				6
TOTAL	4	12	8	9		3	2	5	10						9		5	2	21	10	11	39	37	47	42	8		9		1	3	5				1	2	1			3			309

THE STRIPED BASS FISHERY IN THE ATLANTIC STATES

Ted S. Y. Koo (1970)

Commercial landings of striped bass on the Atlantic coast of America were reviewed briefly for the period prior to 1930 and analyzed in some detail from 1930 to 1966. From the lowest level of barely over 1 million pounds in 1934, annual landings for the entire coast have increased ninefold at the present level.

Catch statistics and fluctuations in landings were analyzed according to regions and states. Chesapeake region, comprising Maryland and Virginia, landed two-thirds of the total catch. The fluctuations in Chesapeake landings were paralleled by Middle Atlantic and New England regions, but with a two-year lag. This was attributed to the fact that the main source of striped bass to all three regions was from the same Chesapeake stock. North Carolina, which is the sole contributor to South Atlantic region in striped landings, had its own distinctive fluctuation pattern.

Fishing gear used in catching striped bass vary from state to state. Handlines are the only gear that land striped bass for commercial market in Massachusetts. Floating traps land the major portion in Rhode Island. Haul seines are the mainstay in New York, as are otter trawls in New Jersey and fixed gillnets in Delaware. Fixed gillnets are also the most important gear in Maryland and North Carolina, although drift gillnets, pound nets, and haul seines contribute significantly to the fishery. In Virginia, pound nets, haul seines, and fixed gillnets each land about 30% of the total poundage.

Seasonal landing patterns differ from state to state. In Massachusetts, the striped bass fishery is primarily a summer fishery; in New York, a fall fishery; in New Jersey, a winter fishery. In Maryland and Virginia, the peak of landings occurs in March and April, just prior to the striped bass spawning season. In North Carolina, good landings are made from November to April.

It has not been possible to calculate catch-per-effort due to lack of necessary data, but the catch-per-unit-gear was calculated and analyzed for a representative state in each region. In all cases, fluctuations in landings were much more closely related to catch-per-unit-gear than to amount of gear.

The cyclic nature of high and low years in Maryland landings was recognized. Dominant year classes seemed to occur at six-year intervals, and possible causes were discussed.

Commercial and Sport Fisheries of Long Island
(Schafer, 1972)

Richard H. Schafer (1972) Aquatic Biologist of the Marine District recently reported in The Conservationist (published by the State of N.Y.; Dept. of Environmental Conservation) with regard to the striped bass as follows.

Accounts indicate that striped bass remained relatively abundant until the latter part of the last century. By 1888, however, the commercial landings of striped bass in New York had declined to 98 thousand pounds, although the catch increased to 212 thousand pounds in the very next year. In years after 1889 the New York commercial landings of striped bass continued to decline steadily until 1933, when the total catch was only 19 thousand pounds. This decline in catch apparently reflected a real decline in the abundance of the species. The decrease in abundance and catch was even noted among the records of striped bass sport fishing clubs (such as that at Cuttyhunk, Massachusetts) as early as 1885.

Without discussing the suspected reasons for the decline, suffice it to say that beginning with 1934 a reversal in the decline of abundance was noted. The magnitude of the reversal is reflected in both the commercial and sport fishery landings which have occurred since that year. By 1944, the New York commercial harvest exceeded one-half million pounds; by 1966, 1 million pounds; and by 1967, 1½ million pounds. It is expected that the commercial catch will exceed 1,600,000 pounds in 1974.

Sport fishery statistics gathered by the U.S. Department of Interior reveal that there were 180,000 anglers who fished for striped bass in the North Atlantic region (New England and New York) in 1960, and 318,000 in

1965. These anglers harvested nearly 3 million striped bass weighing over 12 million pounds, and 13 million weighing 48 million pounds, respectively.

Again, if one assumes that about half of the striped bass anglers in the region reside in New York and that about half of the catch is made in New York waters, then the recreational fishery harvest of striped bass in New York may currently be 30 times greater than that of the commercial fishery.

The enormous increase in striped bass along the Atlantic coast has been attributed to a succession of highly successful but sporadic annual spawnings which have occurred since 1934 in Chesapeake Bay, the major spawning ground. It is important for both sport and commercial fishermen in New York that these dominant year-classes continue to occur if fishing is to remain at a high level. Unfortunately, because the size and survival of annual brood production is determined primarily by environmental factors, occurrences of dominant year-classes are beyond man's control at the present time and are, therefore, largely unpredictable. Some observations made recently, however, suggest that "dominant year-classes" occur about once every six years.

It is encouraging that striped bass brood production in Chesapeake Bay during 1970 was the largest ever recorded. If survival remains high and migration follows normal patterns, then sport and commercial fishermen in New York should continue to experience excellent fishing for striped bass for at least the next 6 to 8 years. In spite of perennial competition and conflict between the commercial and recreational fisheries for the striped bass resource, it would appear that there are presently more than enough striped bass occurring annually in New York waters to satisfy the needs of both fisheries. Furthermore, the current rates of harvest do not appear to offer any immediate threat to the future abundance of the resource. The patient is healthy and the prognosis for continued good health is excellent.

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BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of	)	Docket No. 50-247
New York, Inc.	)	
(Indian Point Station, Unit No. 2)	)	

Testimony of
Dr. James T. McFadden
The University of Michigan

on

Impact of Entrainment and Impingement at Indian Point Units #1 and #2 Upon Fish Populations

October 30, 1972

IMPACT OF ENTRAINMENT AND IMPINGEMENT AT INDIAN POINT UNITS #1 AND #2 UPON FISH POPULATIONS

by

Dr. James T. McFadden

The University of Michigan

INTRODUCTION

This document presents my testimony relative to the impact upon the Hudson River Fishery of entrainment and impingement of fishes at Indian Point Units #1 and #2 during an eight year period, with particular emphasis on the striped bass. A statement of my experience in the field of population dynamics of fishes and my familiarity with the specifics of Hudson River fish population is contained in the attached Appendix II.

Summary

The life history of striped bass in the Hudson River, basic concepts of population dynamics applicable to Hudson River fishes, and specific examples from scientific studies of striped bass on the Atlantic and Pacific coasts of North America are summarized. It is shown that striped bass populations typically fluctuate in abundance over more than a four-fold range and that they have substantial compensatory reserve. This compensatory reserve enables striped bass populations such as that of the Hudson River to offset, through increases in natural surivival rates, losses imposed by the activities of man. A large number of scientific studies which demonstrate that annual removals of 25 to 30% are commonly sustained by fish stocks are summarized. Consistent with this general observation of exploited fish stocks, striped bass in New York waters have persisted or even increased in numbers during periods of increasing exploitation by man.

On the basis of the information summarized above, it is concluded that a significant compensatory response which would appreciably reduce postulated percentage losses in the striped bass population of the Hudson River due to operation of Indian Point Units #1 and #2 would occur. Should this compensatory response be too weak to completely offset losses to the fish population caused by operation of Unit #1 and #2 commencing in spring 1973, the population would begin a gradual decline. This decline would be reflected in population parameters which are currently being monitored before irreversible damage to the population occurred. Examples of scientific studies which clearly demonstrate that changes indicative of population damage can be detected by the methods employed in the Indian Point

ecological study are cited. The Indian Point ecological study begun by Consolidated Edison in 1972 is designed to operate until the summer of 1977, at which point sound conclusions on the actual impact of Indian Point Units #1 and #2 upon the ecosystem of the Hudson River Estuary can be drawn. Should serious ecological damage from the operation of Indian Point Units #1 and #2 occur, it would be clearly demonstrable by 1977 when the ecological study is to be completed. On the basis of any reasonably postulated loss rate due to operation of Indian Point Unit #1 and #2 commencing in spring 1973, the fish stocks of the Hudson River, including the economically important striped bass, would not be subjected to irreversible damage by 1981, the date when alternatives to once-through cooling could be operational if construction were commenced in 1977 following completion of the ecological studies now underway.

Examination of commercial data for New York waters reveals that striped bass landings in recent years have been nine times greater than those of the early 1930's. This increase would be still greater if the unmeasured sport fishing catch were included. Since 1935 striped bass catches have fluctuated over a six-fold range while fishing effort has steadily declined. For striped bass no consistent relationship exists between catch and fishing effort. For white perch the catch has declined during recent years in parallel with the decline in fishing effort. For this species catch and fishing effort are positively related, suggesting that the population is not being exploited anywhere near the maximum sustainable level. It appears likely that the harvest of white perch could be increased to several times present levels without harm.

Typical productivity estimates for natural waters are reviewed and it is shown that postulated losses of striped bass, white perch and all species combined due to operation of Indian Point Units #1 and #2 are well within the range of removals which estuaries can be expected to sustain.

Components of Fish Populations and Interrelationships

From the time of spawning and hatching until eventual death, a fish passes through a succession of life history stages which vary tremendously in terms of physical and biological factors which affect the growth and probability of survival for the individual fish. Thus it is important in any consideration of the abundance and numerical fluctuations of fish populations to consider the various life history stages as separate but interrelated entities. For some species all the life history stages occupy the same environment and hence can interact with one another, as through predation or competition. For other species some life history stages may occupy a fresh water river environment while others are far removed in a high seas environment.

Striped bass require moving fresh water in which to reproduce. They ascend rivers and broadcast their eggs into the open water. The eggs are semi-buoyant and drift gradually downstream, close to the bottom, during the early developmental stages. In the Hudson River the eggs hatch in about 1.5 days, the exact incubation period being temperature dependent. The larval fish, at first planktonic and nourished from food contained in the yolk sac, rapidly develop feeding and swimming capability. By an age of some 21 days the post-larvae have become essentially independent, free-swimming organisms. As they develop further they may be pelagic during certain seasons or select bottom habitats during others.

Spawning takes place from May through June, principally, and the young fish take up residence in shoal water areas of the estuary by the end of the first summer of life. They over-winter in the estuary and at the end of their second summer migrate seaward. While a few fish of almost any age may be found in the estuarine waters at any given time, a majority of the fish are found seaward after the second summer of life except for their return during the spawning season which occurs first between the 3rd and 5th year of life, differing from male and female.

Each life history stage carries its own set of hazards for the fish. Substantial losses of eggs may occur due to failure of fertilization, settling to the bottom out of suspension, exposure to unfavorable temperatures or salinities, or predation. The larval fish remain temperature and salinity sensitive, vulnerable to predation, and upon absorption of the yolk sac, are dependent upon an adequate supply of food for survival. Throughout the remainder of the first year of life the young fish are exposed to predation by other estuarine species and to competition among their own and other species for food and space on the rearing grounds. They are subject to disease and the debilitating effect of parasites which have greater impact when fish are more abundant. Upon migration to the sea the young striped bass are subjected to predation by a wide variety of marine organisms but have access in that environment to adequate food supplies, and are relieved of the space limitation of the estuarine environment. But in nearshore marine areas they first become the prey of commercial and sport fishermen.

Fish populations, including striped bass, are controlled by two general classes of factors: (1) Extrinsic factors, such as predators or other species which compete for food, living space, etc.; (2) Intrinsic factors, such as competition for food among the members of a year class. Frequently, fish of a species are so abundant and hence intraspecific competition so intense, that further population increase is prevented. Where this is the case an increase in mortality due to some extrinsic agent, such as a commercial fishery, natural predator, or operation of a power plant, will be at least partially offset by an increase in survival at some sensitive life history stage, or an increase in growth rate, or an increase in reproductive rate. The fish population has the capacity, within limits, to compensate for an increased rate of mortality. All animal populations tend eventually to reach some average upper limit of abundance around which their numbers fluctuate. A population may be held in balance near its equilibrium through a combination of low mortality rate and low reproductive rate, or through a combination of high mortality rate and high reproductive rate. Either situation could reflect an ecologically health population, and in the latter case a sizable component of the mortality could be man-induced.

A population would be considered ecologically harmed when subjected to a mortality rate so high that the maximum possible increase in reproductive rate could not compensate adequately. The population would then decline to a very low level of abundance at which it might again stabilize, or possibly dwindle to extinction, or begin to fluctuate violently because some balance within the species, or among a complex of interacting species had been disrupted.

Concepts relating to the regulation of natural animal populations have been studied and debated by ecologists for many years. General agreement has been reached that populations are limited in their abundance by the effects of competition and that these competitive effects are the basis of a negative feedback system which tends to deflect extremely large populations downward from unlimited expansion and sparce populations upward away from eventual extinction.

These ideas are summarized for fish populations in the classic study "Stock and Recruitment" by Dr. W. E. Ricker (Journal Fisheries Research Board of Canada 11 (5): 560-561, 1954):

> "Basic in any stock - recruitment relationship is the fact that a fish population, even when not fished, is limited in size; that is, it is held at some more or less fluctuating level by natural controls. Ideas concerning the nature of such controls were first clarified and systematized by the Australian Entomologist Nicholson (1933). He showed that, while the level of abundance attained by an animal can be affected by any element of the physical or biological environment, the immediate mechanism of control must always involve competition, using that word in a broad sense to include any factor of mortality whose effectiveness increases with stock density.....
>
> This almost axiomatic proposition is implied in the writing of various earlier authors as far back as Malthus, but Nicholson was the first to formulate it explicitly and to emphasise its importance: Haldane (1953) calls his inspiration "a blinding glimpse of the obvious.....
>
> There is no necessary relation between the relative magnitudes of the causes of mortality existing at a given time, as measured by the fraction of the stock which each kills, and their relative contribution to compensation."

Some species populations or sub-groups thereof, could conceivably exist for a restricted period of time without the operation of any compensatory processes. The population would soon, however, either increase in density to a point where compensatory processes would become activated and reduce the reproductive rate or increase the mortality rate; or the population might decline in abundance until the remaining individuals, relieved of competition, and having access to choice habitats and unlimited food supplies, would experience an increase in survival or reproductive rate which would lead to an increase in the population over succeeding generations.

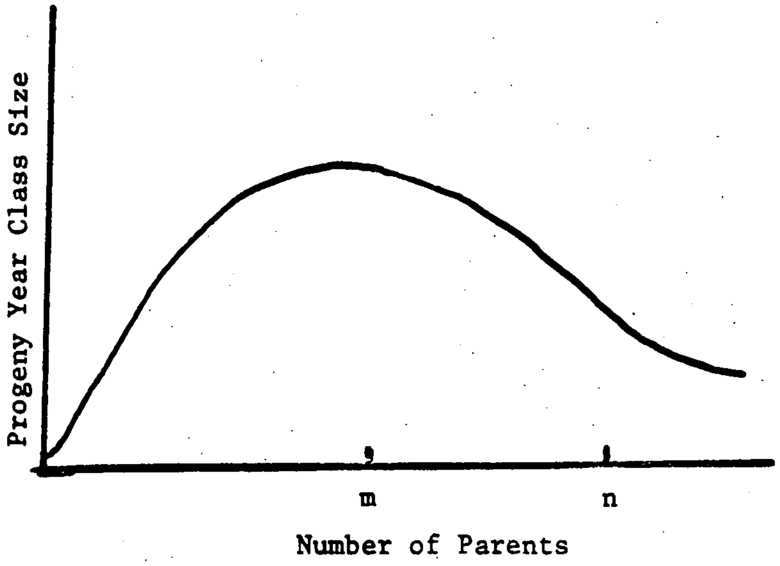
Compensatory processes may be much more active at one life history stage than at others. As a generality it is to be expected that compensation will be most effective during the earlier, more sensitive life history stages of a fish and that the numerical size of each year class will be determined by the end of the first year of life. During subsequent years, variations in environmental factors may cause additional changes in a year class' abundance; but usually these will not involve a compensatory response by the population. While compensatory changes in population may occur at any stage of the life cycle, they usually are most effective early in life. No empirical observations on operation of compensatory processes during different life history stages for striped bass in the Hudson River per se are known by me to exist. Relevant data from other striped bass populations and general principles of fish population dynamics can be applied directly and legitimately to the Hudson River situation however. And the study of fish population dynamics being carried out at Indian Point is designed to obtain direct observations for the Hudson River.

The numerical size of successive generations of striped bass within a population is determined by (a) random variations in freshwater flows, salinity patterns, temperature, predators, etc. and (b) compensatory processes, which tend to maintain the population within certain numerical bounds. The latter enable populations of striped bass to compensate, within limits, for increased mortalities imposed by man through sport or commercial fishing, mortality at power plants such as Indian Point, etc. Losses due to mans' activities are offset in whole or in part by increased survival rates during some phase of the life history, or by increased reproductive rates. If populations are not limited in abundance in part by man, they are limited by more severe operation of natural phenomena.

Random variations in population size and compensatory adjustments occur simultaneously in striped bass populations. River flow in June and July has been shown to account for 85% of the variability in year class size in the striped bass of the San Francisco Bay estuary (P. Sommani, "A Study on the Population Dynamics of Striped Bass (Morone saxatilis Walbaum) in the San Francisco Bay Estuary," University of Washington abstract). The abundance of spawners producing each year class accounts for an additional 13% of the variability in year class size. The largest year classes of progeny are produced by intermediate-sized parental stocks; very large and very small groups of spawners produce fewer progeny. This is an example of a compensatory reproductive process. Year class strength is largely determined by the time the young reach a length of 1.5 inches. In the San Francisco Bay population analysis, Sommani establishes a linear relationship between abundance of fry in year t and abundance of three-year-olds in year (t + 3) by eliminating one of eight available data points. The inference drawn from the resulting linear relationship is that during the life history stages from 1.5 inch fry to three-year-old fish compensatory processes are not operative. The analysis is speculative and inclusion of the arbitrarily elimated datum would have destroyed any statistically significant regression. It is worth noting that one additional datum, if it fell at the "right" values, would make a significant porabolic relationship from which the correct inference would be that during this three year period of the life cycle compensatory processes did operate.

Year class strength in the same San Francisco Bay population has been shown by Turner and Chadwich (Trans. Am. Fish. Soc. 101 (3): 442-452, 1972) to vary over a four-fold range.

In the Maryland commercial fishery, data on catch per unit gear provide an index of abundance of striped bass. Four-fold variation in this index has occurred (Koo, T. S. Y., 1970, Chesapeake Sci. 11 (2): 73-93), which is indicative of even larger variations in year class strength, because the commercial catch in any given year is made up of a number of different age groups and hence tends to be less variable than the abundance of any individual age group over a run of years. Significantly, Koo (page 92) demonstrates: "...that there is an inverse relationship between size of parent stock and recruitment is hardly to be questioned in the case of Chesapeake Bay striped bass...," and (page 92) "...dominate year classes are originated from lower, but not necessarily low, parent stocks." This means that over a certain range of population density as numbers of striped bass spawners are reduced, the size of the year class of progeny they produce will remain the same or even increase. Reduction of parental stocks below some critical minimum will, of course, result in smaller year classes of progeny. This type of compensatory relationship is diagramed below. The size of the Chesapeake Bay population in historical times has ranged between points m and n, hence the inverse relationship between abundance of parents and abundance of progeny observed by Koo. The equilibrium level for the population (the average level of abundance around which the population fluctuates) must be to the right of point m, the spawning stock which produces maximum progeny year class size. Two deductions follow from this: (i) the population has some inherent tendency to oscillate in size (Ricker, 1954), which will reinforce variability due to environmental factors, such as river flow; (ii) the population has a compensatory reserve.



These deductions from specific sets of scientific observations are consistent with the more general, long-term observations that striped bass fluctuate considerably in strength of successive year classes (they are a year class dominate species); that fluctuations consist of both a random component and a cyclic component with about six years between peaks; and that striped bass populations have considerable compensatory reserve. Stocks have persisted or even expanded during periods of increasing exploitation by man.

It is because of the ability of fish populations to respond in a compensating fashion to removals of stock that sport and commercial fisheries can operate for indefinite periods of time, continually removing fish from a population without depleting the stock. Many studies providing estimates of percentage of fish populations removed on a sustained basis have been carried out. Statistics covering 61 recorded cases of exploitation by sport or commercial fisheries are summarized in Appendix I. Removals of fish varied from 5% to 75% in these examples with many cases of 25% to 35% removals being sustained over periods of many years without harm to the population. The maximum percentage harvest which a fish population can sustain on a continuing basis varies with the species and the particular environment in question. As a general proposition fish are extremely resilient and can be expected to sustain substantial removals without exhausting their compensatory reserve.

Hudson River Fishery Statistics

The research of Ted S.Y. Koo (Chesapeake Science 11 (2); 73-93, 1970) indicated that the New York populations of striped bass have been experiencing a healthy increase in abundance in recent years. Recent striped bass landings on the Atlantic coast are nine times greater than those of the early 1930's and greater still if increases in sport fishing landings are included. During varying portions of the period of time in question, commencing in 1951, the Danskammer, Lovett, and Indian Point Unit #1 plants have been operating. The effects of the operation of Indian Point Units #1 and #2 would, therefore, be imposed upon a healthy and apparently expanding fish stock rather than one which has declined to a low ebb and which might be maximally sensitive to imposition of further mortality.

My own examination of Hudson River fishery statistics leads to the following conclusions. Commercial fishery statistics for Hudson River water of New York are available from 1913 to 1969, but must be interpreted with reservations. Fishing effort data are available only for some years between 1935 and 1964. Besides problems of incompleteness, the accuracy of such long historical sets of data is difficult to determine; successive observations are not independent of one another; fishing gear has probably increased in efficiency over the period covered by the data due to improvements in boats and motors, shift to synthetic fibers in construction of nets, etc. without any concomitant change in effort statistics; catches of the various fish species are not tallied separately for the different types of gear employed; and historical changes in environmental conditions, such as water quality, are hopelessly confounded with possible effects of the fishery. Despite these problems some useful insights can be gained from the commercial fishery statistics.

Since 1935 (the first year for which effort statistics are available) the general trend has been steadily downward for all fishing effort indices (Figure 1) and the decline has been especially marked since 1945, the peak year for production of American shad. The shad have always made up the bulk of the commercial catch, and the harvest of this species has declined steadily since 1945, in rough parallel to the effort statistics. It is not clear from these data alone to what extent external conditions, such as economic changes, have contributed to a decline in fishing effort, and a resultant decline in shad catch. However, the historical trends are explained mainly by a marked decline in the shad population due to overfishing, damming of spawning streams and pollution, with a consequent decline in fishing effort.

Catches of striped bass have fluctuated over a six-fold range during the post-1935 period of decline in fishing effort, while the catch of white perch, which are for the most part caught incidental to fishing for other species, has declined in parallel with the effort statistics (Figure 2). Taking all data points as equally reliable, no consistent relationship exists between fishing effort and catch of striped bass (Figure 3). If the large component of "casual fishermen" in the 1935 effort datum is taken into account (Figure 1), effectively shifting the point to a lower abscissal value, it would appear that the striped bass population historically has tended to produce greater yields at higher levels of fishing effort. Some optimum level of effort exists at which the maximum sustained harvest of fish (on a long term average) will be obtained. Levels of effort higher or lower than this optimum produce sub-maximal yields. This historical data, with due reservation on account of their poor quality, suggest that fishing effort has not been great enough to reach

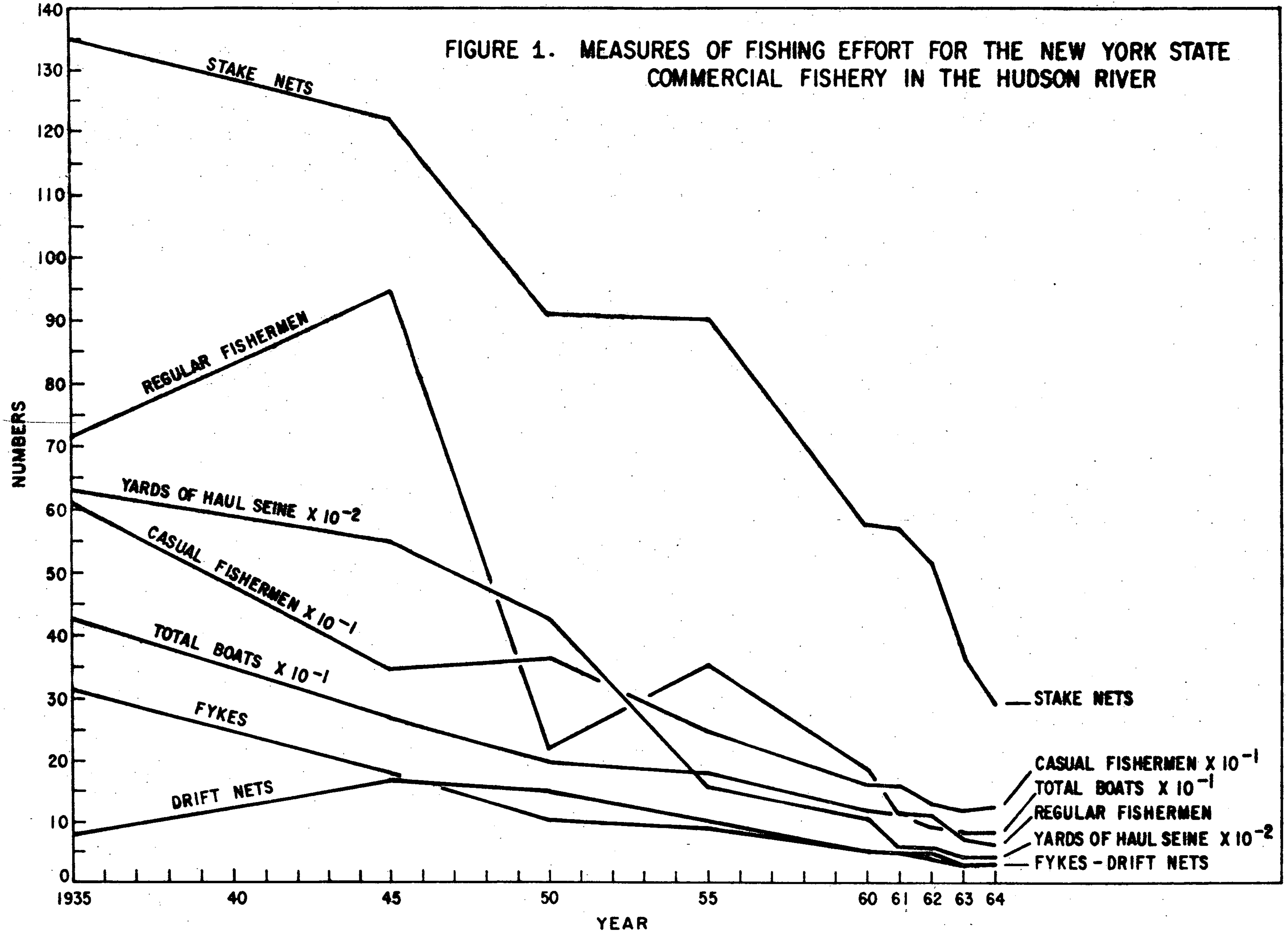


FIGURE 1. MEASURES OF FISHING EFFORT FOR THE NEW YORK STATE COMMERCIAL FISHERY IN THE HUDSON RIVER

FIGURE 2. NEW YORK STATE COMMERCIAL FISHERY FOR STRIPED BASS AND WHITE PERCH IN THE HUDSON RIVER

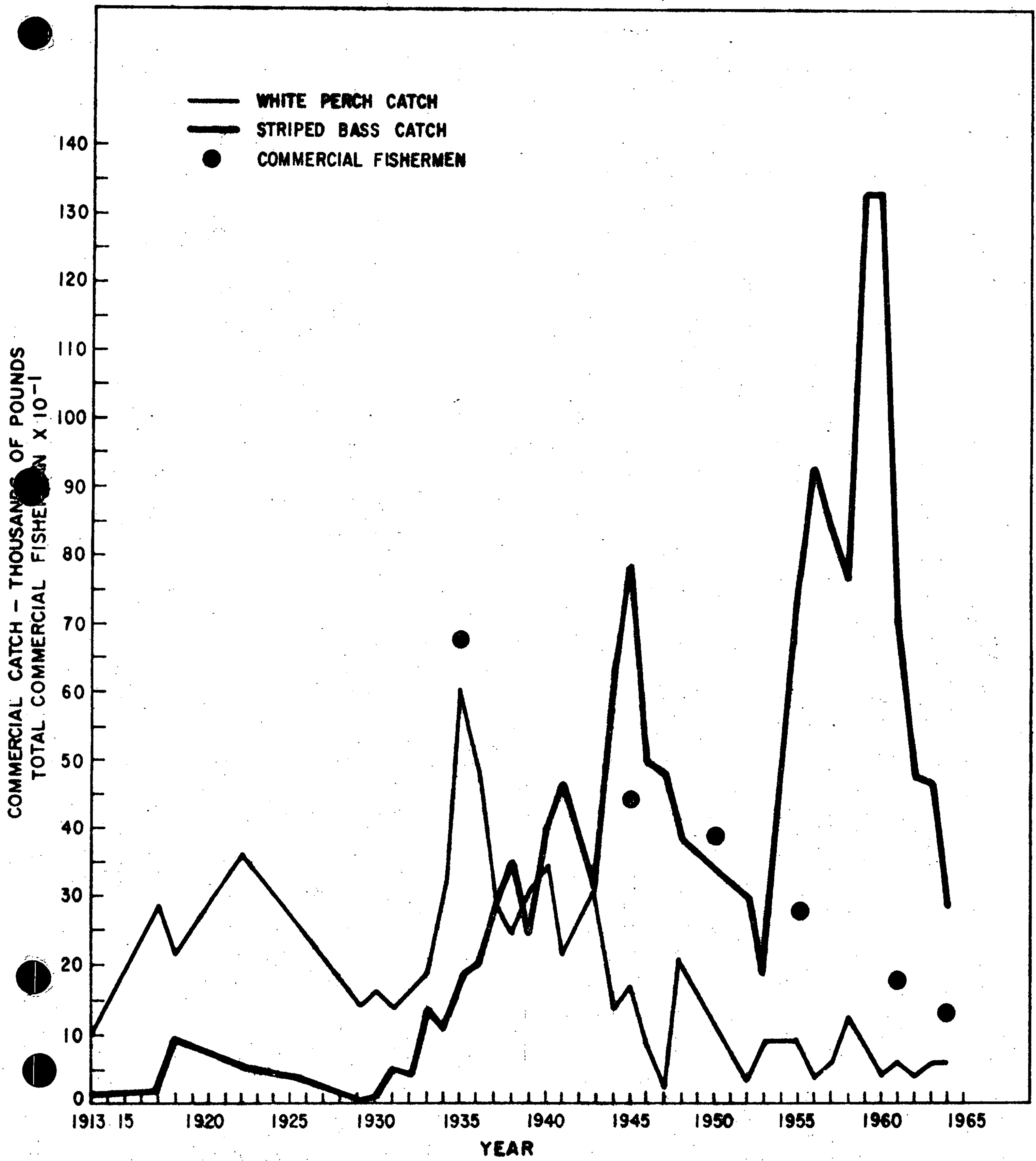
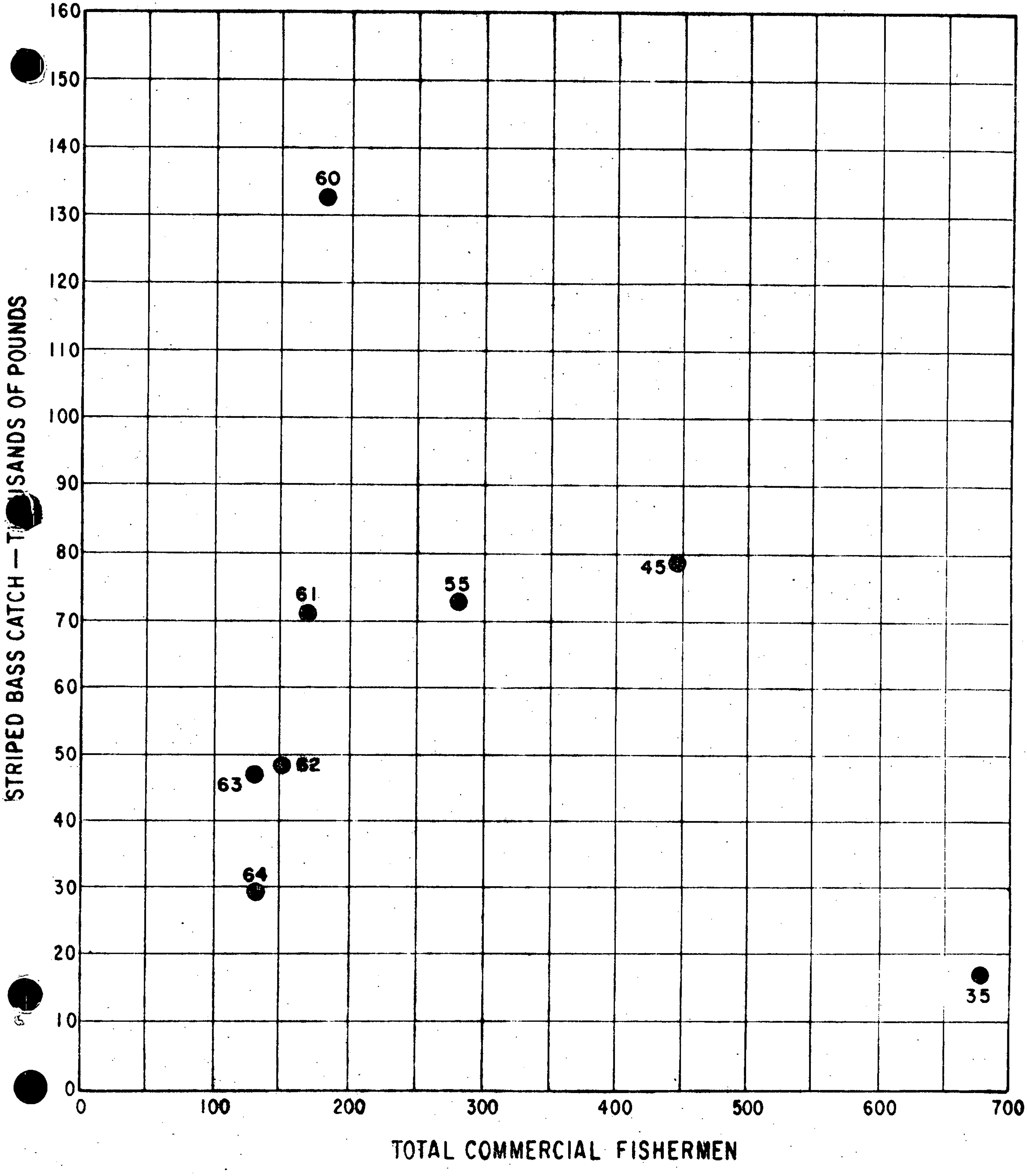


FIGURE 3. STRIPED BASS CATCH IN RELATION TO FISHING EFFORT IN THE NEW YORK STATE COMMERCIAL FISHERY OF THE HUDSON RIVER



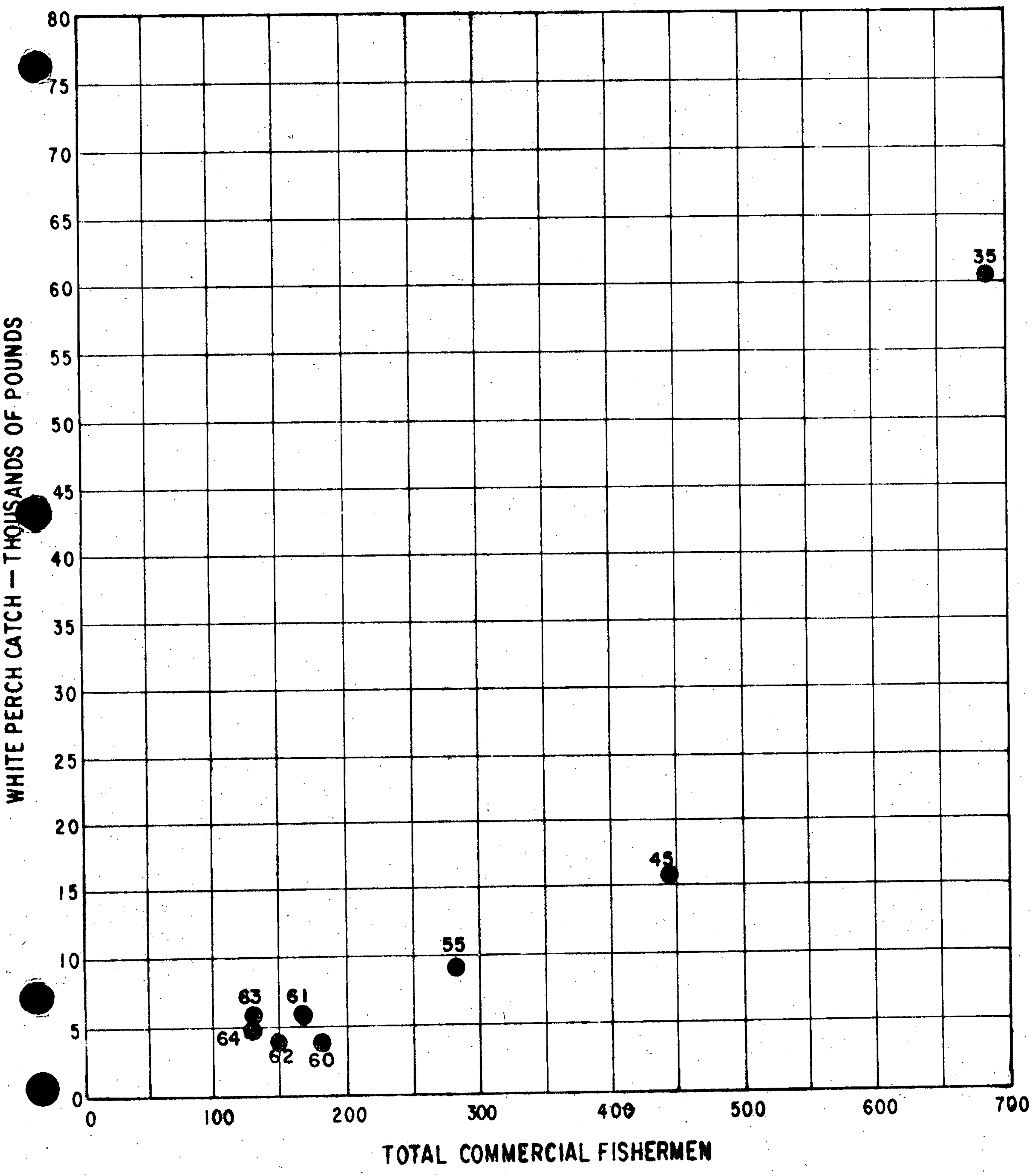
maximum yield, and hence the stock could endure greater mortality without reducing its productivity. The data provide no indication of where the point of maximum sustained yield may be, or, equivalently, how much more removal (from fisheries, power plants, etc.) can be imposed without reducing the population's productivity.

For white perch (Figure 4), a fairly strong positive relationship exists between catch and effort, but no basis exists within the data for determining the limit to which this can be extrapolated (corresponding to maximum yield). It is clear that increases in effort have been accompanied by increases in yield up to the maximum of record, some 60,000 pounds. If this catch is drawn from 50 square miles of river (32,000 acres) it represents a removal of less than two pounds per acre. On the basis of well documented determinations of fish yields from natural waters, it would be conservative to extrapolate to a capacity for sustained annual removals ten times this level or 600,000 pounds annually for the region of the fishery.

The white perch is an abundant, slow-growing companion species of the striped bass. Striped bass are by a large margin the more valuable of the two species to the sport and commercial fisheries combined. These two fishes overlap considerably in food habits and probably compete with one another for food and perhaps for other environmental requisites. Should mortality of white perch due to the operation of Indian Point Units #1 and #2 be great enough to cause a significant decline in their abundance, the more valuable striped bass population might benefit from reduced interspecific competition.

Tht total poundage of fish removed from the Hudson River by the New York commercial fishery has averaged 847,731 pounds annually for the 36 years between 1913 and 1964 for which data are available. Because a number of the most important

FIGURE 4. WHITE PERCH CATCH IN RELATION TO FISHING EFFORT IN THE NEW YORK STATE COMMERCIAL FISHERY OF THE HUDSON RIVER



species involved are anadromous, this harvest does not represent fish production which has taken place solely in the Hudson River estuary, but includes fish produced in other coastal areas and harvested in the Hudson during migration. It has been shown that for some of the species included (white perch and striped bass) the harvest still appears to be below maximum yield due to low fishing intensity, while for the historically important shad, overexploitation by fishermen and environmental changes have drastically reduced the productivity of the stock.

Considerations Based on Overall Estuarine Productivity

Drawing generalizations for different aquatic environments, gross primary production in estuaries averages about ten times treater than in coastal zones and twenty times greater than in the open ocean (Odum, E. T., 1971, Fundamentals of Ecology, W. B. Saunders Company. 574 pp.). Recorded commercial and sport landings of fish may be used as minimum estimates of biomass for these organisms in estuaries. In the Gulf of Mexico, which includes 4.8 million acres of in-shore estuary, 1972 commercial landings of fin fish totaled 282 pounds per acre, not including the sport fish catch. A substantial part of this production came from off-shore waters rather than the estuary itself, and making some adjustment to account for this would reduce the fin fish catch attributable to the estuarine productivity proper to about 50 pounds per acre (McHugh, J. L., 1967, in Estuaries, Lauff, G. H. (Ed.), publication No. 83 AAAS, 757 pp. Washington, D.C.). A similar estimate for Chesapeake Bay and its estuarine tributaries is about 155 pounds per acre based on 1962 commercial fish landings in Maryland and Virginia, and making adjustment for fish from outside Chesapeake Bay included in catch statistics but not making allowance for fish landed in the Bay which had accumulated some growth in other aquatic environments. Addition of sport fish catches would increase these figures substantially. These fish production figures for estuaries are much greater than annual averages of 1.5 pounds per acre per year for all world marine fishing; 27 pounds per acre per year for the productive north sea fishery; and 1 to 7 pounds per acre per year for the Great Lakes (Odum, E. T., 1971), reflecting the extraordinary productivity of estuaries.

The Atomic Energy Commission has postulated annual removals of fish through impingement at Indian Point Units 1 and 2 of from 2 to 5 million. While not agreeing with that estimate, the mean value of 3.5 million can be used to estimate removals of juveniles through impingement of about 0.58 pounds per acre for striped bass; 7.86 pounds per acre for white perch; and 14.99 pounds per acre for all species combined, if the extreme assumption that these postulated removals come from the four square miles of river immediately adjacent to Indian Point is made. When compared to the minimum estimates of fish biomass in estuaries cited above, these postulated removals are insignificant. When it is further considered that the removals almost certainly come from an area larger than the 4 square miles immediately adjacent to Indian Point and hence the poundage removal per acre of estuary is even less than the figures cited here, the significance of mortality by impingement is reduced still further.

Poundage of fish removed is a much more relevant measure, ecologically speaking, than is an estimate based on numbers of individual fish, because the processes of primary and secondary productivity yield a food base for fish which can support a given total mass, regardless of the size of individuals. An analogy might be drawn with a farm pasture which provides enough food for 100 mice per acre (these being very small) but which could support less than a single cow per acre because of their much greater demand for food. In either case, the mass of animal flesh supported by the plant material from an acre of pasture might theoretically be the same.

The postulated removals of all species of fish through impingement at Indian Point Units #1 and #2 are much lower, when expressed in pounds per acre, than expected standing crop of fish in estuarine waters. The effects of operation of Indian Point Plant with once-through cooling, while uncertain with regard to the total assemblage of fish species, would not be expected to cause irreversible damage in as short a period as eight years. The postulated removals through impingement are far lower than those regularly sustained by fish populations in estuaries.

The Need For and Practicability of Further Ecological Studies

From the foregoing bases it is argued that white perch, striped bass, and other fish species in the Hudson can absorb additional mortality such as caused by operation of nuclear power plants with once-through cooling without being damaged in an ecological sense. The exact limits to which these species can absorb additional mortality are not known; but it is possible to prescribe a time period during which Indian Point Units #1 and #2 can operate while badly needed additional data on environmental impacts are collected, without risking irreversible damage to the fish populations.

The response of some fish stocks to increasing rates of mortality is to show little apparent change in stability or productivity up to certain point beyond which the population decreases markedly in abundance. While the impending decrease in abundance may not be foretold by superficial observation, detailed scientific measurement of certain population parameters can foretell the approach to conditions under which the population will be ecologically damaged.

The ecological study now underway at Indian Point will develop the following data from which the ecological impact of Units #1 and #2 can be directly assessed:

Estimates of Population Density - A major contention is that operation of the Indian Point Plant will increase fish mortality to an intolerable level. From the abundance of each age group of striped bass and white perch in the vicinity of Indian Point the recorded mortality due to impingement can be evaluated as a proportion of the fish at large, relative magnitudes of natural and impingement death rates can be determined, and the net effect of plant operation in increasing total mortality rates can be ascertained. Contentions about the operation of compensatory processes can be examined from a base of scientific observations, and the accuracy of the several conflicting models of population processes entered in testimony can be judged.

Growth Rate - Serious depletion of a fish stock is usually accompanied by an increase in growth rate as population density declines and competition for food and other limiting resources is lessened. Growth rates in the Hudson River populations are being measured simply, directly, and accurately in a monitoring program which would detect early changes due to population decline and make possible a forecast of the consequences of the concomitant numerical and growth changes.

Age at Sexual Maturation - Substantial reductions in abundance of fish stocks are normally accompanied by attainment of sexual maturation at an earlier average age. This change is one of the most effective responses to a sustained change in other population parameters, such as mortality rates, which can take place in a fish stock. The proportion of each age group of fish which reaches sexual maturity is readily and accurately measured, and the consequences in terms of maintenance of the population can be deduced directly through life table analysis.

Age Composition - The relative abundance of different age groups in a fish stock changes as a consequence of shifts in reproductive rate or reproductive success or survival. It is a statistic which can be precisely measured and interpreted through the other population measures listed here. The analysis of age frequency data has been extensively developed in fishery science and provides valuable insights into the current and historical status of populations.

Additional ecological measurements directly relevant to assessment of ecological impacts are being made in this study. Species composition, food habits, movement patterns, and related ecological parameters, in combination with the above data, provide a comprehensive monitoring of population response to Indian Point Units #1 and #2.

In my opinion the postulated losses of striped bass or other species due to impingement and entrainment at the Indian Point Units #1 and #2 would not produce an irreversible impact upon fish populations of the Hudson River ecosystem within an eight year period. Estimation of the exact magnitude of the additional losses is an extremely complex procedure and a fairly wide range of values has been produced by the various parties to this licensing hearing. In my opinion a compensatory response which would appreciably reduce postulated percentage losses to the young of the year striped bass would occur, and offset in whole or in part any decline in the population due to operation of Indian Point Units #1 and #2.

Should the compensatory response of the population be too weak to completely offset the additional mortality caused by operation of Indian Point Unit #2 the striped bass population would begin a gradual decline which would be detected by the monitoring program sufficiently in advance of irreversible damage to allow for the installation of alternatives to once-through cooling. It is not argued here that the entrainment and impingement losses postulated from operation of this plant will definitely not damage the population; but rather that such losses would not cause a precipitous and unpredictable decline in the population which would produce irreversible ecological damage.

The multiple age structure of the striped bass spawning stock buffers the population against violent fluctuations in reproductive potential resulting from reduced abundance of any single year class. Operation of Indian Point Units #1 and #2 would have a first order effect of reducing spawning stock size directly due to mortality of potential spawners entrained or impinged, and a second order effect of reduced future spawning stock size resulting from the first order reduction in parental generations.

Striped bass in the Hudson River first spawn at an age of three years. The average relative contribution to egg production by each age group of the spawning stock is calculated below from the fecundity data of Table 5 in the testimony of John Lawler (Testimony of April 5, 1972, TR. 4831) and an assumed adult survival of 50% per year.

Age Group (x)	Thousands of Eggs/Fish (M_x)	Relative Survival (l_x)	$l_x M_x$	Percentage Total Egg Production	Cumulative Percentage
III	345	1.000	345	37	37
IV	438	.500	219	23	60
V	615	.250	154	17	77
VI	752	.125	94	10	87
VII	820	.063	52	13	
VIII	909	.037	34		
IX	910	.018	16		
X	964	.009	9		
XI	1136	.005	6		
XII	908	.003	3		
			$\Sigma = 932$		

Each year class of fish makes its maximum contribution to reproduction in its fourth year of life (Age Group III) and contributes significantly to egg production during four successive years. By the fourth reproductive year (Age Group VI) a year class of fish has completed 87% of its lifetime contributions to spawning.

With Unit #2 beginning operation in spring 1973, the 1973 year class and all successive year classes would be reduced in abundance by entrainment and impingement. The first spawning stock affected by the first order reduction in the 1973 year class would be that of 1976 in which the 1973 year class would be expected to contribute 37% of the eggs. The first year class of striped bass which could conceivably be significantly reduced in size because of both first order and second order effects would be the 1980 year class. The parental stock which produces the 1980 year class will include the 1976 and 1977 year classes which together would be expected to contribute 60% of the eggs spawned.

Realistically, both first order and second order reductions in spawning potential of the striped bass stock would be moderated by a compensatory response by the population.

Consolidated Edison has already undertaken population studies and a monitoring program which will, in my opinion, provide a continuing and detailed assessment of the impact of power plant operations at Indian Point on the fish stocks of the Hudson River and provide warning, with ample lead time for corrective action, in case of any impending irreversible damage to the ecosystem. The workability of a monitoring program such as the one undertaken here has been established in a number of classical fishery studies. The Pacific sardine was studied by G. I. Murphy (Ecology 48 (5): 731-736, 1967). Pacific sardines off the California coast were over-fished over a period of years without any compensatory growth or survival changes among adults over the observed ranges of sardine population density. However, the impending decline of the population was clearly signaled by a reduction in the original multiple age structure of the spawning stock towards one in which a single reproductive age-group predominated. For the sardine the removal of the adaptive adjustment of multiple spawning by each brood in the face of a variable environment ultimately led to serious decline in abundance. Adequate monitoring and early corrective response to over-exploitation clearly could have averted this situation.

A second classical example of population response to increased mortality is given in the studies of R. B. Miller (Biometrics 5 (1): 14-26, 1949) on the white fish populations of Canadian lakes. With increased harvest of these populations the growth rate increased and the fish matured at earlier ages. Once again, these shifts in population statistics clearly indicated an impact on the population which would, if not ameliorated, lead ultimately to severe reduction in abundance of stock. As was the case with the sardine, the changes in measurable characteristics of the fish population took place sufficiently early in the course of increased exploitation, that the eventual depletion of the stock could have been avoided. Studies currently underway at Indian Point are designed to provide reliable estimates of these vital parameters of fish populations of the Hudson River.

The Importance of Combined Ecological Studies and Power Plant Operation

A compensatory reserve of a fish population cannot be measured while the population is in an undisturbed state. The usual scientific course for determining the ability of a stock to sustain a removal has been to impose a mortality in excess of background natural loss and to simultaneously study the response of the fish stock. Accumulation of data over a period of years with varying exploitation rates and environmental conditions provides the only basis for assessing the stock's capacity to absorb additional loss. Methods for estimating maximum sustainable removal rates, given the requisite base data, are well developed.

An ideal approach to utilization of environmental resources for multiple objectives by man is to gradually increase the intensity of the utilization of the environment, remaining ready to retrench if the capacity of the environment to absorb the use is likely to be exceeded, and to subsequently utilize the base line data obtained during early steps of utilization to prescribe the optimum which can be sustained on an indefinite basis. The impact of additional environmental loading through the operation of Indian Point Unit #2 can be measured and used to predict the capacity of fish populations such as striped bass and white perch for sustaining removals. If the operation of Indian Point Unit #2 with once-through cooling is a threat to these fish populations, this fact can be determined sufficiently in advance to avoid irreversible damage. Should serious ecological consequences from operation with once-through cooling be forecast by the data, alternatives such as cooling towers can be adopted in sufficient time to avert permanent damage to fish stocks. Should the ecological studies concurrent with early operation of Unit #2 indicate that the ecosystem can withstand the additional mortality imposed upon fish populations, the operation of Unit #2 with once-through cooling can be continued as a form of environmental utilization which is compatible with maintenance of a healthy fishery.

APPENDIX I

Summary of Published estimates of Exploitation Rates in Fish Populations.

Exploitation Rate(u)	Species	Location	Reference
.25	Lepomis macrochirus (Bluegill)	Sugarloaf Lake, Mich.	(Cooper and Latta, 1954
.36	" "	Spear Lake, Ind.	(Ricker, 1955)
.35	" "	Gordy Lake, Ind.	(Gerking, 1953)
15-.20	" "	Muskellunge Lake, Ind.	(Ricker, 1945)
.29	Lepomis microlophus (Redear sunfish)	Gordy Lake, Ind.	(Gerking,1953)
.23	" "	Muskellunge Lake, Ind.	(Ricker, 1945)
.11	Pomoxis nigromaculatus (Black crappie)	Oliver Lake, Ind. Oliver Lake, Ind.	(Gerking, 1950) [illegible]
.36	Micropterus salmoides (Largemouth bass)	Gordy Lake, Ind.	(Gerking, 1953)
.12	" "	Shoe Lake, Ind.	(Ricker, 1945)
.17	" "	Oliver Lake, Ind.	(Gerking, 1950)
20-[illegible]8	" "	Southerland Res., Calif.	(LaFaunce et.al.,196
.20	" "	Clear Lake, Calif.	(Kimsey, 1957)
.14	" "	Gladstone Lake, Minn.	(Maloney et.al., 1962)
.22	Micropterus dolomieui (Smallmouth bass)	Waugoshance Point, Lake Michigan	(Latta, 1963)
05-.18	" "	Oneida Lake, N.Y.	(Forney, 1961)
.16	Ambloplites rupestris (Rock bass)	Oliver Lake, Ind.	(Gerking, 1950)
.05	Stizostedion vitreum (Walleye)	Fife Lake, Mich.	(Schneider, 1969)
15-.28	" "	Spirit Lake, Iowa	(Rose, 1947; 1955)
20-.40	" "	Escanaba Lake, Wis.	(Patterson, 1953;Niemut et.al.,1959)
[illegible]	" "	Many Point Lake, Minn.	(Olson, 1957)

Exploitation Rate(u)	Species	Location	Reference
.32	*Esox lucius* (Northern pike)	Murphy Flowage, Wis.	(Snow, 1958)
.50	" "	Wisconsin waters	(Threinen *et.al.*, 1966)
.14	" "	Lake George, Minn.	(Groebner, 1964)
.32-.49	" "	Grove Lake, Minn.	(Groebner, 1964)
.23	" "	Ball Club Lake, Minn.	(Petersen, 1955)
.22-.28	" "	Grace Lake, Minn.	(Wesloh and Olson, 1962
.38	" "	Fletcher Floodwater, Mich.	(Christensen and Williams, 1959)
.40	*Coregonus clupeaformis*	Georgian Bay, Lake Huron	(Cucin and Regier, 1965
.21	" "	Lake Superior	(Dryer, 1964)
.13-.17	*Salmo gairdneri* (Rainbow trout)	N.Y. streams	(Hartman, 1959)
.20-.26	" "	N.Y. lakes	(Hartman, 1959)
19-.75	*Salvelinus fontinalis* (Brook trout)	Lawrence Creek, Wis.	(McFadden, 1961)
.30	*Ictalurus punctatus* (Channel catfish)	Sacramento Valley, Calif.	(McCammon and LaFaunce, 1961)
.25	*Ictalurus nebulosus* (Brown bullhead)	Shoe Lake, Ind.	(Ricker, 1945)

[illegible]ploit. Rate (u)	Species	Location/Year	Reference
.49	<u>Pleuronectes platessa</u> (Plaice)	North Sea 1929-1938	Beverton and Holt, 195
.33		1950-1964	Gulland, 1968
.31	<u>Hippoglossoides platessoides</u> (American plaice)	Gulf of St. Lawrence 1957-1966	Poweles, 1969
	<u>Clupea harengus</u> (Atlantic herring)	S. Coast of Ireland	
.29		1906-1936	Burd and Bracken, 1965
.10		1951-1955	
.42		1956-1960	
.25		1961-1963	
		1923-1927	
.19	<u>Cynoscion nebulosus</u> (Spotted seatrout)	Pine Island, Fla. 1961	Iversen and Moffett,196
.40	<u>Pseudotolithus typus</u> <u>P. senegalensis</u>	Coast of Nigeria 1961-1962	Longhurst, 1964
	<u>Gadus morhua</u> (Atlantic cod)	Gulf of St. Lawrence	
.11		1949-1952	Paloheimo, 1968
.25		1955-1965	
	<u>Tilapia esculenta</u>	Lake Victoria, Africa	
.49		1958-1959	Garrod, 1963
.42		1959-1959	
.32		1959-1960	
.34		1960-1960	

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* Where p and i are listed, the exploitation rate, u, was obtained from u=ap from equation 1.8, page 25 of Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Bull. 119. Fish. Res Bd. Ca

Exploit. Rate (u)	Species	Location/Year	(p)*	(i)*	Reference
.25	*Alosa sapidissima* (American shad)	Connecticut River, Conn.	.45	1.31	Walburg, 1960
.47	*Aplodinotus grunniens* (Freshwater drum)	Upper Mississippi River Impoundments 1944-1948	.770	1.07	Butler, 1965
.58			1.07	1.37	
.31			.42	.70	
.11	*Micropterus salmoides* (Largemouth bass)	Browns Lake, Wisconsin 1953	.13	.27	Mraz and Threinen, 1957
.66	*Salmo salar* (Atlantic salmon)	Little Codroy River, Newfoundland 1955-1963			Murray, 1968
.59	*Salvelinus fontinalis* (Brook trout)	Sydenham River, Ontario 1966-1967			Marshall, 1970
.23	*Salmo trutta* (Brown trout)	Sydenham River, Ontario 1966-1967			Marshall, 1970
.07	*Stizostedion vitreum* (Walleye)	Nipegon Bay, Lake Superior 1955			Ryder, 1968
.13		1956			
.34		1957			
.14-.70	*Esox masquinongy* (Muskelunge)	Nogies Creek, Ontario 1952-1960			Muir, 1963

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APPENDIX II

Work on Fish Population Dynamics by Dr. McFadden and Basis for Knowledge of Hudson River.

In 1954 I began eighteen years of experimental and theoretical work on the population dynamics of fishes with emphasis upon factors which determine abundance and numerical variations in populations. Early studies dealt with brook trout populations which were intensively studied under closely controlled experimental conditions for a period of approximately ten years. Population statistics of extraordinary precision for wild fish populations were obtained and provide extremely useful insights into population processes of fish in general. The populations studied were subjected to varying rates of removal and the consequences of these removals were studied over extensive periods of time.

This field research was then broadened to other species and to the question of variations in different environments and their effects on abundance in fish populations. Field work was complemented by a year's theoretical study and work with laboratory animal populations at the University of Chicago under the direction of the eminent ecologist, Thomas Park.

In 1967 an intensive demographic analysis of thirteen years data on numerical changes and regulation in a fish population was completed and published. Another major review and theoretical treatment of dynamics and regulation of fish populations which spend a portion of their lives in fresh water streams and migrate for the remainder of their life cycle to the oceans was completed in 1969.

Additional work on fish population dynamics and management of fishery resources has included examination of long range trends in sport fishing in North America, with development of a rationale for management; comprehensive ecological planning for Great Lakes marine resources; and the impact of hydroelectric power generation facilities on fish populations of African rivers.

From 1961 to 1964 I was responsible for statistical design and ecological interpretation of major fishery studies conducted th the Michigan Department of Natural Resources, which then operated one of the largest state fishery research programs in the country. The projects dealt with the ecology and management of warm-water and cold-water species of fish and aquatic invertebrates in both lakes and rivers.

Since September 1971 I have been associated with the field research on Hudson River fish populations. In 1971 I was first retained by Consolidated Edison of New York to examine their research program dealing with Hudson River fisheries and to recommend an expanded effort to be contracted in the future. At this point I began a study of the published work on striped bass spawning at the Cornwall site, the research carried out under contract by the Northeast Biologists and Raytheon Corporation for Consolidated Edison, study of environmental reports produced by Consolidated Edison and published by various independent authors in the Scientific Literature, and existing data on commercial fishing in the Hudson River. I designed a detailed set of specifications for expanded study of fish populations in the vicinity of Indian Point on the Hudson River and in 1972 began active advising of Consolidated Edison and their contractor, Texas Instruments, on the Indian Point Ecological Study. I continue to be actively involved with this study in an advisory capacity and am continually involved through onsight visits with the progress of that research.

EXPERIENCE:

(a) **Dates:** July 1970 - Present
Position: Dean, School of Natural Resources
Employer: School of Natural Resources, University of Michigan, Ann Arbor, Michigan
Description of Work: Executive responsibility for an educational and research program supported by some 40 faculty and serving over 800 students at the undergraduate, masters, and doctoral levels. Long range planning for enrollment growth and curricular development; stimulation of programmatic research; professional development of faculty; liaison with central administration of the University. The School of Natural Resources is an applied, problem-solving school dealing with management of environmental resources; basic and applied research; and broad scale planning for optimal utilization of natural resources by society. Its programs are highly interdisciplinary -- emphasizing integration of natural and social sciences in resource problem solving.

(b) **Dates:** July 1969 - July 1970
Position: Professor and Chairman, Department of Wildlife and Fisheries
Employer: School of Natural Resources, University of Michigan, Ann Arbor, Michigan
Description of Work: Provide administrative direction for department faculty; facilitate curricular innovation and development of student and faculty research programs; teach courses in Fishery Management and in Dynamics of Exploited Animal Population; supervise graduate students in thesis research; conduct research in fish population ecology.

(c) **Dates:** April 1969 - July 1970
Position: Director, Water Resources & Marine Science Program
Employer: University of Michigan, Ann Arbor, Michigan
Description of Work: Plan and direct an interdisciplinary program of research, teaching, and public service initially focused on development of the marine resources of the Great Lakes, but expanding to include all interdisciplinary aspects of water resources and marine science. The program integrates inputs from the biological and physical sciences, engineering, economics, public health, law, social sciences, etc., as these relate to optimal utilization of environmental resources for the benefit of man.

(d) **Dates:** September 1966 - July 1969
Position: Associate Professor
Employer: Department of Wildlife & Fisheries, School of Natural Resources, University of Michigan, Ann Arbor, Michigan.
Description of Work: Teach courses in Fishery Management and in Dynamics of Exploited Animal Population; supervise graduate students in thesis research; conduct research in fish population ecology.

(e) Dates: July 1964 - September 1966
Position: Assistant Professor to July 1966; Associate Professor July 1966
Employer: Department of Zoology and Institute of Fisheries, University of British Columbia, Vancouver, Canada.
Description of Work: Teach courses in biometrics and population ecology; supervise graduate students in thesis research; conduct research in fish population ecology.

(f) Dates: March 1964 - July 1964
Position: Chief, Fish Divison
Employer: Michigan Conservation Department, Ann Arbor, Michigan.
Description of Work: Develop comprehensive, long-range program for management of the fisheries of Michigan.

(g) Dates: August 1961 - February 1964
Position: Biometrician
Employer: Institute for Fisheries Research, Michigan Conservation Department, Ann Arbor, Michigan.
Description of Work: Assist approximately twenty research biologists in problems of experimental design, analysis of data, ecological and managerial interpretation, etc; carry on personal research in fish population dynamics and application of statistical methods to fishery problems.

(h) Dates: September 1957 - June 1958
Position: Graduate Assistant
Employer: Department of Zoology, The Pennsylvania State University University Park, Pa.
Description of Work: Carry on ecological research on laboratory animal populations; pursue studies in statistics and animal ecology.

(i) Dates: September 1957 - June 1958
Position: Graduate Assistant
Employer: Department of Zoology, The Pennsylvania State University University Park, Pa.
Description of Work: Assist students and occasionally lecture in laboratory phase of general zoology courses.

(j) Dates: April 1955 - August 1957
Position: Fishery Research Project Leader
Employer: Wisconsin Conservation Department, Madison, Wisconsin.
Description of Work: Conduct intensive research on ecology and management of brook trout in a permanent study stream; supervise station personnel; prepare administrative and research reports; carry on related public relations and educational work.

(k) Dates: August 1954 - April 1955
Position: Fishery Management Biologist
Employer: Wisconsin Conservation Department, Madison, Wisconsin.
Description of Work: Biological inventories of lakes and streams; fish population control with toxicants; disease treatment in fish cultural ponds; lake and stream mapping; public relations; etc.

(1) Dates: June 1953 - June 1954
Position: Graduate Assistant
Employer: Department of Botany, The Ohio State University, Columbus, Ohio.
Description of Work: Prepare laboratory teaching facilities and demonstrate on experiments for general botany courses.

PUBLICATIONS:

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upon the understanding that sufficient copies are furnished to the reporter.

(The documents follow.)

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