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
John R. Clark

on

Effects of Indian Point Units 1 & 2
on Hudson River Aquatic Life

April 5, 1972

The lower Hudson is an arm of the sea, a long tidal slough running from Troy to the Atlantic Ocean. In the last 60 miles, from Newburgh to the sea, river water mixes with ocean water in gradually increasing proportions. This is the rich part of the Hudson, the estuarine sector. It is a productive breeding area for fishes, not only for resident species like white perch but also for migratory oceanic species like striped bass, shad, and herrings. The oceanic fishes are anadromous species, meaning that the adults come up the Hudson only to spawn and after spawning, return to the sea. The young grow up in the Hudson; when they are safely through early life, they migrate to the sea, leaving the sanctuary of the Hudson to spread out onto coastal fishing grounds.

It is unfortunate that Con Edison has chosen the Indian Point area to locate a number of nuclear power plants because this site is in the middle of the breeding and nursery zones for the Hudson striped bass (4). Many other species also breed in this same area. The plants are destructive to the young stages of these fish and endanger the continuance of the entire fishery served by the Hudson. The plants pose a general ecological threat to the immediate areas where they are located.

Striped bass are the most important Hudson fish and we have more scientific data concerning their life history than we have for other species, therefore the striped bass serves as a good example of the probable impact on fish life which will occur with operation of Indian Point No. 2, as it is now designed, and of other power plants to come.

The anadromous striped bass is the most important, economically, of the species that spawn in the Hudson. It supports intense recreational and commercial fisheries. For example, over 200,000 anglers fish for striped bass in New York, New Jersey, and Connecticut waters each year, catching an estimated 29,000,000 pounds (10).* These fisheries depend exclusively upon riverine breeding areas. Striped bass spawn only in certain rivers, never in the sea. There are no breeding rivers north of the Hudson and the nearest significant one to the south is the Delaware River. In tagging studies, we have shown that Hudson-bred striped bass are caught principally around Long Island (both in the Sound and along the south shore), New York Harbor, and the northern New Jersey shore (5). Safeguarding the breeding of striped bass in the Hudson is necessary to ensure the future of the species in these areas.

Striped bass breed in the part of the Hudson that extends north from the Tappan Zee(7).The heaviest spawning occurs from the Indian Point sector of the Hudson north to the Saugerties sector (1).** Striped bass spawn once

*Throughout this testimony references in parentheses are to the numbered list of references provided at the end of the testimony.

**Throughout this testimony the Hudson River sectors referred to are those used by Carlson-McCann.

a year and most spawning takes place during a month's period, from about May 15 to June 15; the peak occurs in late May and early June (1).

The eggs are released free into the water. They are semi-buoyant and drift with the flow of the tides. The eggs hatch out in about 2 days releasing yolk-sac larvae into the water at a size of about 1/10th inch (3 mm)(1). The yolk-sac larvae are planktonic; that is, they drift passively with the water flow. Within two weeks they grow to .25 to .30 inches (6 or 7 mm), absorb the yolk-sac (6), and then begin to feed on zooplankton (small planktonic life). At this point they are in the post larval stage during which they remain planktonic. Six or seven weeks after hatching they reach 1 inch (38 mm) or slightly more (1) and transform to the juvenile stage. In this stage they take on a more typical striped bass appearance.

From various studies of striped bass one can deduce the following pattern for the next 2 or 3 months of juvenile life. They apparently lead a somewhat pelagic life foraging at various depths. Their diet expands to include bottom life, such as amphipod crustaceans. At an age of 4 to 5 months after hatching, when they have reached an average size of 3 to 3 1/2 inches in length, they may be considered more bottom oriented than pelagic, except in the winter when they appear to remain at mid-water in a somewhat comatose state (1, 6, 7, 4).

In this first year of life, each brood of striped bass is exposed to a predictable risk from the power plants that draw water from the Hudson for the cooling of their steam condensers. During the first few months the larvae and young fish are entrained with the water pumped into the plant; during entrainment they are subject to lethal conditions of thermal impact, mechanical damage, exposure to toxic chemicals, and other possible effects such as reduction of dissolved oxygen. During their third and fourth months the striped bass gradually become large enough to be stopped by the 3/8" mesh screens (1). Those that are impinged on the mesh suffocate and die.

In order to predict the effect upon the striped bass population of any one of the power plants that draw cooling water from the Hudson breeding areas, it is necessary to consider the risk to each one of the stages in the cycle of the species' first year of life. I have made an analysis of the risk to striped bass, using data furnished by Con Edison and other relevant data. Because of limitations on the extent and usefulness of the data at hand, the analysis includes a number of approximations, based upon interpretive judgments. Certainly it will benefit from refinement whenever in the future the data become available to make this possible. For now, the analysis provides a needed comprehensive view of the potential effects of the Indian Point power plants on striped bass populations of the Hudson.

ANALYSIS OF REMOVALS

The Indian Point plants are located so as to have a maximum potential adverse effect on the striped bass populations. This can be seen in Figure 1 which shows the location of various electrical generating plants and the distribution of young striped bass throughout the Hudson. Specifically, the Indian Point plants are situated in areas of maximum density of all three phases of young striped bass: eggs, larvae, and juveniles. Also they are situated so as to intercept a substantial proportion of larvae and juveniles as they move to the nursery areas.

This analysis is concerned with potential damage to the first year class populations of the striped bass by depletion and death caused by Indian Point Units No. 1 and 2. I have attempted to estimate the potential damage at each major life stage; first, in terms of the actual number that would be exposed to death at Indian Point and, second, in terms of the proportion of the total population affected during each life stage.

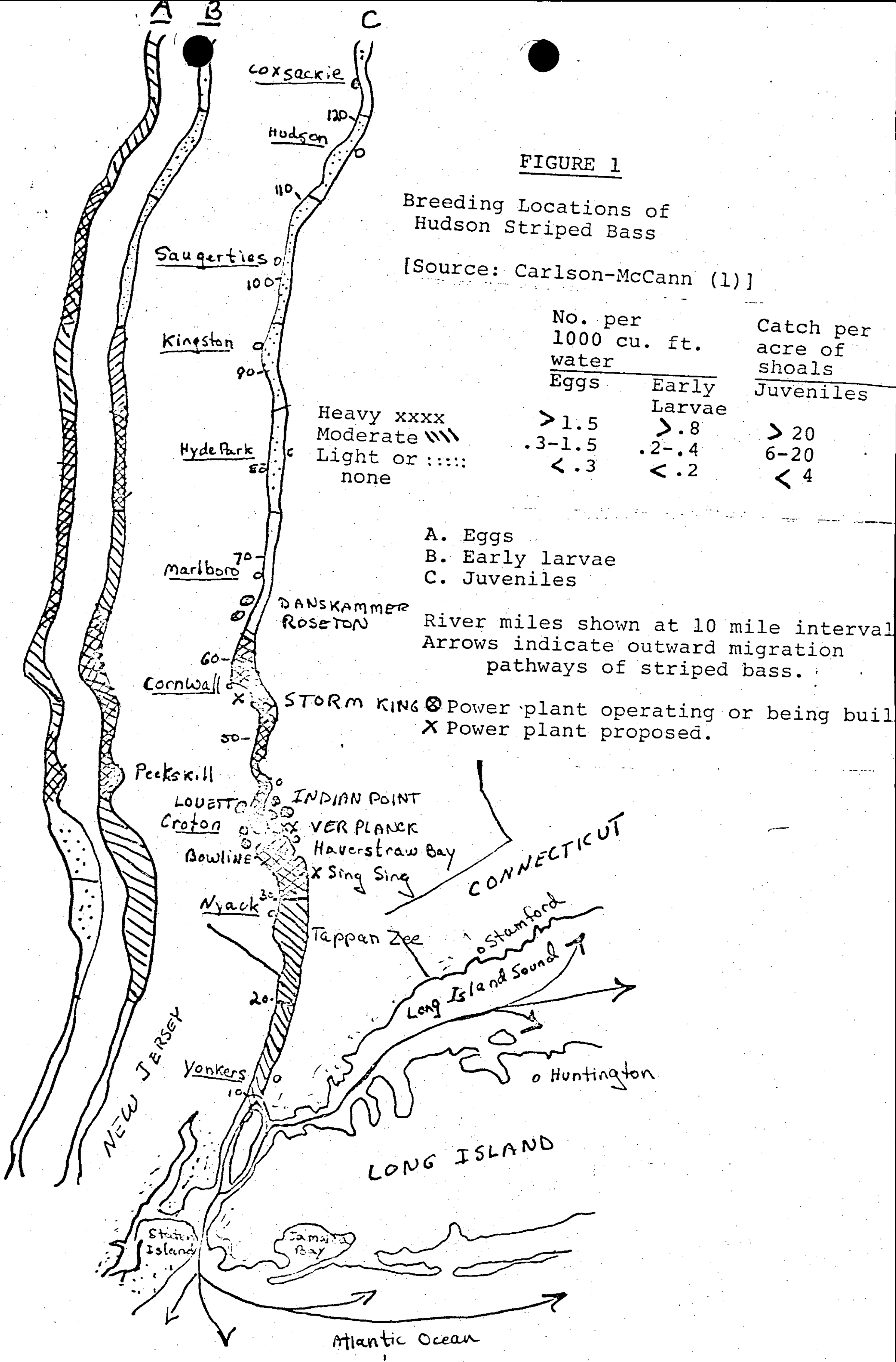


FIGURE 1

Breeding Locations of Hudson Striped Bass

[Source: Carlson-McCann (1)]

	No. per 1000 cu. ft. water: Eggs	No. per 1000 cu. ft. water: Early Larvae	Catch per acre of shoals: Juveniles
Heavy xxxx	> 1.5	> .8	> 20
Moderate \\\\\\\\	.3-1.5	.2-.4	6-20
Light or none :::::	< .3	< .2	< 4

A. Eggs
B. Early larvae
C. Juveniles

River miles shown at 10 mile interval
Arrows indicate outward migration pathways of striped bass.

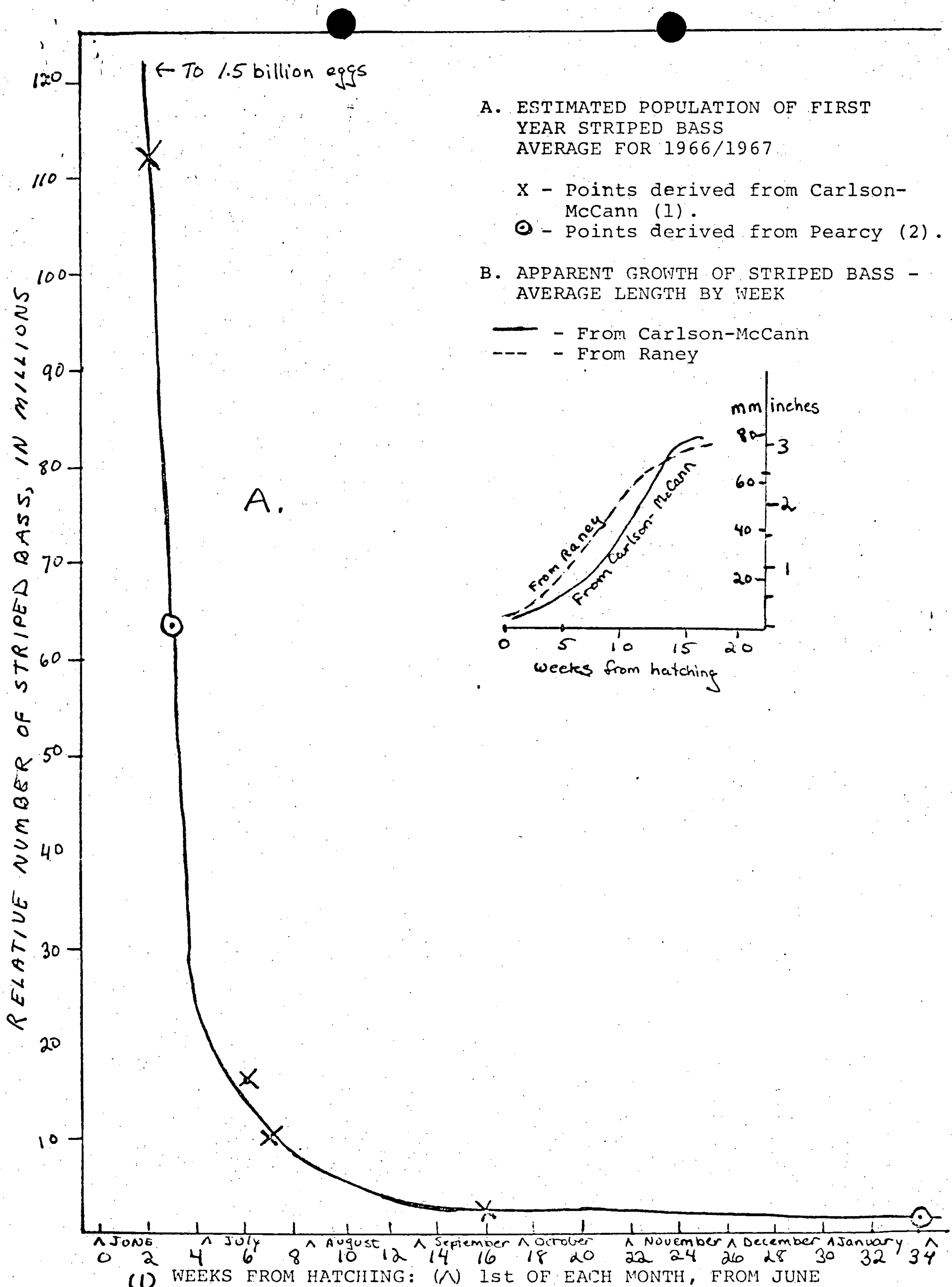
⊗ Power plant operating or being buil
X Power plant proposed.

Derivation of Population Estimates

In making this analysis it was necessary first to construct a relevant model of the survival or population curve for a typical year's brood of striped bass so that the population size could be estimated at any point in the year. The baseline data used were those for striped bass generated in 1966 and 1967 as reported in the "Hudson River Fishery Investigations 1965-1968" by Frank T. Carlson and James A. McCann (1).* The Carlson-McCann data vary widely in their suitability for quantitative analysis, but they provide the only opportunity to make some baseline approximations of striped bass populations in the various early life stages. I was guided in derivation of the population model by studies of Pearcy (2) on the survival of winter flounder in the estuary of the Mystic River, Connecticut.

The approximate population curve for young striped bass in the Hudson estuary is shown in Figure 2A. Base-points for fitting the Hudson population model were estimates of the average mid-point population for each stage derived from the Carlson-McCann data for 1966 and 1967 (1). In these two years sampling of young striped bass was conducted throughout most of the estuary and tidal fresh waters of the Hudson using methods designed to be quantitative (1). The curve follows Pearcy's description "...a concave form of decreasing mortality rates with age."(2, p. 31).

*1968 data were used to aid in interpreting the baseline data.



← To 1.5 billion eggs
A. ESTIMATED POPULATION OF FIRST YEAR STRIPED BASS AVERAGE FOR 1966/1967
X - Points derived from Carlson-McCann (1).
⊙ - Points derived from Pearcy (2).
B. APPARENT GROWTH OF STRIPED BASS - AVERAGE LENGTH BY WEEK
— - From Carlson-McCann
--- - From Raney
A.
RELATIVE NUMBER OF STRIPED BASS, IN MILLIONS
120
110
100
90
80
70
60
50
40
30
20
10
mm
inches
80
60
40
20
3
2
1
From Raney
From Carlson-McCann
0
5
10
15
20
weeks from hatching
^ June
^ July
^ August
^ September
^ October
^ November
^ December
^ January
^
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
(1) WEEKS FROM HATCHING: (^) 1st OF EACH MONTH, FROM JUNE

The steep rate of population reduction at the youngest stages is due to a very high mortality during the first few weeks of life. This is typical of estuarine species that spawn great masses of eggs each year. For instance, a female striped bass aged five years and weighing 8 pounds, sheds a half million eggs (3).

Estimates were made for various stages throughout the first year of life of the striped bass. The stages were chosen partly on the basis of natural life history factors and partly on the basis of sampling methodology and effectiveness. Although absolute numbers are assigned to the population curve, they must be considered relative values because the sampling errors are believed to have the effect of minimizing the population size; i.e., the apparent population would be less than the actual population.

Stage I - Eggs

The distribution and characteristics of striped bass eggs (1) are such that quantitative sampling of them is very difficult. Their life is short, hatching out of the egg occurs about two days after spawning. They have a slight negative buoyancy and tend to remain near the bottom where they avoid capture by conventional plankton sampling equipment.

One can estimate a standing crop of eggs for the Hudson estuary from the Carlson-McCann 1966-1967 sampling and, by adjusting for the period of an average generation, one can estimate the total production of the estuary. This derivation, shown in Table 1, results in an estimate of

TABLE 1 - An Estimate of Average Annual Egg Production of Striped Bass in the Hudson Estuary, 1966 and 1967.

River Sector	Length of River Sector[1]	Cubic Feet of Water[2] (in billions)	Average Number of Striped Bass Eggs Per 1000 Cubic Feet[3]	Average Standing Crop for Season (in millions)	Average Number of days of Spawning[4]	Number of Generations[5]	Production of Fertilized Eggs[6] (in millions)
Coxsackie	22.5	4.15	0.30	1.2	10	5	6
Saugerties	19.3	7.17	1.30	9.3	34	17	158
Kingston	10.2	6.50	0.51	3.3	28	14	46
Hyde Park	11.3	7.10	1.86	13.2	34	17	225
Marlboro	12.2	8.20	1.80	14.8	28	14	207
Cronwall	11.8	9.64	1.40	13.5	48	24	324
Peekskill	11.0	9.00	2.87	25.8	24.5	12	310
Croton	20.0	23.35	0.18	4.2	20	10	42
Total				85.3			1,318

1. From Table 21, Carlson-McCann (1).
2. Cross-Section from Table 21, Carlson-McCann (1) times length of sector.
3. Weekly abundance from Table 21, Carlson-McCann (1) average for 1966 and 1967.
4. From Carlson-McCann (1) Appendix 2-1, 3-1.
5. Number of days spawning divided by 2 (average length of embryonic life).
6. Standing crop times number of generations. Figures are rounded to nearest whole number, indicating confidence level of data.

1.3 billion at the median point or half-life of the egg. Whatever sampling incompleteness existed in the Carlson-McCann study would tend to make this a mininum estimate. It appears that there may have been serious deficiencies in the sampling techniques. For example, in 1967 such fine mesh was used that the plankton nets clogged up and failed to pass sufficient water through to collect eggs efficiently (1, p. 12). The average catch of eggs in 1967 was 1/5 of that in 1966 (0.46 compared to 2.08 per 1000 cu. ft.) for the whole Hudson. At the Peekskill Sector (used to represent Indian Point) the difference was far greater; the 1967 average catch was only 1/16 of that for 1966 (0.34 compared to 5.39 per 1000 cu. ft.). If the population of eggs for the whole river was estimated from the 1966 data alone it would be over 2 billion.

Alternately, one can estimate the egg crop from Carlson-McCann's 1968 data. In the 1968 data Carlson-McCann give predictions of a daily withdrawal of 463,000 planktonic eggs by the proposed Storm King plant for an eleven week period, or a seasonal total of 35.6 million.* Carlson-McCann estimated this to be 0.6% of the fertilized planktonic eggs produced, and thus the total produced in 1968 would be about 6 billion. However, a basic error in the procedures used by Carlson-McCann** led to an

*Slide rule accuracy throughout this testimony.

**The tidal influence was not considered. Since the organisms do not pass the plant once but are carried back and forth past it a number of times, this resulted in underestimating the time of exposure of eggs and larvae to pumping by the plant.

underestimate of the percentage (0.6%) which caused an overestimate of the total produced. Therefore, in my opinion, 6 billion, based on the Carlson-McCann sampling, is an overestimate.

Account must also be taken of the fact that the total number of eggs initially spawned is expected to be much greater than the number of fertilized eggs produced because a substantial proportion is not successfully fertilized and these sink to the bottom and die.

Possible sources of error notwithstanding, I consider the estimate of 1.3 billion viable fertilized eggs to be as good as is now possible and necessary for deriving a population estimate.

Stage II - Early Larvae

The early larvae stage extends from the hatching of the egg until the yolk is absorbed and the larvae begin to feed on zooplankton. During this interval the larvae grow from an average of 3.1 mm in total length at hatching to about 6 mm at the time of yolk absorption (1, 6).

The adequacy and uniformity of the Carlson-McCann larval fish data are affected by sampling deficiencies and by gear changes during the course of the three-year program, 1966-1968. Nevertheless, these are the best data available for estimating larval populations.

Because the lengths of larvae sampled are not given by Carlson-McCann for 1966-1967, the base years for derivation of the population curve, the stage or development for the larvae that were caught is not apparent.

However, comparison of the 1966-1967 data (1, figures 7 & 8) with the 1968 data (1, figure 9) and examination of the lengths of larvae taken in 1968 (1, table 1) indicate that the method and the nets used in much of the 1966-1967 plankton sampling were such that the catch was preponderately of the smaller yolk larvae. The 1968 data indicate that the larvae caught would range from 3-7 mm and average between 5 and 6 mm in the time of greatest larval occurence May 20-June 15. (1, figure 9, table 1).

In June of 1966 the early larvae were undersampled, apparently because the mesh was oversized (1, p. 12). Following this a standard .012 x .020 in. mesh was used until July 1967, when larger meshes were used in order to lower water resistance and to take the larger post larvae more efficiently (1, p. 12). This last change appears to have succeeded (although lengths are not given). The average of the two years may be used as an acceptable approximation of the average density of larvae in the Hudson during the period of their early existance. But the sampling in these two years is in no way representative of the density of the later larvae which avoid capture because they escape small mesh plankton nets.

To make an estimate of the average population of early larvae produced in the Hudson in 1966-1967, I found it necessary to estimate the number produced in the estuary during each week of the breeding season. This was accomplished by estimating the proportion of each week's standing crop of early larvae that was produced in that week and recruited to the existing population.

The standing crop for each week for each sector was calculated from the data in Carlson-McCann (1, app. 2-2, 3-2) and a total was drawn for the entire Hudson for each week of the larval recruitment season in 1966 and 1967, i.e., the period when new yolk larvae are added to the population from breeding activities. The recruitment season extends from the first significant occurence of yolk larvae in the samples in mid-May until one week after the last significant occurence of young yolk larvae in mid-June. The first occurence for 1966 and 1967 is the time of the initial catch of larvae in each year (week of May 15 in 1966, May 14 in 1967). Estimating the time of last occurence is more difficult. Significant spawning ended in the two years during the weeks of June 5-11 and June 4-10. Therefore, significant additions of yolk larvae should end two weeks later because the yolk stage, 3-6 mm, lasts for no more than 2 weeks. Therefore the last week of larval recruitment should be June 19-26 and June 18-25 in the two years. This cannot be directly substantiated in the 1966 and 1967 catches because larval sizes are not given, but the 1968 data for Cornwall (1, table 1) show that the average size of larvae (gear 1, mesh 2) begins to increase from mid to late June and often exceeds 8 mm. (.32 inches) by June 23-29. This indirectly confirms

TABLE 2 - The Number of Striped Bass Early Larvae Produced Each Week and Recruited to the Hudson Estuary (population average for 1966-1967)

Week of Production of Larvae[1]	Standing Crop, Number of Larvae in Hudson[2] (in millions)	Number Remaining from Previous Weeks' Recruitments[3]	Number of New Recruit Produced in Week (in million
May 5 - 21	0.1	-	0.1
May 22 - 28	2.4	.1	2.3
May 29 - June 4	7.7	2.0	5.8
June 5 - 11	37.6	4.7	32.9
June 12 - 18	80.1	23.9	56.2
June 19 - 25	63.2	49.4	14.8
TOTAL			112.1

1. In 1966; one day earlier for each week in 1967.

2. Calculated by multiplying the average density of larvae for each week, for each sector, (1, Appendix 2,3) by the volume of water in the sector (Table 1, Col. 2).

3. Calculated by assuming a reduction to 2/3 in the first week following recruitment, to 1/3 in the second, and to nil in the third (from net escapement and changes in distribution (1)).

the choice of June 19-26 and June 18-25 as the periods of last significant recruitment of larvae in 1966 and 1967.

The estimated average numbers produced and recruited to the Hudson populations each week for in 1966 and 1967 are given in Table 2. The total, 112 million, is plotted in Figure 2 as a base point representing the population of early larvae at the median point of the 28-day period of substantial larvae production, June 1-28.

According to Pearcy's model, the reduction in population that corresponds to a larval length of 8 mm is 43.4 percent, or 62.5 million remaining of 112 million, at an age of about 3 weeks (see figure 2B). This value is used as a baseline point in fitting the population curve.

Stage III - Later larvae and pre-juveniles

This stage extends from the end of the yolk stage through the larval and pre-juvenile stages during which the striped bass developsthe essential features of the adult form and ceases its planktonic existence. The endpoint of this stage is reached at the size of 1 1/2 inches which corresponds to an age of 10 1/2 weeks (figure 2B). During most of this period the fish are difficult to sample, being large enough to escape capture by the plankton nets and not large enough nor distributed so as to be captured efficiently by the trawls used by Carlson-McCann. In 1968, when sampling was confined to the Cornwall sector, more intensive development of sampling gear was conducted and a progression of mesh sizes was used throughout the season (1, table 1). These results show more accurately the natural rate of decline in population and are useful in estimating the density of the later larvae and pre-juvenile fish (1, App. 4) based on the density of the early larvae.

At Cornwall in 1968 the peak of abundance of yolk larvae was 12.19 per 1,000 cubic feet during the week of June 9-15 (average size of fish was 5 - 6 mm). By the week of June 30-July 6 catches reached a low of 0.37 per 1000 cubic feet, apparently because the larvae drifted out of the sampling area. Then in the week of July 7-13 abundance increased nearly fivefold to 1.74 per 1000 cubic feet (average size of fish was 11 mm). It is likely that this represents the measure of their true abundance in the Hudson; the increase may have been caused by the penetration of the salt front up the estuary to Cornwall, bringing the later larvae and pre-juvenile fish with it. In any event, between June 9-15 and July 7-13 there was a decline from 12.19 to 1.74 fish per 1000 cubic feet, a reduction of 85.7% in the four weeks following the peak of yolk density. There was a further reduction to 1.08 fish per 1000 cubic feet, or 91.1%, in the course of next week, July 14-20.

If the 1966-1967 population of 112 million is reduced by these amounts, the population size remaining at the end of the 6th and 7th weeks following hatching is 16.0 and

TABLE 3 - Striped Bass Catch in Trawls at Cornwall, 1967

WEEK	Bottom Trawl, Number per tow	Surface Trawl, Number per tow
Aug. 13 - 19	15.4	1.3
Aug. 20 - 26	8.3	2.8
Aug. 27 - Spet. 2	15.7	133.8
Sept. 3 - 9	7.0	0.5
Sept. 10 - 16	28.0	0.8
Sept. 16 - 23	1.9	0.3
Sept. 24 - 31	3.5	0.0
Oct. 1 - 7	1.4	2.2
Oct. 8 - 14	28.7	0.7
TOTAL	109.9	142.4
AVG. per tow	12.2	15.8
EST. Amount of Water Sampled Per Tow (in thousands of cubic feet)	300.0	200.0
AVG. Number per 1000 cubic feet	.041	.079
AVG. for both gears	.060	

Source: 1, Table 16

TABLE 4 - Computation of the Proportion of Early Junveniles at the Cornwall Sector, in Trawl Sampling - 1968 .

	Number of Fish per tow[1]	% of Water Volume in Hudson at Sector	Index of Relative Abundance[2]
Saugerties	0.2	9.2	2
Kingston	0.5	8.3	4
Hyde Park	1.7	9.2	16
Marlboro	4.2	10.5	44
Cornwall	48.5	12.3	597
Peekskill	47.4	11.5	545
Croton-Nyack	37.4	30.0	1120
Yonkers	8.2	9.0	74
TOTAL			2402
Cornwall as a percentage of total.			24.8%

1 Source: (1) Table 11

2 Fish/tow X percent of water volume at station. Figures are rounded to nearest whole number, indicating confidence level of data.

10.0 million. These points are used in deriving the population curve (Figure 2A).

Stage IV - Early juveniles

The juvenile stage begins at the time the striped bass ceases its planktonic mode, becomes pelagic and finally bottom oriented at about 1 1/2 inches (38 mm) in length and extends throughout the first year of life. It appears that the early juvenile stage is a period of fast growth and within the 28 days of this stage (August 13-Sept 9) the young stripers will almost double their length, from 1 1/2 to nearly 3 inches (38-76 mm) (1, table 24; reflected in Figure 2B).

The Cornwall sector is the only one with reliable data for this life stage and I have estimated the population for the whole Hudson from this sector. The population of pelagic early juveniles can be estimated from sampling in 1967 at the Cornwall sector (1, table 16) with bottom and surface trawls. The average density of early juveniles in the Cornwall sector is 0.60 per 1000 cu. ft. of water, as compgted in Table 3. Since there are 9.64 billion cu. ft. of water in the sector, there is an estimated average population of about 0.6 million early juveniles at Cornwall in the summer period.

The data for 1966 are less complete but an average catch of 13.5 fish per bottom trawl tow in 1966 (1, table 15) compares closely enough to the 12.2 per bottom tow in 1967 to indicate that the 1967 data represents an acceptable average for both years.

I have used for reference the 1968 sampling data for bottom trawls (1, table 11). I have assumed that the distribution of young throughout the Hudson in 1966-1967 was generally similar to that of 1968. From Table 4 it can be seen that the population of juveniles in the Cornwall sector was about 25 percent of the whole Hudson in 1968 based on the bottom trawl sampling. Therefore, on the assumption that the same proportionate distribution applies to 1966-1967, the population of early juveniles would be about 2.4 million for the whole Hudson. This point is used in deriving the population curve and is plotted at 16 weeks, the median point of the interval 11 1/2-20 1/2 weeks from hatching (Figure 2A).

Stage V - Later juveniles

I was not able to establish the population of later juveniles from the Carlson-McCann data because sampling was not conducted in late fall or winter. However, Pearcy (2, p. 57) indicated that of the fish which survive to become juveniles 41% would survive through ten months of juvenile life. At this rate, 75% of the 2.4 million striped bass population at the 16th week would survive to the 34th week, leaving a population of 1.8 million in mid-February. No other estimate is possible with the data at hand.

Estimation of Removals

The purpose of this part of the analysis is to estimate the number of striped bass removed from the Hudson by the Indian Point plants, i.e., the numbers of each stage which would be withdrawn from the Hudson along with the condenser cooling water and either killed on the protective screens or carried through the screens into the plant where they are exposed to lethal conditions.

For eggs (Stage I) and early larvae (Stage II) this estimate was made by simply taking the average number of fish per unit of water (1000 cubic ft.) from plankton net data for the sector representing Indian Point in 1966-1967 (Peekskill stations) for the breeding season and multiplying it by the number of units of water pumped during the season. This estimate of the quantity removed can be expressed as a percentage of the whole population as it is determined from the population curve (Figure 2A).

For larvae and pre-juvenile fish (Stage III) the computation was similar except that the number of larvae per unit of water was based on the rate of population reduction from early larvae (Stage II) to larval and pre-juvenile fish (Stage III), per unit of water. For early juvenile fish (Stage IV) the same general procedure was followed. Estimates of the number of juveniles per unit of water were obtained from the Carlson-McCann trawl data for 1967 (1, table 16). Only those of prescreenable size were included; the larger, screenable sizes are made up of later juveniles (Stage V).

For later juvenile fish (Stage V), estimates were made separately for each month, using Con Edison reports of fish kills for Indian Point 1 and making suitable adjustments.

Separate estimates were given for each of the assigned stages in the first year of life of the striped bass. Taken together, the estimates span the period from spawning (peak about May 29-30) and the emergence of early larvae to the end of the first year of life (May 28 of the following year). They cover the period when the species is most vulnerable to the operations of power plants at Indian Point using once through cooling. Estimates, of the number of fish subject to removal by the plants are made for each stage. The eggs are treated separately. The larval and juvenile stages are treated sequentially by stage. The stage assignments are as follows:

Life Stage	Assigned Dates	Length of Period	Median Date
I	5/17 – 6/11	24 1/2 days	6/1
II	6/1 – 6/28	28 days	6/16
III	6/29 – 8/12	45 days	7/21
IV	8/13 – 9/9	28 days	8/27
V	9/10 – 5/28	261 days	1/21

Stage I - Eggs

The egg stage would be the least affected by power plant operation at Indian Point. Their exposure time would be brief because egg deposition occurs over a long stretch of the Hudson above Indian Point and because the life of the eggs is only two days.

In Table 1 the average density of eggs at the Indian Point sector (Peekskill stations) for 1966-1967 was estimated at an average of 2.87 per 1000 cu. ft. of water (5.39 and 0.34 per 1000 cu. ft. in 1966 and 1967) from the Carlson-McCann data for a spawning period averaging 24 1/2 days - 3 weeks in 1966 and 4 weeks in 1967 at Peekskill (1, App. 2-9, 3-9). In this 3 1/2 weeks, 5.45 billion cu. ft. of water would be pumped into the Indian Point No. 1 and 2 plants at a planned rate of 1,157,000 gallons per minute (8, p. 2.3.2-3). Consequently, the removal by the plant operations would be 15.6 million eggs per year based on the average density for the 1966 and 1967 spawnings.

Stage II - Early larvae

The estimates of removal of early larvae (Stage II) were made following the same general procedure as outlined for eggs. This stage is comprised of young larvae taken in the plankton nets, which appear, because of the nature of the sampling, to be mostly yolk larvae. One cannot be more specific because Carlson-McCann give no size data for larvae sampled in 1966 and 1967. However, the size data are given for Cornwall sampling in 1968 (1, table 1) which indicate that the larvae catch was made up of yolk larvae (averaging 5-7 mm) and some small post-larvae (averaging 8-9 mm) through to the end of June when the larvae become very scarce. The larvae then reappear in greater abundance at a larger size (about 12 mm) in July. The same scarcity and reappearance shows in the 1967 data for Peekskill but not in the 1966 data (when the finer mesh used in the net greatly reduced its efficiency for catching larger larvae). I have used this low point in abundance to mark the end of the early larvae phase (Stage II). This seemed appropriate because spawning terminates in mid-June so there can be no further additions of yolk larvae, because there is a temporary diminution at this point, and because the 1966 sampling failed to take significant numbers of larvae past this point. Thus I have used the period from first appearance of larvae (June 1) at Peekskill to the temporary low point (June 28th) for the period of removal by the plants at Indian Point of the early larvae, those effectively sampled by the plankton nets in 1966-1967.

In this 28-day period the average denisity of the early larvae can be deduced to be 0.92 per 1000 cu. ft. of water from the Carlson-McCann data, as shown in Table 5. Since the Indian Point 1 and 2 plants would pump 6.2 billion cu. ft. of water in the 28 days, there would be 5.7 million larvae removed by the plants in one season, or 5.1% of the median population of 112 million.

Stage III - Later larvae and pre-juveniles

The later larvae and pre-juveniles stage occurs during a sampling hiatus in the Carlson-McCann data. The period involved is 45 days, including weeks 5 to 11 1/2 (June 29-August 12) as previously mentioned. In order to estimate the densities of the later larvae and pre-juvenile fish (Stage III) that would be subject to removal by Indian Point Units No. 1 and 2 during this period, I have used the population curve (Figure 2A) to estimate the survival density at the mid-point of the period, 7 3/4 weeks. The median population of early larvae (112 million) corresponds to the time of peak density of larvae at Peekskill in mid-June --2.36 and 1.51 per 1000 cu. ft. for 1966 and 1967 (1, App. 2-9, 3-9) or an average of 1.93 per 1000 cu. ft. The survival indicated at week 7 3/4 is 8.5% corresponding to a density of 0.16 fish per 1000 cu. ft. of water.

The Indian Point No. 1 and 2 plants would pump 10.0 billion cu. ft. in the 45 days of the period removing 1.6 million larvae. This is 16.7% of the 9.5 million population at the 7 3/4 week median.

During this period the fish grow from less than 0.5 inch (6 mm) to about 2 inches (51 mm). Near the end of the period a small proportion are large enough to be caught on the intake screens. They die there but are prevented from entering the plant (1, table 24). These fish are not treated separately.

TABLE 5 - Calculation of Average Larvae Densities for June 1 - June 28 from Plankton Net Samples 1966-1967

Sampling Week[1]	Average of Larvae Densities, Number per 1000 cubic feet[2]
May 28 - June 3	.06
June 4 - 10	.44
June 11 - 17	1.77
June 18 - 24	1.20
June 25 - July 1	.40
Weighted Average[3]	.92

Source 1, appendix 2-9, 3-9

1 For 1967; 1966 is one day later each week

2 Average of weekly averages for 1966 and 1967.

3 Based on 3 days of week 1, 7 days each of weeks 2-4, and 4 days week 5.

Stage IV - Early juveniles

The early juvenile stage is assigned to a period of 28 days, from August 13-September 9. This is a period of fast growth (Figure 2B) during which the juveniles increase from about 2 inches (51 mm) to about 3 inches (76 mm), a size large enough for nearly all to be impinged on the intake screens (1, table 24). The juveniles become less pelagic at this time and more bottom oriented. This stage, then, carries them through the transition from mostly pre-screenable to fully screenable and from a more pelagic life to a more bottom oriented life. It is assumed that once they abandon the pelagic life habit they are no longer uniformly distributed through the water and subject to simple entrainment in the plant cooling water. Therefore, over this period I have reduced entrainment from nearly 50% to nil, as well as their passability by the intake screens (1, table 24).

Estimates of the number of early juveniles (Stage IV) subject to removal can be made from the quantitative trawl sampling conducted in 1967; the weekly results are listed in Table 3. Following the data and the procedure developed in Table 3, but for only the four weeks from August 13 to September 3 we find an average density of 0.11 fish per 1000 cu. ft. of water. This is an even higher density than later larvae and pre-juveniles (Stage III) owing to peculiarly high catches in one week, particularly by the surface trawl. Nevertheless, the data are presented as valid by Carlson-

McCann and since one can only assume that chance variation is the cause, I have no reason to discard this one high estimate in drawing a monthly average. However, it does make a week by week analysis unreasonable.

The total of water withdrawn by Indian Point Units 1 and 2 in the 28-day period is 6.2 billion gallons. The total number of fish in this amount of water would be 0.68 million ($0.11 \times 6.2 \times 10^9 / 10^3$). The change from pelagic to bottom oriented mode is reflected in a linear reduction from full vulnerability to removal by entrainment on the first day, to nil on the last day. The average would be 50%, resulting in a total for the 28-day period of 0.34 million. The size of the fish results in 77.5% being screened at the intake (average for the weeks August 11-September 7; 1, table 24). Reducing the 0.34 million by 77.5% leaves a total of 0.077 million subject to withdrawal into the plant.

In addition, from the data in Table 6 it can be estimated that in the 28-day period (August 13-September 9) a total of 399,000 fish of all species would actually be impinged on the screens. If 5% of these were striped bass then 0.020 million of the species would be impinged. Added to 0.077 million above, the total for the period becomes 0.097 million --2.8% of 3.5 million, the average population for the period.

Stage V - Later juveniles

This stage comprises the remainder of the first year of life of the striped bass following hatching, 261 days from September 10th to May 28th. The fish are assumed to be bottom oriented, nektonic, and fully screenable. Their vulnerability to eradication by the plants is affected by behavioral characteristics, most of which are, presently, quite unpredictable.

The number of striped bass that would be killed on the screens by Indian Point Units 1 and 2 can be projected from the records of fish kills at Indian Point No. 1 that are available from 1965 to 1971 (8, App. S, and additional records supplied by Consolidated Edison). These records are not continuous over the 6 years, nor are they complete for the intervals of sampling. The effect of the errors is to understate the number of fish killed. Therefore, I made a number of adjustments and interpolations in order to make the record more complete for the periods when fish counting was done.

The reported data for the period when the plant was in operation and counts were made are listed, as I have been able to assemble them from records supplied by Consolidated Edison, in Table 6. The daily average counts for all species for each month were averaged, with 1971 given a weight of 2 in the averaging, because it is the latest year and would tend to reflect any recent changes in conditions, such as reduced flow operation in winter. It is known that the records do not represent the total daily fish kill, but only a part of it. For example, fish counting was not carried out continuously; i.e., for all hours of the day and all days of the week. Typically, fish counting rarely has been done on weekends. To account for this incompleteness I added 25% as my best estimate of the amount of fish not included because of sampling periods missed.

A second source of underestimation arose from the sampling methods used; i.e., the incomplete method of collecting the fish from a sluice after they were cleaned by a water jet from the traveling screens which resulted in a substantial number washing away without being counted. The amount so lost is estimated at 25% by Con Edison. Together, the two sources of error are corrected by increasing the raw daily average kill of all species by 50% for each month as shown in Table 6. This is only an approximation but there does not appear to be a better basis for arriving at the average kill for Indian Point No. 1 and obtaining an estimate of potential Indian Point No. 2 screen kills.

Specific data for Indian Point No. 2 are available from pre-operation tests conducted in 1971 during which no power was produced but the pumps were operated. The most useful test series is that of February 4th to 10th when the pumps were operated continuously for 3 out of 6 bays, with the following results:

Table 6 Estimation of daily average screen kills at Indian Point for all species and the total annual kill for all species and for striped bass.

Month	Indian Point Unit Number 1: Screen kill per day from Con Ed reports 1965	1966	1967	1970	1971	Reported Average[1] (in 1000's of fish)	Estimated Total kill per day[2]	I.P.No.2 Projected screen kill per day[3]	Combined Kill for I.P.No.1 and No.2 per day	Combined Kill per month (thousands) all species	striped bass[4]
January			7,200	20,000	-	13.50	20.3	81.4	101.5	3,150	160
February			4,300	6,000	5,000	5.10	7.6	30.4	38.0	1,060	53
March	1,100		4,400	8,000	350	2.80	4.2	16.8	22.0	680	34
April	1,500	500			400	.70	1.0	4.0	5.0	150	8
May	-	700			150	.35	.5	2.0	2.5	80	4
June	500	600			150	.35	.5	2.0	2.5	80	4
July	3,100	1,600			150	1.25	1.9	7.6	9.5	290	14
August	6,300	1,000			800	2.20	3.3	13.4	16.5	510	26
September	1,400	900			1,400	1.25	1.9	7.6	9.5	280	14
October	1,000	1,300			-	1.15	1.7	6.8	8.5	260	13
November	700	1,400			-	1.05	1.6	6.4	8.0	240	12
December	-	4,600			-	4.60	6.9	27.6	34.5	1,070	54
								Total Annual Kill		7,850	396

[1] 1971 given 2 x weight in computing the average.

[2] The average increased by 25% for missed sampling periods and 25% for undersampling.

[3] Indian Point No. 1 x 4.0.

[4] At 5% of total.

Bay	Operation	All species. Reported average kill in 1,000 Per bay	For 6 bays
26	Full flow (140 gallons per min.)	4.0	24.0
23	Reduced flow (105 gallons per min.)	3.7	22.2
22	Reduced flow (105 gallons per min.)	3.1	18.5
Average for 22 & 23	Reduced flow (105 gallons per min.)	3.4	20.4
Adjusted to represent total kill (50%)			30.6

The reduced flow rate is most appropriate for estimating kills because Con Edison intends to operate Indian Point No. 2 at reduced flow in the winter period (Indian Point No. 1 is apparently operating now at reduced flow). Because there are no concurrent records for Indian Point No. 1 for this time, I compared the average rate of 30.6 thousand for Indian Point No. 2 to the average February kill of 7.6 thousand for Indian Point No. 1 (Table 6). The Indian Point No. 2 kill of 30.6 thousand is 4.0 times the February average for Indian Point No. 1. The total for both plants would be 38.2 thousand fish killed per day, or a combined kill 5.0 times greater than that for Indian Point No. 1 alone. This is a conservative estimate because it is based upon reduced flow operation for all seasons, not just winter alone.*

The total projected kill per year for Indian Point No. 1 and 2 is 396,000 striped bass per year (Table 6). By seasons the kill of striped bass (not adjusted for sequential reduction) is as follows:

*In late February, 1972. 2 bays at Indian Point 2 were operated and more than 130,000 fish were killed in four days. This indicates that this estimate is indeed conservative.

Season	No. of fish killed
September-November	39,000
December-February	267,000
March-May	46,000
June-August	44,000

During the later juvenile period (Stage V) (September 10 to May 28) the kill would be 348,000 (September: 10,000; October-November: 25,000; December-February: 267,000; March-May: 46,000) or 18.3% of the population of 1.9 million (at the median point, mid-January).

Older Fish

Striped bass appear to be vulnerable to Indian Point power plant operations principally in their first year of life. Screen kill records available from Con Edison for Indian Point No. 1 show that kills of striped bass of one year of age and older have been infrequent in recent years and consequently we have not included them in the analysis.

Other Species

Screen kill records of Consolidated Edison show clearly that white perch, tomcod, herrings, anchovy, and other important species are killed in great numbers on the Indian Point No. 1 screens. Much higher kills would occur on the Indian Point No. 2 screens, probably increasing the total kill of these species at the Indian Point site each year by a factor of 5 or greater, as previously shown for striped bass. The kill of species other than striped bass is estimated at 7.5 million fish per year (Table 6).

Thus the populations of other valuable species can be expected to suffer serious adverse effects from Indian Point No. 1 and 2 alone. If Indian Point No. 3, Roseton, and Bowline should also be operated with once through cooling the combined effect could be disastrous to the fish life of the Hudson.

Although I have not made quantitative estimates of the effects on other Hudson fishes, it is clear that planktonic and pelagic pre-screenable stages of the other species would be exposed to risks from entrainment and death in the Indian Point No. 2 cooling system similar to those for striped bass. The breeding periods of such important species as white perch, anchovy, and herring, also occur from May to July and their planktonic early life stages would be vulnerable to withdrawal in this period.

Impact on Populations

The extent of the removals indicates that operation of Indian Point plants No. 1 and No. 2 with once through cooling would have a serious adverse impact on the striped bass populations of the Hudson. There are some possible mitigating factors that must be considered but none that offer any certainty of significant reduction of the adverse impact.

Proportion of the Population Removed

To approximate the total removals from the population of first year striped bass by the Indian Point plants, one may accumulate the losses of the various early life stages. I have added the removals in sequential order and the loss for each stage is based on the population remaining after the loss for the preceding stage is subtracted. This procedure is necessary if one assumes that all fish entrained and carried into the plant are killed. The results are shown in Table 7. Egg removals are not included because they are so small a portion of the whole population.

The effect of full time operation of Indian Point No. 2 along with Indian Point No. 1, with both using once through cooling, would be to remove from the Hudson 40 percent of the striped bass in their first year of life, from early larvae through to advanced juveniles. This estimate of removals is based upon year round operation of the plants. It is clear that the plant will be off line at times, but any reduction because of partial operation, "down time" for maintenance, and so forth, would depend upon the time of year involved. For example, if the plant were not operated in May the reduction in removals would be low, if it were not operated in July or January the reduction would be great. On average, an allowance of 15% or 10% non-operating days would reduce the removals to a total of approximately 34 to 37 percent of the Hudson population.

TABLE 7 - Removals of striped bass by Indian Point Units Nos. 1 and 2 at various stages in the first year of life.

		STRIPED BASS SUBJECT TO REMOVAL INDIAN POINT No.1 & 2				
LIFE HISTORY STAGE AND LENGTH OF STAGE	Original Population (Median)	Unadjusted fish removed (millions)	Adjusted population (millions)[1]	Adjusted removal (millions)[1]	Percent of population (millions)	Remaining population (millions)
EARLY LARVAE 28 DAYS	112	5.7	112	5.7	5.1	106.3
LATER LARVAE 45 DAYS	9.5	1.6	9.0	1.5	16.7	7.5
EARLY JUVENILES 28 DAYS	3.5	0.10	2.7	0.08	3.0	2.62
LATER JUVENILES 268 DAYS	1.9	0.35	1.4	0.26	18.6	1.14

PERCENTAGE OF ORIGINAL POPULATION REMAINING AT END OF FIRST YEAR: 60%

1. Adjusted at each stage for removals at the prior stage.

Mortality of Removals

For screenable sizes (generally above 2 inches or 51 mm) it is accepted that virtually all fish are dead or mortally injured as they come off the traveling screens at Indian Point No. 1. Indian Point No. 2 is fitted with the same type of screens and therefore the effect of screen impingement should be just as lethal.

For the smaller pre-screenable striped bass, larvae and juveniles that are entrained there is a serious absence of data. There are no studies of the effects on pre-screenable stages of striped bass of passage through Indian Point No. 1 or No. 2. However, there are studies by Barton C. Marcy that show the effects on white perch, a very closely related species (11). This work, done at the Connecticut Yankee plant, Haddam Neck, Connecticut River, shows clearly that white perch yolk larvae are all killed by passage through the plant; at least when temperatures are elevated to 83° F. (28.2°C) or higher at the discharge. This temperature condition would be reached in the cooling water of Indian Point No. 2 in early June and remain until early October, the period when Hudson ambient temperatures exceed 68° F. Marcy got a complete kill at 83° F but tried no lower temperatures. Therefore, it is quite possible that a complete kill, or virtually complete kill, would occur at even lower temperatures.

It is valid to assume that striped bass would be affected in the same manner as white perch because they are such closely related species. Consequently one must assume that beginning in early June, a lethal condition for them would exist in the Indian Point No. 2 cooling system. Since the peak of striped bass early larvae abundance occurs in June in the Hudson, those entrained in the cooling water would be exposed to the conditions of the Marcy experiment and would die (See Marcy experimental Set A for June 30th.(11)).

Marcy stated that the majority of the dead larvae and juveniles emerging from the plant were "mangled" and this condition "was more apparent in larger specimens." Thus for the species Marcy studied, the damage apparently was even greater for stages following the yolk larvae; thus later larval and prescreenable juvenile stages can be expected to suffer heavy mechanical damage and death. It is probable that virtually all of the striped bass entrained and carried through the plant will be killed--from early larvae to pre-screenable juveniles.

In determining the potential impact of plant removals on striped bass stocks one must assume that all fish withdrawn by the plant are killed, including those entrained in the cooling water and carried through the plant as well as those impinged upon the screens. There is no proof that any significant number will escape death.

Compensatory Effects, Predation, and Competition

One cannot be certain of the type of relation that may exist between the quantity of striped bass and other species steadily removed from the Hudson and the size and vigor of the steady state population of striped bass. The number of variables involved in a natural estuarine habitat are so great so to have prevented anyone from completing a really comprehensive analysis of this type. However, there is a background of knowledge, mostly fresh water, from which certain relationships are drawn and held to be true by many fishery researchers.

The principle of overcrowding is generally accepted by fresh water fishery experts. It is quite demonstrable that if too many fish are crowded into a pond or small lake, the result is that individual fish become stunted from a shortage of food and do not reach a size desirable to fishermen (12).

No applicable experimental results demonstrating overcrowding in a natural estuary are known to me, but we might assume that this could happen in some situations. Estuaries are known to be very productive and a standing crop of 100 pounds or more of fishes per acre would not be unexpected (9). Productive fresh water ponds, lakes, and reservoirs also hold more than 100 pounds of fish per acre. Certainly, any typical estuary holding far less than 100 pounds per acre of fishes could not be considered overcrowded. It has been estimated that the Hudson estuary in the vicinity of Indian Point (Haverstraw Bay to the Bear Mountain Bridge) holds only 7.2 pounds per acre of white perch, the most abundant demersal species there (13). This low standing crop certainly indicates that the Hudson near Indian Point is not overcrowded with demersal species for an estuary considered at one time to be as productive as the richest of fresh water lakes (14).

The trawl catches of Carlson-McCann (1) also appear to suggest that overcrowding does not exist in the lower Hudson. The various samplings reported show that standing crops rarely exceeded 200 or 300 small fishes per acre, weighing altogether not more than 5-10 pounds. Striped bass were found to occur at about 25-30 per acre in the vicinity of Indian Point (1, table 11) -- a standing crop of less than 1/2 pound per acre.

From the information at hand one gains the impression that the Hudson estuary is carrying less than its natural capacity of demersal fishes, rather than more. If this is so, there should be no shortage of food for the young striped bass nor serious competition for food with other species, such as white perch. Consequently, it appears that there would be no beneficial compensatory effect from thinning populations by killing fish at Indian Point.

Since there appears to be no overpopulation of fishes in the Hudson, the removal of millions of fish that striped bass feed upon by the Indian Point plants would reduce the available food supply for striped bass. A shortage of forage fishes certainly would be a detriment to the striped bass that spawn in the Hudson and then feed heavily before leaving for the sea. The recorded kills for Indian Point No. 1 are made up in large part of white perch, a species that striped bass are known to feed upon in the Chesapeake Bay, particularly in the late spring and early summer(15). (There have been no detailed studies of feeding habits reported for Hudson striped bass older than 1 year.)

Additional Power Plants

The adverse effects on the striped bass populations of removals at Indian Point will be far more serious in combination with the effects of other power plants being built on the lower Hudson. Certainly the total number of striped bass and other species removed and killed will increase greatly. With Roseton and Bowline Point operating the remaining population would drop to less than 35 percent of the original population. With the proposed Verplanck, Sing Sing, and Storm King plants the numbers remaining would fall to a nearly negligible proportion of the original population and the resource would be gravely endangered.

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