50-247
RESPONSE to encl 2 of NRC's ltr of 7/26/77 Furnishing requested info relative to requested license amen titled "Request for License Amend to Eliminate Requirement for Termination of Operation w/Once-Through Cooling System" dtd 3/77

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Attachment A

The following are the identification numbers for questions in Enclosure 2 to Mr. George W. Knighton's letter of July 26, 1977 to Mr. William Cahill, Jr. These numbers were identified by Dr. Sigrid Christensen, Oak Ridge National Laboratory, in a phone conversation with Dr. Kenneth L. Marcellus on November 16, 1977 and again on February 24, 1978 as questions remaining to be answered.

Question No.
I
II
IV-2
V-1
V-2
V-3
V-9
VI-1
VI-2
VI-3
VII-1
VII-2
VIII-1
VIII-2
IX-1
IX-2
X-1
X-2
XI-1
XI-2
XII-1
XII-2
XIII-1
XIII-2

Attachment A (Cont'd)

Question No.

XIV-1
XIV-2

XV-1*
XV-2*
XV-3*

XVI-1

XVII-1

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* Response to be provided shortly

Attachment B

Responses to Questions

I. Information needed to calculate estimates of F_c (the fraction of live organisms killed by entrainment).

Response: Information to calculate estimates of F_c for Indian Point, Bowline Point and Roseton Generating Stations has been provided to Oak Ridge National Laboratory (ORNL) Staff (Dr. Webster Van Winkle) on magnetic tapes pursuant to a request by the U. S. Environmental Protection Agency with one exception. The exception is the provision of 1977 entrainment survival data on magnetic tape. A tape containing this data will be sent to the ORNL staff very shortly. (Please note: this data was contained in a report which was provided to the ORNL staff by copy of Kenneth L. Marcellus' letter of November 30, 1977 to Henry Gluckstern, Esq. EPA Staff Attorney.)

II. Information needed to calculate estimates of f_I, the intake f-factor.

Request: Table II-3 provides a format for presentation of information about sampling gear and conditions for net samples. While much of this information is contained in existing reports, much is not, and there is a need to have a unified comparison of sampling information. For clarification of terms, see pages V-195 and V-196 of USNRC (1975), Final Environmental Statement related to operation of Indian Point Nuclear Generating Plant, Unit No. 3. Where conditions are not constant through a year, an additional table or tables may be needed. For example, if velocities in intake and discharge areas vary, a table of velocities on particular dates will be needed.

Table II-4 provides a format for presentation of sampling information where pumps have been used instead of nets to collect data. Additional tables may be needed if sampling conditions varied during the season.

Supply sets of tables for relevant sampling at Bowline, Lovett, Indian Point, Roseton, Danskammer, and Albany. Priorities are as follows:

1. Indian Point, 1977, striped bass (NYU and EA)

2. Indian Point, 1974, striped bass (NYU; any other relevant data).

   Albany, 1974, striped bass

   Roseton, 1974, striped bass

   Bowline, 1974, striped bass

   Lovett, 1974, striped bass

   Danskammer, 1974, striped bass

3. 1975 striped bass data, as in (2)

   1974 white perch data, as in (2)

   1975 white perch data, as in (2)

1976 striped bass data, as in (2)

1976 white perch data, as in (2)

1973 striped bass data, as in (2)

1973 white perch data, as in (2)

High priority should, however, be given to situations where both pump and net sampling has been conducted in intakes and/or discharges (e.g., Bowline and Roseton from 1975 on). High priority should also be given to any situation in which comparable nets have been used comparably (i.e., with similar sampling velocities) at both in-plant and at river stations.

References should be provided to sections of reports in which the studies are documented. Maps indicating station locations should be supplied or referenced by report and page number. If estimates of the volume of water filtered are not directly obtained from flowmeter readings, the source of the volume estimates should be clearly indicated.

Response: Tables II-3 and II-4 for Indian Point, Bowline Point, Lovett, Roseton, Danskammer and Albany Steam Generating Stations have been completed and are attached.

References to sections of reports in which the gear described in Tables II-3 and II-4 are documented in the same tables. An index to these tables is provided.

The dates that the raw data were transmitted to the EPA and references to results and analysis of this data are being compiled and will be forwarded shortly.

Index to Tables II-3 and II-4

Table	Gear	Location	Year	Contractor
II-3 A	Net	Bowline Point, Lovett	1974	LMS
II-3 B	"	" " "	1975, 76	"
II-3 C	"	" " "	1975, 76	EAI
II-3 D	"	Roseton, Danskammer	1974-76	LMS
II-3 E	"	Albany	1975	LMS
II-3 F	Net	Indian Point Plant	1974	NYU
II-3 G	"	" " "	1975	"
II-3 H	"	" " "	1976	"
II-3 I	"	" " "	1977	"
II-3 J	"	" " River	1974-77	"
II-4 A	Pump	Bowline Point	1975	EAI
II-4 B	"	Bowline Point, Lovett	1976	EAI
II-4 C	"	Roseton	1976, 77	EAI
II-4 D	Pump	Indian Point Plant	1977	EAI

Table II-3.A

Information Concerning Gear and Conditions used in Daytime and Nighttime Net Sampling for Ichthyoplankton at or near Bowline Point and Lovett in 1974 by Lawler, Matusky and Skelly Engineers

	Stations	
	BE, BCH, BW, BPS, BPL,* BDP, LE , LC, LW	BI, BD, LI, LD*
Effective Mouth Area (m^2)	0.785	0.196
Opening Shape	Conical	Conical
Opening Plane	**perpendicular**	**perpendicular**
Mesh Size (micron)	571	571
Net Length (meters)	6	3
Suspension Technique	towline, depressor, Bridle, epibenthic sled	intake, discharge sampling rig
Flowmeters	TSK	TSK
Towing Direction	Against tide	Intake flow
Towing Velocity (m/sec) relative to water	0.85-0.95	Variable (0.04-0.33)
Sample Duration (minutes)	5	90

*BE - Bowline East
BCH - Bowline Channel
BW - Bowline West
BPS - Bowline Pond Short
BPL - Bowline Pond Long
BDP - Bowline Discharge Plume
LE - Lovett East
LC - Lovett Channel
LW - Lovett West
BI - Bowline Intake
BD - Bowline Discharge
LI - Lovett Intake
LD - Lovett Discharge

Table II-3.A (cont'd) References

	Stations	
Station Locations	BE, BCH, BW, BPS, BPL, BPD LE, LC, LW	BI, BD, LI, LD
	LMS 1976, Figure VB-1 LMS 1977, Figure V-1	LMS 1975, p. IX-3
Effective Mouth Area	Orange and Rockland 1977**, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p.9.1A-13
Opening Shape	Orange and Rockland 1977**, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p.9.1A-13 and 9.1A-14
Opening Place	Orange and Rockland 1977**, p.9.1A-7 and 9.1A-9	Orange and Rockland 1977**, p.9.1A-14
Mesh Size	Orange and Rockland 1977**, p. 9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p. 9.1A 13
Net Length	Orange and Rockland 1977**, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p. 9.1A-13
Suspension Technique	Orange and Rockland 1977**, p.9.1A-7 and 9.1A-9	Orange and Rockland 1977**, p.9.1A-14
Flowmeters	Orange and Rockland 1977**, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p.9.1A-15
Towing Direction	Orange and Rockland 1977**, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p.9.1A-14
Towing Velocity	Orange and Rockland 1977**, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, Table 9.1A-4 LMS 1975, p.1X-4
Sample Duration	Orange and Rockland **, p.9.1A-9 and 9.1A-11	Orange and Rockland 1977**, p.9.1A-15

** Gear and Techniques used at Lovett in 1974 are identical to those used at Bowline (see LMS 1975 p. V-19, V-20, and IX-3).

References:

Lawler, Matusky and Skelly Engineers, 1975. 1974 Hudson River Aquatic Ecology Studies-Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Table II-3.A (cont'd) References - continued

Lawler, Matusky and Skelly Engineers (LMS), 1976. 1975 Hudson River Aquatic Ecology Studies-Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky and Skelly Engineers (LMS), 1977. 1976 Hudson River Aquatic Ecology Studies at Lovett Generating Station. Prepared for Orange and Rockland Utilities, Inc.

Orange and Rockland Utilities, Inc. Bowline Point Generating Station Nearfield Effects of Once-Through Cooling System Operation on Hudson River Biota-

Table II-3.B

Information Concerning Gear and Conditions used in Daytime and Nighttime Net Sampling for Ichthyoplankton at or near Bowline Point and Lovett in 1975 and 1976 by Lawler, Matusky and Skelly Engineers.

	Stations
	BE, BCH, BPL, BDP, LE, LC, LW
Effective Mouth Area (m^2)	0.785
Opening Shape	Conical
Opening Plane	**perpendicular**
Mesh Size	571
Net Length (meter)	6
Suspension Technique	towline, depressor, bridle, epibenthic sled
Flowmeters	TSK
Towing Direction	Against Tide
Towing Velocity (m/sec) relative to water	0.85-0.95
Sample Duration (minutes)	5

Table II-3.B (cont'd) References

Station Locations	Orange and Rockland 1977 LMS 1976 LMS 1977	Figures 9.1A-1 and 9.1A-2 Figure VB-1 Figure V-1
Effective Mouth Area	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Opening Shape	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Opening Plane	Orange and Rockland 1977*	p.9.1A-7 and 9.1A-9
Mesh Size	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Net Length	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Suspension Technique	Orange and Rockland 1977*	p.9.1A-7 and 9.1A-9
Flowmeters	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Towing Direction	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Towing Velocity	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11
Sample Duration	Orange and Rockland 1977*	p.9.1A-9 and 9.1A-11

*Gear and Techniques Used at Lovett in 1975 and 1976 Are Identical to Those Used at Bowline (see LMS 1976 V-16 to V-18, LMS 1977 V-1 and V-2)

References:

Lawler, Matusky and Skelly, Engineers (LMS); 1976. 1975 Hudson River Aquatic Ecology Studies-Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky and Skelly, Engineers (LMS), 1977. 1976 Hudson River Aquatic Ecology Studies at Lovett Generating Station. Prepared for Orange and Rockland Utilities, Inc.

Orange and Rockland Utilities, Inc. 1977. Bowline Point Generating Station Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota.

Table II-3.C

Information Concerning Gear and Conditions used in Daytime and Nighttime Net Sampling for Ichthyoplankton at or near Bowline Point and Lovett in 1975 and 1976 by Ecological Analysts, Inc.

	Stations
	Bowline Intake; Lovett Intake
Effective Mouth Area (m^2)	0.196 m^2
Opening Shape	Conical
Opening Plane	Perpendicular
Mesh Size (Micron)	505
Net Length (Meter)	3
Suspension Technique	Intake Rig
Flowmeters	General Oceanics, Cushing Electromagnetic
Towing Direction	Intake Flow
Towing Velocity (m/sec) relative to water	Variable (0.04-0.33)
Sample Duration (minutes)	90, 5, 30

Table II-3.C (cont'd)

	References	
Station locations	Orange and Rockland 1977* EA 1977b	p.9.1A-13 p.5.1-2
Effective Mouth Area	Orange and Rockland 1977*	p.9.1A-13
Opening Shape	Orange and Rockland 1977*,	pp.9.1A-13 and 9.1A-14
Opening Plane	Orange and Rockland 1977*,	p.9.1A-14
Mesh Size	Orange and Rockland 1977*	p.9.1A-13
Net Length	Orange and Rockland 1977*	p.9.1A-13
Suspension Technique	Orange and Rockland 1977*,	p.9.1A-14
Flowmeters	Orange and Rockland 1977*, EA 1977a EA 1977b	p.9.1A-15 p.5.1-2 p.5.1-2
Towing Direction	Orange and Rockland 1977*,	p.9.1A-14
ing Velocity	Orange and Rockland 1977*, LMS 1975 EA 1977a, EA 1977b	Table 9.1A-4 (1975) p. 1X-4 (1975) Table 5.1-1 (1976) Table 5.1-1 (1976)
Sample Duration	Orange and Rockland 1977*	p.9.1A-15

*Gear and Techniques Used at Lovett in 1975 and 1976 Are Identical to Those Used at Bowline (see EA 1976, Part II, p. 3-1 to 3-3 and EA 1977b, p.5.1-1 to 5.1-2)

<u>References</u>:

Ecological Analysts, 1976 Lovett Generating Station Entrainment Survival and Abundance Studies 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

EA, 1977a. Bowline Point Generating Station Entrainment and Impingement Studies, 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

EA, 1977b. Lovett Generating Station Entrainment and Impingement Studies, 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Table II-3.C (cont'd)

References: (cont'd)

Lawler, Matusky and Skelly Engineers (LMS), 1975. 1974 Hudson River Aquatic Ecology Studies-Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilies, Inc.

Orange and Rockland Utilities, Inc. 1977 Bowline Point Generating Station Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota.

TABLE II-3 D

INFORMATION CONCERNING ICHTHYOPLANKTON SAMPLING GEAR AND CONDITIONS OF USE AT OR NEAR ROSETON AND DANSKAMMER POINT ELECTRIC GENERATING STATIONS DURING 1974-1976 BY LAWLER, MATUSKY & SKELLY ENGINEERS

	S_1 HUDSON RIVER LOCATIONS 1973-1976	S_2 HUDSON RIVER LOCATIONS 1973-1974 (INTERMITTANT)	S_3 ROSETON ELECTRIC GEN. STATION 1973-1976	S_4 DANSKAMMER PT. ELECTRIC GEN. STATION 1973-1976	S_5 DANSKAMMER PT. ELECTRIC GEN. STATION 1973-1974
EFFECTIVE NET MOUTH AREA (m^2)	0.785[6]	0.196[6]	0.196[6]	0.196[6,11]	0.785[6,11]
OPENING SHAPE	Round[3,7]	Round[3]	Round[4,5]	Round[11]	Round[11]
OPENING PLANE	Perpendicular[7,9]	Perpendicular[7,9]	Perpendicular[5]	Perpendicular[11]	Perpendicular[11]
MESH SIZE (μm)	570 x 570[3]	570 x 570[3]	570 x 570[4]	570 x 570[12]	570 x 570[12]
NET LENGTH (m)	6 m net + 1 m reduction cone[3]	3[12]	3[4]	3[12]	6 m net + 1 m reduction cone[12]
SUSPENSION TECHNIQUE	Bridle[1,7]	Bridle[7]	Frame[5]	Frame[11]	Frame[11]
FLOWMETER	In Net Mouth[7]	In Net Mouth[7]	In Net Mouth And On Frame[2,5]	In Net Mouth And On Frame[2,11]	In Net Mouth[11]
TOWING DIRECTION	Against Current[8]	Against Current[8]	Fixed At Intake[4,5]	Fixed in Intake Canal[11]	Fixed in Intake Canal[11]
TOWING VELOCITY (m/sec) RELATIVE TO WATER	0.60-0.90[3]	0.60-0.90[3]	0.09-0.61[10]	0.09-0.91[12]	0.09-0.91[12]
SAMPLE DURATION (min)	5[3]	5[3]	Variable: 5-20[10]	Variable: 5-20[11]	Variable: 5-20[11]

[1]Bottom samples 1974-1976 net mounted in frame on epibenthic sled
[2]Frame mounted meter not used in 1973-1974
[3,4,8]Central Hudson Gas & Electric Corp. 1977. Roseton Generating Station, nearfield effects of once-through cooling system operation on Hudson River Biota, Specific references: [3]Table 9.1-1; [4]Table 9.2-1; [8]Page 9.1-3
[5,7,9,10]Central Hudson Gas & Electric Corp. 1977. Appendices, Roseton Generating Station, nearfield effects of once-through cooling system operation on Hudson River Biota. Appendix 9.1A: [5]Figure 9.1A-3; [7]Figure 9.1A-4; [9]Page 9.1A-9; [10]Page 9.1A-13;
[6]Calculation $A = \pi r^2$
[11]Central Hudson Gas & Electric Corp. 1974. 1973 Hudson River aquatic ecology studies of Roseton and Danskammer Point. Volume II, pages V-6 - V-7
[12]No references available

TABLE II -3-E

INFORMATION CONCERNING ICHTHYOPLANKTON SAMPLING GEAR AND CONDITIONS OF USE AT OR NEAR THE ALBANY STEAM ELECTRIC GENERATING STATION DURING 1975 BY LAWLER, MATUSKY & SKELLY ENGINEERS

	S_1 HUDSON RIVER LOCATIONS	S_2 HUDSON RIVER LOCATION AT INTAKE OPENING
EFFECTIVE NET MOUTH AREA (m^2)	0.785	0.785
OPENING SHAPE	Round	Round
OPENING PLANE	Perpendicular	Oblique
MESH SIZE (μm)	570 x 570	570 x 570
NET LENGTH (m)	6 m net + 1 m Reduction Cone	6 m net + 1 m Reduction Cone
SUSPENSION TECHNIQUE	Bridle[1]	Bridle
FLOWMETER	In Net Mouth	In Net Mouth
[illegible]WING VELOCITY (m/sec) [illegible]LATIVE TO WATER	0.80 - 0.90	0.2 - 0.4
SAMPLE DURATION (min)	5	0.5 - 1.0

[1] Bottom samples collected by net mounted in frame on epibenthic sled

Table II-3.E (Cont'd)

The general reference for the information presented in the table is:

Niagara Mohawk Power Corp. 1976. Albany Steam Electric Generating Station, 316(a) Demonstration submission NPDES Permit N.Y. 0005959. Submission prepared by Lawler, Matusky & Skelly Engineers.

Specific information on gear and deployment is in Appendix B, page B-3.

Station locations are shown in Figure B-1 of Appendix B.

Table II-3.F. Information concerning gear and conditions used in daytime and nighttime net sampling for ichthyoplankton at intake stations of Indian Point in 1974 by New York University.

	Unit I	Unit 2
Effective mouth area (m^2)	0.099 *	0.099 *
Opening shape	circular	circular
Opening plane	perpendicular	perpendicular
Mesh size	571 µm	571 µm
Net length	1.9 m	1.2 m
Suspension technique	surface: bridle, towline middle & bottom: intake rig	surface: bridle, towline middle & bottom: intake rig
Flowmeters	No*	No*
Towing direction	Intake Flow	Intake Flow
Towing velocity (m/sec) relative to water	variable: 0.14 m/sec - 0.27 m/sec	variable: 0.06 m/sec - 0.46 m/sec
Sample duration (min)	5	5

* Velocity reduction cones were used on nets, the dimensions of the cone are given in Figure 1 (B).

Table II-3.F cont'd

References:

	Unit I and Unit II
Station locations	p. 29 and p. 34
Effective mouth area (m^2)	p. 33 and pp. 281-282
Opening shape	p. 33 and p. 281
Opening plane	p. 32 and p. 34
Mesh size	p. 33 and p. 281
Net length	p. 33
Suspension technique	pp. 34-35
Flowmeters	p. 282
Towing direction	pp. 34-35
Towing velocity (m/sec) relative to water	p. 17 of NYU 1976; Table 1-9 of Con Ed 1977
Sample duration (min)	p. 196
Volume estimate of samples	p. 283

Unless otherwise noted, all references are to NYU 1976

New York University Medical Center (NYU) 1976. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1974

Consolidated Edison of New York, Inc. (Con Ed) and Power Authority for the State of New York (PASNY). 1977. Indian Point Unit No. 2 Indian Point Unit No. 3. Near-field Effects of Once-through Cooling System Operation on Hudson River Biota. New York, N.Y.

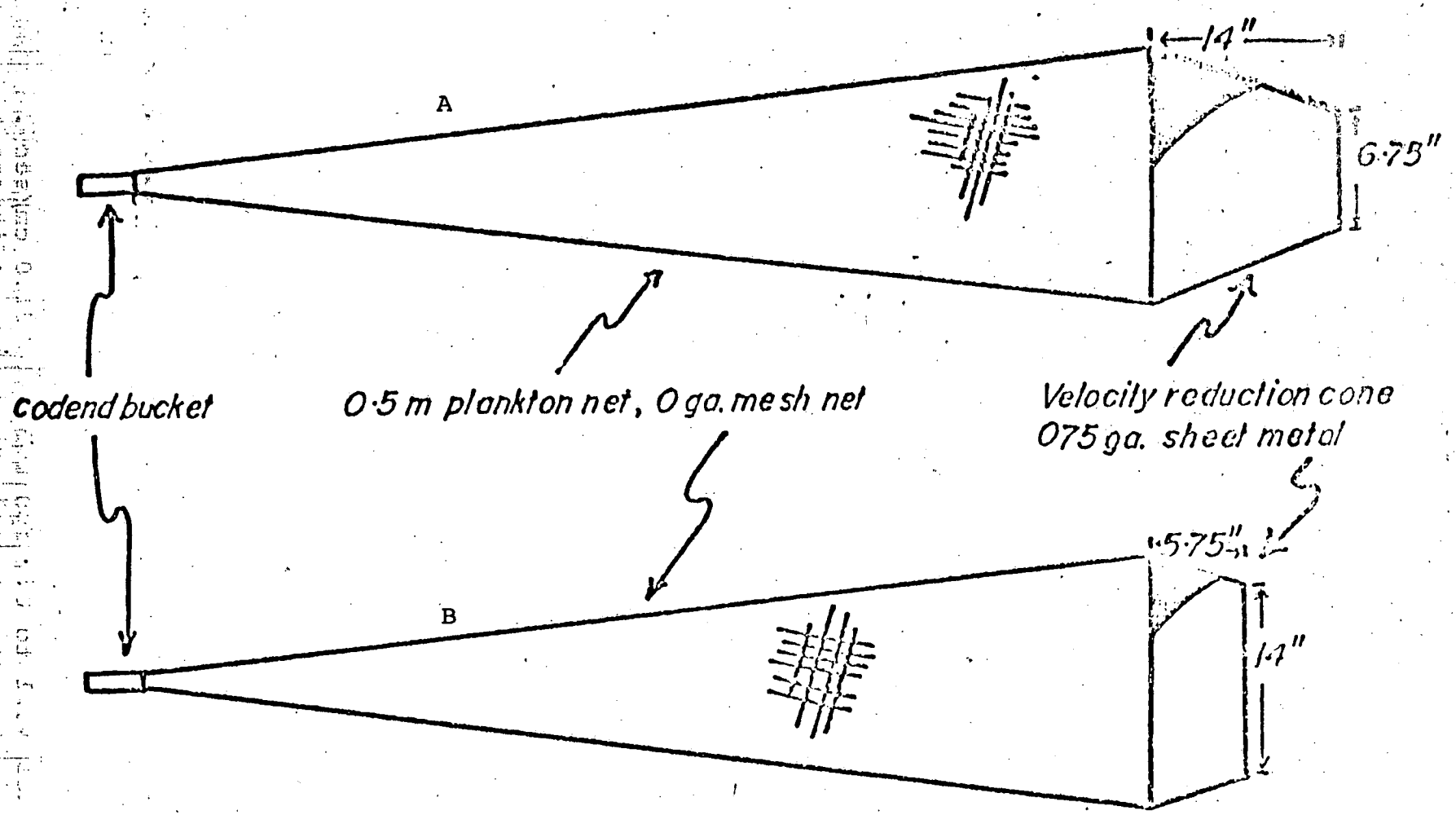

Figure 1. Schematic diagram of plankton nets equipped with velocity reduction cones of 14" and 6.75" mouth openings.
A:discharge net
B:intake net

Source:

[illegible] York University 1976. Mortality of S[illegible]ed Bass Egg and Larvae in Nets. A spe[illegible] [illegible]port to Consolidated Edison Co. of New [illegible]k

Table II-3.G Information concerning gear and conditions used in daytime and nighttime net sampling for ichthyoplankton at intake stations of Indian Point in 1975 by New York University

	Unit 2
Effective mouth area (m^2)	0.099 m^2*
Opening shape	circular
Opening plane	perpendicular
Mesh size	571 um
Net length	1.2 m
Suspension technique	surface: bridle, towline middle & bottom: intake rig
Flowmeters	No*
Towing direction	Intake Flow
Towing velocity (m/sec) relative to water	variable 0.06 m/sec - 0.46 m/sec
Sample duration (min)	5 minutes

* Velocity reduction cones were used on nets, the dimensions of the cone are given in Figure 1 (B).

Table II-3.G cont'd

References:

	Unit II
Station locations	pp. 29, 31, 34 and 36
Effective mouth area (m^2)	p. 33 and p. 328
Opening shape	p. 33
Opening plane	p. 32 and p.34
Mesh size	p. 33 and p. 328
Net length	p. 33
Suspension technique	p. 32
Flowmeters	p. 328
Towing direction	p. 32 and p. 35
Towing velocity (m/sec) relative	p. 18 of NYU 1977 and Table 1-9 of Con Ed, 1977
Sample duration (min)	p. 233
Volume estimate of samples	p. 329

Unless otherwise noted, all references are to NYU 1977

New York University Medical Center (NYU) 1977. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1975

Consolidated Edison of New York, Inc. (Con Ed) and Power Authority for the State of New York (PASNY). 1977b. Indian Point Unit No. 2. Indian Point Unit No. 3. Near-field Effects of Once-through Cooling System Operation on Hudson River Biota. New York, N.Y.

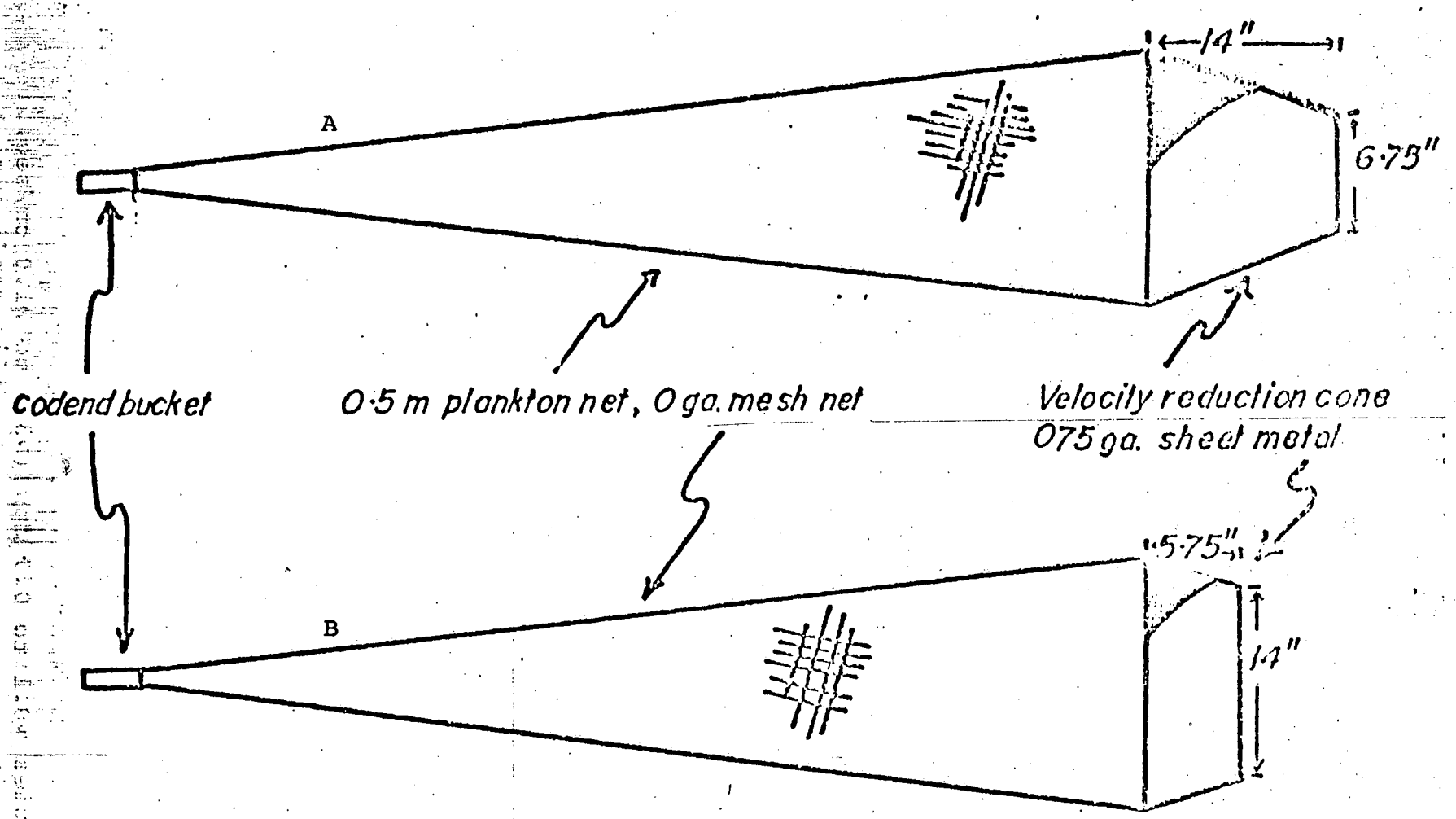

Figure 1. Schematic diagram of plankton nets equipped with velocity reduction cones of 14" and 6.75" mouth openings.

A:discharge net
B:intake net

Reference: New York University, 1976. Mortality of Striped Bass Eggs and Larvae in Nets. A special report to Consolidated Edison Co. of New York. page 6

Table II-3.H Information concerning gear and conditions used in daytime and nighttime net sampling for ichthyoplankton at intake stations of Indian Point in 1976 by New York University

	Unit 3
Effective mouth area (m^2)	0.196
Opening shape	circular
Opening plane	perpendicular
Mesh size	571 µm
Net length	1.9 m
Suspension technique	bridle, towline (all depths)
Flowmeters	General Oceanics fitted with R-2 rotor in net mouth
Towing direction	Intake Flow
Towing velocity (m/sec) relative to water	variable 0.03 m/sec - 0.24 m/sec
Sample duration (min)	10

References:

References are not available; methodologies used will be described in forthcoming report on these studies.

Table II-3.I Information concerning gear and conditions used in daytime and nighttime net sampling for ichthyoplankton at intake of Indian Point in 1977 by New York University

	Unit II	Unit III
Effective mouth area (m^2)	0.196	0.196
Opening shape	circular	circular
Opening plane	perpendicular	perpendicular
Mesh size	571 µm	571 µm
Net length	1.2	1.9
Suspension technique	surface: bridle, towline middle+bottom: intake rig	surface: bridle, towline; middle & bottom: intake rig
Flowmeters	TSK or General Oceanics in net mouth	TSK or General Oceanics in net mouth
Towing direction	Intake flow	Intake Flow
Towing velocity	variable: 0.06 m/sec - 0.46 m/sec	variable: 0.03 m/sec - 0.24 m/sec
Sample duration (min)	5	5

References:

References not available; methodologies used will be described in forthcoming reports on these studies.

Table II-3.J Information concerning gear and conditions used in daytime and nighttime net sampling for ichthyoplankton near Indian Point in 1974, 1975, 1976, 1977 by New York University

	Seven Standard River Stations (A-G)
Effective mouth area (m^2)	0.196
Opening shape	circular
Opening plane	perpendicular
Mesh size	571 µm
Net length	3.8 m
Suspension technique	bridle, towline with depressor
Flowmeters	TSK or General Oceanic in net mouth
Towing direction	against tide (current)
Towing velocity (m/sec) relative to water	0.6 - 0.9 m/sec*
Sample duration (min)	10

* The nets were towed against the current, the boat maintained a speed such that the surface net was maintained slightly below the surface; the motor of the boat was maintained at approximately 2000 RPM.

Table II-3.J cont'd

References:

In general the references to methodologies used in ichthyoplankton sampling are given in the macrozooplankton sections of the annual reports, the reason being that the macrozooplankton and ichthyoplankton were collected together.

1974

New York University Medical Center 1976. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1974.

station locations pages 22-23
all other information on pages 158-159

1975

New York University Medical Center. 1977 Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1975.

station locations pages 23-24
all other information on page 188

1976 and 1977

References are not available; methodologies used will be described in forthcoming report on these studies.

Table II-4.A

Information Concerning Gear and Conditions used in Daytime and Nighttime Pump Sampling for Ichthyoplankton at or near Bowline Point in 1975 by Ecological Analysts, Inc.

	Stations	
	Bowline Intake	Bowline Discharge
Pump Type	Midwhirl Trash Pump (recessed impellar)	Midwhirl Trash Pump (recessed impellar)
Collection Device	larval table	larval table
Intake Pipe Diameter	4 inch	4 inch
Elevation of Pump with respect to water surface (meters)	3-5	1-3
Elevation of collection device with respect to water surface (meters)	approximately same as above	approximately same as above
Maximum pressure in pipe	not available (N.A.)	N.A.
Minimum pressure in pipe	N.A.	N.A.
Pump Speed	Variable	Variable
Number of Pumps	one	one
Pumping Rate (m^3/min)	0.44-0.52	0.44-0.52
Duration of Sampling (minutes)	15	15
Volume Pumped/Sample (m^3)	6.6-7.8	6.6-7.8

Table II-4.A (cont'd)

	References	
Stations	Bowline Intake Bowline Discharge EA - 1976	Figure 1.2-2
Pump Type	Orange and Rockland 1977	p.9.4-3
Collection Device	EA 1976	Figures 3.2-1A and 3.2-1b
Intake Pipe Diameter	Orange and Rockland 1977	p.9.4-3
Elevation ofpump with respect to water surface (meters)	Will be described in forthcoming reports on these studies	
Elevation of collection device with respect to water surface	Will be described in forthcoming reports on these studies	
Maximum pressure in pipe	Not Available	
Minimum pressure in pipe	Not Available	
Pump Speed	Will be described in forthcoming reports on these studies	
Number of pumps	Orange and Rockland 1977	Figures 9.4-1 and 9.4-2
Pumping rate (m^3/min)	EA 1976	p.3-2
Duration of Sampling	EA 1976	p.3-2
Volume Pumped/Sample (m^3)	EA 1976	p.3-2

Ecological Analysts 1976. Bowline Point Generating Station Entrainment Survival and Abundance Studies, 1975 Annual Interpretive Report, Prepared for Orange and Rockland Utilities, Inc.

Orange and Rockland Utilities, Inc. 1977. Bowline Point Generating Station Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota.

Table II-4.B

Information Concerning Gear and Conditions Used in Daytime and Nighttime Pump Sampling for Ichthyoplankton at or near Bowline Point and Lovett in 1976 by Ecological Analysts, Inc.

	Bowline Point and Lovett Intake	Bowline Point and Lovett Discharge	Bowline Intake
Pump Type	Bowline-Midwhirl Trash Pump* Lovett-Homelite Trash Pump*	Bowline-Midwhirl Trash Pump* Lovett-Homelite Trash Pump*	Homelite Trash Pump*
Collection Device	Larval Table	Larval Table	½ m ring net
Intake Diameter	4 inch	4 inch	3 inch
Elevation of pump with respect to water surface (meters)	3-5	1-3	3-5
Elevation of collection device with respect to surface	approximately same as above	approximately same as above	approximately same as above
Maximum Pressure in Pipe	Not Available (N.A.)	N.A.	N.A.
Minimum Pressure in Pipe	N.A.	N.A.	N.A.
Pump Speed (rpm)	800-900 (Bowline) 1700-1800 (Lovett)	800-900 (Bowline) 1700-1800 (Lovett)	Variable Variable
Number of Pumps	One	One	One
Pumping rate (m^3/min)	0.13-1.4	0.47-1.3	0.77-1.13
Duration of Sampling (minutes)	15	15	30
Volume Pumped/Sample (m^3)	2-21	7-20	23-34

*recessed impellar

Table II-4.B (cont'd)

References

	Stations		
	Bowline Point and Lovett Intake	Bowline Point and Lovett Discharge	Bowline Point Intake
	EA 1977a Figure 3.1-2 EA 1977b p.4.1-2	EA 1977a Figure 3.1-2 EA 1977b p.4.1-2	EA 1977a Figure 3.1-2
Pump Type	EA 1977a p.4.1-2 EA 1977b p.4.1-2	EA 1977a p.4.1-2 EA 1977b p.4.1-2	EA 1977a p.5.1-3
Collection Device	EA 1977a, Figure 4.1-1 EA 1977b, Figure 4.1-1	EA 1977a, Figure 4.1-1 EA 1977b, Figure 4.1-1	EA 1977a p.5.1-2 and 5.1-3
Intake Diameter	EA 1977a,p.4.1-2 EA 1977b p.4.1-2	EA 1977a,p.4.1-2 EA 1977b p.4.1-2	EA 1977a, p.5.1-3
Elevation of pump with respect to water surface	will be described in forthcoming reports on these studies.		
Elevation of pump with respect to water surface	will be described in forthcoming reports on these studies		
Maximum pressure in pipe	Not Available		
Minimum pressure in pipe	Not Available		
Pump Speed	will be described in forthcoming reports on these studies		
Number of Pumps	EA 1977a, Figure 4.1-1 EA 1977b, Figure 4.1-1	EA 1977a, Figure 4.1-1 EA 1977b, Figure 4.1-1	EA 1977a, p.5.1-3
Pumping Rate m^3/min	EA 1977C	EA 1977C	EA1977C

Table II-4.B (cont'd)

References (cont'd)

	Stations		
	Bowline Point and Lovett Intake	Bowline Point and Lovett Discharge	Bowline Point Intake
Duration of Sampling	EA 1977a 4.1-2 EA 1977b 4.1-2	EA 1977a 4.1-2 EA 1977b 4.1-2	EA 1977a 5.1-2 and 5.1-3
Volume Pumped Sample	EA 1977c	EA 1977c	EA 1977c

References

Ecological Analysts, Inc., 1977a. Bowline Point Generating Station Entrainment and Impingement Studies, 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1977b. Lovett Generating Station Entrainment and Impingement Studies, 1976 Annual Report, Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1977c. Hudson River Power Plants Entrainment Abundance and Survival Raw Data Summaries 1976. Prepared for Central Hudson Gas and Electric Corporation and Orange and Rockland Utilies, Inc.

Table 11-4.C

Information Concerning Gear and Conditions Used in Daytime and Nighttime Pump Sampling for Ichthyoplankton at or near Roseton in 1976 and 1977 by Ecological Analysts, Inc.

Pump type	4" Homelite Trash Pump (Discharge seal well) Station
Collection Device	No. 0 (nominal 571-μm) mesh net
Intake pipe diameter	4"
Depth of removal	(variable depending on tide height in seal well -approx 10' below mean low tide)
Elevation of pump with respect to water surface	(Variable depending on tide height - approximately level with water surface)
Elevation of collection device with respect to water surface	Same as above
[illegible]mum pressure in pipe	Information Not Available
Minimum pressure in pipe	Same as Above
Pump speed (rpm)	1800 rpm
Number of pumps	One
Pumping rate (total)	900 l/min.
Duration of sampling	3 hr. and 6 hr. composite samples
Volume pumped per sample	approx. $150m^3$ for 3 hr., $300\ m^3$ for 6 hr. sample.

References not available; methodologies used will be described in forthcoming reports on these studies.

Table II-4.D Information concerning gear and conditions used in (daytime and nighttime) pump sampling for ichthyoplankton at or near Indian Point in 1977 by Ecological Analysts, Inc.

	Intakes of Unit II and Unit III
Pump type	4" Homelite Trash Pump - recessed impellar
Collection device	larval table - 571 um mesh net
Intake pipe diameter	4 inch
Depth of removal	mid-depth, approximately 10 ft.
Elevation of pump with respect to water surface	varied with tide, 1 - 4 ft.
Elevation of collection device with respect to water surface	varied with tide, 12 - 15 ft.
Maximum pressure in pipe	Not Available
Minimum pressure in pipe	Not Available
Pump speed (rpm)	1800 - 2000 rpm
Number of pumps	two at each intake
Pumping rate (total)	900 - 1000 liters/min.
Duration of sampling	15 minutes
Volume pumped per sample	approximately 15m^3 range (9.4 - 21.4m^3)

References not available; methodologies used will be described in forthcoming reports on these studies

IV. Questions relating to studies by NYU at Indian Point

IV 2. In the NYU 1973 PR, page 28, reference is made to a study of the effects of net size in the discharge canal. Please present the results of this study.

Response: Data collected in the study of the effects of net size on abundance estimates of organisms in the entrainment samples as well as the size of the organisms collected are contained in the attached tables Nos. 1-4.

Table 1. Striped Bass Density Estimates for Station D-1 Based on One Meter Collections

(No./1000 m^3)

		Surface		Mid Depth	
Date	Time	L	J	L	J
7/3/73	1530-1545	0	0	66	5
	1605-1620	0	1	31	8
	1730-1745	0	0	38	0
	1805-1820	0	0	57	2
	Total	0	1	192	15
	Mean	0	0	48	4
7/10/73	0930-0945	7	0	0	0
(24 hr sur)	1005-1020	0	0	3	0
	1130-1145	0	3	0	0
	1205-1220	0	0	2	0
	1330-1345	3	0	4	0
	1405-1420	2	0	4	0
	1530-1545	3	0	2	2
	1605-1620	0	0	0	2
	1730-1745	0	0	0	0
	1805-1820	9	0	10	0
	1930-1945	0	0	0	0
	2005-2020	0	8	0	0
	2130-2145	5	0	10	25
	2205-2220	0	0	0	46
	2330-2345	0	0	0	51
7/11/73	0005-0020	0	0	0	20
	0130-0145	0	0	4	18
	0205-0220	0	5	0	58
	0330-0345	0	11	12	131
	0405-0420	5	5	3	97
	0530-0545	0	10	0	54
	0605-0620	0	0	0	53
	0730-0745	7	0	0	17
	0805-0820	0	0	0	8
	Total	41	42	55	579
	Mean	2	2	2	24

Table 1 (Cont'd)

		Surface		Mid Depth	
Date	Time	L	J	L	J
7/17/73	0930-0945	0	0	0	0
(24 hr sur)	1005-1020	0	0	0	0
	1130-1145	2	0	0	0
	1205-1220	0	0	0	0
	1330-1345	0	3	0	0
	1405-1420	0	0	0	2
	1530-1545	0	0	0	0
	1605-1620	3	0	6	0
	1730-1745	0	0	0	0
	1805-1820	0	0	0	0
	1930-1945	0	0	0	0
	2005-2020	2	0	0	0
	2130-2145	5	0	2	2
	2205-2220	0	3	6	6
	2330-2345	3	0	0	0
7/18/73	0005-0020	3	0	9	0
	0130-0145	3	0	0	12
	0205-0220	0	0	12	0
	0330-0345	0	4	33	6
	0405-0420	0	5	47	2
	0530-0545	11	2	12	0
	0605-0620	0	2	4	0
	0730-0745	0	0	4	4
	0805-0820	0	0	0	0
	Total	82	19	135	34
	Mean	3	1	6	1
7/24/73	0930-0945	0	0	0	0
	1005-1020	0	0	0	0
	1130-1145	0	0	0	0
	1205-1220	0	0	0	0
	1330-1345	0	0	0	0
	1405-1420	0	0	0	0
	1530-1545	0	0	0	0
	1605-1620	0	0	2	0
	1730-1745	0	0	2	2
	1805-1820	0	0	4	0
	1930-1945	0	0	4	0
	2005-2020	0	0	0	5
	2130-2145	0	0	0	2
	2205-2220	0	0	0	0
	2330-2345	0	13	0	6

Table 1 (Cont'd)

		Surface		Mid Depth	
Date	Time	L	J	L	J
7/25/73	0005-0020	0	0	0	0
	0130-0145	0	0	0	0
	0205-0220	0	0	0	0
	0330-0345	0	0	10	0
	0405-0420	0	0	0	0
	0530-0545	0	10	0	0
	0605-0620	0	0	0	0
	0730-0745	0	0	2	0
	0805-0820	0	0	0	0
	Total	0	23	24	15
	Mean	0	1	1	1
8/7/73	0930-0945	0	2	0	0
	1005-1020	0	0	0	0
	1130-1145	0	0	0	0
	1205-1220	3	0	0	0
	1330-1345	0	0	0	0
	1405-1420	0	0	0	0
	1530-1545	0	0	0	0
	1605-1620	0	0	0	0
	1730-1745	0	0	0	0
	1805-1820		No Sample		
	1930-1945	0	0	0	0
	2005-2020	0	0	3	0
	2130-2145	0	0	0	0
	2205-2220	0	0	0	0
	2330-2345	0	0	0	0
8/8/73	0005-0020	0	0	0	0
	0130-0145	0	0	0	0
	0205-0220	0	0	2	0
	0330-0345	0	0	0	0
	0405-0420	0	0	0	0
	0530-0545	0	0	0	0
	0605-0620	0	0	0	0
	0730-0745	0	0	0	0
	0805-0820	0	0	0	0
	Total	3	2	5	0
	Mean	0	0	0	0

Table 2 Striped Bass Density Estimates for Station D-1 Based on One Half-Meter Net Collections

(No./1000 m^3)

			Surface		Mid-Depth	
Date	Time	Sample	L	J	L	J
7/3/73	0930-1020	1	0	0	22	7
		2	46	0	8	12
	1130-1220	1	0	0	23	15
		2	0	6	0	0
	1330-1420	1	0	0	121	0
		2	71	0	101	0
	1530-1620	1	0	8	98	14
		2	10	10	81	6
	1730-1820	1	0	0	90	7
		2	14	0	46	19
	1930-2020	1	N.S.			
		2				
	2130-2220	1	0	7	9	84
		2	0	0	13	101
[illegible]/3/73	2330-0020	1	0	0	28	54
		2	0	4	63	45
7/4/73	0130-0220	1	41	6	213	144
		2	43	9	138	150
	0330-0420	1	7	0	52	72
		2	0	0	54	115
	0530-0620	1	3	3	7	5
		2	0	0	7	23
	0730-0820	1	3	0	0	0
		2	3	3	11	7
	Total		241	56	1185	880
	Mean		11	3	54	40
7/10/73	0930-1020	1	6	0	3	0
		2	0	0	15	0
	01130-1220	1	0	0	0	0
		2	0	0	5	0
	1330-1420	1	0	2	0	0
		2	0	0	2	5
	1530-1620	1	3	0	2	0
		2	3	0	5	2

Table 2 (Cont'd)

Date	Time	Sample	Surface L	Surface J	Mid Depth L	Mid Depth J
7/10/73	1730-1820	1	14	0	4	0
		2	0	0	6	3
	1930-2020	1	0	0	47	0
		2	0	0	44	4
	2130-2220	1	0	0	32	43
		2	0	0	14	32
7/10/73	2330-0020	1	0	0	0	26
		2	0	0	4	14
7/11/73	0130-0220	1	0	0	0	0
		2	0	0	7	27
	0330-0420	1	0	19	6	80
		2	0	0	0	74
	0530-0620	1	0	0	23	66
		2	0	0	22	47
	0730-0820	1	0	0	0	18
		2	0	0	4	0
	Total		26	21	245	441
	Mean		1	1	10	18
7/17/73	0930-1020	1	0	0	3	0
		2	0	0	0	0
	01130-1220	1	0	0	0	0
		2	0	3	0	0
	1330-1420	1	0	0	0	2
		2	0	0	0	2
	1530-1620	1	0	0	0	0
		2	0	0	18	0
	1730-1820	1	0	0	0	0
		2	0	0	0	0
	1930-2020	1	N.S.			
		2				
	2130-2220	1	N.S.			
		2				
7/17/73	2330-0020	1	3	0	N.S.	
		2	0	0	N.S.	
7/18/73	0130-0220	1	134	0	N.S.	
		2	5	0	N.S.	
	0330-0420	1	0	3	N.S.	
		2	0	0	N.S.	
	0530-0620	1	0	6	N.S.	
		2	0	0	N.S.	

Table 2 (Cont'd)

Date	Time	Sample	Surface L	Surface J	Mid Depth L	Mid Depth J
7/18/73	0730-0820	1	0	0	N. S.	
		2	0	0	N. S.	
	Mean		7	1	2	0
	Total		142	12	21	4
7/24/73	0930-1020	1	0	0	2	2
		2	0	0	0	0
	01130-1220	1				
		2				
	1330-1420	1				
		2				
	1530-1620	1				
		2				
	1730-1820	1	0	0	2	2
		2	0	0	0	2
	1930-2020	1				
		2				
	2130-2220	1	0	0	6	0
		2	0	0	0	0
24/73	2330-0020	1	0	6	0	0
		2	0	0	0	6
7/25/73	0130-0220	1				
		2				
	0330-0420	1	0	0	0	0
		2	0	0	5	5
	0530-0620	1	0	0	0	5
		2	0	0	0	0
	0730-0820	1	0	0	3	0
		2	0	0	0	0
	Mean		0	0	1	1
	Total		0	6	18	22
8/7/73	0930-1020	1	0	0	0	0
		2	0	3	0	0
	01130-1220	1				
		2				
	1330-1420	1				
		2				
	1530-1620	1				
		2				
	1730-1820	1				
		2				

Table 2 (Cont'd)

			Surface		Mid Depth	
Date	Time	Sample	L	J	L	J
8/7/73	1930-2020	1				
		2				
	2130-2220	1				
		2				
	2330-0020	1				
		2				
8/8/73	0130-0220	1				
		2				
	0330-0420	1	0	2	0	0
		2	0	0	0	0
	0530-0620	1				
		2				
	0730-0820	1				
		2				
	Mean		0	1	0	0
	Total		0	5	0	0

Table 3 Bay Anchovy Density Estimates for Station D-1 Based on One Meter Net Collections

(no/1000 m^3)

		Surface		Mid Depth	
Date	Time	L	J	L	J
7/10/73	0930-0945	0	0	0	0
(24 hr sur)	1005-1020	0	0	0	0
	1130-1145	0	0	4	0
	1205-1220	0	0	2	0
	1330-1345	3	0	0	0
	1405-1420	0	0	0	0
	1530-1545	0	0	2	0
	1605-1620	0	0	0	0
	1730-1745	0	0	0	0
	1805-1820	0	0	0	0
	1930-1945	0	0	0	0
	2005-2020	0	0	3	0
	2130-2145	0	0	0	0
	2205-2220	0	0	0	0
	2330-2345	0	0	7	0
	0005-0020	16	0	16	0
	0130-0145	80	0	109	0
	0205-0220	16	0	0	0
	0330-0345	17	0	4	0
	0405-0420	5	0	0	0
7/11/73	0530-0545	0	0	0	0
	0605-0620	0	0	0	0
	0730-0745	0	0	0	0
	0805-0820	8	0	0	0
	Total	145	0	147	0
	Mean	6	0	6	0
7/17/73	0930-0945	0	0	60	0
(24 hr sur)	1005-1020	0	0	38	7
	1130-1145	15	0	36	6
	1205-1220	23	0	0	0
	1330-1345	433	0	306	6
	1405-1420	5	0	32	4
	1530-1545	0	0	54	0
	1605-1620	18	0	46	0
	1730-1745	91	0	64	5
	1805-1820	63	2	177	3
	1930-1945	17	0	38	2
	2005-2020	0	0	15	0
	2130-2145	21	0	8	3
	2205-2220	17	0	8	6

Table 3 (Cont'd)

		Surface		Mid Depth	
Date	Time	L	J	L	J
7/17/73	2330-2345	0	0	0	0
7/18/73	0005-0020	31	3	27	14
	0130-0145	46	0	0	0
	0205-0220	6	0	18	2
	0330-0345	22	16	23	19
	0405-0420	5	7	33	12
	0530-0545	360	48	467	116
	0605-0620	395	30	700	0
	0730-0745	1313	3	782	13
	0805-0820	186	0	0	0
	Total	3069	109	2932	218
	Mean	128	5	122	9
7/24/73	0930-0945	222	0	0	0
	1005-1020	89	0	145	3
	1130-1145	55	0	113	0
	1205-1220	38	0	99	0
	1330-1345	29	0	38	0
	1405-1420	13	0	32	0
	1530-1545	17	0	25	0
	1605-1620	15	0	14	0
	1730-1745	44	0	89	2
	1805-1820	36	8	85	2
	1930-1945	131	0	236	6
	2005-2020	42	0	31	0
	2130-2145	36	0	22	2
	2205-2220	45	0	77	0
	2330-2345	153	0	106	6
7/25/73	0005-0020	261	23	210	6
	0130-0145	117	0	53	0
	0285-0220	36	0	308	0
	0330-0345	38	0	0	0
	0405-0420	32	0	36	0
	0530-0545	10	0	24	0
	0605-0620	0	0	36	0
	0730-0745	88	0	147	10
	0805-0820	88	2	262	0
	Total	1635	33	2188	34
	Mean	68	1	91	2

Table 3 (Cont'd)

Date	Time	Surface L	Surface J	Mid Depth L	Mid Depth J
8/7/73	0930-0945	5	0	9	0
	1005-1020	9	0	13	0
	1130-1145	15	0	15	0
	1205-1220	3	0	8	0
	1330-1345	3	0	2	0
	1405-1420	2	0	9	0
	1530-1545	7	0	4	0
	1605-1620	4	0	2	0
	1730-1745	3	0	4	0
	1805-1820		(No Sample)		
	1930-1945	0	0	0	2
	2005-2020	0	0	2	0
	2130-2145	6	0	8	0
	2205-2220	0	0	3	0
	2330-2345	7	2	19	0
8/8/73	0005-0020	18	2	20	0
	0130-0145	20	0	28	0
	0205-0220	22	0	31	0
	0330-0345	8	0	9	3
	0405-0420	17	0	18	0
	0530-0545	2	0	9	5
	0605-0620	4	0	18	4
	0730-0745	0	0	8	0
	0805-0820	4	0	3	0
	Total	159	4	242	14
	Mean	7	0	10	6
8/21/73	0930-0945		No Sample		
	1005-1020	53	0	70	4
	1130-1145	14	0	30	0
	1205-1220	4	0	18	2
	1330-1345	3	0	2	0
	1405-1420	0	0	15	0
	1530-1545	0	0	0	0
	1605-1620	0	0	0	4
	1730-1745	4	0	4	0
	1805-1820	0	0	2	0
	1930-1945	13	3	10	3
	2005-2020	3	16	11	15
	2130-2145	7	17	4	61
	2205-2220	51	139	89	379
	2330-2345	23	66	9	42

Table 3 Cont'd)

		Surface		Mid Depth	
ate	Time	L	J	L	J
/22/73	0005-0020	11	35	28	101
	0130-0145	5	15	6	42
	0205-0220	2	7	2	21
	0330-0345	5	23	5	23
	0405-0420	0	22	3	33
	0530-0545	0	18	11	36
	0605-0620	7	21	14	51
	0730-0745		(No Sample)		
	0805-0820	2	0	5	5
Total		207	382	338	818
Mean		9	17	15	36
9/11/73	0930-0945	0	0	0	0
	1005-1020	0	0	0	0
	1130-1145	0	0	0	0
	1205-1220	0	0	0	0
	1330-1345	0	0	0	0
	1405-1420	0	0	0	0
	1530-1545	0	0	0	0
	1605-1620	0	0	0	0
	1730-1745	4	0	0	0
	1830-1820	0	0	0	0
	1930-1945	0	4	0	0
	2005-2020	0	0	0	0
	2130-2145	0	6	0	0
	2205-2220	0	8	0	4
	2330-2345	0	0	0	4
9/12/73	0005-0020	0	0	0	8
	0130-0145	4	0	0	11
	0205-0220	0	8	0	15
	0330-0345	0	11	0	6
	0405-0420		(No sample)		
	0530-0545	0	0	0	0
	0605-0620	0	0	0	20
	0730-0745		(No Sample)		
	0805-0820		(No Sample)		
Total		8	37	0	68
Mean		0	2	0	3

Table 4 Bay Anchovy Density estimated for Station D-1 based on one half-meter net collections

Date	Time	Sample	No./1000 M^3 Surface L	Surface J	Mid-Depth L	Mid-Depth J
7/3/73	0930-1020	1	0	0	0	0
		2	0	0	0	0
	1130-1220	1	0	0	0	0
		2	0	0	0	0
	1330-1420	1	0	0	0	0
		2	0	0	0	0
	1530-1620	1	0	0	0	0
		2	0	0	0	0
	1730-1820	1	0	0	0	0
		2	0	0	0	0
	1930-2020	1	0	0	0	0
		2	0	0	0	0
	2130-2220	1	0	0	0	0
		2	0	0	0	0
	2330-0020	1	0	0	0	0
		2	0	0	0	0
7/4/73	0130-0220	1	0	0	0	0
		2	0	0	0	0
	0330-0420	1	0	0	0	0
		2	0	0	0	0
	0530-0620	1	0	0	0	0
		2	0	0	0	0
	0730-0820	1	0	0	0	0
		2	0	0	0	0
	Total	0	0	0	0	0
	Mean	0	0	0	0	0
7/10/73	0930-1020	1	0	0	3	0
		2	0	0	0	0
	1130-1220	1	0	0	0	0
		2	0	0	2	0
	1330-1420	1	0	0	0	0
		2	3	0	2	0
	1530-1620	1	0	0	0	0
		2	0	0	2	0
	1730-1820	1	0	0	0	0
		2	0	0	0	0
	1930-2020	1	0	0	0	0
		2	0	0	0	0
	2130-2220	1	0	0	0	0
		2	0	0	0	0
	2330-0020	1	0	0	0	10
		2	0	0	0	4

Table 4

Date	Time	Sample	Surface L	Surface J	Mid Depth L	Mid Depth J
7/11/73	0130-0220	1	0	60	0	0
		2	17	34	3	47
	0330-0420	1	0	0	0	10
		2	6	0	10	3
	0530-0620	1	0	0	0	0
		2	0	0	0	0
	0730-0820	1	0	0	0	0
		2	0	0	0	0
	Total		26	94	22	74
	Mean		1	4	1	3
7/17/73	0930-1020	1	36	0	73	10
		2	49	0	5	0
	1130-1220	1	30	0	3	0
		2	19	0	5	0
	1330-1420	1	149	0	97	0
		2	46	0	48	7
	1530-1620	1	29	0	15	0
		2	17	0	31	0
	1730-1820	1	78	0	152	0
		2	3	0	92	0
	1930-2020	1	0	0	0	0
		2	0	0	0	0
	2130-2220	1	5	0	0	0
		2	0	0	0	0
	2330-0020	1	3	0	0	0
		2	22	0	0	0
7/18/73	0130-0220	1	178	89	0	0
		2	41	5	0	0
	0330-0420	1	21	3	0	0
		2	4	0	0	0
	0530-0620	1	72	15	0	0
		2	141	26	0	0
	0730-0820	1	444	3	(no sample)	
		2	636	0	"	
	Total		2023	146	521	7
	Mean		84	6	24	0

Table 4

Date	Time	Sample	Surface L	Surface J	Mid Depth L	Mid Depth J
7/24/73	0930-1020	1	76	0	174	0
		2	50	0	201	0
	1130-1220	1	37	0	55	0
		2	0	0	68	0
	1330-1420	1	19	0	24	0
		2	10	0	35	0
	1530-1620	1	15	0	20	0
		2	7	0	11	0
	1730-1820	1	49	5	93	2
		2	6	3	105	0
	1930-2020	1	88	0	101	0
		2	0	0	66	0
	2130-2220	1	(no sample)		44	0
		2	6	0	33	0
	2330-0020	1	198	0	180	0
		2	298	0	266	0
7/25/73	0130-0220	1	(no Sample)		17	0
		2	0	0	12	0
	0330-0420	1	7	0	37	0
		2	28	0	25	0
	0530-0620	1	11	0	29	0
		2	16	0	14	0
	0730-0820	1	51	0	258	0
		2	82	0	219	0
	Total		1054	8	2174	2
	Mean		48	0	91	0
8/7/73	0930-1020	1	3	0	4	0
		2	0	0	6	0
	1130-1220	1	3	0	9	0
		2	3	0	0	0
	1330-1420	1	0	0	0	0
		2	0	0	2	0
	1530-1620	1	116	0	0	0
		2	2	0	2	0
	1730-1820	1	2	0	9	0
		2	3	0	2	0

Table 4

Date	Time	Sample	Surface L	Surface J	Mid-Depth L	Mid-Depth J
/7/73	1930-2020	1	0	0	0	0
		2	54	0	0	0
	2130-2220	1	3	0	0	0
		2	0	0	0	0
	2330-0020	1	2	0	13	0
		2	11	0	11	0
8/8/73	0130-0220	1	21	2	6	0
		2	60	0	29	0
	0330-0420	1	7	2	12	0
		2	(no sample)		4	0
	0530-0620	1	8	0	3	0
		2	6	0	6	3
	0730-0820	1	0	0	0	0
		2	5	0	9	0
	Total		309	4	114	3
	Mean		13	0	5	0
8/21/73	1000-1050	1	24	0	58	0
		2	60	0	44	0
	1130-1220	1	3	0	7	0
		2	5	0	29	0
	1330-1420	1	0	0	18	0
		2	3	0	0	0
	1530-1620	1	0	0	8	0
		2	0	0	0	0
	1730-1820	1	0	5	0	0
		2	0	0	0	0
	1930-2020	1	0	8	17	17
		2	0	3	12	5
	2130-2220	1	19	51	39	54
		2	18	58	15	60
	2330-0020	1	10	70	6	53
		2	13	39	4	67
8/22/73	0130-0220	1	0	5	0	13
		2	0	4	0	5
	0330-0420	1	3	8	0	13
		2	7	29	0	0

Table 4

Date	Time	Sample	Surface L	Surface J	Mid-Depth L	Mid-Depth J
8/22/73	0530-0620	1	9	9	5	21
		2	0	0	14	22
	0730-0820	1	0	0	4	7
		2	4	9	4	6
	Total		178	298	284	343
	Mean		7	12	12	14
9/11/73	0930-1020	1	0	0	4	0
		2	0	29	0	0
	1130-1220	1	0	0	0	0
		2	0	0	0	0
	1330-1420	1	0	0	0	0
		2	0	0	0	0
	1530-1620	1	0	0	0	0
		2	0	0	0	0
	1730-1820	1	0	0	0	0
		2	0	0	7	0
	1930-2020	1	0	0	0	0
		2	0	0	0	0
	2130-2220	1	0	0	0	0
		2	0	0	0	0
	2330-0220	1	0	0	0	0
		2	0	0	0	0
9/12/73	0130-0220	1	0	0	0	10
		2	0	0	0	0
	0330-0420	1	0	12	3	31
		2	0	10	0	26
	0530-0620	1	0	0	0	4
		2	4	9	0	0
	0730-0820	1	0	0	0	4
		2	0	0	0	10
	Total		4	60	14	85
	Mean		0	3	1	4

V. Questions Relating to the McFadden (February 1977) Report

V.1 On page 12.26, reference is made to projections of plant flow conditions (Con Edison, 1976) Please supply ORNL with three copies of this document.

Response: Three copies of the projected plant flow rates (Tables A-1 through A-5) are attached. The data were presented in Appendix A of the Supplement I to the McFadden Report.

APPENDIX A

PROJECTED PLANT FLOW RATES

TABLE A-1

PROJECTED PLANT FLOW RATES (1000 GPM)
ROSETON GENERATING STATION (UNITS 1 AND 2)

	ONCE THROUGH COOLING					CLOSED CYCLE COOLING				
YEAR	APRIL	MAY	JUNE	JULY	AUGUST	APRIL	MAY	JUNE	JULY	AUGUST
1976	412.09	519.12	561.17	561.17	561.17	412.09	519.12	561.17	561.17	561.17
1977	278.29	465.60	640.68	640.68	640.68	278.29	465.60	640.68	640.68	640.68
1978	418.20	489.30	535.18	640.68	640.68	418.20	489.30	535.18	640.68	640.68
1979	418.20	561.17	640.68	640.68	640.68	418.20	561.17	640.68	640.68	640.68
1980	244.65	376.15	508.42	640.68	640.68	244.65	376.15	508.42	640.68	640.68
1981	418.20	507.65	517.59	640.68	640.68	418.20	507.65	517.59	640.68	640.68
1982	418.20	501.54	526.00	640.68	640.68	418.20	501.54	526.00	640.68	640.68
1983	418.20	495.42	535.18	640.68	640.68	418.00	495.36	535.00	641.00	641.00
1984	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
1985	251.53	376.15	500.01	640.68	640.68	9.33	8.00	11.73	16.00	16.00
1986	418.20	513.00	508.42	640.68	640.68	16.00	13.94	12.00	16.00	16.00
1987	418.20	507.65	517.59	640.68	640.68	16.00	13.66	12.27	16.00	16.00
1988	418.20	495.42	535.18	640.68	640.68	16.00	13.16	12.80	16.00	16.00
1989	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
1990	257.65	376.15	517.59	640.68	640.68	9.60	8.00	11.47	16.00	16.00
1991	418.20	477.07	561.17	640.68	640.68	16.00	12.39	13.60	16.00	16.00
1992	418.20	507.65	517.59	640.68	640.68	16.00	13.68	12.27	16.00	16.00
1993	418.20	501.54	526.00	640.68	640.68	16.00	13.42	12.53	16.00	16.00
1994	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
1995	217.89	376.15	543.59	640.68	640.68	8.00	8.00	13.07	16.00	16.00
1996	418.20	477.07	561.17	640.68	640.68	16.00	12.39	13.60	16.00	16.00
1997	418.20	513.00	508.42	640.68	640.68	16.00	13.94	12.00	16.00	16.00
1998	418.20	507.65	517.59	640.68	640.68	16.00	13.68	12.27	16.00	16.00
1999	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
2000	217.89	376.15	543.59	640.68	640.68	8.00	8.00	13.07	16.00	16.00
2001	418.20	483.19	552.76	640.68	640.68	16.00	12.65	13.33	16.00	16.00
2002	418.20	477.07	561.17	640.68	640.68	16.00	12.39	13.60	16.00	16.00
2003	418.20	513.00	508.42	640.68	640.68	16.00	13.94	12.00	16.00	16.00
2004	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
2005	224.77	376.15	535.18	640.68	640.68	8.27	12.80	16.00	16.00	16.00
2006	418.20	489.30	543.59	640.68	640.68	16.00	12.90	13.07	16.00	16.00
2007	418.20	483.19	552.76	640.68	640.68	16.00	12.65	13.33	16.00	16.00
2008	418.20	513.00	508.42	640.68	640.68	16.00	13.94	12.00	16.00	16.00
2009	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
2010	231.65	376.15	526.00	640.68	640.68	8.53	8.00	12.53	16.00	16.00
2011	418.20	495.42	535.18	640.68	640.68	16.00	13.16	12.80	16.00	16.00
2012	418.20	483.19	552.76	640.68	640.68	16.00	12.65	13.33	16.00	16.00
2013	418.20	477.07	561.17	640.68	640.68	16.00	12.39	13.60	16.00	16.00
2014	418.20	561.17	640.68	640.68	640.68	16.00	16.00	16.00	16.00	16.00
2015	237.77	376.15	517.59	640.68	640.68	8.80	8.00	12.27	16.00	16.00
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE A-2

PROJECTED PLANT FLOW RATES (1000 GPM)
INDIAN POINT UNIT 2 GENERATING STATION

	ONCE THROUGH COOLING					CLOSED CYCLE COOLING				
YEAR	APRIL	MAY	JUNE	JULY	AUGUST	APRIL	MAY	JUNE	JULY	AUGUST
1976	26.41	0.0	79.13	0.0	0.0	26.41	0.0	79.13	0.0	0.0
1977	190.00	840.00	840.00	840.00	840.00	190.00	840.00	840.00	840.00	840.00
1978	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1979	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1980	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1981	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1982	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1983	840.00	840.00	840.00	840.00	840.00	20.00	20.00	50.00	50.00	50.00
1984	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1985	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1986	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1987	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1988	190.00	840.00	840.00	840.00	840.00	30.00	50.00	50.00	50.00	50.00
1989	190.00	20.00	840.00	840.00	840.00	30.00	20.00	50.00	50.00	50.00
1990	540.00	840.00	840.00	840.00	840.00	40.00	50.00	50.00	50.00	50.00
1991	190.00	20.00	840.00	840.00	840.00	30.00	20.00	50.00	50.00	50.00
1992	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1993	840.00	20.00	190.00	840.00	840.00	50.00	20.00	30.00	50.00	50.00
1994	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1995	190.00	840.00	840.00	840.00	840.00	30.00	50.00	50.00	50.00	50.00
1996	20.00	840.00	840.00	840.00	840.00	20.00	50.00	50.00	50.00	50.00
1997	840.00	20.00	190.00	840.00	840.00	50.00	20.00	30.00	50.00	50.00
1998	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1999	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2000	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2001	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2002	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2003	840.00	370.00	20.00	540.00	840.00	50.00	35.00	20.00	40.00	50.00
2004	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2005	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2006	20.00	540.00	840.00	840.00	840.00	20.00	40.00	50.00	50.00	50.00
2007	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2008	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2009	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2010	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2011	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2012	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2013	840.00	190.00	20.00	840.00	840.00	50.00	30.00	20.00	50.00	50.00
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: The flow rate of 840,000 gpm presented here is used for computation of thermal-induced entrainment mortality (section 3.IV.D.2.d) only. The monthly average flow rate reflecting down times is 720,000 gpm. This value was used in the RTLC model runs.

TABLE A-3

PROJECTED PLANT FLOW RATES (1000 GPM)
INDIAN POINT UNIT 3 GENERATING STATION

	ONCE THROUGH COOLING					CLOSED CYCLE COOLING				
YEAR	APRIL	MAY	JUNE	JULY	AUGUST	APRIL	MAY	JUNE	JULY	AUGUST
1976	301.96	508.68	573.11	633.36	579.52	301.96	508.68	573.11	633.36	579.52
1977	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1978	840.00	20.00	20.00	840.00	840.00	840.00	20.00	20.00	840.00	840.00
1979	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1980	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1981	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1982	840.00	20.00	20.00	840.00	840.00	840.00	20.00	20.00	840.00	840.00
1983	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00	840.00
1984	840.00	840.00	840.00	840.00	840.00	20.00	20.00	50.00	50.00	50.00
1985	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1986	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1987	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1988	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
1989	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1990	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1991	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1992	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
1993	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1994	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1995	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1996	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
1997	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1998	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
1999	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2000	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
2001	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2002	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2003	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2004	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
2005	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2006	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2007	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2008	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
2009	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2010	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2011	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2012	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00
2013	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2014	840.00	20.00	20.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2015	840.00	840.00	840.00	840.00	840.00	50.00	50.00	50.00	50.00	50.00
2016	840.00	840.00	840.00	840.00	840.00	50.00	20.00	20.00	50.00	50.00

Note: The flow rate of 840,000 gpm presented here is used for computation of thermal-induced entrainment mortality (section 3.IV.D.2.d) only. The monthly average flow rate reflecting down times is 720,000 gpm. This value was used in the RTLC model runs.

TABLE A-4

PROJECTED PLANT FLOW RATES (1000 GPM)
BOWLINE GENERATING STATION (UNIT 2)

	ONCE THROUGH COOLING					CLOSED CYCLE COOLING				
YEAR	APRIL	MAY	JUNE	JULY	AUGUST	APRIL	MAY	JUNE	JULY	AUGUST
1976	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1977	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1978	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1979	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1980	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1981	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1982	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1983	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1984	257.00	257.00	350.00	384.00	384.00	257.00	257.00	350.00	384.00	384.00
1985	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1986	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1987	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1988	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1989	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1990	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1991	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1992	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1993	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1994	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1995	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1996	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1997	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1998	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
1999	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2000	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2001	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2002	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2003	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2004	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2005	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2006	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2007	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2008	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2009	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2010	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2011	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2012	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2013	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2014	257.00	257.00	350.00	384.00	384.00	8.00	8.00	8.00	8.00	8.00
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE A-5

PROJECTED PLANT FLOW RATES (1000 GPM)
BOWLINE GENERATING STATION (UNIT 1)

	ONCE THROUGH COOLING					CLOSED CYCLE COOLING				
YEAR	APRIL	MAY	JUNE	JULY	AUGUST	APRIL	MAY	JUNE	JULY	AUGUST
1976	0.00	193.00	350.00	384.00	384.00	0.00	193.00	350.00	384.00	384.00
1977	129.00	257.00	350.00	384.00	384.00	129.00	257.00	350.00	384.00	384.00
1978	0.00	193.00	350.00	384.00	384.00	0.00	193.00	350.00	384.00	384.00
1979	0.00	193.00	350.00	384.00	384.00	0.00	193.00	350.00	384.00	384.00
1980	0.00	193.00	350.00	384.00	384.00	0.00	193.00	350.00	384.00	384.00
1981	0.00	193.00	350.00	384.00	384.00	0.00	193.00	350.00	384.00	384.00
1982	129.00	257.00	350.00	384.00	384.00	129.00	257.00	350.00	384.00	384.00
1983	0.00	193.00	350.00	384.00	384.00	0.00	193.00	350.00	384.00	384.00
1984	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1985	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1986	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1987	129.00	257.00	350.00	384.00	384.00	4.00	8.00	8.00	8.00	8.00
1988	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1989	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1990	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1991	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1992	129.00	257.00	350.00	384.00	384.00	4.00	8.00	8.00	8.00	8.00
1993	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1994	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1995	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1996	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1997	129.00	257.00	350.00	384.00	384.00	4.00	8.00	8.00	8.00	8.00
1998	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
1999	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2000	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2001	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2002	129.00	257.00	350.00	384.00	384.00	4.00	8.00	8.00	8.00	8.00
2003	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2004	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2005	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2006	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2007	129.00	257.00	350.00	384.00	384.00	4.00	8.00	8.00	8.00	8.00
2008	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2009	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2010	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2011	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2012	129.00	257.00	350.00	384.00	384.00	4.00	8.00	8.00	8.00	8.00
2013	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2014	0.00	193.00	350.00	384.00	384.00	0.00	6.00	8.00	8.00	8.00
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

V.2 On page 12.26, it is stated that "all other model input parameters (besides plant flows) were held constant at either the 1974 or 1975 values in the long-range projections of impact." On page 12.27, it is stated that "...the estimates of the number of striped bass impinged (Section 9) were input directly to the model..." Does this imply that the absolute number of fish impinged was held constant? Please identify the particular numbers for impingement which were input directly.

Response: No, the absolute number of fish impinged was not held constant in the model in making long-range projections of impact. The absolute number of fish impinged during 1974 and 1975 was input to the model along with the plant flow rates during these years and the model calculated f factors for juvenile II and juvenile III life stages based on the model predictions of juvenile standing crops. These f factors, used as input to the model, were held constant in the long-range impact model runs. The f-factor approach allows for year to year variation in the striped bass impingement in the model to reflect variation in projected plant flow rates and model predictions of juvenile standing crops.

The striped bass impingement data have been updated since the release of the McFadden Report. The updated data are shown in Section 3-IV.D.4 (Table 3-IV-31 through 3-IV-33) of Supplement I to the McFadden Report. Table 3-IV-34 in Supplement I shows the updated absolute numbers of striped bass juveniles II and III input to the model to compute impingement f factors.

V.3. For the present simulations of 1974, of 1975, and of 1976 conditions with the Lawler, Matusky, and Skelly real-time model (Sections 10 and 12 of the McFadden 1977 Report), provide tables in the format of Table V-1 for both the "no compensation, with power plants" runs (step (4), p. 10.66) and the "with compensation, with power plants" runs (step (6), p. 10.66). A total of six such tables is therefore requested. Document the full set of input parameters for these model runs. Also provide the relevant "output" biological parameters (e.g., adult survival rates).

Response: The requested information is being prepared and will be provided to you very shortly.

V.9. Provide a copy of the paper by Schuermann and Curry (1973) mentioned on p. 7.207. Is the paper by Curry (1973) supplied to us as a result of the Indian Point Unit 2 hearings in February 1977 the same paper? The iterative procedure is described on pp. 7.208 and 7.209, but no references are given. Provide copies of all references material relating to this procedure.

Response: The paper by Schuermann and Curry (1973) which you have requested is the same paper as prepared by Curry (1973) which was provided to the staff during the Indian Point Unit 2 extension of time for once through cooling hearings in February 1977. Another copy of the paper by Curry 1973 is enclosed.

With respect to the iterative procedure described on page 7.208 and 7.209, no literature references have been found which exactly describe the procedure used here. However, there are several references in which either prior probabilities or iterative techniques are used to discriminate among populations. A manuscript by Casetti (1962) described discrimination procedures which iteratively allocate individuals to classes. McLachlan (1976) gives an iterative reclassification procedure which updates discriminant functions. Copies of these two manuscripts are also enclosed.

The following references are offered as additional information on this subject:

Anderson, T.W. 1958 An introduction to multivariate statistical analysis. John Wiley & Sons, New York 374 p.

Dixon, W.J. (Ed.) 1975 BMDP Biomedical computer programs. Univ. of Calif. Press Berkely, Cal. 789 p.

Morrison, D.F. 1967 Multivariate statistical methods. McGraw-Hill, New York 338 p.

Notes on Parametric Programming

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2.0 Single Parameter Analysis

Several methods for single-parameter parametric analysis have been devised. The sensitivity analysis approach for linear programming problems is well known. In addition to the linear programming problem method, procedures have been devised for quadratic programming and general convex programming problems.

The main concentration here will be on objective function and right-hand side or resource vector analysis. Parametric technological coefficient problems will not be discussed, mainly due to the limitations on its application. The greatest effort has been on procedures for objective and resource vector analysis. In addition, the emphasis in this material is on the utilization of the parametric approach to solve other problems. The parametric solutions can be used to deal with chance-constrained programming problems and nonlinear constraint problems. Other fruitful applications have occured in the area of nonconvex objective functions over convex constraint sets.

A nonstandard approach is utilized for the linear and quadratic single parameter problems. The normal simplex method for linear programming is not discussed. Rather, a primal-dual method and its extension to quadratic programming gives a more consistant base for the computational procedures.

2.1 Linear Programming

The single parameter parametric linear programming problem is the most widely known and utilized of all parametric methods. The ease with which these parametric solutions can be obtained, contributes significantly to its utilization. Parametric objective function

and right-hand side or resource vector analysis lend solutions which are linear segments of the single parameter θ. These solutions are discontinuous for objective function analysis. However, for the resource vector analysis problem, the solution vectors are connected linear segments and hence continuous. Several excellent discussions of linear sensitivity or parametric analysis are available. Notable among these is the concise chapter in Taha [1971].

The basic linear programming problem before parameterization is defined as:

$$\text{(LP)} \qquad \begin{aligned} &\text{maximize} \quad x_0 = \underline{c}^T \underline{x} \\ &\text{subject to} \\ &\underline{Ax} \leq \underline{b} \\ &\underline{x} \geq \underline{0} \end{aligned}$$

The single parameter objective function problem based on (LP) is:

$$\text{(LPC)} \qquad \begin{aligned} &\text{maximize} \quad x_0 = (\underline{c} + \theta \underline{d})^T \underline{x} \\ &\text{subject to} \\ &\underline{Ax} \leq \underline{b} \\ &\underline{x} \geq \underline{0} \\ &\theta \geq 0. \end{aligned}$$

Where the vector $\underline{d}$ is the change in the vector $\underline{c}$ as a function of the parameter θ. The parametric resource vector problem (LPR) is:

$$\text{(LPR)} \qquad \begin{aligned} &\text{maximize} \quad x_0 = \underline{c}^T \underline{x} \\ &\text{subject to} \\ &\underline{Ax} \leq \underline{b} - \theta \underline{e} \\ &\underline{x} \geq \underline{0} \\ &\theta \geq 0. \end{aligned}$$

Thus, the vector $\underline{e}$ is defined as the change in the vector $\underline{b}$ as a function of θ.

The method of solving the two parametric problems (LPC) and (LPR) is to first solve the basic linear programming problem (LP). The solution to this problem is, of course, the solution to the parametric problems at $\theta=0$. The solution tableau for the (LP) problem is then utilized for the parametric problem. The basic idea for resource vector analysis is to append θ to the list of decision variables and then maximize θ. At each pivot for this problem, the resulting values of the decision variables can be read from the tableau in the same manner as a normal linear programming problem. The intermediate values of the decision variables are obtained by taking convex linear combinations of the critical point values of the variables.

The linear and quadratic programming solution techniques are based on the "Symmetric" method of linear programming developed by Talacko [ ]. A brief summary of this primal-dual method is given in the next section.

2.2 Symmetric Method of Linear Programming

The symmetric linear programming method was developed by Talacko [ ]. The method discussed here is an extention of that procedure to handle equality constraints implicitly rather than adding two inequalities for each equality. The symmetric method name is an adequate synonym of the method since it is based on the primal inequality problem.

$$\text{maximize} \quad x_0 = \underline{c}^T \underline{x}$$

subject to

$$\underline{A}^0 \underline{x} \leq \underline{b}$$

$$\underline{x} \geq \underline{0}$$

and the associated symmetric dual problem

$$\text{minimize} \quad y_0 = \underline{b}^T \underline{y}$$
$$\text{subject to} \quad \underline{A}^T \underline{y} \geq \underline{c}$$
$$\underline{y} \geq \underline{0}.$$

The duality relationship of linear programming lends the result that for feasible primal and dual solutions the value of the dual problem $y_0 \geq x_0$ the value of the primal problem. In addition, at optimality the two problems have the same value, $y_0^* = x_0^*$. Exploiting this relationship, if both problems can be operated on simultaneously, it may be possible to obtain a good computational procedure for the solution of the problem. The advantage of a primal-dual procedure is the ability to handle infeasible constraints without expanding the problem in terms of slacks and artificial variables. With the extension of the method to include equality constraints, a very general method results which requires no slacks or artificial variables.

There are three basic components in the symmetric linear programming procedure. These are: (1) the inversion-in-place pivot method, (2) a primal simplex pivot selection, and (3) a dual simplex pivot selection. Each of these procedures is discussed in detail in the following sections. These sections are intentionally brief and more detailed discussion can be found in several texts dealing exclusively with linear programming. The primal and dual simplex methods are well presented in the text by Taha [1971]. Both primal and dual pivot candidates are considered. Then a selection is made corresponding to the pivot which leads to the greatest change in the solution.

The basic tableau to be used is that of the primal problem. The dual problem is then dealing with rows rather than columns since only

one tableau is necessary. The primal tableau is:

iteration number	$\underline{x}$		
basic primal variables	$\underline{A}$	$\leq$	$\underline{b}$
	$\underline{c}^T$		x_0

Thus, the dual tableau in the same form is:

k	basic dual variables	
$\underline{y}$	$\underline{A}$	$\underline{b}$
	$\geq$	
	$\underline{c}^T$	y_0

Combining the two tableaux, the symmetric method tableau becomes:

(2.1)

k	$\underline{x}$	
$\underline{y}$	$\underline{A}$	$\underline{b}$
	$\underline{c}^T$	x_0

2.2.1 Primal Pivot Selection

In the primal simplex method, the pivot selection procedure can be paraphased as "Select the largest positive element in the pricing row. The associated variable becomes the entering variable and hence the pivot column. The leaving basic variable, and hence the pivot row, is the row associated with the minimum ratio of positive

pivot column elements into positive resources". This scheme is thus; + indicator, + column element, and + or 0 resource elements. Any deviation from this scheme is not considered in the candidate selection. The primal procedure is concerned with selecting non-optimal columns and then choosing as the pivot row the one which will retain the feasibility of all currently feasible rows.

The symmetric method of primal pivot selection deviates slightly from the procedure just discussed. This deviation is in the selection of the largest pricing row element as the pivot column. The largest pricing element does not insure the greatest resulting objective function change. Although this is certainly a valid method, the procedure here is to consider all positive pricing columns as possible pivot columns. Then the required pivot element in the column, if it exists, is located and the objective function change is computed. The pivot element with the largest change is then retained as the possible primal pivot element. This element will become the eventual pivot element if the dual pivot candidate does not produce a greater change in the objective function.

2.2.2 Dual Pivot Selection

The dual pivot selection is similar to the primal selection except that the resource column is inspected for negative elements, infeasible primal constraints, then the minimum ratio of negative row elements to nonpositive pricing elements is obtained. Thus, the dual scheme is; - resource, - row element, and - or 0 pricing element. Any other combination is of course neglected. For each possible pivot that satisfies the dual selection criterion, the one which produces the

largest change in the objective is retained as the dual pivot candidate. This pivotal change is compared with the primal pivotal change and the pivot with the largest change is selected as the pivot element.

If no primal or dual pivots can be found then one of two conditions exists. A finite optimal solution exists if all primal indicators, pricing elements, are negative and all dual indicators, resource elements, are positive. Otherwise, no finite optimum exists. Infeasible problems and unbounded problems both terminate with this condition. However, no distinction will be made in the resulting conditions. If any indicator, primal or dual, has the correct sign but no pivot element exists then a finite optimum solution does not exist and the procedure is terminated.

2.2.3 Pivot Method

The pivot procedure is that of inversion-in-place. This method is a compact inverse method. There are four element operation rules.

(1) Replace the pivot element P by one over the pivot element, $P' = 1/P$.

(2) Divide all elements in the pivot row, excluding the pivot element itself, by the pivot, $PR' = PR/P$.

(3) Divide all elements in the pivot column, excluding the pivot element itself, by the negative of the pivot element, $PC' = -PC/P$.

(4) Perform gaussian reduction on all other elements in the tableau,

$$E' = E - \frac{(PR)(PC)}{P} .$$

2.2.4 Equality Constraints

Equality constraints can be handled by pivoting the dual variables associated with these constraints into the basis at the outset of the problem solution. Then these dual variables are maintained as basic variables throughout the remainder of the problem solution. Since the dual variables associated with equality constraints are free variables, or unrestricted in sign, then these variables are always feasible.

2.2.5 Example Problem

Consider the problem,

maximize $3x_1 + 2x_2 + 5x_3$

subject to

$$x_1 + 2x_2 + x_3 = 430$$

$$3x_1 \qquad + 2x_3 \leq 460$$

$$x_1 + 4x_2 \qquad \leq 420$$

$$x_1, x_2, x_3 \geq 0 .$$

The first constraint is an equality and the associated dual variable will have to be pivoted into the basis first and retained there. The sequence of tableaux is:

0	x_1	x_2	x_3	
y_1	1	2	1	430
y_2	3	0	2	460
y_3	1	4	0	420
	3	2	5	0

1	y_1	x_2	x_3	
x_1	1	2	1	430
y_2	-3	-6	-1	-830
y_3	-1	2	-1	-10
	-3	-4	2	-1290

2	y_1	x_2	x_1	
x_3	1	2	1	430
y_2	-2	-4	1	-400
y_3	0	4	1	420
	-5	-8	-2	-2150

3	y_1	y_2	x_1	
x_3	0	1/2	3/2	230
x_2	1/2	-1/4	-1/4	100
y_3	-2	1	2	20
	-1	-2	-4	-1350

The optimal primal solution is $x_o = y_o = 1350$, $x_1 = 0$, $x_2 = 100$ and $x_3 = 230$. The dual solution is the negative of the pricing row. Thus, $y_1 = 1$, $y_2 = 2$, and $y_3 = 0$.

Problem 2.2.1

Solve the problem,

$$\text{maximize} \quad x_o = 3x_1 + 2x_2 + 5x_3$$

$$\text{subject to} \quad x_1 + 2x_2 + x_3 = 430$$

$$3x_1 + 2x_3 = 460$$

$$x_1 + 4x_2 \leq 420$$

$$x_1, x_2, x_3 \geq 0 .$$

Problem 2.2.2

Solve the problem,

$$\text{maximize} \quad x_o = 12x_1 - 10x_2$$

$$\text{subject to} \quad 4x_1 - x_2 \leq 0.9$$

$$2x_1 - 4x_2 \leq 0.4$$

$$2x_1 - 2x_2 \leq 0.6$$

$$x_1, x_2 \geq 0$$

Problem 2.2.3

Solve the problem,

$$\text{maximize} \quad x_o = x_1 + x_2 + x_3$$

$$\text{subject to} \quad x_1 + 2x_2 + 3x_3 \leq 14$$

$$3x_1 + 2x_2 + x_3 \leq 10$$

$$2x_1 + x_2 + 2x_3 \leq 10$$

$$x_1, x_2, x_3 \geq 0$$

Problem 2.2.4

Find the inverse by inversion-in-place of the following matrices:

$$\underline{A} = \begin{bmatrix} 1 & 3 \\ 2 & 1 \end{bmatrix}, \qquad \underline{B} = \begin{bmatrix} 2 & -1 & -3 \\ -1 & -3 & 2 \\ 3 & 2 & -2 \end{bmatrix}.$$

2.3 Linear Parametric Programming

In this section, a solution method for the single parameter linear programming problem is developed. The method utilizes the symmetric method for linear programming. The parametric resource vector problem is addressed first.

Consider the problem (LPR) given by:

maximize $\quad x_0 = \underline{c}^T \underline{x}$

subject to

(LPR) $\quad \underline{Ax} \leq \underline{b} - \theta \underline{e}$

$$\underline{x} \geq \underline{0}$$

$$\theta \geq 0 .$$

Writing this in the tableau form for the symmetric method, treating θ as a decision variable and denoting dual variables to $\underline{x}$ by $\underline{y}$:

$$\begin{array}{|c|c|c|c|}
\hline
0 & \underline{x} & \theta & \\
\hline
\underline{y} & \underline{A} & \underline{e} & \underline{b} \\
\hline
 & \underline{c} & 0 & 0 \\
\hline
\end{array}$$

The value of the objective coefficient for θ does not differ from the standard value if θ was truely treated as a variable. The basic idea is to first not allow θ into the basis, thus solving the standard problem (LP). However, the parameter change vector, column under θ, is being updated to correspond to current basis. Once this problem is solved, assuming that a finite optimal solution exists, the problem will be changed to one of maximizing θ. Therefore, in the present form the optimal tableau will be correct for undertaking the second phase maximization. The first phase is completed by allowing only the first n primal variables to become basic. That is, only consider x's as primal pivot candidates and of course the dual variables $\underline{y}$ as dual pivot candidates. Thus, yielding the tableau:

$$\begin{array}{|c|c|c|c|}
\hline
k & (\underline{x}, \underline{y}) & \theta & \\
\hline
\begin{pmatrix} \underline{y} \\ \underline{x} \end{pmatrix} & \underline{A}' & \underline{e}' & \underline{b}' \\
\hline
 & \underline{c}' & f & x_0 \\
\hline
\end{array}$$

By the conditions for a finite feasible solution, the vector $\underline{b}' \geq \underline{0}$ and the vector $\underline{c}' \leq \underline{0}$. The value of f is irrelevent since θ is not truely a variable in the problem at this time. The parametric analysis, phase two, can now be accomplished by replacing the vector $\underline{c}'$

by $\underline{0}$ and f by the number one. Then proceeding to maximize, the problem is equivalent to maximizing θ while retaining the optimality of the basis. If the solution then proceeds to become optimal, no feasible solution exists for larger values of θ. However, if the procedure arrives at a solution which is not optimal and no feasible pivot exists, then the current solution is optimal for all values of θ greater than this critical value of θ.

The proposed method works quite well for parametric right-hand side analysis. To study the parametric objective function problem (LPC), merely taking the dual problem and then solving the resulting (LPR) problem is not adequate. Certainly the correct critical values of θ are obtained, but since in the procedure the optimal pricing vector was replaced by zeros, the dual variables of the problem have been destroyed. Since originally the problem was transformed to its dual to facilitate solving the parametric problem, the true decision variables of interest are now actually the dual variables of the problem. Hence, this exact procedure does not yield the desired results. However, the procedure can be adjusted, with minimal effort, to yield both the primal and dual decision variables. This method will then be an acceptable one for the analysis of both linear parametric programming problem types, (LPC) and (LPR).

The adjustment to the procedure is slight. Instead of replacing the pricing row by zeros and a one, the pricing row will be retained and a new row added to the tableau for the new prices. To maintain the correct values of the dual variables (pricing row), one additional

adjustment must be made. When the pivot element has been located, the minimum ratio of the negative elements in the pivot row to the original pricing row is obtained along with the corresponding column for this ratio. This is equivalent to finding the leaving variable in the primal revised-simplex parametric resource problem. The original pricing vector value for the designated column is replaced by the minimum ratio times the value of the pivot element. This method insures that the dual variables have the correct values. The optimization is of course performed on the new pricing row and is continued until either no new pivot exists (optimal solution for greater θ) or the problem becomes optimal (infeasible solution for greater θ). This adjustment procedure to maintain the correct value of the dual variables doesn't maintain the correct value of the solution x_0. Thus, the solution value must be recomputed at each critical value of θ.

Example 2.3.1. The following example problem is solved by the simplex parametric programming procedure in Chapter 9 of Taha [1970]. The problem is now solved by the symmetric parametric method. The problem is:

$$\text{maximize} \quad x_0 = 3x_1 + 2x_2 + 5x_3$$

$$\text{subject to} \quad \begin{aligned} x_1 + 2x_2 + x_3 &\leq 430 + \theta \\ 3x_1 + \quad + 2x_3 &\leq 460 - 4\theta \\ x_1 + 4x_2 \quad &\leq 420 - 4\theta \\ x_1, x_2, x_3, \theta &\geq 0 \end{aligned}$$

The starting tableau for this problem is:

0	x_1	x_2	x_3	θ	
y_1	1	2	1	-1	430
y_2	3	0	2	4	460
y_3	1	4	0	4	420
	3	2	5	0	0

The solution for $\theta = 0$ is found by not allowing θ basic and forcing all other indicators optimal. This solution is found in two pivots. The final tableau is augmented by the new pricing row yielding:

2	x_1	y_1	y_2	θ	
x_2	-1/4	1/2	-1/4	-3/2	100
x_3	3/2	0	1/2	2	230
y_3	2	-2	1	10	20
x_0	-4	-1	-2	-7	-1350
	0	0	0	1	

The solution for $\theta = 0$ is then $x_1 = 0$, $x_2 = 100$, $x_3 = 230$ and the objective function value $x_0 = 1350$. The dual solution is $y_1 = 1$, $y_2 = 2$, and $y_3 = 0$. Recall that the negative of the indicator or pricing row is the value of the dual variables and the objective function x_0. The parametric analysis is now continued by proceeding to maximize the augmented problem. Of course, pivots are not allowed in the original pricing row, designed by x_0 as the basic variable.

The first step is to find the pivot element by the normal symmetric method. The circled element in the tableau is the new pivot

element. Next the adjustment for the dual variable values is found by finding the minimum ratio of the negative elements in the y_3 row into the x_0 row. This operation has only one candidate and thus the ratio is 1/2. Now, replace the indicator in the true pivot column, θ column for this iteration, -7 by the minimum ratio of 1/2 times the pivot element 10. The result is that -7 is replaced by 5. Now proceeding with a normal symmetric pivot and then recomputing the objective function value x_0 the result is:

3	x_1	y_1	y_2	y_3	
x_2	0.05	0.20	-.10	0.15	103
x_3	1.10	0.40	0.30	-0.20	226
θ	0.20	-0.20	0.10	0.10	2
x_0	-5	0	-2.50	-0.5	-1336
	-0.2	0.2	-0.1	-0.1	

Thus, the next critical value is $\theta = 2$. The solution at this point is $x_1 = 0$, $x_2 = 103$, $x_3 = 226$ and $x_0 = 1336$. The dual solution at this critical value is $y_1 = 0$, $y_2 = 2.5$ and $y_3 = 0.5$. The next pivot is circled in the tableau. Again there is only one negative element in the pivot row, x_2 row, thus the ratio is -2.5/-0.10 = 25. Thus, replace the x_0 row indicator for the pivot column, y_1 column, by 25 (0.20) = 5. Now performing the pivot the final tableau is obtained.

4	x_1	x_2	y_2	y_3	
y_1	1/4	5	-1/2	3/4	515
x_3	1	-2	1/2	-1/2	20
θ	1/4	1	0	1/4	105
x_o	-25/4	-25	0	-17/4	-100
	-1/4	-1	0	-1/4	

The problem's final solution is at a critical value of $\theta = 105$ with values $x_o = 100$, $x_1 = 0$, $x_2 = 0$, and $x_3 = 20$. The dual variables are $y_1 = 0$, $y_2 = 0$, and $y_3 = 1/4$. Since the problem now has optimal indicators, there is no feasible solution for $\theta > 105$ and the parametric analysis is complete.

Problem 2.3.1

Solve for the complete parametric solution to:

$$\text{maximize} \quad x_o = 3x_1 + 2x_2 + 5x_3$$

$$\text{subject to} \quad \begin{aligned} x_1 + 2x_2 + x_3 &\leq 430 + 100\,\theta \\ 3x_1 \qquad + 2x_3 &\leq 460 - 200\,\theta \\ x_1 + 4x_2 \qquad &\leq 420 + 400\,\theta \\ x_1, x_2, x_3, \theta &\geq 0 . \end{aligned}$$

Problem 2.3.2

Solve the parametric pricing problem for the complete solution.

$$\text{minimize} \quad x_o = (3 - 6\theta)x_1 + (2 - 2\theta)x_2 + (5 + 5\theta)x_3$$

$$\text{subject to} \quad x_1 + 2x_2 + x_3 \leq 430$$

$$3x_1 + 2x_3 \leq 460$$

$$x_1 + 4x_2 \leq 420$$

$$x_1, x_2, x_3, \theta \geq 0 .$$

2.4 Quadratic Programming

The field of quadratic programming is large in the number of papers and the variety of techniques that have been proposed. This class of problems is one step up in difficulty from linear programming. Generally linear programming based methods are used in the solution of quadratic programs. This is due to the linear nature of the Kuhn-Tucker conditions when applied to this class of problems. The only nonlinearity being the complimentary slackness conditions.

A few of the different solution techniques merit mention any time solution methods for quadratic programs are discussed. These techniques included the well-known method of applying the restrictive basis method and linear programming developed by Frank and Wolfe [1956]. A gradient type procedure is discussed in Wagner [1969]. Later methods are those of Lemke [1965] and the complimentary problem of Cottle and Dantzig [1968]. A general and fairly complete discussion including some parametric results is given in Eaves [1971]. The first parametric quadratic method was presented by Wolfe [1959]. This article develops the computational method for parametric analysis of the linear term in the objective function. This procedure is the basis for the one discussed here. The quadratic programming solution method to be

discussed was developed by Schuermann [1971] and is well described as a-symmetric pivot method.

The basic problem is one of maximizing a concave quadratic objective function subject to a linear constraint set. The problem is:

$$\text{(QP)} \qquad \begin{aligned} &\text{maximize} \quad x_0 = \underline{c}^T\underline{x} + \underline{x}^T\underline{Dx} \\ &\text{subject to} \\ &\underline{Ax} \le \underline{b} \\ &\underline{x} \ge \underline{0}. \end{aligned}$$

The two associated parametric problems are the parametric objective function problem (QPC) and the parametric resource problem (QPR). The (QPC) problem is

$$\text{(QPC)} \qquad \begin{aligned} &\text{maximize} \quad \theta\, \underline{c}^T\underline{x} + \underline{x}^T\underline{Dx} \\ &\text{subject to} \\ &\underline{Ax} \le \underline{b} \\ &\underline{x} \ge \underline{0} \\ &\theta \ge 0 \end{aligned}$$

and the (QPR) is

$$\text{(QPR)} \qquad \begin{aligned} &\text{maximize} \quad \underline{c}^T\underline{x} + \underline{x}^T\underline{Dx} \\ &\text{subject to} \\ &\underline{Ax} \le \underline{b} + \theta\, \underline{e} \\ &\underline{x} \ge \underline{0} \\ &\theta \ge 0\ . \end{aligned}$$

As was the procedure for the linear programming problem, the first phase of the two phase parametric solution method is to solve the quadratic problem (QP) obtained by specifing $\theta = 0$. This problem can be made easier by first applying the necessary and sufficient

conditions of Kuhn and Tucker for the general mathematical programming problem,

$$\text{(GP)} \qquad \begin{array}{ll} \text{maximize} & f(\underline{x}) \\ \text{subject to} & \\ & \underline{g}(\underline{x}) \leq \underline{0}. \end{array}$$

The Kuhn-Tucker conditions are:

$$\text{(K-T)} \qquad \begin{array}{ll} \nabla_{x_i} f(\underline{x}) - \sum_{j=1}^{m} \lambda_j \nabla_{x_i} g_j(\underline{x}) = 0 & (\forall i) \\ \underline{g}(\underline{x}) \leq \underline{0} & \\ \underline{\lambda} \geq \underline{0} & \\ \underline{\lambda} \cdot \underline{g}(\underline{x}) = 0 \ . & \end{array}$$

For quadratic programming problems, all of the Kuhn-Tucker conditions yield linear constraints except the last constraint known as the complimentary slackness condition. This condition merely states that if the jth constraint in (QP) is not tight, then the multipler must be zero. Or if the jth slack is basic then the associated dual variable or multipler can not be basic for the dual problem. The Kuhn-Tucker conditions applied to (QP) yields the following system of equations where $\underline{s} \geq \underline{0}$ is the vector of constraint slacks for $\underline{Ax} \leq \underline{b}$ with multipliers $\underline{y} \geq \underline{0}$. The nonnegativity conditons on $\underline{x} \geq \underline{0}$ have multipliers $\underline{u} \geq \underline{0}$.

$$\begin{array}{lll} & -2\underline{Dx} + \underline{A}^T\underline{y} - \underline{u} = \underline{c} & \\ & \underline{Ax} \qquad\qquad + \underline{s} = \underline{b} & \\ (2.4.1) & u_j x_j = 0 = y_i s_i & (\forall i,j) \\ & \underline{y} \geq \underline{0},\ \underline{u} \geq \underline{0},\ \underline{x} \geq \underline{0},\ \underline{s} \geq \underline{0}\ . & \end{array}$$

Temporarily ignoring the nonlinear constraints and rewriting the system in the symmetric linear programming tableau, the u_j's and s_i's being dropped, the following tableau results:

(2.4.2)

0	$\underline{x}$	$\underline{y}$	
$\underline{u}$	$2\underline{D}$	$-\underline{A}^T$	$-\underline{c}$
$\underline{s}$	$\underline{A}$	$\underline{0}$	$\underline{b}$
	$\underline{0}$	$\underline{0}$	0

If the symmetric method of linear programming is directly applied to this problem, the conditions $\underline{y}\cdot\underline{s} = 0 = \underline{u}\cdot\underline{x}$ will not necessarily be satisfied. Schuermann's approach to the problem is to restrict pivoting in such a manner as to always satisfy these conditions. This can be done by merely considering pivot candidates along the diagonal. Thus any time x_i becomes basic, automatically u_i becomes nonbasic. The same holds for the (s_i, y_i) pairs. Hence, any feasible solution is optimal for the quadratic programming problem. Computational experience with this method has been quite satisfactory for problems of 25 variables or less. The ease of implementing and the consistency with the linear programming approach make it a good method to use in teaching the basic concepts and for small scale applications.

The problem is now merely one of finding a feasible solution to the given system of equations. Since any feasible solution is optimal, the primal pivot candidates no longer need be considered. Hence, any possible dual feasible candidate can be used without regard to the change in the objective function. Thus, the pricing row of tableau (2.4.2) can be omitted. The dual pivot candidates are restricted to be

diagonal elements.

Example 2.4.1

To demonstrate the symmetric pivot quadratic programming method, consider the problem,

$$\text{maximize} \quad x_0 = -x_1^2 - 2x_2^2 - 3x_3^2 + x_1x_3 + x_2x_3 + 5x_1 + 6x_2 - x_3$$

subject to

$$\begin{aligned} x_1 + 3x_2 \qquad &\le 8 \\ -x_1 + x_2 + 2x_3 &\le 5 \\ x_1, x_2, x_3 &\ge 0. \end{aligned}$$

Writing the problem in the tableau form (2.4), the pivots are selected as indicated yielding:

0	x_1	x_2	x_3	y_1	y_2	
u_1	-2	0	1	-1	1	-5
u_2	0	-4	1	-3	-1	-6
u_3	1	1	-6	0	-2	1
s_1	1	3	0	0	0	8
s_2	-1	1	2	0	0	5

1	u_1	x_2	x_3	y_1	y_2	
x_1	-1/2	0	-1/2	1/2	-1/2	2.5
u_2	0	-4	1	-3	-1	-6.0
u_3	1/2	1	-11/2	-1/2	-3/2	-1.5
s_1	1/2	3	1/2	-1/2	1/2	5.5
s_2	-1/2	1	3/2	1/2	-1/2	7.5

2	u_1	u_2	x_3	y_1	y_2	
x_1	-1/2	0	-1/2	1/2	-1/2	2.5
x_2	0	-1/4	-1/4	3/4	1/4	1.5
u_3	1/2	1/4	-21/4	-5/4	-7/4	-3.0
s_1	1/2	3/4	5/4	-11/4	-1/4	1.0
s_2	-1/2	1/4	7/4	-1/4	-3/4	6.0

3	u_1	u_2	u_3	y_1	y_2	
x_1	-.55	-.02	-.10	.62	-.33	2.79
x_2	-.02	-.26	-.05	.81	.33	1.64
x_3	-.10	-.05	-.19	.24	.33	0.57
s_1	.62	.81	.24	-3.05	-.67	0.29
s_2	-.33	.33	.33	-.67	-1.33	5.00

The tableau for iteration three has all positive dual indicators, thus, the solution obtained is feasible and hence optimal. The solution vector is $x_1 = 2.79$, $x_2 = 1.64$ and $x_3 = 0.57$. The objective function value must be computed using the solution vector and has a value $x_o = 11.61$.

Problem 2.4.1

Using the symmetric pivot method for quadratic programming problems solve the problem

maximize $\quad x_o = -\frac{x_1^2}{2} - \frac{x_2^2}{2} - \frac{x_3^2}{2}$

subject to $x_1 - x_2 + x_3 = 1$

$$x_1, x_2, x_3 \geq 0 .$$

2.5 Parametric Quadratic Programming

The parametric quadratic programming procedure is based on the technique by Wolfe [1959]. However, Wolfe only considered parametric analysis on the linear portion of the objective function. A slight modification of the technique allows for parametric resource analysis or simultaneous variations in both the objective and resource vectors. The two parametric problems to be discussed were defined in Section 2.4 and labeled as (QPC) and (QPR) for objective and resource problems, respectively.

The solution procedure is to first find the solution for the parameter $\theta = 0$. Under this restriction, the problem reduces to the standard quadratic program (QP). Assuming that a solution to the problem exists and is finite, (QP) can be solved by the symmetric quadratic method of Section 2.4. This solution yields a feasible solution to the system of equations derived from the Kuhn-Tucker conditions (2.4.1). As was the procedure for linear parametric analysis, the parameter θ is added to the decision variable set and the problem shifted to one of maximizing θ. The Kuhn-Tucker necessary and sufficient conditions for (QP) form a linear system of equations (2.4.1) except for the complimentary slackness conditions. If a column for θ is added to the system, the maximization of θ becomes a linear program, again subject to the complimentary slackness conditions. The symmetric method can be used to solve the θ maximization problem by including in it a re-

stricted basis check. The restrictive basis augmentation is strictly a check that insures that complimentary pairs (x_i, u_i) and (y_j, s_j) are never basic simultaneously. For the (QPC) problem, the θ maximization problem is:

$$
\begin{aligned}
&\text{maximize} && \theta \\
&\text{subject to} && \underline{Ax} + \underline{s} + \underline{0}\,\theta = \underline{b} \\
& && 2\underline{Dx} - \underline{A'y} + \underline{u} + \underline{c}\,\theta = \underline{0} \\
& && \underline{x} \geq \underline{0},\ \underline{y} \geq \underline{0},\ \underline{u} \geq \underline{0},\ \underline{s} \geq \underline{0},\ \theta \geq 0 \\
(2.5.1) & && \underline{x}\cdot\underline{u} = 0,\ \underline{y}\cdot\underline{s} = 0.
\end{aligned}
$$

Fixing $\theta = 0$, the resulting solution satisfies the conditions (2.5.1). To maintain these conditions, merely insure that if a given variable, say x_i, has an indicator such that it should become basic, allow it into the basis only if the complimentary variable u_i is nonbasic or u_i is the leaving variable. One additional adjustment to the symmetric linear programming method is necessary. That is, choose as the entering variable the one which produces the minimum change in the objective function rather than the maximum change. This adjustment is necessary to insure that all critical points of θ are found and not passed over.

The optimal parametric solution is made up of connected linear segments. These segments are linear convex combinations of the extreme points associated with adjunct critical values of θ. If the maximum θ problem terminates in an optimal solution, then there is no feasible value of θ greater than the maximum. However, if the linear problem terminates with an unbounded solution, then the external ray which is generated constitutes the last linear segment of the parametric

solution. The solutions generated by the ray are valid for all θ from the last criterical point to $+\infty$.

Parametric resource analysis can be conducted in the manner described above with the θ column changed from $[\underline{0}, \underline{c}]^T$ to $[\underline{e}, \underline{0}]^T$. The right-hand sides of the equations should contain the linear cost coefficients $\underline{c}$. Thus, in addition to the θ column change, replace the resource vector $[\underline{b}, \underline{0}]^T$ by $[\underline{b}, -\underline{c}]$. Thus, the problem (QPR) is,

$$
\begin{aligned}
\text{maximize} \quad & \theta \\
\text{subject to} \quad & \underline{Ax} + \underline{s} + \underline{e}\,\theta = \underline{b} \\
& 2\underline{Dx} - \underline{A}^T\underline{y} + \underline{u} + \underline{0}\,\theta = -\underline{c} \\
& \underline{x} \geq \underline{0},\ \underline{y} \geq \underline{0},\ \underline{u} \geq \underline{0},\ \underline{s} \geq \underline{0},\ \theta \geq 0 \\
& \underline{x}\cdot\underline{u} = 0,\ \underline{y}\cdot\underline{s} = 0.
\end{aligned}
$$

Example 2.5.1

Consider solving the parametric resource problem,

$$\text{maximize} \quad x_0 = -x_1^2 - x_2^2 - x_3^2 + 5x_1 + 6x_2 + 3x_3$$

subject to

$$
\begin{aligned}
5x_1 + x_2 + 6x_3 &\leq 10 \\
x_1 + 3x_2 + 9x_3 &\leq 8 - \theta \\
x_1, x_2, x_3, \theta &\geq 0.
\end{aligned}
$$

The initial and final symmetric quadratic tableaux are given. With $\theta = 0$, the problem required 6 iterations. Then the maximization of θ problem is solved, requiring 3 more iterations.

0	x_1	x_2	x_3	y_1	y_2	θ	
u_1	-2	0	0	-5	-1	0	-5
u_2	0	-2	0	-1	-3	0	-6
u_3	0	0	-2	-6	-9	0	-3
s_1	5	1	6	0	0	0	10
s_2	1	3	9	0	0	1	8

6 / 0	u_1	u_2	x_3	s_1	s_2	θ	
x_1	0.0	0.0	.643	.214	-.071	-.071	1.571
x_2	0.0	0.0	2.786	-.071	.357	.357	2.143
u_3	-.643	-2.786	-18.35	.122	-1.90	-1.90	2.969
y_1	-.214	.071	.122	-.102	.082	.082	0.276
y_2	.071	-.357	-1.90	.082	-.265	-.265	0.480
	0	0	0	0	0	1	

1	u_1	u_2	x_3	s_1	s_2	y_1	
x_1	-.19	.06	.75	.13	0	.88	1.81
x_2	.94	-.31	2.3	.38	0	-4.4	0.94
u_3	-5.6	-1.1	-15.	-2.2	0	23.	9.38
θ	-2.6	.88	1.5	-1.3	1	12.	3.38
y_2	-.63	-.13	-1.5	-.25	0	3.2	1.38
	2.63	-.88	-1.5	1.3	-1	-12.	

2	u_1	u_2	x_3	x_2	s_2	y_1	
x_1	-.50	.17	0	-.33	0	2.3	1.50
s_1	2.5	-.83	6	2.67	0	-11.3	2.50
u_3	0	-3	-2	6	0	-3	15.0
θ	.50	-.17	9	3.3	1	-2.3	6.50
y_2	0	-.33	0	.67	0	.33	2.00
	.50	.17	-9	-3.3	-1	2.3	

3	u_1	x_1	x_3	x_2	s_2	y_1	
u_2	-3	6	0	-2	0	14	9
s_1	0	5	6	1	0	0	10
u_3	-9	18	-2	0	0	39	42
θ	0	1	9	3	1	0	8
y_2	-1	2	0	0	0	5	5
	0	-1	-9	-3	-1	0	

There is no feasible solution for $\theta > 8$. The results are summarized in Table 2.5.1.

θ	0	3.375	6.5	8
$X_1^*(\theta)$	1.571	1.813	1.5	0
$X_2^*(\theta)$	2.143	0.938	0	0
$X_3^*(\theta)$	0	0	0	0

Table 2.5.1: Display of Quadratic Parametric Example Problem Solution

2.6 Concave Nonlinear Parametric Analysis

In this section parametric objective function and parametric constraint analysis for general concave functions over a compact convex set are studied. Two types of results are developed. These are the characteristics of the parametric objective function values reported by Hocking [1970] and the characteristics of the parametric solution vectors. The proof of the continuity of the solution vector for the parametric objective function problem was given by Geoffrion [1965]. The proof for the parametric constraint problem is by the authors. In addition to the continuity result, Geoffrion proposed a computational procedure for obtaining the parametric solution. The method requires the repeated solution, generally by a Newton-Raphson technique, of the Kuhn-Tucker conditions for the primal and dual variables.

The continuity of the parametric solution is a very important property. This property is exhibited for strictly concave functions. The strict concavity excludes linear functions which were discussed in Section 2.3 and which display discontinuous linear solutions for the parametric objective function problem. If strict concavity is relaxed to merely concave functions, then the solutions can be shown to be upper semicontinuous, Geoffrion [1967].

Another useful result for the maximization of parametric objective function problems is the convexity of the optimal objective function value as a function of the parameter. This result is given in a paper

by Hocking [1970] and it can be utilized in the proof of the continuity of the optimal solution vector.

<u>Theorem 2.6.1</u>: For γ a nonnegative parameter, the maximization problem (P_γ) has a convex optimal objective function value. The constraint space described by X is assumed to be a compact convex set.

$$(P_\gamma) \quad Z(\gamma) = \underset{x \in X}{\text{maximize}} \; f_1(\underline{x}) + \gamma \, f_2(\underline{x})$$

Proof: Let x_i^* be optimum solutions for $\gamma = \gamma_i$, $i = 0, 1, 2$ where $\gamma_0 = \alpha \, \gamma_1 + (1 - \alpha) \, \gamma_2$ for $0 \leq \alpha \leq 1$. Then

$$Z(\gamma_0) = f_1 \, (\underline{x}_0^*) + \gamma_0 \, f_2(\underline{x}_0^*)$$

$$= f_1(\underline{x}_0^*) + [\alpha\gamma_1 + (1-\alpha)\gamma_2] \, f_2(\underline{x}_0^*)$$

$$= \alpha f_1(\underline{x}_0^*) + \alpha\gamma_1 \, f_2(\underline{x}_0^*) + (1-\alpha) \, f_1(\underline{x}_0^*) + (1-\alpha) \, \gamma_2 f_2(\underline{x}_0^*)$$

$$= \alpha[f_1(\underline{x}_0^*) + \gamma_1 f_2(\underline{x}_0^*)] + (1-\alpha)[f_1(\underline{x}_0^*) + \gamma_2 f_2(\underline{x}_0^*)]$$

$$\leq \alpha \, [f_1(\underline{x}_1^*) + f_2(\underline{x}_1^*)] + (1 - \alpha) \, [f_1(\underline{x}_2^*) + \gamma_2 f_2(\underline{x}_2^*)]$$

$$= \alpha \, Z(\gamma_1) + (1 - \alpha) \, Z(\gamma_2).$$

Q.E.D.

The convexity property of $Z(\gamma)$ is valid regardless of the specific form of $f_1(\underline{x})$ and $f_2(\underline{x})$. The convexity of $Z(\gamma)$ implies it is continuous on any open nonnegative convex set. However, a set can be closed and convexity doesn't imply continuity, as illustrated by the example represented in Figure 2.6.1. The function is convex and continuous on the interior of the set X. But, on the boundary, a discontinuity exists and the function is still convex.

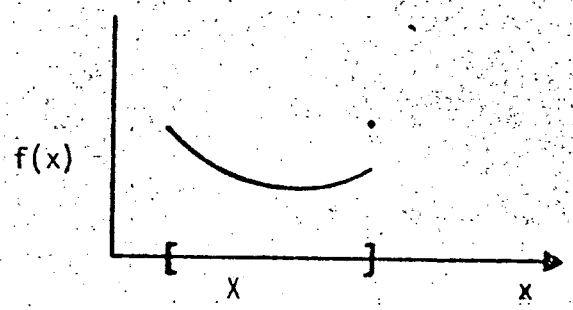

Figure 2.6.1: Example of a Convex Function Over a Closed Set Which is Not Continuous

Now consider the problem of demonstrating that the optimal solution vector $\underline{x}^*(\alpha)$ is a continuous function of the parameter α. This result, of course, does not hold independent of the assumptions on the objective function forms as does Theorem 2.6.1. First a definition about continuous functions is given [Liusternik and Sobolev, 1961].

Definition 2.6.2. Let X and Y be two vector spaces and let $\underline{y} = A(\underline{x})$ be an operator defined on X whose range is Y. The operator A is continuous if $\{x_n\} \to x_0$ in the sense of convergence in X, then $\{A(x_n)\} \to A(x_0)$ in the sense of convergence in Y.

The problem under consideration is $(P\alpha)$, where the functions $f_i(\underline{x})$ are analytic and strictly concave on some open region containing X. The constraint space X is a nonempty compact convex set.

$$(P\alpha) \qquad \begin{array}{l} \text{maximize } \alpha f_1(\underline{x}) + (1-\alpha) f_2(\underline{x}) \\ \underline{x} \in X \\ \alpha \in [0,1]. \end{array}$$

Theorem 2.6.3. The problem (P_α) has a unique optimal solution $x^*(\alpha)$,

and $\underline{x}^*(\alpha)$ is continuous on some open interval containing [0,1].

Proof: Let the function $f(\underline{x},\alpha) = \alpha f_1(\underline{x}) + (1-\alpha)f_2(\underline{x})$. The function $f(\underline{x},\alpha)$ is a continuous function of $\underline{x}$ and α simultaneously (Problem 2.6.3). For fixed α, the continuous function $f(\underline{x},\alpha)$ on the compact convex set X takes on both a maximum and a minimum value. The uniqueness of the optimal solution follows from the strict concavity of $f(\underline{x},\alpha)$ in $\underline{x}$ over the compact convex set X for each value of α in some open region $I \supset [0,1]$. This unique optimal solution is denoted by $\underline{x}^*(\alpha)$.

To prove that $\underline{x}^*(\alpha)$ is continuous on I, assume otherwise. Then there exists a sequence $\{\alpha^i\} \to \bar{\alpha}$ with $\alpha^i, \bar{\alpha} \varepsilon I$ such that $\{\underline{x}^*(\alpha^i)\} \not\to \underline{x}^*(\bar{\alpha})$. Hence there is an open neighborhood $N\{\underline{x}^*(\bar{\alpha})\}$ of $\underline{x}^*(\bar{\alpha})$ such that $\underline{x}^*(\alpha^i) \notin N\{\underline{x}^*(\bar{\alpha})\}$ infinitely often. Now by taking a subsequence of the sequence $\{\underline{x}^*(\alpha^i)\}$, it may be assumed that this holds for all i. Since $X-N\{\underline{x}^*(\bar{\alpha})\}$ is a compact set, again taking a subsequence, a sequence $\{\underline{x}^*(\alpha^k)\} \to \hat{\underline{x}} \varepsilon X-N\{\underline{x}^*(\bar{\alpha})\}$. Thus, by the simultaneous continuity of $f(\underline{x},\alpha)$ with respect to its arguments,

(2.6.4) $\{f(\underline{x}^*(\alpha^k),\alpha^k)\} \to f(\hat{\underline{x}},\bar{\alpha})$.

Now consider the problem

$f(\underline{x}^*(\alpha),\alpha) = \underset{\underline{x}\varepsilon X}{\text{maximize}}\ f(\underline{x},\alpha)$. This function (by Problem 2.6.2) is convex in $\alpha \varepsilon I$. Since $I \supset [0,1]$ and is an open set, then $f(\underline{x}^*(\alpha),\alpha)$ is a continuous function of α and

(2.6.5) $\{f(\underline{x}^*(\alpha^i),\alpha^i)\} \to f(\underline{x}^*(\bar{\alpha}),\bar{\alpha})$. Assertions (2.6.4) and (2.6.5) imply that $f(\hat{\underline{x}},\bar{\alpha}) = f(\underline{x}^*(\bar{\alpha}),\bar{\alpha})$. But, by construction

$\hat{\underline{x}} \neq \underline{x}^*(\bar{\alpha})$, so the uniqueness of the optimal solution $\underline{x}^*(\bar{\alpha})$ is violated. Hence, $\underline{x}^*(\alpha)$ must be continuous on $I \supset [0,1]$.

Q.E.D.

Now consider the parametric constraint problem (P_β). The functions $f(\underline{x})$ and $\underline{g}(\underline{x})$ are assumed to be continuous and concave over the convex compact set X.

<u>Theorem 2.6.4</u>. $z(\beta)$ is concave for (P_β).

$$(P_\beta) \qquad z(\beta) = \text{maximize} \quad f(\underline{x})$$
$$\text{subject to} \quad \underline{g}(\underline{x}) \geq \beta\underline{e}$$
$$\underline{x} \in X.$$

<u>Proof</u>: The proof is given for a single parametricly restricted constraint (Problem 2.6.4 is concerned with the extension to multiple i $g_i(\underline{x}) \geq \beta$). Define $\underline{x}^*(\beta_i)$ as the optimal solution to (P_β) for $\beta = \beta_i$, $i = 1,2$ and let $\beta_3 = \lambda\beta_1 + (1-\lambda)\beta_2$, $0 \leq \lambda \leq 1$. Then by the continuity of $g(\underline{x})$, $\exists\, t$, $0 \leq t \leq 1 \ni g[t\underline{x}^*(\beta_1) + (1-t)\underline{x}^*(\beta_2)] = \beta_3$. This result follows from the intermediate value theorem. Since $t\underline{x}^*(\beta_1) + (1-t)\underline{x}^*(\beta_2)$ is feasible for (P_β) with $\beta = \beta_3$ and $f(\underline{x})$ is concave, then since

$$z(\beta_3) = \max_{\underline{x} \in X \;\; g(\underline{x}) \geq \beta_3} f(\underline{x}),$$

$$(2.6.6) \quad z(\beta_3) \geq f[t\underline{x}^*(\beta_1) + (1-t)\underline{x}^*(\beta_2)]$$
$$\geq t\, f[\underline{x}^*(\beta_1)] + (1-t) f[\underline{x}^*(\beta_2)]$$
$$= t\, z(\beta_1) + (1-t)\, z(\beta_2).$$

To show concavity, it is necessary to demonstrate that $z(\beta_3) \geq \lambda z(\beta_1) + (1-\lambda) z(\beta_2), 0 \leq \lambda \leq 1$. Thus, by concavity of $g(\underline{x})$,

$$(2.6.7)\quad \beta_3 = g[t\underline{x}^*(\beta_1) + (1-t)\underline{x}^*(\beta_2)]$$
$$\geq t\, g[\underline{x}^*(\beta_1)] + (1-t)g[\underline{x}^*(\beta_2)]$$
$$\geq t\,\beta_1 + (1-t)\beta_2 .$$

Assuming, $\beta_1 < \beta_2$ then $z(\beta_1) \geq z(\beta_2)$ and $t \geq \lambda$. Thus, $\lambda\beta_1 + (1-\lambda)\beta_2 \geq t\beta_1 + (1-t)\beta_2$, and

$$t\, z(\beta_1) + (1-t)z(\beta_2) \geq \lambda z(\beta_1) + (1-\lambda)z(\beta_2).$$

Therefore,

$z(\beta_3) \geq \lambda z(\beta_1) + (1-\lambda)z(\beta_2)$ and the concavity of $z(\beta)$ is established.

Q.E.D.

The last result is that the parametric solution vector $\underline{x}^*(\beta)$ is a continuous function of β. The proof is given for multiple constraints $g_i(\underline{x})$. The vector $\underline{e} = (1,1,\cdots,1)^T$.

<u>Theorem 2.6.5.</u> The problem (P_β) has continuous optimum solutions $\underline{x}^*(\beta)$ as a function of β when the following conditions are satisfied: (i) X is a convex compact set, (ii) $f(\underline{x})$ is a strictly concave continuous function on X, (iii) $g_i(\underline{x})$ for all i is a concave continuous function on X .

$$(P_\beta)\qquad \text{maximize}\quad f(\underline{x})$$
$$\text{subject to}\quad \underline{g}(\underline{x}) \geq \beta\,\underline{e}$$
$$\underline{x} \in X$$

<u>Proof</u>: Denote the compact region for β by $[\beta_1,\beta_2]$, where $\beta_1 = \min_i \{\min_{\underline{x}\in X} g_i(\underline{x})\}$ and $\beta_2 = \min_i \{\max_{\underline{x}\in X} g_i(\underline{x})\}$.

Suppose that $\underline{x}^*(\beta)$ is not continuous, then for some sequence $\{\beta_n\} \to \beta_0$, $\{\underline{x}^*(\beta_n)\} \to \hat{\underline{x}} \neq \underline{x}^*(\beta_0)$. There are four cases to be considered.

Case I: Let $\{\beta_n\} \to \beta_o$, $\beta_n > \beta_o$ for all n where β_o is an interior point of $[\beta_1, \beta_2]$. The optimal solution of

$$\begin{aligned} &\text{maximize} && f(\underline{x}) \\ &\text{subject to} && \underline{g}(\underline{x}) \geq \beta_o \underline{e} \\ & && \underline{x} \in X \end{aligned}$$

is $\underline{x}^*(\beta_o)$ which implies that $\underline{g}[\underline{x}^*(\beta_o)] \geq \beta_o \underline{e}$. In addition the point $\hat{\underline{x}}$ satisfies $\underline{g}(\hat{\underline{x}}) \geq \beta_o \underline{e}$ by the continuity of $\underline{g}$ and since

$$\underline{g}[\underline{x}^*(\beta_n)] \geq \beta_n \underline{e} > \beta_o \underline{e}$$

and $\lim_n \underline{g}[\underline{x}^*(\beta_n)] = \underline{g}(\hat{\underline{x}}) \geq \beta_o \underline{e}$. Thus, $f(\hat{\underline{x}}) < f[\underline{x}^*(\beta_o)]$ by the strict concavity of $f(\underline{x})$ and the fact that $\hat{\underline{x}}$ is feasible for (P_{β_o}). Define $f[\underline{x}^*(\beta_o)] - f(\hat{\underline{x}}) = \varepsilon > 0$. Suppose $g_i[\underline{x}^*(\beta_o)] = \beta_o$ for some i, then for any m $\underline{g}[\underline{x}^*(\beta_m)] \geq \beta_m \underline{e} > \beta_o \underline{e}$. Consider $\underline{x}_\lambda = \lambda \underline{x}^*(\beta_m) + (1-\lambda)\underline{x}^*(\beta_o)$, $0 \leq \lambda \leq 1$) and by the continuity of $\underline{g}$, $\underline{g}(\underline{x}_\lambda) > \beta_o \underline{e}$. By the continuity and strict concavity of f, there exist a λ such that

$$f[\underline{x}^*(\beta_o)] - f(\underline{x}_\lambda) < \frac{\varepsilon}{2}.$$

Now there exists an M_1 such that $n > M_1$ implies $\underline{g}(\underline{x}_\lambda) \geq \beta_n \underline{e}$ since $\{\beta_n\} \to \beta_o$ from above. Also $f[\underline{x}^*(\beta_n)] > f(\underline{x}_\lambda)$ and thus

$$f[\underline{x}^*(\beta_o)] - f[\underline{x}^*(\beta_n)] < \varepsilon/2.$$

However, since $\{\underline{x}^*(\beta_n)\} \to \hat{\underline{x}}$ and f is continuous, then there exists an M_2 such that $n > M_2$ implies

$$|f[x^*(\beta_n)] - f(\hat{\underline{x}})| < \varepsilon/2.$$

Hence, for $M = \max(M_1, M_2)$ and $n > M$ implies

$$|f[\underline{x}^*(\beta_o)] - f[\underline{x}^*(\beta_n)] + f[\underline{x}^*(\beta_n)] - f(\hat{\underline{x}})| < \varepsilon$$

which is a contradiction on the noncontinuity of $\underline{x}^*(\beta)$.

It was assumed that for some i $g_i[\underline{x}^*(\beta_o)] = \beta_o$. If this was not

true then for some value of M_3, $n > M_3$ implies $\underline{x}^*(\beta_n) = \underline{x}^*(\beta_o)$ and $\{\underline{x}^*(\beta_n)\} \to \underline{x}^*(\beta_o)$ which contradicts the assumed limit of the sequence.

Case II: Suppose $\{\beta_n\} \to \beta_o$ and $\beta_n \leq \beta_o$ for all n and β_o is an interior point of $[\beta_1, \beta_2]$.

$$\underline{g}[\underline{x}^*(\beta_n)] \geq \beta_n \underline{e}$$

$$\underline{g}[\underline{x}^*(\beta_o)] \geq \beta_o \underline{e} \geq \beta_n \underline{e} \quad \text{for all in}$$

Thus, $f[\underline{x}^*(\beta_o)] \leq f[\underline{x}^*(\beta_n)]$ for all n and by continuity of f,

$f[\underline{x}^*(\beta_o)] \leq f(\hat{\underline{x}})$. But

$f[\underline{x}^*(\beta_o)] > f(\hat{\underline{x}})$ by definition of $\underline{x}^*(\beta_o)$ and strict concavity of f: contradiction on the noncontinuity of $\underline{x}^*(\beta)$.

Case III: Let $\beta_o = \beta_2$ (right-hand interval boundary). Only left-hand limits need be considered here. Thus, assume $\{\beta_n\} \to \beta_o = \beta_2$ and $\beta_n \leq \beta_o$ $\forall$ n. Case II is satisfied and $\underline{x}^*(\beta)$ is continuous at the point β_2.

Case IV: Let $\beta_o = \beta_1$ (left-hand interval boundary). Only right-hand limits need be considered. Thus, assume $\{\beta_n\} \to \beta_o = \beta_1$ and $\beta_n > \beta_o$ for all $\forall$n. Case I is satisfied and $\underline{x}^*(\beta)$ is continuous at the point β_1.

Therefore $\underline{x}^*(\beta)$ is continuous on $[\beta_1, \beta_2]$.

Q. E. D.

It should be noted that the left end point β_1 of $[\beta_1, \beta_2]$ can be relaxed to any finite number less than or equal to β_1. This is true since all optimal solutions are unconstrainted and hence equal to the solution at β_1. Thus, the optimal solution vector $\underline{x}^*(\beta)$ is continuous

on any closed nonempty region with upper bound of β_2.

Problem 2.6.1

Prove that for the minimization problem (P_γ) that the parametric optimal solution value $z(\gamma)$ is concave, $\gamma \geq 0$.

$$(P_\gamma) \qquad \underset{\underline{x} \in X}{\text{minimize}} \quad f_1(\underline{x}) + \gamma f_2(\underline{x}).$$

Problem 2.6.2

Prove that the form of the optimal solution value $z(\gamma)$ of the problem (P_γ) is concave, $0 \leq \alpha \leq 1$.

$$(P_\gamma) \qquad \underset{\underline{x} \in X}{\text{minimize}} \quad \alpha f_1(\underline{x}) + (1-\alpha) f_2(\underline{x}).$$

Problem 2.6.3

Prove that $f(\underline{x},\alpha) = \alpha f_1(\underline{x}) + (1-\alpha)\, f_2(\underline{x})$ for (P_α) is a continuous function of $\underline{x}$ and α simultaneously.

Problem 2.6.4

Prove Theorem 2.6.4 where the concave constraint $g(\underline{x})$ is replaced by $g_i(\underline{x}) \geq \beta\ \forall_i$.

Problem 2.6.5

Obtain the parametric solution for the problem,

$$\text{maximize} \quad \alpha(x_1 + 2x_2 - x_1^2 - 2x_2^2) + (1-\alpha)(3x_1 + 6x_2 - x_1^2 - 2x_2^2)$$

subject to

$$x_1 + x_2 \leq 3$$

$$-2x_1 + 3x_2 \leq 6$$

$$x_1,\ x_2 \geq 0.$$

Problem 2.6.6

Solve for the parametric solution to

maximize $2x_1 + 3x_2 - 2x_2^2$

subject to $x_1 + x_2 \leq 2$

$x_1 + 4x_2 \geq \beta$

$x_1 \geq 0,\ x_2 \geq 0.$

2.7 Parametric Solution Methods for Nonconvex Programs

The characteristics and solution procedures of parametric programming can be utilized in generating solution methods for nonconvex, as well as complex, mathematical programming problems. In Chapter 3 several problem types whose solutions can be facilitated by applying parametric programming are discussed. In this section, three techniques which are structurally based on parametric methods and characteristics are presented. These techniques are concerned with obtaining global optima to nonconvex programs, and with the relaxation to some extent of exact knowledge about the functional forms being studied. Two of the methods are concerned with similar problem types. A parametric objective function approach to the problem is presented by Geoffrion [1967]. Hocking [1971] proposes a somewhat conceptually simpler method which utilizes a parametric constraint approach. The third method requires greater restrictions on certain functions but utilizes the extra structure in such a manner as to not actually require the general parametric solution. The computational advantage is paramunt for certain nonlinear problems. In addition, it is possible to approach problems with this procedure that have some constraints that are not explicitly known, but which can be evaluated, for specified decision variable values, by some means such as simulation. It should be mentioned that this method is an approximation procedure and can be used on a wider variety of problems than those for which theoretical results have been obtained to characterize the "closeness" of the solution. In chapter 4, the theoretical results obtained to date which characterize this solution

method and exactness are discussed.

2.7.1 Parametric Objective Function Method

Consider a bicriterion objective function problem which has some increasing utility function whose domain is the space of objective functions. The problem takes the form,

$$\text{(2.7.1.1)} \qquad \begin{array}{ll} \text{maximize} & H[f(\underline{x}),g(\underline{x})] \\ \text{subject to} & \underline{x} \in X, \end{array}$$

where H is a real-valued increasing function defined on the outcomes of the continuous concave objective functions f and g, and $\underline{x}$ is a decision vector constrainted to be in a compact convex set X.

A variety of problems conform to the general structure of problem (2.7.1.1). Several problems are discussed in the paper by Geoffrion [1967] and a few of these are: (a) the Chebyshev problem of maximizing the minimum value of f and g over X, (b) generalized fractional programming problems concerned with maximizing the ratio of f to g over X, (c) additive utility functions commonly utilized in the theory of consumer's choice, $\max_{\underline{x}\in X} v_1[f(\underline{x})]^{\beta_1} + v_2[g(\underline{x})]^{\beta_2}$, and (d) $\max_{\underline{x}\in X} [f(\underline{x})]^{\beta} g(\underline{x})$.

The method for solving problems of the form of (2.7.1.1) is to first solve the parametric objective function problem

$$(P\alpha) \qquad \underset{\underline{x}\in X}{\text{maximize}} \quad \alpha f(\underline{x}) + (1-\alpha)g(\underline{x})$$

for the parametric solution vector $\underline{x}^*(\alpha)$, $0\leq\alpha\leq 1$. If the functions f and g are strictly concave on X the solution vector $\underline{x}^*(\alpha)$ is unique and continuous over $\alpha\in[0,1]$, as was discussed in Section 2.6. However,

method and exactness are discussed.

2.7.1 Parametric Objective Function Method

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A variety of problems conform to the general structure of problem (2.7.1.1). Several problems are discussed in the paper by Geoffrion [1967] and a few of these are: (a) the Chebyshev problem of maximizing the minimum value of f and g over X, (b) generalized fractional programming problems concerned with maximizing the ratio of f to g over X, (c) [illegible] functions commonly [illegible] in the theory of consumer's choice, $\max_{\underline{x}\in X} v_1[f(\underline{x})]^{\beta_1} + v_2[g(\underline{x})]^{\beta_2}$, and (d) $\max_{\underline{x}\in X} [f(\underline{x})]^{\beta} g(\underline{x})$.

The method for solving problems of the form of (2.7.1.1) is to first solve the parametric objective function problem

$$(P\alpha) \qquad \underset{\underline{x}\in X}{\text{maximize}} \quad \alpha f(\underline{x}) + (1-\alpha) g(\underline{x})$$

for the parametric solution vector $\underline{x}^*(\alpha)$, $0 \le \alpha \le 1$. If the functions f and g are strictly concave on X the solution vector $\underline{x}^*(\alpha)$ is unique and continuous over $\alpha \in [0,1]$, as was discussed in Section 2.6. However,

if the functions are not strictly concave over X, then multiple optimal solutions for fixed α can occur. The idea is then for fixed α to obtain the function $H[\alpha]$ which is the solution to (2.7.1.1) for $\underline{x}$ restricted to the set $\underline{x}^*(\alpha)$,

(2.7.1.2) $$H[\alpha] = \underset{\underline{x}\varepsilon\underline{X}^*(\alpha)}{\text{maximize}}\ H[f(\underline{x}),g(\underline{x})].$$

Then solve the one-dimensional maximization problem,

(2.7.1.3) $$\underset{0 \le \alpha \le 1}{\text{maximize}}\ H[\alpha].$$

Now, consider the optimal value of α, α^*, for (2.7.1.3), the original problem (2.7.1.1) is solved by any $\underline{x} \varepsilon \underline{x}^*(\alpha^*)$ such that $H[f(\underline{x}),g(\underline{x})] = H[\alpha^*]$.

The development of the method is based on the vector maximization problem for two citerion functions $f_i(\underline{x}), i=1,2$,

(P_v) $$\underset{\underline{x}\varepsilon X}{\text{maximize}}\ (f_1(\underline{x}),f_2(\underline{x})).$$

A point $\underline{x}^0$ is said to be <u>efficient</u> for (P_v) if and only if there does not exist another point $\underline{x}^1 \varepsilon X$ such that $f_i(\underline{x}^1) \ge f_i(\underline{x}^0)$, $i = 1,2$, with strict inequality holding for at least one i. Two basic lemmas provide the motivation for the solution method of Geoffrion [1967].

<u>Lemma 2.7.1.1</u> At least one point at which $H[f(\underline{x}),g(\underline{x})]$ achieves its maximization over X is efficient.

Proof: Since X is a compact set and H, f and g are continuous functions over X, then (2.7.1.1) has a least one point in X, $\underline{x}^0$, at which (2.7.1.1) achieves its maximum value. Consider the problem

$$(2.7.1.4) \qquad \underset{\underline{x}\in X}{\text{maximize}} \quad f(\underline{x}) + g(\underline{x})$$

$$f(\underline{x}) \geq f(\underline{x}^0)$$

$$g(\underline{x}) \geq g(\underline{x}^0)$$

Suppose $\underline{x}^1$ solves this problem. Then $\underline{x}^1$ is efficient for (P_v) since if not there exists a point $\underline{x}^2 \in X$ such that $f(\underline{x}^2) \geq f(\underline{x}^1)$ and $g(\underline{x}^2) \geq g(\underline{x}^1)$ with strict inequality holding for at least one constraint. Thus, $\underline{x}^2$ would achieve a larger value for (2.7.1.4) and $\underline{x}^1$ would not be optimal. In addition $\underline{x}^1$ must also solve (2.7.1.1) since $f(\underline{x}^1) \geq f(\underline{x}^0)$, $g(\underline{x}^1) \geq g(\underline{x}^0)$ and H is increasing which implies $H[f(\underline{x}^1)],g(\underline{x}^1)] = H[f(\underline{x}^0),g(\underline{x}^0)]$.

Q.E.D.

<u>Lemma 2.7.1.2</u>. If $\underline{x}^0$ is efficient, then there exists a scalar $\alpha^0 \in [0,1]$ such that $\underline{x}^0$ is an optimal solution to $(P\alpha^0)$.

Lemmas 2.7.1.1 and 2.7.1.2 imply the solution method previously given. A partial converse to Lemma 2.7.1.2 is that every point of $\underline{x}^*(\alpha)$ is efficient if $\alpha \in (0,1)$, and some point of $\underline{x}^*(\alpha)$ is efficient when $\alpha = 0$ or 1.

The method of solving for $H[\alpha]$ in (2.7.1.2) requires little effort beyond solving for the parametric optimum solution $\underline{x}^*(\alpha)$ of $(P\alpha)$. In fact, $H[\alpha] = H\{f[\underline{x}^*(\alpha)],g[\underline{x}^*(\alpha)]\}$ at every point of continuity of α in $[0,1]$. At a point of discontinuity of α in $(0,1)$, say α^1, then one of two possible one-dimensional maximization problems must be solved. If $\underline{x}^*(\underline{\alpha}')$ and $\underline{x}^*(\bar{\alpha}')$ represent the left and right hand limits, respectively, then,

(2.7.1.5) $$H[\alpha'] = \underset{\lambda\epsilon[0,1]}{\text{maximum}}\ H\{f[\lambda\underline{x}^*(\underline{\alpha}') + (1-\lambda)\underline{x}^*(\bar{\alpha}')],\ g[\lambda x^*(\underline{\alpha}') + (1-\lambda)\underline{x}^*(\bar{\alpha}')]\}$$

and $$H[\alpha'] = \underset{\lambda\epsilon[0,1]}{\text{maximum}}\ H\{\lambda f[\underline{x}^*(\underline{\alpha}')] + (1-\lambda)f[\underline{x}^*(\bar{\alpha}')],\ \lambda g[\underline{x}^*(\underline{\alpha}')] + (1-\lambda)g[\underline{x}^*(\bar{\alpha}')]\}.$$

<u>Example 2.7.1.3</u> .

Consider the example problem from Geoffrion [1967],

maximize $[32-40x_2 + 23x_3 - 7x_4]^{2/3}[32-10x_1 - 4x_2 + 7x_3 - 7x_4]$

subject to

$$\begin{aligned} 2x_1 + x_2 - 0.37x_3 + 0.37x_4 \qquad + 4x_6 &= 9.08 \\ x_1 + 3x_2 - 0.91x_3 - 1.91x_4 \qquad + 5x_6 &= 8.44 \\ x_1 - x_2 - 0.97x_3 - 0.07x_4 + x_5 - x_6 &= 1.88 \\ x_1 + x_2 - 0.81x_3 + 0.19x_4 \qquad + x_6 &= 4.04 \\ \underline{x} \geq \underline{0}. \end{aligned}$$

Let $f(\underline{x}) = 32 - 40x_2 + 23x_3 - 7x_4$

$g(\underline{x}) = 32 - 10x_1 - 4x_2 + 7x_3 - 7x_4$

and $H[f,g] = [f]^{2/3}[g]$.

The parametric program $(P\alpha)$ becomes a parametric linear programming problem with objective function,

$$\max\ \alpha[32 - 40x_2 + 23x_3 - 7x_4] + (1-\alpha)[32 - 10x_1 - 4x_2 + 7x_3 - 7x_4]$$

$$= \max\ [32 - 10x_1 - 4x_2 + 7x_3 - 7x_4] + \alpha[10x_1 - 36x_2 + 16x_3].$$

The optimal parametric solution is given in Table 2.7.1.4. Since $H[f,g]$ is unimodal, only a portion of the parametric solution is required.

Table 2.7.1.4

Parametric Solution For Example Problem 2.7.1.3

	α^1	α^2	α^3
α	0	.0278	.053
$x_1(\alpha)$	132/50	60/35	0
$x_2(\alpha)$	30/50	0	0
$x_3(\alpha)$	0	0	60/19
$x_4(\alpha)$	0	60/35	144/19
$x_5(\alpha)$	32/50	20/35	4/19
$x_6(\alpha)$	40/50	2	98/19

Taking advantage of the unimodal nature of $H[f,g]$ to reduce the search space and realizing $\underline{x}^*(\alpha)$ is constant over each region of α, evaluations need only be made at the critical points of α.

$$H[\alpha] = H\{f[\underline{x}^*(\alpha^1)], g[\underline{x}^*(\alpha^1)]\} = (8)^{2/3}(16/5) = 12.8 \text{ for } \alpha\varepsilon[0,0.0278).$$

since

$$f[\underline{x}^*(\alpha^1)] = 32 - 40(\tfrac{30}{50}) + 23(0) - 7(0) = 8,$$

$$g[\underline{x}^*(\alpha^1)] = 32 - 10(\tfrac{132}{50}) - 4\ (\tfrac{30}{50}) + 7(0) - 7(0) = \tfrac{16}{5}.$$

$$H[\alpha] = (20)^{2/3}(\tfrac{20}{7}) = 21.1 \text{ for } \alpha\varepsilon[0.0278,0.053),$$

$$H[\alpha] = (51.6)^{2/3}(1.05) = 14.55 \text{ for } \alpha\varepsilon[0.053,0.0736).$$

Thus, $H[\alpha]$ achieves its maximum either at $\alpha = 0.053$ or 0.0278. Now either of the one-dimensional search problems (2.7.1.5) can be used to interrogate the discontinuities. The optimal solution is $H[\alpha^2] = 22.13$ with $\lambda^* = 0.747$. The optimal solution vector is

$$\underline{x}^* = 0.747\ \underline{x}^*(\alpha^2) + 0.253x^*(\alpha^3)$$

$$= (32/25,\ 0,\ 0.8,\ 3.2,\ 0.48,\ 2.8).$$

Problem 2.7.1.1

Prove Lemma 2.7.1.2 (Hint: The proof is an application of a separation property of convex sets, page 217 of Karlin [1959].)

Problem 2.7.1.2

Prove that every point of $\underline{x}^*(\alpha)$ is efficient if $\alpha \varepsilon (0,1)$.

Problem 2.7.1.3

Assume that H is quasiconcave over the smallest convex set containing the admissible payoff set. If $\underline{x}^*(\alpha)$ is any optimal solution function of $(P\alpha)$ on [0,1], then $H\{f[\underline{x}^*(\alpha)], g[\underline{x}^*(\alpha)]\}$ is unimodal on [0,1]. (A function z(x) is unimodal if $x^1 \leq x^0 \leq x^2$ implies $z(x^0) \geq \min\{z(x^1), z(x^2)\}$.)

Problem 2.7.1.4

Solve the problem of maximizing H[f,g]

subject to

$$x_1 + x_2 \leq 3$$
$$-2x_1 + 3x_2 \leq 6$$
$$x_1, x_2 \geq 0$$

where $f(\underline{x}) = x_1 + 2x_2 - x_1^2 - 2x_2^2$

$g(\underline{x}) = 3x_1 + 6x_2 - x_1^2 - 2x_2^2$,

for each of the forms of H[f,g].

(a) $H[f,g] = f^2(g)$

(b) $H[f,g] = f^{3/2}(g)$

(c) $H[f,g] = (f)(g)$.

(Hint: The parametric solution was obtained in Problem 2.6.5)

2.7.2 Parametric Constraint Method

An alternate solution procedure for problem (2.7.1.1) which utilizes parametric constraint methods is that of Hocking and Shepard [1971]. Instead of solving a parametric objective function problem which could have discontinuous optimal solutions, the parametric constraint approach utilizes the optimal solution value $z(\beta)$ and the parameter β. Since $z(\beta)$ is always continuous on the interior of the feasible parameter region, no auxiliary one-dimension search at discontinuous solution points need be made.

The basic approach is to solve the parametric problem

$$(P_\beta) \qquad \underset{\underline{x}\in X}{\text{maximize}} \quad f(\underline{x}) \qquad g(\underline{x}) \geq \beta$$

for β in the critical region $[\beta_1,\beta_2]$. This region is defined in Lemma 2.7.2.1 below. Denote the optimal value of (P_β) by $z(\beta)$ and the optimal solution vector by $\underline{x}^*(\beta)$. If solving the one-dimension maximization problem

$$(2.7.2.1) \qquad \underset{\beta\in[\beta_1,\beta_2]}{\text{maximize}} \quad H[z(\beta),\beta]$$

yields a solution β_0, then $\underline{x}^*(\beta_0)$ is optimal for problem (2.7.1.1) and the optimum value $H[z(\beta_0),\beta_0]$ is the same as the optimal value for (2.7.1.1).

In developing the solution procedure, it is necessary to establish $[\beta_1,\beta_2]$, demonstrate that for each efficient point of P_v (Section 2.7.1) there exists a β such that the solution satisfies (P_β), and show that an optimal solution of problem (2.7.1.1) is found among the optimal solutions of P_β. These results are given in the following lemmas.

Recall from Lemma 2.7.1.1 that a least one point which solves (2.7.1.1) is efficient.

Lemma 2.7.2.1. The interval $[\beta_1, \beta_2]$ to be considered in problem (P_β) is determined by (i) $\beta_1 = g(\underline{x}^1)$ where $\underline{x}^1$ solves

(2.7.2.2) $$\underset{\underline{x}\in X}{\text{maximize}} \quad f(\underline{x})$$

and (ii) β_2 is the optimum value of

(2.7.2.3) $$\underset{\underline{x}\in X}{\text{maximize}} \quad g(\underline{x})$$

Proof: Let X^1 be the set of optimal solutions to (2.7.2.2) and consider the problem

(2.7.2.4) $$\underset{\underline{x}\in X^1}{\text{maximize}} \quad g(\underline{x})$$

Denote β_1' as the solution value of (2.7.2.4). If $\beta < \beta_1'$, (P_β) has the same solution as $(P_{\beta_1'})$ and thus it is not necessary to consider values of $\beta < \beta_1'$. Now β_1 from (i) is less than β_1' and any value for β_1 is acceptable as long as it is less than or equal to β_1'. The upper limit β_2 is the maximum β for which a feasible solution to (P_β) exists.

Q.E.D.

Lemma 2.7.2.2. If $\underline{x}^0$ is efficient for (P_v) then there exists a $\beta_0 \in [\beta_1, \beta_2]$ such that $\underline{x}^0$ is optimal for (P_{β_0}).

Proof: Let $\beta_0 = g(\underline{x}^0)$ and consider (P_{β_0}). $\underline{x}^0$ is feasible in (P_{β_0}) and therefore it is optimal for (P_{β_0}) since it is efficient for (P_v). From Lemma 2.7.2.1, $\beta_0 \leq \beta_2$. Since $\underline{x}^0$ is efficient, $\beta_0 \geq \beta_1$ for otherwise $g(\underline{x}^0) < g(\underline{x}^1)$, $\underline{x}^1$ from Lemma 2.7.2.1, which violates the

efficiency of $\underline{x}^o$.

Q.E.D.

It remains to be shown that a solution to problem (2.7.1.1) is found among the optimal solutions to (P_β). However, from Lemma 2.7.2.2 efficient points are in the set of optimal solutions to (P_β) and by Lemma 2.7.1.1 this result is established. However, as was stated above, the optimal solution can be found by solving (2.7.2.1). It remains to be shown that the solution to (2.7.2.1) solves

$$(2.7.2.5) \quad \underset{\underline{x}\epsilon X^*(\beta)}{\text{maximize}} \quad H[f(\underline{x}),\ g(\underline{x})].$$

<u>Theorem 2.7.2.3</u>. If β_o maximizes (2.7.2.1) then it also maximizes (2.7.2.5).

Proof: Since $f(\underline{x})$ is constant on $\underline{x}^*(\beta)$ for fixed β, $\underline{x}^*(\beta)$ solves (P_β), and H is increasing, problem (2.7.2.5) can be replaced by

$$(2.7.2.6) \quad \begin{array}{ll} \underset{\underline{x}\epsilon X}{\text{maximize}} & g(\underline{x}) \\ & f(\underline{x}) \geq z(\beta) \\ & g(\underline{x}) \geq \beta. \end{array}$$

Denote this solution value by $\omega(\beta)$ and define $H[\beta] = H[z(\beta),\omega(\beta)]$. Since $g(\underline{x}) \geq \beta$, $\omega(\beta) \geq \beta$ and $H[z(\beta),\omega(\beta)] \geq H[z(\beta),\beta]$. However, if $g(\underline{x}) = \beta$, then $H[z(\beta),\omega(\beta)] = H[z(\beta),\beta]$. Suppose $g(\underline{x}) > \beta$, in problem (P_β) the parameter β can be increased until $\beta = \omega(\beta)$ without changing $z(\beta)$. Thus, over $[\beta,\omega(\beta)]$ $H[z(\beta),\omega(\beta)]$ is constant and $H[z(\beta),\beta]$ is increasing with equality at $\omega(\beta)$. Thus, if β_o maximizes (2.7.2.6) $\beta_o = \omega(\beta_o)$ and the theorem is proved.

Q.E.D.

Thus, the two solution methods, Sections 2.7.1 and 2.7.2, can be used to solve problem (2.7.1.1). One-dimensional searchs are necessary in both methods to find the optimum value of the parameter. It was stated in Section 2.7.1 that if $H[f,g]$ is quasiconcave, then $H[\alpha]$ is unimodal, thus allowing for a more efficient search procedure. The same result is true for $H[z(\beta),\beta]$ being unimodal when $H[f,g]$ is quasiconcave (see Problem 2.7.2.1). The same example problem as was utilized in Section 2.7.1 is given to demonstrate the technique and also to facilitate comparisons between the procedures.

<u>Example 2.7.2.4.</u>

$$\text{maximize } [f(\underline{x})]^{2/3}[g(\underline{x})]$$

subject to

$$\begin{aligned}
2x_1 + x_2 - 0.37x_3 - 1.37x_4 \quad + 4x_6 &= 9.08 \\
x_1 + 3x_2 - 0.91x_3 - 1.91x_4 \quad + 5x_6 &= 8.44 \\
x_1 - 1x_2 - 0.07x_3 + 0.93x_4 + x_5 - x_6 &= 1.88 \\
x_1 + x_3 - 0.81x_3 + 0.19x_4 \quad + x_6 &= 4.04 \\
\underline{x} &\geq \underline{0}
\end{aligned}$$

and $f(\underline{x}) = 32 - 40x_2 + 23x_3 - 7x_4$

$g(\underline{x}) = 32 - 10x_1 - 4x_2 + 7x_3 - 7x_4.$

The parametric problem (P_β) is the linear parametric resource problem,

$$\begin{aligned}
\text{maximize} \quad & f(\underline{x}) \\
\text{subject to} \quad & \underline{Ax} = \underline{b} \\
& g(\underline{x}) \geq \beta \\
& \underline{x} \geq \underline{0}.
\end{aligned}$$

The parametric solution is given in Table 2.7.2.5. Using this parametric solution and maximizing $H[z(\beta),\beta]$ with respect to β, the maximum value is 22.13 with $\beta^* = 2.4$. The corresponding solution vector is $\underline{x}^*(\beta^*) = (32/25,0,.8,3.2,.48,2.8)$, which agrees with the solution for example problem 2.7.1.3.

Table 2.7.2.5

Parameter Solution For Example 2.7.2.4

β	[0,20/19]	[20/19,20/7]	[20/7,16/5]
$x_1^*(\beta)$	0	$\frac{19}{20}\beta-1$	$\frac{27}{10}\beta-6$
$x_2^*(\beta)$	$1-\frac{19}{20}\beta$	0	$-5+\frac{7}{4}\beta$
$x_3^*(\beta)$	$6-\frac{27}{10}\beta$	$5-\frac{7}{4}\beta$	0
$x_4^*(\beta)$	$10-\frac{23}{10}\beta$	$11-\frac{13}{4}\beta$	$16-5\beta$
$x_5^*(\beta)$	β	$\frac{\beta}{5}$	$\frac{\beta}{5}$
$x_6^*(\beta)$	$6-\frac{4}{5}\beta$	$7-\frac{7}{4}\beta$	$12-\frac{7}{2}\beta$
$z(\beta)$	$60-8\beta$	$70-\frac{35}{2}\beta$	$120-35\beta$

Problem 2.7.2.1

Solve by the parametric constraint procedure,

maximize $(2x_1 + 3x_2 - 2x_2^2)(x_1 + 4x_2)$

subject to $x_1 + x_2 \leq 2$

$x_1 \geq 0, x_2 \geq 0.$

Problem 2.7.2.2

Prove that if $H[f,g]$ is quasiconcave then $H[z(\beta),\beta]$ is unimodal on $[\beta_1,\beta_2]$.

2.7.3 Approximation Method Via Contraction Maps

Frequently occasions arise when certain portions of a mathematical programming problem are not known in precise form. If the particular imprecise or unknown functions can be evaluated for given decision policies, it is sometimes possible to take advantage of the remaining known structure of the problem, along with measured values of the unknown structure, such that a solution to the problem can be obtained. The auxiliary problem which is solved generally does not yield the exact solution for the true problem. However, the optimal solution to the auxiliary problem is obtained.

The approximation method to be discussed is applicable in many problem situations and particularly when the evaluations of the unknown functions are results of simulation methods. Thus, the procedure could be considered as a guide for selection of simulation runs so as to obtain a good, if not optimal, solution. Other advantages of this type of procedure are (i) the avoidance of handling extremely complex structural forms as opposed to readily solvable forms, and (ii), in accord with the emphasis of this material, the procedure utilizes parametric programming methods and characteristics without the necessity of actually obtaining the parametric solutions. Thus, the method effords the problem solver some of the power of analytical techniques for problems that otherwise might be solvable only by exhaustive enumeration methods.

The mathematical characterization of the conditions for which the method converges to the true solution and some measure of the closeness when it doesn't obtain the true solution is taken up in Chapter 4. The cmphasis in the section is on the conditions for which the auxiliary problem can be solved and the method of obtaining this solution. Generally

in actual applications, there are usually current or utilized solutions for the problems being studied. The emphasis is then on improved solutions and the improvements are measured against the current solutions. If simulation models can be used to describe certain operations, the accuracy of the mathematical optimization with respect to the true system being approximated is better and it is easier to demonstrate to the user that the model is an appropriate reflection of the actual process.

The use of submodels, either analytical or simulated, are common in applied optimization. The nonlinear decomposition method by Rosen has been successfully applied to optimization of chemical processing operations [Lasdon, Chapter 7, 1970] although the convergence of the complex mathematical structure has yet to be proven. However, in most applications that use complex submodels within an optimization framework, numerical approximations to derivatives are obtained by repeated evaluations of the submodels for small perturbations in the decision variables. In the following approach, measurements from the submodels are utilized in an essential way in the optimization method and numerical derivatives are not required. In fact the structure studied allows the decomposition of multiple decision variable problems into a series of much smaller problems. The interlated effect of the subproblem variables enters the problem through the simulation measurements.

Simulation models and mathematical submodels can all be thought of mathematical mapping with complex relationships. Even if the exact functions are not explicitly known, knowledge of the properties that these functions must satisfy is useful in the development of solution procedures for the associated problems.

A relaxation procedure for solving certain forms of nonlinear programming problems is the topic of this section. The procedure is based on constraint relaxation, parametric programming for multi-criterion functions, and contraction mappings. However, it is not necessary to solve the general nonlinear parametric programming problem since the technique utilizes only selected values of the general solution functions. These values can be obtained by merely solving an associated numerical nonlinear problem.

Consider problem (2.7.3.1). The problem as stated is not separable in the objective function but is separable in the constraints. It is the purpose of this section to develop an approximation solution for the problem and to demonstrate that the approximation problem's solution can be obtained by a decomposition procedure. Three ideas are basic to this method: relaxation, general parametric solutions, and contraction maps.

$$(2.7.3.1)\quad \text{minimize} \sum_{i=1}^{N} \{ g_i(\underline{x}) f_i^1(\underline{x}_i) + [1-g_i(\underline{x})] f_i^2(\underline{x}_i) \}$$

subject to

$$\underline{h}_i(\underline{x}_i) \leq \underline{0} \quad \text{for } i=1,\cdots,N.$$

where $\underline{x} = (\underline{x}_1,\cdots,\underline{x}_N)$, $\underline{h}_i$ is a vector function each component of which is convex, the feasible region $X = \{\underline{x} \,/\, \underline{h}_i(\underline{x}_i) \leq \underline{0} \text{ for all } i\}$ is nonempty and bounded, the functions f_i^1 and f_i^2 are strictly convex over X, and the functions g_i are continuous over X.

Problem (2.7.2.1) can be restated as problem (P_y) which is the form that will be addressed in the remainder of this section.

$$(P_y)\qquad \text{minimize} \sum_{i=1}^{N} \{ y_i f_i^1(\underline{x}_i) + (1-y_i) f_i^2(x_i) \}$$

subject to $\underline{h}_i(\underline{x}_i) \leq \underline{0}$ for all i,

$$\underline{y} = \underline{g}(\underline{x}).$$

Before proceeding, two basic lemmas from mathematical analysis are needed.

<u>Lemma 2.7.3.1.</u> If f is a continuous mapping from X to Y and if g is a continuous mapping from Y to Z, then the mapping $f \circ g$ from X to Z is also continuous.

<u>Lemma 2.7.3.2.</u> (Brower Fixed-Point Theorem) Let f be a continuous mapping of a compact convex subset X of R^n into itself. Then there is a point $\underline{x} \in X$ such that $f(\underline{x}) = \underline{x}$.

To obtain a separable form of problem (P_y), relaxation is utilized for the equality constraints $\underline{y}=\underline{g}(\underline{x})$. Then each subproblem (2.7.3.2) is a convex program since $0 \leq y_i \leq 1$ for all i.

$$(2.7.3.2) \quad \text{minimize } y_i f_i^1(\underline{x}_i) + (1-y_i) f_i^2(\underline{x}_i)$$

$$\text{subject to} \quad \underline{h}_i(\underline{x}_i) \leq \underline{0}$$

$$y_i \in [0,1].$$

Theorem 2.7.3.3, below, establishes under certain assumptions the existance of a solution $(\underline{x}^*,\underline{y}^*)$ to problem (P_y). However, the solution is not necessarily optimal. The parametric solution to subproblem (2.7.3.2) is denoted by $\underline{x}_i^*(y_i)$, while the solutions of the total collection of these problems is denoted by $\underline{x}^*(\underline{y})$. Several additional restrictions need to be made on the functions of the problem, these are:

(a) if $y_i \in [0,1]$ and $\underline{x}^*(y_i)$ is an optimal parametric solution to subproblem (2.7.3.2), then the matrix whose rows are gradients $\nabla_{\underline{x}} h_i^j(\underline{x}_i)$, j such that $h_i^j(\underline{x}_i)=0$, is of maximal rank,

(b) $\underline{h}_i$, f_i^1, f_i^2 are analytical on some open region containing X, and

(c) $\nabla \underline{h}_i$, ∇f_i^1, ∇f_i^2 are bounded on X.

<u>Theorem 2.7.3.3.</u> Problem (2.7.3.2) has optimal solutions which can be expressed as continuous functions of $y_i, \underline{x}_i^*(y_i)$. Also there exist a feasible solution $(\underline{x}^*(\underline{y}^*), \underline{y}^*)$ to problem (P_y).

Proof: In Theorem 2.6.3 it was shown that there exist unique optimal solutions $\underline{x}_i^*(y_i)$ to problem (2.7.3.2) and that $\underline{x}_i^*(y_i)$ are continuous solutions. Thus, $(\underline{x}^*(\underline{y}), \underline{y})$, where $\underline{y} = \underline{g} \circ \underline{x}^*(\underline{y})$, is feasible in (P_y), if a solution to $\underline{y} = \underline{g} \circ \underline{x}^*(\underline{y})$ exists. Since $\underline{x}^*(\underline{y})$ is continuous and $\underline{g}(\underline{x})$ is continuous then by Lemma 2.7.3.1 $\underline{g} \circ \underline{x}^*(y)$ is a continuous function such that $\underline{g} \circ \underline{x}^* : S \to S$ where S is the domain of $\underline{y}$ and is a compact convex set. Thus, by Lemma 2.7.3.2, a solution to $\underline{g} \circ \underline{x}^*$ exists.

Q.E.D.

The characterization of the general form of the optimal parametric solutions to (2.7.3.2) was given by Geoffrion [1965]. Under the restrictions imposed on the functions, these characteristics are:

(a) $\underline{x}_i^*(y_i)$ is unique and continuous for $y_i \in [0,1]$,

(b) the solution $\underline{x}_i^*(y_i)$ consists of connected segments $\underline{x}_i^s(y_i)$ which are analytic over their range of validity, and

(c) the number of segments, $\underline{x}_i^s(y_i)$, and hence the number of points of connection is finite.

The optimal solutions $\underline{x}^*(\underline{y})$ of problem (2.7.3.2) can be shown to satisfy Lipschitz's condition under the additional restrictions that gradients of the functions are bounded.

<u>Lemma 2.7.3.4.</u> The optimal solution $\underline{x}_i^*(y_i)$ to subproblem (2.7.3.2) satisfies Lipschitz's condition for $y_i \in [0,1]$, when $\nabla_{\underline{x}_i} f_i^1(\underline{x}_i)$, $\nabla_{\underline{x}_i} f_i^2(\underline{x}_i)$, and $\nabla_{\underline{x}_i} \underline{h}_i(\underline{x}_i)$ are bounded.

Proof: Let $\underline{x}_i^s(y_i)$ be the segment of $\underline{x}_i^*(y_i)$ which is optimal when the constraints indexed by s are strict equalities and all other constraints are inequalities. By Theorem 2 Geoffrion [1965], $\underline{x}_i^s(y_i)$ is analytic. Thus, by definition $\underline{x}_i^s(y_i)$ has a continuous derivative with respect to y_i.

Since $\underline{x}_i^*(y_i) = \underline{x}_i^s(y_i)$ for the range of y_i where the indexing set s remains valid, $\underline{x}_i^*(y_i)$ is analytic except possibly at the points of y_i where s changes. But by Theorem 3 Geoffrion (1965), there are only a finite number of points of change on [0,1]. Hence $\underline{x}_i^*(y_i)$ is analytic a.e. (almost everywhere).

Since $\underline{x}_i^s(y_i)$ is analytic on each region of [0,1] where s remains constant, then $\dfrac{d(\underline{x}_i^s(y_i))}{dy_i}$ is bounded there. Thus, $\dfrac{d(\underline{x}_i^*(y_i))}{dy_i}$ is bounded except possibly at the points of change. Therefore,

$$\frac{d(\underline{x}_i^*(y_i))}{dy_i} \leq \alpha_i < \infty \quad \text{a.e.}$$

By the Lebesque Theorem [Royden, 1963], $\dfrac{d(\underline{x}_i^*(y_i))}{dy_i}$ is Riemann integrable, since it is a bounded function on [a,b] and the set of discontinuities has measure zero. Further, $\dfrac{d(\underline{x}_i^*(y_i))}{dy_i}$ is measurable and Lebesque integrable by Proposition 4 [Royden, 1963], which states that a bounded function over a closed and bounded region which is Riemann integrable is measurable and Lebesque integrable.

Define $$\underline{x}_i^*(y_i) = \int_0^{y_i} \frac{d(\underline{x}_i^*(z))}{dz}\, dz + \underline{x}_i^*(0)$$

and hence by Theorem 13 [Royden, 1963] $\underline{x}_i^*(y_i)$ is absolutely continuous.

From [Timan, 1963] a function which is absolutely continuous and has a derivative a.e., such that the derivative is bounded, satisfies Lipschitz's condition.

Therefore,

$$\| \underline{x}_i^*(y_i^1) - \underline{x}_i^*(y_i^2) \| \leq \alpha_i \| y_i^1 - y_i^2 \| \text{ for all } i \text{ and}$$

hence

$$\| \underline{x}^*(\underline{y}^1) - \underline{x}^*(\underline{y}^2) \| \leq \alpha \| \underline{y}^1 - \underline{y}^2 \|.$$

Q.E.D.

Lemma 2.7.3.5. If the relaxed constraints $\underline{g}(\underline{x})$ satisfy Lipschitz's conditions with a constant of β, then the composition function $\underline{g} o \underline{x}^*$ satisfies Lipschitz's condition with a constant $\alpha\beta$.

Proof: By Lemma 2.7.3.4 and the assumption on $\underline{g}(\underline{x})$,

$$\| \underline{x}^*(\underline{y}^1) - \underline{x}^*(\underline{y}^2) \| \leq \alpha \| \underline{y}^1 - \underline{y}^2 \|$$

$$\| \underline{g}(\underline{x}^1) - \underline{g}(\underline{x}^2) \| \leq \beta \| \underline{x}^1 - \underline{x}^2 \|.$$

Consider $\underline{g} o \underline{x}^*(\underline{y})$;

$$\| \underline{g} o \underline{x}^*(\underline{y}^1) - \underline{g} o \underline{x}^*(\underline{y}^2) \| = \| \underline{g}[\underline{x}^*(\underline{y}^1)] - \underline{g}[\underline{x}^*(\underline{y}^2)] \|$$

$$\leq \beta \| \underline{x}^*(\underline{y}^1) - \underline{x}^*(\underline{y}^2) \| \leq \alpha\beta \| \underline{y}^1 - \underline{y}^2 \|.$$

Therefore $\underline{g} o \underline{x}^*$ satisfies Lipschitz's condition with constant $\alpha\beta$.

Q.E.D.

The framework has now been established for the development of a solution procedure for problem (P_y). The method consists of three steps

and the proof of convergence of the method is given in Theorem 2.7.3.6. Again it should be emphasized that the procedure converges to the solution $\underline{x}^*(\underline{y})$ of the problem

$$(P_c) \quad \begin{array}{ll} \text{minimize} & \sum_{i=1}^{N} \{y_i f_i^1(\underline{x}_i) + (1-y_i) f_i^2(\underline{x}_i)\} \\ \text{subject to} & \\ & \underline{h}_i(\underline{x}_i) \leq \underline{0} \quad \text{for all } i \end{array}$$

with $g[\underline{x}^*(\underline{y})] = \underline{y}$. The solution $(\underline{x}^*(\underline{y}^*),\underline{y}^*)$ to this problem is of course feasible for problem (P_y) but it need not be the optimal solution (Problem 2.7.3.1 gives a contradiction to the optimality of $(\underline{x}^*(\underline{y}^*),\underline{y}^*)$).

<u>Iterative Procedure</u>

Step 0: Set $k = 1$ and select an initial $\underline{y}^k$ such that $y_i^k \in (0,1)$ for all i and establish an ε convergence tolorance.

Step 1: Solve the subproblems (2.7.3.2) for the optimal solutions $\underline{x}_k^*$ where $\underline{y}^k$ is a specified numerical vector and k designates the interation number.

Step 2: Obtain $\underline{y}^{k+1} = \underline{g}(\underline{x}^*_k)$; if $||\underline{y}^{k+1} - \underline{y}^k|| \leq \varepsilon$ convergence has occurred, otherwise set $k = k+1$ and repeat Steps 1 and 2.

<u>Theorem 2.7.3.6.</u> The iterative procedure converges to the unique solution of problem (P_c), if the product $\underline{g} \circ \underline{x}^*$ is contractive.

Proof: By Theorem 2.7.3.3 a solution to problem (P_c) exists since (P_c) is merely the explicit statement of a solution pair $(\underline{x}^*(\underline{y}^*),\underline{y}^*)$ which is feasible for (P_y). Since $\underline{g} \circ \underline{x}^*$ is contractive, $\alpha\beta<1$, then by the Banach Fixed-Point Theorem [Saaty, 1967, page 54] there exists a unique solution $\underline{y}^*$ to $\underline{g} \circ \underline{x}^*(\underline{y}) = \underline{y}$ and the sequence $\{\underline{y}^k\} \to \underline{y}^*$ where $\underline{y}^{k+1} = \underline{g}(\underline{x}^*_k)$. Since $\underline{x}^*(\underline{y}^*)$ are optimal solutions to subproblems (2.7.3.2) which satisfy the relaxed

constraints $\underline{y} = \underline{g}(\underline{x})$, then $(\underline{x}^*(\underline{y}^*),\underline{y}^*)$ solves (P_c).

Q.E.D.

Example 2.7.3.7. Consider solving the problem

$$\begin{aligned} \text{minimize} \quad & y_1(x_1-1)^2 + (1-y_1)(x_1-2)^2 \\ & + y_2(x_2-0)^2 + (1-y_2)(x_2-4)^2 \\ & + y_3(x_3-3)^2 + (1-y_3)(x_3-6)^2 \end{aligned}$$

subject to

$$1 \le x_1 \le 2$$
$$0 \le x_2 \le 4$$
$$3 \le x_3 \le 6$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} \frac{1}{10} & \frac{1}{20} & \frac{1}{12} \\ \frac{1}{8} & \frac{1}{12} & \frac{1}{18} \\ \frac{1}{10} & \frac{1}{20} & \frac{1}{10} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}.$$

Relaxing the equality constraints of the form $\underline{y} = \underline{A}\ \underline{x}$ and solving the remaining system for the parametric solution, denoting the upper and lower bounds on x_i by b_i and a_i respectively, then

$$x_i^*(y_i) = b_i + (a_i-b_i)y_i \text{ for all } i.$$

Obtaining the composition functs.

$$\underline{y} = \underline{g} \circ \underline{x}^*(\underline{y}) = \underline{A} \cdot [\underline{b} + (\underline{a}-\underline{b})\underline{y}]$$

$$\underline{y} = \underline{B}\ \underline{y} + \underline{d}$$

with

$$\underline{B} = \begin{bmatrix} -\frac{1}{10} & -\frac{1}{5} & -\frac{1}{4} \\ -\frac{1}{8} & -\frac{1}{3} & -\frac{1}{6} \\ -\frac{1}{10} & -\frac{1}{5} & -\frac{3}{10} \end{bmatrix} \text{ and } \underline{d} = \begin{bmatrix} 0.9 \\ .917 \\ 1.0 \end{bmatrix} .$$

This system of equations has a solution and can be solved by the iterative procedure [Luisternik and Sobolev, 1961, page 29]. Starting with $\underline{y}^1 = (1,1,1)$, in 21 iterations the answer is

$$\underline{x}^* = \begin{bmatrix} 1.420 \\ 2.009 \\ 4.056 \end{bmatrix} , \underline{y}^* = \begin{bmatrix} 0.580 \\ 0.498 \\ 0.648 \end{bmatrix}$$

with the objective function value of 6.296. The convergence criterion used was a change of 0.0001 units in the objective function value. The true optimal solution to this problem is $\underline{x}^* = (1.578, 2.855, 4.138)$ with an objective function value of 6.246.

Problem 2.7.3.1

Show that the global solution and iterative procedure obtain different solutions for

$$\underset{x}{\text{minimize}} \; y(x^2) + (1-y)(x-0.5)^2$$
$$0 \leq x \leq 1$$
$$y = \frac{x}{2} .$$

Problem 2.7.3.2

Prove Lemma 2.7.3.1.

Problem 2.7.3.3

Solve by the iterative procedure,

$$\text{minimize } y(x^2-20x + 102) + (1-y)(x^2-40x + 402)$$

$$\text{subject to} \qquad 10 \leq x \leq 20$$

$$y = g(x)$$

where

(a) $g(x) = \frac{1}{2}$ global solution $x^* = 15$,

(b) $g(x) = \frac{x}{25}$ global solution $x^* = 14.4\bar{4}$,

(c) $g(x) = \frac{x^2}{625}$ global solution $x^* = 15.7013$,

(d) $g(x) = \frac{5}{x}$ global solution $x^* = 17.5752$.

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CLASSIFICATORY AND REGIONAL ANALYSIS BY DISCRIMINANT ITERATIONS

by

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Prefatory Remarks

This report is one of a series of computer program manuals arising from a continuing study of computer applications in the earth and environmental sciences, including geology, geography, geophysics, geochemistry, and environmental engineering. In some of these subjects, notably oceanography, atmospheric science, and solid-earth geophysics, computer capability has advanced far beyond that in the more classical fields of geology and geography, as well as in such aspects of environmental science as soil mechanics and sanitary engineering. Our study is concerned mainly with these more classical fields in which computer utilization is less far advanced.

Our project has as its purposes the evaluation of developments in computer capability in our fields through assessment of present activities; and an obligation to make available in the public domain a series of computer programs especially adapted to the needs of workers in our fields. The first purpose is being met through conferences and literature search; and the second is being met by reports such as this, which include programs arising from our own studies, as well as program reports contributed by others active in the field.

The present paper discusses a method for evaluating to what extent a classification of items defined by a set of measures reflects a "rationale" rather than "errors." A geometrical interpretation is provided of the concepts of systematic and random elements of a classification and of the analytic tools proposed. The methods are illustrated by an application to the analysis of a classification of climatic stations. A listing and description of the computer program used is appended.

Classifications are of paramount importance within the earth science and the present document is a contribution to the development of quantitative methods and computer capabilities in the study of classifications.

W. L. Garrison

W. C. Krumbein

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CLASSIFICATORY AND REGIONAL ANALYSIS BY DISCRIMINANT ITERATIONS

By Emilio Casetti

Chapter I

Introduction

Classificatory problems arise within all branches of science. Some of the classification problems are specific to particular disciplines, others are more general and abstract and have very similar characteristics in practically every area of research. Abstract problems deal particularly with the creation and the analysis or the evaluation of classifications. The creation of classifications involves both classifying objects ex novo[1] and extending a given classification to new objects[2] on the basis of constrained[3] or unconstrained optimization criteria.[4] The quantitative analysis of classifications has been developed mainly along three approaches dealing respectively 1) with the problem of the randomness of classifications, 2) with the relationships between "clusters" and classifications, and 3) with the identification of dimensions of classifications.

The randomness problem involves testing the hypothesis that a classification arises by random allocation of objects to classes.

The evaluation of classifications is clearly related to the so-called "cluster analysis." The objects in a classification can be thought of as points (see page 6) in a multidimensional space, and the clustering of some of these points indicates homogeneity of the corresponding objects, and is therefore a basis of classification. The

study of clusters has been developed for determining on probabilistic grounds whether given clusters could have arisen by a random allocation of points,[5] and for optimally extracting clusters from a distribution of points.[6]

Recently, multiple discriminant functions were used in order to analyze classifications by identifying their "dimensions".[7] The technique involved is similar to that used in component analysis for identifying dimensions of variability.

The distinction between the creation of or the extension and analysis of classifications is somewhat artificial. Actually, the same techniques can be used for both purposes and in practical work they can be tightly intertwined. For instance an evaluation of a classification can be used for investigating and criticizing the classificatory method used, and the classification then can be modified on the basis of results of this evaluation.

The present study deals both with creating and with analyzing classifications. It proposes a new tool for evaluating classifications; a tool based upon discriminant procedures, usually employed for extending classifications to new objects. The discussion provides an opportunity for analyzing the links between creation ex novo, extension, and evaluation of classifications. The structure of classifications is investigated by identifying what will be referred to as "cores of classifications" and "limiting classifications." The effect of random factors on classifications will be treated by restricting the bases of classifications to

systematic influences rather than using the classical probabilistic framework.[8] This point will be extended later.

The analytical tool proposed will be referred to as "discriminant iterations." It can be used 1) for investigating the roles of random and of systematic elements in classifications, and 2) for deriving from a given classification a limit classification from which random elements and inconsistencies are eliminated. Discriminant iterations require a theoretical setting within which concepts such as "principles", "inconsistencies", and "cores" of classifications acquire a precise meaning.

Discriminant iterations (DI's) are based on discriminant procedures (DP's). A discriminant procedure is a set of rules for allocating a new object to one of the classes of a classification. The DP's considered here are functions of the classification to be extended to the new object. A DI is the application of a DP on all the objects of the classification to which the DP is functionally related. A DI reallocates the objects in a classification to their original class, or moves them to another class. Consequently, it generates a classification on which a new DI can be applied. And so on, iteratively. The next few sections contain an articulated and more precise presentation of the concepts introduced above.

Chapter II

Classification: Quantitative Setting

Assume a classification of n objects or items (areal units for instance) into m classes. Each areal unit is measured with respect to

t properties. Therefore each item in the classification is associated with a vector having as elements the values of the t variables which correspond to the t properties.

Call $X = (x_{hij})$ the matrix of the values of the t variables for the n items. x_{hij} is the value of the jth variable for the ith item. The subscript h indicates that the ith item belongs to the hth class. Indicate by $X_{hi.}$ the row vector having as elements the values of the t variables for the ith item in the hth class and by $X_{..j}$ the column vector the elements of which are values of the jth variable for the n objects in the classification. That is

$$X_{hi.} = \left[x_{hi1}, x_{hi2}, \ldots\ldots x_{hit} \right]$$

$$X^T_{..j} = \left[x_{11j}, x_{12j}, \ldots\ldots, x_{mnj} \right]$$

Call $x_1, x_2, \ldots x_t$ the variables whose values for the n items constitute the elements of X. Assume that the t variables have been orthonormalized[9] so that

$$X^T_{..i} X_{..j} = \begin{cases} 1 & \text{if } i = j \\ 0 & \text{if } i \neq j \end{cases}$$

Each class in the classification is associated with a vector of the measures with respect to the t variables. This vector will be referred to as the "representative vector" of the class. Call $X_{h..}$ the representative vector of the hth class

$$X_{h..} = \left[x_{h.1}, x_{h.2}, \cdots x_{h.t}\right]$$

In a particularly important case the elements of $X_{h..}$ are equal to the arithmetic average of the corresponding elements of the vectors $X_{hi.}$ for all the i's in the hth class. That is

$$X_{h..} = \frac{1}{n_h} \sum_{i \in h} X_{hi.}$$

where n_h is the number of elements in the hth class. The entire classification is associated with a representative vector $X_{...}$

$$X_{...} = \left[x_{..1}, x_{..2}, \cdots x_{..t}\right]$$

that in the special case indicated above is obtained by taking the arithmetic average of the $X_{hi.}$'s for all i's.

$$X_{...} = \frac{1}{n} \sum_{i}^{n} X_{hi.}$$

Define a linear transformation T identified by a matrix B of order txd, where d≤t, which associates a new vector of transformed measures to any object in the classification and to any representative vector. Term $Y_{hi.}$ the row vector associated to the ith object, which is included in the hth class.

$$Y_{hi.} = X_{hi.}B = \left[y_{hi1}, y_{hi2}, \cdots y_{hit}\right]$$

Term Y the matrix of order nxd, in which $Y_{hi.}$ constitutes the ith row

$$Y = XB$$

Term $Y_{h.}$ the vector associated with the representative vector of the hth class, obtained by applying the transformation T on $X_{h..}$

$$Y_{h..} = X_{h..} B$$

Term $Y_{...}$ the vector associated with the representative vector of the classification, obtained by applying the transformation T on $X_{...}$

$$Y_{...} = X_{...} B$$

The objects and the classes of a classification, as well as the classification itself, can be thought of as points in a problem space and in a discriminant space. In both spaces the positions of the points are determined by coordinates with respect to axis which are orthogonal if the original data are orthogonal. The vectors $X_{hi.}$, $X_{h..}$, $X_{...}$ identify respectively, in the problem space, the points corresponding to the ith objects, to the hth class, and to the entire classification. The points $X_{h..}$ and $X_{...}$ will be referred to as representative points of the hth class and the representative point of the classification. The vectors $Y_{hi.}$, $Y_{h..}$, $Y_{...}$ identify in the discriminant space, respectively, the point corresponding to the ith item and the representative points of the hth class and of the classification. The transformation T maps the problem space into the discriminant space.

Discriminant Procedures

Discriminant procedures were defined as set of rules or operations by means of which additional objects are assigned to one of the classes of a classification. Basically all discriminant procedures allocate a new

object to the class whose representative point in a given discriminant space is nearest to the point associated with the object. Discriminant procedures can differ however:

1) in transformations generating the discriminant space from the originary problem space,
2) in rules for determining representative points, or, which is the same thing, in the relationships between class representative points and points corresponding to the objects in the classes,
3) in the distance function[10] adopted for measuring the "nearness" of points in the discriminant space.

The discriminant procedure used in this paper will be referred to as discriminant-functions-discriminant-procedure (DFDP). The DFDP's:

1) use class centers of gravity and the classification center of gravity, respectively, as class and classification representative points, 2) are based on Euclidean distance functions[11], and 3) are based on a linear transformation identified by a matrix whose columns are formed by coefficients of linear discriminant functions. Linear discriminant functions were reviewed in an earlier paper[12] to which the reader is referred. In that paper it was noted that relative to normalized and orthogonalized data the matrix of the discriminant functions represents an orthogonal transformation,[13] a transformation, namely, that preserves distances. Therefore, when the data used are orthogonalized and normalized, and provided that <u>all</u> the discriminant functions are used, the DFDP is identical to a simpler DP to be called distance-discriminant-procedure (DDP). The DDP also uses centers

of gravity and the Euclidean distance function, but differs from the DFDP in having an identity transformation as the transformation generating the discriminant space from the problem space. In other words, the DDP has a discriminant space identical to the problem space and, therefore, allocates items to classes whose centers of gravity are nearest in the problem space. DFDP and DDP, however, are not identical if we disregard the DF's associated with the smaller eigenvalues, which account for a small part of the discrimination between classes, and that within a probabilistic framework are interpreted as errors. Even in this case, however, the two procedures are still likely to be very similar, that is, they are more similar the smaller is the fraction of the discriminant power of the initial variables contained in the LDF's being disregarded.

DFDP is preferred to DDP 1) because it yields approximately the same results as does the DDP, but using a much smaller set of derived variables, and 2) because the derived variables that are used identify mathematical and empirical dimensions of classifications.[14] The interpretation of the DF's will be extensively discussed in a later part of this paper. However, it is perhaps useful to introduce now the rationale behind the use of DF's. Why should DF's be preferred to a random allocation of new objects to a class? The use of DF's is an orderly allocation of the new objects, and consequently has a meaning only if it is assumed that the classificaion in question is based on "principles" which should be applied on the new objects, so that the "structure" of the classification is not obliterated but preserved. The DF's reflect such rationale

and structure. These considerations emphasize the usefulness of research directed to identifying and interpreting the dimensions of classificatory structures by LDP's, and pinpoints basic differences between LP's and procedures designed to generate optimal classifications from unclassified objects. The allocation of objects by DP's is guided by an initial structure, while no "initial" condition, at any stage, controls or affects optimal classifications procedures.

Discriminant Iterations

Again assume a classification of n objects into m classes. Define a_{hi} as the ith object, which is located in the hth class. Call $a_{0,n+1}$ an additional (n+1 th) object which belongs to no one of the classes (that is, it belongs to the zeroth class). Indicate by D a discriminant procedure. The allocation of the additional object $a_{0,n+1}$ to, say, the hth class by the discriminant procedure D can be written as follows:

$$Da_{0,n+1} = a_{h,n+1}$$

D can be applied to any of the objects in the classification, which in this case is either reallocated to its own class or moved to another class. For example the ith object in the hth class can remain in h or be sent to, say, class p.

$$Da_{hi} = a_{hi} \quad \text{or} \quad Da_{hi} = a_{pi}$$

Indicate an "initial" classification by A_s. A classification, is a set of n objects each assigned to one of m classes. Therefore

$$A_s = \left[a_{s,r_i,i}\right]$$

where $a_{s,t_i,i}$ represents the ith object which in the classification A_s is located in class t_i.

The application of D on all the objects in A_s yields a new classification A_{s+1} of same objects. The transformation of A_s into A_{s+1} by the operator D can be written as follows:

$$DA_s = \left[Da_{s,t_1,1} ; \; Da_{s,t_2,2} ; \; \ldots \; Da_{s,t_n,n} \right]$$

$$= A_{s+1}$$

$$= \left[a_{s+1,t_1,1} ; \; a_{s+1,t_2,2} ; \; \ldots \; a_{s+1,t_n,n} \right]$$

Classifications A_s and A_{s+1} are equal, that is $A_s = A_{s+1}$ if $a_{s,t_i,i} = a_{s+1,t_i,i}$ for $i=1,n$.

Classifications A_s and A_{s+1} are not equal if $a_{s,t_i,i} \neq a_{s+1,t_i,i}$ for at least one i.

Clearly D can be applied again and again on classifications obtained from an initial classification by some operator D. The repeated ("iterative") application of D can be represented as a power of D. For instance

$$DA_1 = A_2$$

$$DA_2 = D(DA_1) = D^2A_1$$

$$\ldots\ldots\ldots\ldots$$

$$DA_{n-1} = A_n = D^nA_1$$

The classification A_n is obtained from A_1 by iterative application of the discriminant operator D or, more concisely, by discriminant iterations.

Limit Classifications

Imagine a sequence of classifications of a finite number of objects

$$A_0, A_1, A_2, \ldots\ldots A_v, \ldots\ldots A_w, A_{w+1},$$

such that the vth term of the sequence (A_v) is obtained by v discriminant iterations from A_0. That is:

$$A_v = D^v A_0$$

DEFINITION: The classification A_w is a limit classification, with w being a finite positive integer, when the following holds:

$$A_z = A_w \quad \text{if } z \geq w$$

$$A_z \neq A_w \quad \text{if } z < w$$

This definition implies that the initial classification A_0 is a limit classification when w=1. The determination of the initial classification is purely arbitrary. A classification is called initial when other classifications are derived from it by discriminant iterations. The definition above has a meaning only if the limit classification can be reached by a finite number of discriminant iterations. A reformulation of the definition of limit classification applicable when classification of an infinite number of objects is involved and when w is not finite will not be attempted here. It is evident that several initial classifications can yield a same limit classification. However, the opposite is not true. This will be shown by proving the following theorem.

THEOREM I. An initial classification cannot have more than one limit.

Proof: Assuming two limits leads to a contradiction. Suppose that A_v and A_r (where $r > v$) are both limit of A_0. By the definition if A_v and A_r are limits

$$A_v = A_{v+1} \cdot \cdot \cdot \cdot = A_{r-1} = A_r \qquad (1)$$

$$A_v \neq A_{v+1} \cdot \cdot \cdot \cdot \neq A_{r-1} = A_r \qquad (2)$$

But both (1) and (2) cannot be true, and therefore A_v and A_r both cannot be limits of A_0.

It will now be shown that a limit classification can be generated from an initial classification of a finite number of objects by a finite number of discriminant iterations. The proof of this proposition requires the following result: The within-classes variability of a classification generated by a DI from an initial classification is smaller than the within-classes-variability of the initial classification. The following definitions and notations are required.

1) Indicate by A_i a classification of n items into m classes. Each item is defined by a vector of t values of t variables.

2) Term x_{hij} the value of the jth variable for the ith item. The subscript h indicated that the ith item belongs to the hth class.

3) Term $\bar{x}_{h.j}$ the average of the jth variable over the hth class.

4) Term $\hat{x}_{hij}$ the deviation of the value of the jth variable for the ith item from the average of the jth variable over the hth class. That is

$$\hat{x}_{hij} = x_{hij} - \bar{x}_{h.j}$$

5) Indicate the total within-classes variance of A by v_A^2 where

$$v_A^2 = \frac{1}{nt} \sum_{j,i}^{t,n} \hat{x}_{hij}$$

6) Call B a classification generated from A by one discriminant iteration

$$B = DA$$

7) Term v_B^2 the total-within-classes variance of B.

<u>THEOREM II:</u> $v_B^2 = v_A^2$ if B is a limit classification. Otherwise

$$v_B^2 < v_A^2$$

<u>PROOF:</u> 1.1 If B is a limit classification $B=A$ and then

$$v_B^2 = v_A^2$$

Suppose instead that $B \neq A$

2.1 Term d_i the distance of the point image of the ith object from the center of gravity of its class. Then

$$d_i^2 = \sum_j^t \hat{n}_{hij}^2$$

2.2 Clearly $$tv_A^2 = \frac{1}{n} \sum_i d_i^2$$

2.3 $B \neq A$ implies that when A is operated upon by a discriminant iteration, some of the items are removed from their class in A and allocated to the class whose center of gravity is nearest.

2.4 Suppose that the ith item corresponds to one of these points, and call b_i the distance of the point from the center of gravity of the class to which the item is assigned.

2.5 Therefore $b_i < d_i$

and as $b_i, d_i > 0$ also $b_i^2 < d_i^2$

2.6 Term $\hat{v}_A^2$ a quantity obtained from v_A^2 by substituting in v_A^2 the distances b_i's to the distances d_i's for all the items reallocated by the discriminant iteration.

2.7 Because $b_i < d_i$ also $\hat{v}_A^2 < v_A^2$

2.8 However $\hat{v}_A^2$ is <u>not</u> the within-class-variability of the new classification B because the removal of points from their classes in A and their reallocation to other classes changes the position of the centers of gravity of both classes of origin and destination.

2.9 Therefore $t\hat{v}_A^2$ is also the average of distances of the points in each class from a central point which is not the centroid of the class.

2.10 But the centroid of a set of points is the point such that the sum of its squared distances to the points of the set is a minimum. In classification B the average of the distances of the points in each class from the centers of gravity of the classes is, by definition tv_B^2

2.11 Therefore

$$tv_B^2 < t\hat{v}_A^2$$

and

$$v_B^2 < \hat{v}_A^2 < v_A^2$$

which proves that $v_B^2 < v_A^2$

Theorem II implies the following Corollary

<u>Corollary</u>: If $A_0, A_1, A_2, \ldots$ is a sequence of classifications of same

objects into some number of classes, generated from A_0 by repeated application of the discriminant operator D

$$A_i = D^i A_0$$

and if $A_p = D^{q-p} A_q$ where $p < q$, it is not possible that for some y

$$A_q = D^y A_p$$

PROOF: By theorem II $\quad v^2_{A_p} < v^2_{A_q}$

If there was a y such that $A_q = D^y_{A_p}$ this would imply that

$v^2_{A_q} < v^2_{A_p}$ which is a contradiction.

The corollary of Theorem II shows that the discriminant iterations do not proceed "circularly" in the sense that if classification B was generated from A, and C from B, it is impossible that classification A be obtained from C by DI's. It is now possible to prove the proposition that a limit classification can be generated from an initial classification of a finite number of objects by a finite number of DI's. The proposition is embodied in the following theorem.

THEOREM III: If $A_0, A_1, A_2, \ldots\ldots$ is a sequence of classifications of n objects into m classes (where $m \leq n < \infty$) generated from A_0 by repeated application of the discriminant operator D, then $A_{x-1} = A_x$ for

$$x \geq z = (n!/(n-m)!m!)+1$$

PROOF:

1) the number of possible classifications of n objects into m classes is $n!/(n-m)!m! = z-1$

2) D can be applied on a classification an arbitrarily large number of times, and certainly more than z times.

3) Let A_0 be one of the z-1 possible classifications, and suppose that for $x < z$ $A_{x-1} \neq A_x$ which is equivalent to saying that each of the first z DI's generated one of the z-1 possible classifications.

4) Assuming $A_{z-1} \neq A_z$ leads to a contradiction. All possible classifications are exhausted, and therefore $A_{z-1} \neq A_z$ implies that $A_z = A_p$ where $p < z$. But this is impossible by the corollary to THEOREM II. Consequently the assumption $A_{z-1} \neq A_z$ leads to a contradiction.

5) Suppose that $A_{h-1} = A_h$ for $h < z$, which is equivalent to saying that the limit classification is reached at the hth iteration. In this case it is true that $A_{x-1} = A_x$ for $x > h$ and therefore, *a fortiori*, for $x > z$, by the definition of a limit classification.

Non-Linear Discriminant Procedures and Iterations

The DI's considered to this point can be called linear because they are based on DP's which use a linear transformation for generating the discriminant space from the problem space. Non-linear DP's and DI's will not be treated here formally. The interested reader is referred to Chapter 3 of *Decision-Making Processes in Pattern Recognition*, by G. S. Sebestyen, which deals with "Non-Linear Methods in Classificatory Analysis." The following informal discussion of some aspects of the non-linear transformations of problem spaces into discriminant spaces is suggested by their bearing upon the interpretation of the meaning of non-linear and random classifications.

Suppose that the problem space is turned into the discriminant space by a (non-linear) polynomial transformation such that 1) any coordinate y_i in the discriminant space is equal to a non-linear combination of the coordinates in the problem space (For instance in a quadratic two-dimensional case

$$y_i = a_{11}x_1^2 + a_{22}x_2^2 + a_{12}x_1x_2 + a_1x_1 + a_2x_2$$

where x_1, x_2, are coordinates of the problem space.) and 2) that the coefficients of the transformation are chosen so as to maximize the ratio of between classes to within-classes variances in the discriminant space. The transformation corresponds to a stretching and compressing-without-tearing of the problem space, so as to cluster the point images of objects in same classes, and to separate the clusters corresponding to different classes. Suppose also that the discriminant space is divided into as many regions as classes, each class being associated to the region formed by all points which are nearer to the class representative point than to any other representative point.

The straight lines separating the regions in the discriminant space will correspond in the problem space to curves of a degree equal to the degree of the highest of the coordinate transformations involved. For instance if $y_1 = f_1(x_1x_2)$, $y_2 = f_2(x_1x_2)$ are two quadratics, it is clear that the straight line $b_1y_1 + b_2y_2 + c = 0$ in the discriminant space corresponds to a quadratic curve in the problem space.

The non-linear transformation is by definition derived so as to achieve maximum separation of different classes in the discriminant

space, and the straight line boundaries, in the discriminant space, divide points which are as well separated according to class membership as they can by a transformation of the degree used. It follows therefore that the curved lines in the problem space that correspond to the straight line boundaries in the discriminant space separate the points according to class membership of the corresponding objects, as well as it is possible by a curve of the degree given.

Assume a DP employing centers of gravities as representative points, the Euclidean distance function, and a polynomial transformation of, say, second degree. Clearly a DI based on this DP will tend to allocate to the initial classes a larger portion of the points than a DI based on a linear transformation. Regions in the problem space, which are bounded by quadratic curves developed so as to achieve optimal class separation, can obviously include a greater proportion of the points in the class associated with them than regions bounded by straight lines. The same reasoning can be repeated for a cubic DP with respect to a quadratic, and so on. This suggests that quadratic DI's can reach a limit in a smaller number of iterations than linear DI's and, in general, nth degree DI's reach a limit in a smaller number of steps than do DI's based on mth degree transformations where $m < n$. This also suggests that a finite number of points can be separated according to class membership, irrespective of their arrangement, provided that curved boundaries of degree sufficiently high are used. Therefore, any classification is a limit provided that a DI based on a transformation of sufficiently high degree is used.

Suppose that a, say, linear DI removes from a class a cluster of points which falls outside the straight line boundary of its initial class. The increase in the degree of the transformation, that is, of the degree of the curved boundary sufficient to get the cluster inside the class boundary, is much smaller than the increase in degree of the boundary curves required to get inside the class regions points scattered along the border and intermingled with points belonging to other classes. Therefore when linear DI's cause the transfer of clusters of points from one class to another, this can be interpreted as indication of a low degree non-linearity in the classification. The transfer of scattered points instead indicates non-linearity of a high degree, or, which is the same thing, the presence of a random classificatory element. A purely random allocation of points to classes would generate a classification that could be a limit classification only with respect to DI's based on a transformation of a very high degree. Conversely, the farther from randomness a classification is, the smaller the degree of the DI with respect to which the classification is a limit. These considerations pose the interesting problem of determining whether the difference between a classification and its limit can be associated to low degree non-linearity or to high degree "random" non-linearities.

The Stability of Limit Classifications

n objects can be classified into m classes in $\binom{n}{m}$ ways. Some of these $\binom{n}{m}$ different classifications are limit classifications with respect to a given DI. The number of limit classifications is determined by the arrangement of the points in the discriminant space (see page 25).

The non-limit classifications can be divided into groupings, each including all the non-limit classifications that would generate by discriminant iterations the same limit classification. Let us say that a limit classification is the more stable the greater is the number of non-limit classifications in its grouping. Then the degree of stability of a limit classification can be measured by the ratio of the number of non-limit classifications associated with it to the total number of non-limit classifications.

Uses and meanings of limit classification stability can be better discussed after investigating the geometric interpretation of DP's, DI's, limit classifications, and stability. This investigation is carried out in the following section.

The Geometry of the Discriminant Iterations

In the previous section it was noted that the items in a classification, as well as the representative points of the classes and of the classification, can be thought of as points in a t dimensional discriminant space. The classes can be associated with regions that partition the discriminant space. For instance, the regions R_h corresponding to the hth class can be defined as the set all points of the discriminant space which are nearer to the representative point of the hth class than to any other class-representative-point. In set notation

$$R_h = \left[x \middle| d(xr_h) < d(xr_i), \quad i \neq h, \quad i = 1, n \right]$$

where x is a point in the discriminant space and $d(xr_i)$ is the distance between the representative point of the ith class (r_i) and x. The

boundaries of any region are formed by hyperplanes made of all points equidistant from two representative points. In a two-dimensional two-classes case, the discriminant space is divided into two regions bounded by a straight line perpendicular through the midpoint of the segment connecting the two representative points. In a two-dimensional three-classes case, the discriminant space is divided into three regions by perpendiculars through the midpoints of the three segments connecting the representative points, as in Figure 1.

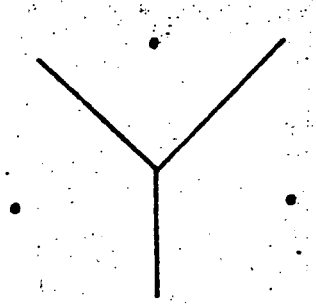


Figure 1

Allocating a new item to a classification by a discriminant procedure D is equivalent, from a geometrical point of view: 1) to dividing the discriminant space of the classification into regions associated with the representative points of the classes and 2) to assigning the item to the class associated with the regions in which the points image lies. A discriminant iteration $DA_i = A_{i+1}$ is geometrically equivalent: 1) to partitioning the discriminant space on the basis of A_i and 2) to generating a new classification by assigning each point to the class associated with the region in which the image of the point lies.

Figures 2a, 2b and 2c illustrate the application of a DI in a two-dimension three-classes case.

Classification A_i

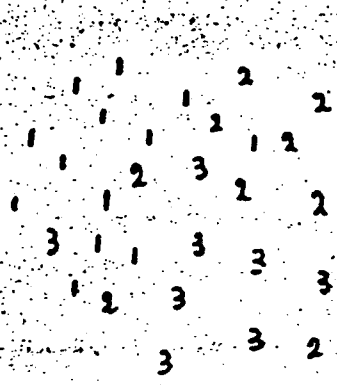


Figure 2a

Figure 2b

Classification A_{i+1}

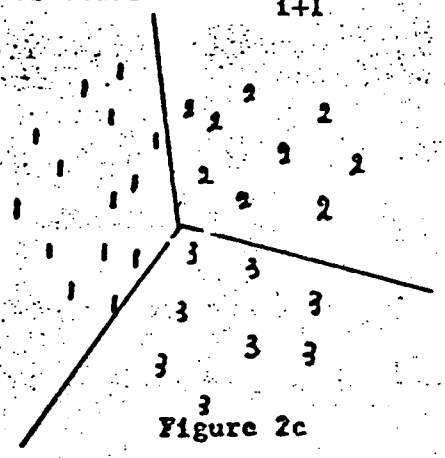


Figure 2c

The initial classification is represented in Figure 2a. The numbers 1,2,3 identify, respectively, members of the first, second and third class. In Figure 2b the discriminant space is divided into three regions by lines perpendicular to the segments connecting the representative points (indicated by Roman numerals). In Figure 2c the items are reallocated to the region (class) in which their point-images lie. Further iterations would reapply the routine on the classification A_{i+1}, then on A_{i+2}, and so on. A limit classification is reached when the point images of the objects in any class are found only in the regions associated with that class. For instance the classification A_i in the example above would have been a limit classification if Figures 2a and 2c were identical, or, which is the same thing, if in Figure 2b the regions I, II, and III contained respectively only 1's, 2's, and 3's. The iterations generating a limit from a non-limit classification can be portrayed geometrically as a "migration" of class boundaries and of class representative points toward limiting positions. Figure 3

illustrates this migration of boundaries and representative points to a limit in a simple two-dimensions two-class case.

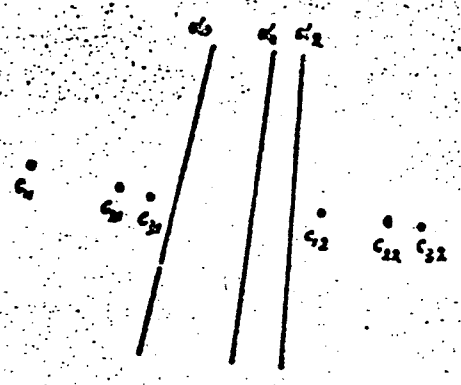


Figure 3

The initial partition into classes is indicated by the boundary α_0. c_{11} and c_{12} are the representative points of the two classes which generate the boundary α_1, and so on. In the figure the limiting boundary and representative points are respectively α_2, c_{31}, and c_{32}.

The number of limit classifications of n objects into m classes depends upon the arrangement of the points associated with the objects. When the object-images are clustered into sufficiently differentiated groupings, there is only one limit classification in as many classes as there are groupings. For instance, the two dimensional point arrangements in Figure 4 and 5 clearly admit as limit classification only the classification in the two and three classes indicated by the boundary lines.

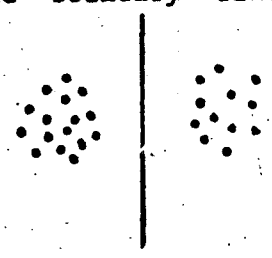


Figure 4

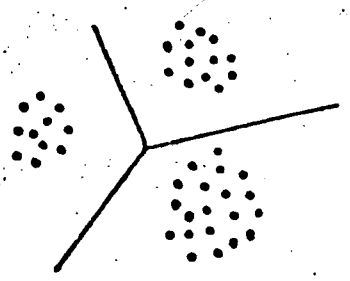


Figure 5

The point configuration in Figure 4 would probably admit several limit classifications into 3 or 4 groupings. On the other hand, a point configuration as in Figure 6 would probably admit a large number of limit classifications in 2, 3, 4, and so forth classes (but only one classification into n classes if the points are n in number).

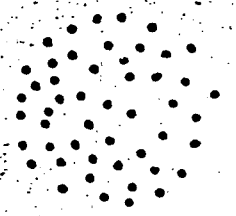


Figure 6

These empirical rules may not apply in the case of configurations characterized by axis of symmetry. For instance, the regular point pattern in Figure 7 shows two well defined clusters but clearly admits

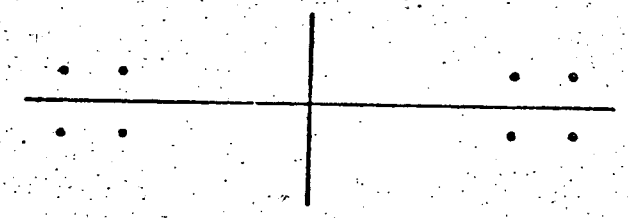


Figure 7

the two two-class classifications indicated by the boundary lines. In the preceding section, a measure of the stability of a limit classification was indicated as the fraction of the non-limit classifications associated with it on the total number of non-limit classifications. A comparison between two-class-limit-classification of the point configurations in Figures 4 and 6 illustrates the geometrical meaning of stability. The configuration in Figure 4 admits only one limit

classification allocating the two-point clusters to two classes. This limit classification possesses, therefore, the highest possible degree of stability. The point configuration in Figure 6 instead admits a large number of limit two class classifications identified by boundary lines such as those in Figure 8.

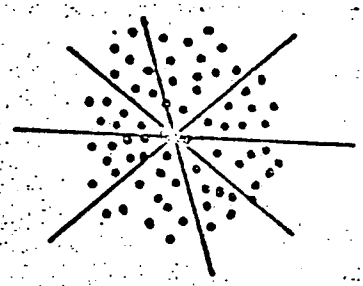


Figure 8

All these limit classifications are associated with approximately equal fractions of non-limit classifications. Therefore, the stability of any of these limit classifications is very low. An initial classification such as that indicated by the boundary line α in Figure 9 will have a limit

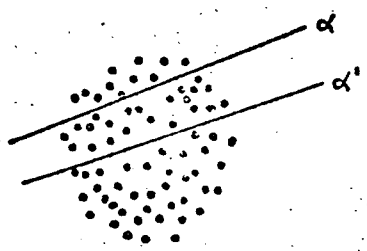


Figure 9

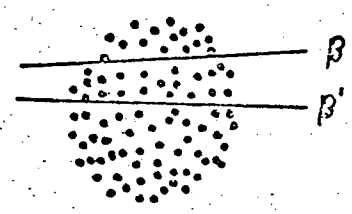


Figure 10

classification α', and a slighly different classification (line β in Figure 10) will lead to a different limit classification (line β' in Figure 10). A similar low stability characterizes limit classifications into m classes of points grouped into p clusters where $m \neq p$ These geometric

illustrations clarify why the degree of stability of limit classifications indicates to what extent a classification into a given number of classes is suited to objects having a given configuration of point images.

Chapter III

Interpretation of DP's

Why is it preferable to allocate an item using a DP, rather than allocating at random? The reply to this question is the key to the meaning of the DP's. When a new item is allocated at random, any class is equally likely to be chosen. Therefore, the allocation by DP's is justified when the classes are different from each other and it is desired to preserve the distinctive peculiarities of the classes by associating the new items with the items more similar to them.[15]

The peculiarities of the classes that the DP's are designed to preserve can be called rationale, principle, or spirit of the classificatio

The elusive and vague connotation of principles and rationales of classifications perhaps can be explained in terms of the non uniqueness of the DP's. The DP's are arbitrary sets of rules, leading to "interpretation of principles of classifications which are related, but are not identical. Therefore, the word "principles" covers a variety of distinct and related interpretations. A situation of this type is not unique. For instance, the variability of a statistical distribution can be expressed by an infinite r of measures (that is, rules) which in fact identify distinct and related i tions of variability. The concept of variability appears more precise and than that of principles of classifications only because in the former case

established usage has resulted in a universally accepted choice of a few measures (that is, interpretations) of variability.

The discriminant iterations were defined as the application of a discriminant procedure on all the objects in a classification for generating a new classification from the initial one. DP's allocate objects consistently with an interpretation of the principles, if any, on which a classification is based. Consequently, the new classification generated from an initial classification by a DP is also based on the principles of the initial classification. If the initial and the derived classification are not equal, the initial classification contained another element together with the "principles." The element which is not transferred to the derived classification(at least in its entirety) can be interpreted as a classificatory error because of the very fact that it is not a classificatory principle. The classifications obtained by repeated applications of DP's from an initial classification tend to be more and more exclusively based on the principles that in the initial classification were partially obliterated by "errors." A limit classification can be interpreted as being entirely purified of the errors contained in the initial classification, and as being an expression of the rationale of the initial classification as revealed by the DP.

Geometric Interpretation of Principles of a Classification

Vague expressions such as "principles of a classification" and "classificatory inconsistencies and errors" have a definite geometric meaning. Groupings of a classification can be conceived as swarms of points in a discriminant space. A given allocation of items is justified

if and to the extent that the point images of the items in any class are dominant over a region of the discriminant space. The concept of classificatory principles and errors is related to this association between point images of the items in a class and a region in the discriminant space. The more distinct this association is, the more a given classification can be related to classificatory principles rather than to classificatory errors. This partitioning of the discriminant space into regions such that the points of a class are dominant in a region can be equated to a formulation of the principles of a classification. Therefore, the discriminant procedures that perform such partitioning of the discriminant space lead to a formulation of the principles of a classification. The partitioning of the discriminant space, or formulation of the principles of a classification, involves objective and subjective phases. The incidence of the points in a class over a region of the discriminant space where the points in a given class are dominant form the objective basis of the partitioning. However, the actual delimitation of regions in the discriminant space requires the application of rules embodied in a given discriminant procedure. But very many sets of rules are possible which aim at dividing the discriminant space into regions characterized by the dominance of the points in a class. Therefore, the selection of a specific set of rules is arbitrary and forms the subjective element in the formulation of the principles of a classification.

Discriminant procedures partition the discriminant space into regions according to rules that identify a particular formulation of the principles of a classification. That is to say, the dominance of points associated with a given class over areas of the discriminant space is translated into a specific delimitation of regions by the rules embodied in a given DP.

Classifications are always characterized by some dominance, tenuous as it may be, of the points in each class over some areas in the discriminant space. This is true even when a classification is based on a random allocation of points to classes because it is always possible to find portions of the discriminant space where the points belonging to a given class are prevalent. Therefore, a classification is always based on "principles," the difference between good and bad classifications consisting in the degree of dominance of the principles, or, in other words, in the extent of overlap and intermixture of the swarms of points associated with the classes of a classification.

All classifications generated by discriminant iterations are based on the principles of the initial classifications, that is, on the dominance of the swarms of points in the classes of the initial classification over certain areas of the discriminant space. The discriminant iterations remove errors and inconsistencies from the initial classification because they generate a limit classification which is in agreement with the partition of the discriminant space based on it. In the limit classification the objects in any class have point images lying within the region of the discriminant space belonging to the class. The errors and inconsistencies in the non limit classifications correspond to the fact that some points in a class lie outside the region of the discriminant space associated with that class.

The distance between two points in the discriminant space can be interpreted as a measure of similarity of the objects associated with the points (Berry 1960). The discriminant procedures allocate items to the nearest representative point of a class, that is, to the class to which the

item is more similar. In a previous section of this paper it was shown that when the centroids of classes are chosen as representative points, the classification generated by DI's from an initial classification has a smaller within class variability that the initial classification. In turn, smaller variability corresponds to a smaller average distance among the points in the same classes.[16] Therefore, DI's generate new classifications in which the items in the same classes are more homogeneous, that is, more similar to each other.

This interpretation of the DI's is clearly consistent with the previous interpretation: eliminating errors and discrepancies is the same as increasing the degree of homogeneity of the classes. Limit classifications posses a greater within classes homogeneity than any other of the classificati of which they are the limit. By combining the "similarity" and "principles" interpretations, limit classifications can be said to maximize the within classes homogeneity, subject to the preservation of principles characterizing the classifications of which it is the limit. Geometrically, this means that limit classifications possess minimum average within grouping distances compatible with the preservation of the dominance of the classes items over given areas of the discriminant space.

Meaning of "Stability"

In previous sections it was pointed out that 1) the degree of stability of a limit classification is measured by the number of non-limit classifications of which it is the limit and 2) a limit classification and the non-limit classifications associated with it are based on the same classificatory principles. Therefore, a limit classification is the more stable the larger is the number of non limit classifications with which

it has in common some classificatory principles. In turn, the number of classifications based on a set of principles measures the compatibility between principles and the configuration of point images representing the objects. The larger this number is in proportion to the total number of classifications, the more the principles are suited to the objects classified. The most stable limit classification (and its principles) is best suited to the configuration of point images representing the objects in the problem and the discriminant space.

Stability can also be used for comparing classifications of the same objects into different number of classes. Suppose that the best limit classifications of m objects into 1,2,3....m classes are compared with respect to degree of stability. In a previous section it was indicated that high stability tends to be attained 1) when the point images are to some extent clustered, and 2) when the classes correspond to the clusters. The best limit classifications, therefore, will have classes corresponding to the well differentiated clusters of point images. When a definite differentiation into clusters is lacking, the best of the best limit classifications will differ only slightly from the 2nd, 3rd best etc. The classifications into one and into m classes should be disregarded because obviously they always have maximum stability.

The conceptual definition and practical identification of "natural" classifications has been of concern in many fields of science. Stability can be interpreted as an indication of "naturality" in classifications. A classification is generally considered natural when it is based on

similarities of objects, so that it appears imposed by the very nature of the objects as they are identified by the variables used, rather than by an arbitrary choice. But in one sense an arbitrary choice is unavoidable because similarities are based on a viewpoint which is arbitrary. But given a viewpoint it is possible to distinguish between arbitrary and natural classifications, the latter ones being characterized by optimal homogeneity within the classes. The degree of stability of a limit classifica measures to what extent the classification is suited to objects having the characteristics expressed by the point image configuration corresponding to them. Therefore stable and natural can be considered equivalent connotations of classifications.

Subjective and objective elements in classifications are related in two different ways. Any classification is based on characteristics or aspects of objects which are results of an arbitrary choice, and in this sense any classification is arbitrary. When the aspects to be considered are given, the objects can display various degrees of similarity. This corresponds to the degree of clustering of their point images in a space whose axis are related to those of their characteristics which are being considered. When low or no clustering exists, any classification is arbitrar Instead classifications that group into the same classes objects whose images are in same clusters tend to be natural and stable, not arbitrary or artificial.

Within a probabilistic framework distinct clusters correspond to distinct populations. Therefore, the connotations of stability and naturality can be related to classifications the classes of which correspond

to statistically identifiable populations.

Chapter IV

Uses of Discriminant Iterations

Discriminant iterations can be used 1) for assessing the relative quality of a classification (quality relative to given variables and to a given discriminant procedure), 2) for determining and analyzing cores of classifications (for instance, cores of systems of regions), and 3) for deciding whether and to what extent different sets of variables support a classification (for instance, is a given regionalization equally valid with respect to physical and economic data?). These uses will be discussed in this chapter.

Evaluation of the Relative Quality of a Classification

Assessing a classification with respect to given data and DP involves determining to what extent the classification is based on the principles interpreted by the DP. This is equivalent to determining the respective roles played by these principles and by the random or non-linear factors which the DI rejected. A convenient basis for this assessment is provided by the relationships between the classification and its limit. This can be investigated by considering: 1) the number of DI's required in order to generate the limit classification, 2) the difference between the classification and its limit with respect to ratios such as the within-class to the total variability, or the between classes to the within-classes variability, and 3) the item dispacement which generated a limit from the initial classification.

The number of discriminant iterations which transform a classification

into a limit classification are somehow indicative of the "distance" between the two classifications, and of the weight of random and/or non linear elements present in the originary classification. The classification "nearer" to its limit is "better" with respect to given variables and to a given discriminant procedure. However, this distance should be used only for comparing different classifications of the same objects into the same number of classes.

The ratio R^* of the within classes to the total variability is a measure of the homogeneity of the items in same groupings, smaller values of R correspond to higher homogeneity. Clearly R^* is the smaller 1) the more the items are clustered and 2) the more the groupings coincide with the clusters. Therefore, R^* indicates to what extent a given classification is suited to given objects and it can be used for comparing which one of several classifications is better adapted to the objects. In contrast with S which has purely theoretical value due to the difficulties involved in its computation, R^* can be easily obtained from the eigenvalue output of discriminant iterations routines based on discriminant functions. The sum of these eigenvalues ($\sum E$) is the ratio of the between to the within classes variability. Therefore $R=(1+\sum E)^{-1}$ Call V_I^2, V_{II}^2, and V^2, respectively, the between classes, within classes and total variability. Then $R^* = V_{II}^2/V^2$ is easily proved. By definition,

$\sum E = V_I / V_{II}$. Considering that $V_I^2 + V_{II}^2 = V^2$, it is clear that

$$R^* = 1/ (1 + V_I^2 / V_{II}^2) = V_{II}^2 / V^2.$$

The ratio R of the between classes to the within classes variability (where $R = \sum E$) is also a measure of the quality of classifications, for the

reasons discussed for R°. R can assume values from zero to infinity, small values corresponding to poor classifications (within classes variability large with respect to the between class variability) and, conversely, large values indicating good classifications. The values zero and infinity are obtained, respectively, when n items are classified in one class, and in n (non empty) classes. Perhaps R is more difficult to interpret than R because the range of values 0 to infinity is less convenient than that of R°, from 0 to 1.

The differences between the class location of the items in a classification and in its limit are useful for investigating the extent and nature of the changes caused by the DI's.

A simple tool for measuring these changes is the ratio V of the number of items not in same classes in the initial and limit classification, divided by the total number of the items. V is a measure of quality of the initial classification. The smaller the value of V, the fewer are the items displaced, and therefore the stronger is the systematic classificatory element in the initial classification that is "interpreted" by the DP in the DI's.

The differences in the items' class location can be used for evaluating on a probabilistic basis the comparative roles, within the initial classification, 1) of the systematic classificatory elements "interpreted" by the DP used in the DI's, 2) of the systematic classificatory elements that would require a DP of a higher degree, and 3) of the random classificatory elements. To this effects two tests can be used. These will be referred to as test I and test II. Test I is designed to determine at a given significance level whether the difference

between an initial classification and its limit is due to an error. The limit classification is based entirely on the principles of the initial classification as they are interpreted by the DI's. Therefore, the null hypothesis that that initial classification and its limit are not significantly different in fact is the hypothesis that the principles dominant in the limit classification are also the dominant elements in the initial classification. Rejecting the null hypothesis is equivalent to asserting that in the initial classification there are significant classificatory elements later removed by the DI's. The limit classification can be considered as expected and the initial classification as observation, and the null hypothesis tested by chi square. The test can be applied by using the difference between the number of items predicted for a grouping (that is the number of items found in the grouping in the limit classification) and the number of items predicted for that grouping and actually found in it (that is the number of core items for that grouping). An example of application of test I is discussed in next chapter.

Test II is intended to differentiate between two situations which can be considered as the extremes of a continuum. In the first extreme the items are allocated to classes at random, so that the point images of the items are intermingled and the association of these classes with certain regions of the problem space is a very vague one. In the second extreme situation, instead, the points in different classes are not intermingled and the association between classes and regions in the problem space is very distinct one. DI's, for instance linear DI's in the first situation, reshuffle the classes in such a way that any item in any class has an equal probability of being sent to any other class. In the second

situation the DI's send items from their classes to the classes which occupy contiguous regions in the problem space. The first situation identifies random or high degree non linear classificatory factors. The second situation, instead, corresponds to low degree non linearities. The differentiation between the two cases can be obtained by testing the hypothesis that the items moving out of any class of the initial classification have an equal probability of moving into any other class. Rejecting and failing to reject the hypothesis indicate, respectively, situations of the second and of the first kind.

For determining the probabilities above, some assumptions are needed. The simplest assumption is that all classes occupy approximately equal portions of the problem space. In this case the probability of an item from class i being allocated to class j is 1/(m-1), where m is the number of the classes. This assumption, however, has an indesirable rigidity and perhaps it is better to use some measure of class size for assessing the portion of problem space occupied by each class. In the application of test II in the following chapter, it was assumed that the number of items in the classes of the limit classification measures the portions of problem space occupied by each class.

Test II was constructed as follows. Call $n_1, n_2, \ldots n_m$ the number of items in class 1,2,....m of a limit classification. The probability that an item removed from class i is allocated to class j can be indicated by a_{ij} where

$$a_{ij} = n_j \Big/ \sum_{\substack{p=1 \\ (p \neq i)}}^{m} n_p$$

The subscript of sigma indicates that the summation is performed for all the values of p with the exception of i. The matrix $A = (a_{ij})$ has zero in the principal diagonal, and obviously $\sum_j a_{ij} = 1$

Call $d = [d_1, d_2, \ldots\ldots d_n]$ a vector in which the ith element d_i indicates the number of items removed from class i of the initial classification.

Call t_i the number of items allocated to the ith class of the limit classification under the null hypothesis that any item moved out of any class had an equal probability of being allocated to any other grouping.

Term t the vector

$$t = (t_1, \ldots\ldots t_n)$$

Clearly

$$dA = t$$

t is the expectation vector opposed to an observation vector

$t^\circ = (t^\circ_1, \ldots\ldots t^\circ_n)$

in which t°_i is the number of non core items in the limit classification.

Then the null hypothesis can be tested by $\chi^2 = \sum_i \left[(t_i - t^\circ_i)^2 / t_i \right]$ for n-1 degrees of freedom.

Core of Classifications

In geography the part of a region where the characteristics which differentiate the region are particularly evident is referred to as "core" of the region. By analogy the core of a classification can be defined as the items displaying most distinctly the peculiarities of the groupings of the classification. If the items are thought of as points in a t dimensional space, the cores of a grouping are formed by the items which are nearer to the center of the grouping.

Often classifications are obtained: 1) by selecting certain items

or groups of items considered most representative of the principles of the classification and 2) by allocating to them the remaining items. Probably the majority of empirical classificatory procedures, especially in geography, are of this nature. The discriminant iterations can be also used 1) for a quantitative determination of the cores of a classification and 2) for determining whether a classification of a subset of the items classified by G, is a core of G.

The cores of a classification are defined here as the sets of items found in the same groupings in the classification and in the limit classification generated from it by discriminant iterations. In other words, given two classifications, G of n items and G' of k of the n items ($k<n$), G' is core of G with respect to a given discriminant procedure if G' is the collection of sets of items found in same groupings in G and in its limit. The relationship between G and G' can be expressed by the ratio V' of the number of items in G' divided by the total number of items in G. V' measures the weight of the core in the classification and is the larger the nearer the classification is to its limit. V' is linearly related to the coefficient V measuring the distance between a classification and its limit. That is

$$V' = 1-V$$

Clearly a limit classification is equal to its own core. The core can be useful to identify the distinctive features of the classifications. The core items are vivid picture of the principles of the classifications as they are formulated by a given discriminant procedure. Furthermore, when G has been obtained from a classification H of r of the n items of

G(n-n) by allocating by some empirical or non empirical procedure the remaining n-r items to the groupings in H, a comparison of the cores of G and H can throw light on the conditions and limits of validity of the classificatory procedure. This procedure assumes that a subset of better differentiated items can determine the structure of a classification into which the remaining items will fit without substantially changing this structure. If the groupings in the cores of H are subsets of the groupings in the core of G, the principles of the classification were not changed when H was expanded into G, and, therefore, the use of this procedure was justified. A strong difference between the cores of G and H would indicate, instead, that when H was expanded into G the principles of the classification were substantially changed, in which case the classificatory procedure used was not justified.

Testing a Classification with Respect to Different Sets of Data

The discriminant iterations can be employed for deciding whether and to what extent a classification can be associated with different sets of variables measuring different characteristics of items. Suppose that the same discriminant iterations, based on the same discriminant procedure, are applied on a classification G by using different sets of variables. The variables in one set may be only partly different from those in the other set, or one of the sets may be a subset of the other. Each set of variables will be associated with a limit generated from G by DI's. The set(s) of variables yielding the limit classification(s) nearest to G are optimally associated with G. By using the procedures outlined in this chapter it can be decided with respect to what sets of variables a given classification is random, and with respect to what other sets of

variables it shows strong non linear factors. Suppose that G' and G" are two limit classifications generated from G by two different sets of variables. The intersection of G' and G", that is the groupings of items found in corresponding groupings in G' and G", indicates that portion of G is optimally associated with both sets of variables. The ratio W of the number of items in the intersection of G' and G" divided by the total number of the items measures to what extent both sets of variables "support" or "justify" the classification G. If V'(GG') and V'(GG") are the core-weight measures V' for G, G' and for G, G", it is evident by the definition of V' and W that

$$W \leqq V'(GG') \qquad \text{and} \qquad W \leqq V'(GG")$$

The equality holds when both sets of variables support G to same extent. The more the two sets of variables differ in their support of G, the smaller is W in relation to the right-sides of the inequalities.

The techniques discussed in this chapter can be viewed as tools for applying scientific methodology to the analysis of classifications. Initial classifications can be considered as empirical data to be evaluated against models. A model is generated from a classification by a priori rules (discriminant iterations) and assumptions (the association of set(s) of variables to the classification). The comparison of the model (limit classification) with the initial classification is based on rules and techniques designed to give meaning to differences between empirical datum and model. The analysis proposed reaches conclusions regarding a classification, its cores, and its association with sets of variables.

These follow when certain procedures and assumptions are accepted.

Chapter V

Discriminant Iterations Analysis of Climatic Data

A discriminant iteration analysis was attempted on three classificatio of North American climatic stations by using the Discriminant Iterations program (see Appendix I). The climatic stations were originally associated with 24 variables (monthly averages of temperature and precipitation). The information contained in the initial variables was condensed into a smalle number of orthonormal variables by the component analysis program BMD 02 (modified so as to ouput labeled orthonormal scores on card format). The scores with respect to the first six components formed the input of the Discriminant Iterations Program.

The DI analysis was performed:

1) On a modified Koeppen classification of the climatic stations.
2) On a "disordered" classification obtained from the classification above by changing at random the position of the cards separating the stations in same climatic regions.
3) On a "shuffled" classification obtained by shuffling the input cards and by locating the separating cards at random.

The disordered and the shuffled classifications are based on random factors, in contrast to the climatic classification which is dominated by systematic classificatory factors. Therefore the DI technique was tested in situations spanning the two extremes of the continuum which links random and "reasonable"

classifications.

Discriminant Iterations Program

This section outlines the structure and uses of the discriminant iterations computer program. For "write up" and text of the program see the Appendix. The discriminant iterations program accepts an input made up of a name followed by a sequence of up to ten values. The name identifies one of the objects in the classification, and the values are orthonormalized measures, that is orthonormal coordinates associating the object to one point in the problem space. In the input the cards corresponding to objects in a same class are separated by subset cards from the cards corresponding to the preceding and following class. The program performs in sequence the following steps: 1) Multiple Discriminant Functions are computed from the input and are subsequently employed for determining the coordinates (scores) of the objects in the discriminant space,

2) the Euclidean distances of each object from each class' center of gravity are calculated from the coordinates of the objects in the discriminant space,

3) for each object the "nearest" class is determined,

4) the objects are allocated to the nearest classes. The data are reordered in conformity to the new classification. The reordered data form a new input, on which the operations in steps from 1 to 4 are performed again, iteratively. The computation is ended if a limit is reached, that is if any object is reallocated to the class

to which it belonged, or after the maximum number of iterations indicated in the control card.

The printout which is important for interpreting the results of the discriminant analysis is : 1) the "Result" and "RX" matrices, 2) the sum of the eigenvalues, 3) the "Final Tables".

The Result Matrix contains the loadings of the initial variables on each discriminant function, each column being associated with a discriminant function and each row with an initial variable. The RX matrix contains the scores of each object with respect to each discriminant function. The Result and RX matrix are calculated and printed out at each iteration. They can be used for determining for any classifications the dimensions of discrimination (see Caratti 1964).

The sum of the eigenvalues R (see pages 34-35) required for calculating the discriminant functions is also computed and printed out at each iteration. R equals the ratio of the between classes to within classes variability of the classification. It was shown that R is a measure of quality of classifications because in "better" classifications the between class variability occupies a larger share of the total variability. The increases of the R's corresponding to an initial classification and to classifications generated from it by DI's, measure the improvement in quality obtained as a result of the iterations.

The Final Table, which is output after the last of the iterations, indicates in what class each object is located in the initial classification and in all the classifications generated from it by DI's. In the Table the names of the objects are ordered and divided into classes the same

as the initial classification. Next to each object's name there is a row of integers indicating in which class the objects were located in the first, second,... nth iteration, in that order. Therefore the first, second,... nth column of the Table correspond to the first, second,...nth classification generated by DI's. From the Final Table it is easy to separate "core" and "non core" objects. For instance an object located in the ith class of the initial classification is core or non core respectively if the last digit in its row in the Final Table is 1 or not.

Data

The discriminant iterations analysis was attempted on classifications of North American climatic stations. Some 70 climatic stations located in the United States and Canada were used. Each station was initially associated with 24 measures corresponding to average precipitation and temperature, by month, published in Kendrew,1961,p.458-63, (Table I). A component analysis of these measures was performed in order to collapse the information available into a smaller number of orthonormalized variables required by the discriminant iterations program. The main results of the analysis are shown in Tables II, III, and IV containing, respectively, the variance accounted for by the first six components, the loadings of the variables in the first six components, and the stations' scores with respect to the first six components*. The component analysis revealed that 93 per cent of variability of the 24 initial variables is concentrated in the first three principal components. The first component, which accounts for 60 per cent of the total variability,

* The components referred to in Tables II,III and IV are orthogonal but not orthonormal. See note at page 54.

ranks the stations according to precipitation and temperature levels. High positive scores denote stations characterized by scanty precipitation and low temperature High negative scores denote abundant precipitation and high temperature Map 2 shows that negative scores identify a belt along the West and East Coast, and that positive scores demarcate the North and the interior of the continent. The second component (22 per cent of the variability) identifies a continuum with arid climates at one extreme (high positive scores associated with low precipitation and high temperature) and climatic conditions characterized by low temperature and high precipitation at the other extreme (high negative scores, see Map 3). The third component (11 per cent of the variability) identifies a continuum at the extreme of which are West Coast climates (high positive scores associated with precipitation and relative high temperature in Winter and Spring) and East Coast climates (high negative scores associated with high precipitation and temperature in Summer, see Map 4).

The stations were grouped to form 1) a classification of the U.S. and Canada into climatic regions,2) a disordered classification and 3) a shuffled classification.

The classification into climatic regions reflects the climatic classification embodied in the map at page 9 of Goode's School Atlas revised by E.B.Espenshade Jr.,1949, and is based on the modifications made by G.T.Trewartha on the Koeppen classification. The climatic regions considered are those referred to by symbols B, Caf, Cbf, Ca, Daf, Dbf, Dcf, and Et. Subclassifications were ignored and undifferentiated highland, H, was not used. Stations in H were allocated to the nearest

climatic regions. The AH region was disregarded because of its limited representation (Miami only) in the area studied.

The disordered classification was obtained from the deck of IBM cards containing the climatic classification by removing and reallocating at random the cards separating the subsets (climatic regions).

The shuffled classification was obtained from the climatic classification card deck 1) by removing the cards separating the subsets, 2) by shuffling the deck, and 3) by reallocating at random the subset partitions. Empty subsets were avoided. The three classifications were used as input to the discriminant iterations program.

The portions of the computer output that were used for interpreting the results of the DI's are given in Table V, VI, VII, and VIII, and in the maps derived from them. Tables V, VI, and VII are the Final Tables for the climatic, disordered, and shuffled classifications, respectively. Some of the information contained in Tables V, VI, VII, was transferred to maps. In Map 5 each station is associated with two digits indicating respectively the number of the subset to which the station belongs in the Climatic classification and in the limit classification generated from it by DI's. Maps 6 and 7 give same information for the disordered and the shuffled classifications respectively. In Maps 5, 6, and 7 the stations associated with two <u>equal</u> digits such as 11, 33, 55, etc., indicate "core" stations, which the DI's did not remove from their initial subset. The cores are shown by a line surrounding the core stations. In Maps 8 and 9 the stations are associated with the number of the subset to which they belong respectively in the climatic classification and in its limit. Similar information for the disordered and shuffled

classifications and their limits is contained in Maps from 10 to 13. Lines separating stations belonging to different subsets and which therefore identify regions were drawn in Maps 8, 9, 11 and 13. In Maps 10 and 12 (disordered and shuffled initial classifications) regions cannot be identified because of the prevalence of random factors. Table VIII shows the ratio of the between to the within class variance for the three initial classifications and for the classifications obtained from them by DI's.

The purpose of the DI's analysis is 1) assessing the quality of given initial classification relative to a set of data and a DP, 2) improving an initial classification from the viewpoint embodied in a given data and DP, by generating a limit classification that preserves its rationale and at the same time is in optimal agreement with the data and the DP used, 3) identifying cores of classes, and 4) determining whether the difference between an initial classification and its limit is to be accounted for in terms of non linear or random classificatory elements. The climatic, disordered, and shuffled classifications on which the DI analysis was performed provide a good test for the techniques proposed in this paper because they were arranged so as to contain an amount of noise increasing from the first to the last. For simplicity, the climatic, disordered, and shuffled initial classifications will be henceforth referred to as CL1, CL2, CL3.

Table VIII shows that CL1 is "nearer" to its limit in terms of iterations than CL2, and CL3, in agreement with the tendency for classifications richer of random elements to be farther from their limit. The ratio R,

which is an indication of the quality of a classification, is highest for CL1 and lowest for CL3. The limits of CL2 and CL3 have lower R's than the limit of CL1, which means that the systematic elements in CL2 and CL3 correspond to inferior classifications to that associated with the systematic elements in CL1. The overall increases of the R's for the sequence of classifications generated from CL1, CL2, and CL3 by DI's shows that the iterations bring about improvements on the classifications operated upon. The minor decreases marked by asterisks are in all likelihood due to computational (round off) errors.

The core items are 46, 36, and 20 in number (on a total of 63 items) respectively for CL1, CL2, and CL3. This confirms that the size of the cores of classifications is inversely proportional to the weight of random (and in general non linear) classificatory elements. From Maps 5, 6, and 7 it is evident that the cores identify homogeneous sets of stations irrespective of the weight that random and linear classificatory elements have in the initial classification. The cores in the shuffled classification (map 7) are smaller for the number of stations and areas involved but are not less homogeneous than, say, those of the climatic classification. This conferms that the DI's single out the "sound" aspects of a classification even when they are hidden by a prevalent noise. In the cores the same stations tend to appear associated together. This probably reflects the existence of well identified clusters in the point configuration corresponding to the stations and to the data used. A comparison of Map 10 and 12 with Maps 11 and 13 shows that the DI's generate limit classifications dominated by systematic elements which were completely obliterated in the initial classifications. Maps 10 and

12 demonstrate clearly that random classificatory elements are present in the CL2 and CL3 and from Maps 11 and 13 it is equally clear that the limits of CL2 and CL3 are dominated by systematic classificatory elements. Actually, in Maps 11 and 13 1) the stations belonging to same classes are contiguous and not widely scattered and intermingled with stations in other classes, 2) regions including stations located in the same classes can be delimited by relatively simple (that is, low degree) curves, and 3) the boundaries of regions tend to follow N-S and NE-SW directions perpendicular to the maximum gradient of climatic elements. A comparison of Maps 8 and 9 does not suggest the presence in CL1 of a strong random classificatory factor, but rather indicates that CL1 and its limit differ by some low degree non linearities. Maps 9, 11, and 13 present traits strikingly similar. There are groupings of stations, for instance, on the West Coast, on the SE Coast, in Alaska, in the Southern interior of the continent etc., that are located together in same classes in the limits of CL1, CL2, and CL3. These similarities, as those noticed in the cores, probably reflect peculiarities of configuration of the points which are the images of the stations. Certain groupings of stations correspond to well defined clusters in the problem and discriminant spaces, which explains both their appearing in the same classes and the similarity of the boundaries in the limit classifications Maps. Possibly the three limit classifications correspond 1) to different regroupings of well identified point clusters which behave as units in the sense that are not divided among different classes and 2) to a different apportionment of the points which do not form well defined clusters, among clusters.

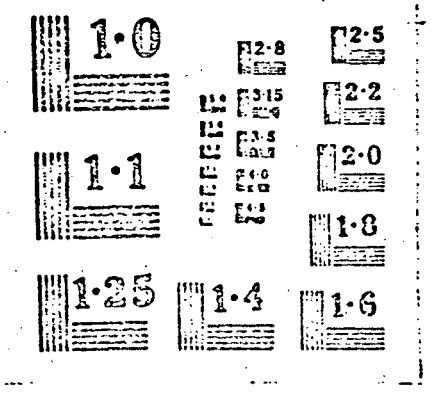
Tests I and II were applied on CL1, and CL2 and CL3. The results

are given in Table IX. Table X shows the vectors d, t, t* and the matrices A's required for Test II.

Table IX indicates that the null hypothesis that the initial classification and its limit are not significantly different (Test I) cannot be rejected for CL1, but is to be rejected at the level of .001 for CL2 and CL3. This confirms that Test I actually differentiates between classifications dominated by systematic elements, and classifications dominated by "noise." The null hypothesis that the stations moving out of any class of the initial classification had an equal probability of being allocated to any other class of the limit classification (Test II) is rejected at the level .05 for CL1, and cannot be rejected for CL2 and CL3. This means that the differences between initial and limit classifications are due to non linearities in CL1, and are instead due to random perturbations in CL2 and to a larger extent in CL3. The results are consistent with what is known about the nature of the three classifications.

Conclusion

The discriminant iteration analysis of classifications of North American climatic stations demonstrates the potentialities that the methods proposed have for evaluating classifications from the viewpoint embodied in given data and DI's. In the earth sciences and particularly in geography, a wealth of useful and valid classifications have been developed, modified, and improved by generations of researchers. This paper is an attempt to contribute tools and to sharpen concepts that could be used to investigate, criticize, and improve these classifications.


1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·8
1·1
1·25
1·4
1·6

CONT.

TABLE I

NORTH AMERICAN CLIMATIC DATA

A Temperatures

	altitude	J	Feb	Mar	Apr	May	Ju	Jul	Aug	Sep	Oc	No	De
ATLIN	2240	7	10	21	33	43	51	54	53	46	37	24	14
BANFF	4521	13	15	26	37	46	52	58	56	48	39	20	15
CALGARY	3540	16	17	26	39	50	56	62	60	52	42	20	19
CHURCHILL		43	-14	-15	-05	12	30	42	55	53	43	29	7
COPPERMINE		13	-19	-21	-14	1	22	39	49	47	36	19	-04
DAWSON CITY	1062	-16	-11	6	28	47	57	60	55	43	27	2	-13
EDMONTON	2219	0	11	23	40	52	50	63	60	51	41	24	12
F GOOD HOPE	214	-21	-19	-08	14	39	56	60	53	41	22	-05	-19
HALIFAX	99	24	23	31	40	50	58	65	65	59	50	40	29
HEBRON	49	1	-03	10	23	32	40	50	50	41	34	26	14
LILLOET	840	26	32	45	51	59	66	72	70	62	51	39	29
LONDON	912	23	22	32	43	55	65	70	68	65	49	37	26
MEDICINE HAT	2365	14	16	29	44	55	62	70	67	56	46	29	19
MONTREAL	107	15	16	20	42	56	66	70	68	60	48	35	21
MOULD BAY		50	-29	-33	-25	-07	12	31	38	34	20	1	-15
OTTAWA	339	12	13	25	41	54	64	69	66	58	46	33	17
PORT ARTHUR	644	8	10	21	35	47	57	63	62	53	43	27	14
PRINCE GEORGE	2218	15	19	30	41	50	56	60	58	50	41	26	18
PRINCE RUPERT	1700	36	37	39	43	49	53	56	57	54	48	42	37
QUEBEC	296	12	13	25	38	52	62	68	65	57	45	32	18
ST JOHN	243	24	22	28	35	43	52	60	61	54	46	38	30
TORONTO	379	25	24	32	44	55	66	71	69	62	50	39	28
VANCOUVER	22	39	40	44	50	56	61	64	64	59	52	44	40
F VERMILLION	950	-09	-04	11	32	43	57	62	58	46	34	11	-05
VICTORIA	228	39	42	45	49	54	57	60	60	57	52	45	41
WINNIPEG	786	1	4	19	38	52	62	68	66	55	43	23	8
ALBANY	97	24	24	34	47	59	68	73	71	63	52	40	28
BARROW		22	-16	-19	-15	1	20	35	40	39	31	17	1
BOISE	2844	29	35	43	50	58	66	74	72	62	52	41	32
BOSTON	124	28	29	36	46	57	67	72	70	63	54	42	32
CHARLESTON	9	50	52	58	65	73	79	82	81	77	68	58	51
CHICAGO	824	24	27	36	47	57	67	73	72	65	54	40	29
CLEVELAND	571	26	28	34	46	58	67	71	70	64	54	41	31
DENVER	5272	30	32	39	47	56	67	72	71	63	51	39	32
DES MOINES	800	21	24	36	50	61	71	75	73	65	53	39	26
DULUTH	1128	8	12	24	37	47	58	64	63	55	44	30	16
EUREKA	60	47	47	48	50	52	55	56	56	56	54	51	48
GALVESTON	69	54	56	63	69	75	81	83	83	80	73	63	56
HARRISBURG	361	30	30	40	51	62	70	75	73	66	55	43	33
HELENA	3893	20	24	33	44	52	60	67	66	56	45	33	25
INDIANAPOLIS	718	29	31	41	52	63	72	76	74	67	56	42	32
LAS VEGAS		44	50	55	63	70	80	85	84	76	65	53	45
LITTLE ROCK	357	43	45	53	62	70	78	81	80	74	64	52	44
MIAMI	25	68	68	71	74	77	80	82	82	81	78	73	69
MONTGOMERY	201	49	51	58	65	73	80	82	81	77	66	56	49
NASHVILLE	546	39	41	50	59	68	76	79	78	72	61	49	41
NEW ORLEANS	3	55	57	63	69	75	81	83	83	79	71	62	56
NEW YORK	314	31	31	38	49	60	69	74	73	69	59	44	35
NOME	13	4	6	9	20	34	46	50	49	42	29	16	8
OMAHA	1103	22	26	37	51	62	72	77	75	66	54	39	27
OSWEGO	335	24	24	31	43	53	63	70	68	61	51	39	29
PIKES PEAK	14111	2	4	8	13	23	33	40	39	32	22	11	6
PITTSBURGH	749	31	31	40	51	62	70	74	72	67	55	43	34
PORTLAND 3	154	39	42	46	52	56	62	66	66	61	54	47	41
RALEIGH	390	41	43	50	59	68	75	78	77	71	61	51	43
SACRAMENTO	69	46	51	54	59	64	70	74	73	70	63	54	46
SALT LAKE	4260	26	33	41	50	59	67	77	75	64	53	38	31
SANT ANTONIO	701	53	56	63	69	75	81	83	84	79	71	61	54
SAN DIEGO	19	55	55	57	59	61	64	67	69	67	64	60	56
SAN FRANCISCO	52	50	53	54	55	57	59	59	59	62	61	57	52
SITKA	15	33	34	37	41	47	52	55	56	52	46	39	35
ST LOUIS	568	32	35	45	56	66	75	79	78	71	59	46	36
ST PAUL	840	12	16	29	45	58	67	72	69	61	48	32	19
SANTA FE	7000	29	33	40	47	55	65	68	67	61	50	39	30
SEATTLE	125	40	42	45	50	55	60	63	64	59	58	46	42
VICKSBURG	247	48	51	59	66	73	79	82	81	77	66	57	50
WASHINGTON	72	34	36	44	54	64	73	77	75	68	57	46	37
FORT YUKON	417	-19	-16	1	22	44	53	61	55	43	21	-05	-20
YUMA	141	54	59	64	70	76	85	91	90	85	73	62	55

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NORTH AMERICAN CLIMATIC DATA

B Precipitations

	J	F	M	A	M	J	J	A	S	O	N	D
ATLIN	12	7	4	3	4	8	12	10	11	16	13	10
BANFF	10	11	10	11	17	26	16	20	16	15	13	16
CALGARY	6	7	11	15	19	35	24	20	18	9	8	6
CHURCHILL	4	3	7	7	6	14	25	24	19	15	8	6
COPPERMINE	6	4	7	7	6	9	15	17	13	12	8	6
DAWSON	9	6	6	4	11	12	17	18	13	11	10	10
EDMONTON	9	8	9	11	18	30	31	23	12	8	9	9
F GOOD HOPE	7	6	6	5	8	12	16	21	12	12	10	6
HALIFAX	52	40	43	45	44	43	36	41	46	51	50	52
HEBRON	20	17	16	19	22	35	15	20	36	12	12	25
LONDON	35	28	29	30	31	34	37	28	35	28	35	33
MEDICINE HAT	7	7	8	10	15	23	14	14	15	7	7	8
MONTREAL	35	27	33	34	33	38	40	35	37	34	39	34
MOULD BAY	1	1	1	1	3	3	6	5	5	2	1	1
OTTAWA	27	22	28	26	28	34	35	30	31	27	30	30
PORT ARTHUR	22	16	20	21	25	43	28	37	33	26	25	21
PRINCE GEORGE	19	15	13	10	15	22	21	23	22	21	21	21
PRINCE RUPERT	94	75	79	68	51	40	47	55	80	123	123	105
QUEBEC	36	28	30	33	36	45	44	44	42	37	40	33
ST JOHN	53	51	46	38	39	31	31	40	37	48	57	60
TORONTO	27	23	26	26	27	27	32	24	27	23	26	23
VANCOUVER	79	60	53	36	27	21	14	16	32	65	69	95
F VERMILLION	7	7	7	6	14	17	19	17	13	6	7	9
VICTORIA	41	31	22	12	10	9	5	7	13	29	36	48
WINNIPEG	9	8	11	12	21	26	27	25	23	14	11	9
ALBANY NY	24	24	27	26	29	35	35	36	31	28	27	24
BARROW	2	1	1	1	1	3	9	8	5	5	3	2
BOISE	19	16	12	14	8	9	2	2	5	11	14	17
BOSTON	36	33	38	35	31	32	33	36	32	33	36	34
CHARLESTON	29	33	34	28	32	47	73	66	51	32	23	28
CHICAGO	20	20	26	28	34	35	33	32	31	26	24	20
CLEVELAND	26	21	27	26	26	28	34	27	31	26	24	25
DENVER	3	5	11	21	20	13	16	15	12	10	6	7
DES MOINES	11	11	18	29	44	48	34	36	36	25	15	12
DULUTH	10	10	15	20	32	41	38	32	35	24	15	11
EUREKA	75	65	52	33	18	7	1	2	10	23	52	63
GALVESTON	35	28	25	35	35	35	41	38	53	45	33	41
HARRISBURG	30	27	31	30	29	37	35	41	34	30	20	29
HELENA	9	6	8	11	21	22	11	8	12	9	7	8
INDIANAPOLIS	30	27	40	36	39	40	39	33	32	28	33	30
MIAMI	28	21	25	32	68	70	61	63	80	92	28	20
MONTGOMERY	51	55	63	47	39	41	47	40	31	24	35	47
NASHVILLE	46	41	51	43	38	41	40	36	34	26	25	40
NEW ORLEANS	46	42	47	48	45	55	66	58	48	35	38	46
NEW YORK	37	38	36	32	32	33	42	43	34	35	30	36
NOME	11	11	9	8	6	11	27	38	28	16	11	11
OMAHA	7	9	13	27	37	46	40	34	33	23	12	9
OSVEGO	27	25	27	26	29	30	28	26	29	33	30	30
PIKES PEAK	16	15	20	35	38	16	42	38	17	14	19	26
PITTSBOURGH	30	26	30	30	31	37	42	32	25	26	23	28
PORTLAND	40	39	40	35	33	33	33	32	32	32	35	39
RALEIGH	36	42	38	38	45	53	53	53	37	28	23	35
SACRAMENTO	38	28	28	15	8	1	1	1	3	8	19	38
SALT LAKE	13	15	20	20	20	8	6	8	10	15	14	14
SAN ANTONIO	14	18	18	32	32	25	21	24	31	22	19	16
SAN DIEGO	19	21	15	7	3	1	1	1	1	4	9	20
SAN FRANCISCO	47	38	31	15	7	1	1	1	3	10	25	44
SITKA	78	67	61	55	42	33	43	72	104	128	102	91
ST LOUIS	23	25	35	38	45	45	35	34	32	29	28	25
ST PAUL	9	10	14	24	32	42	35	29	31	22	13	11
VICKSBURG	51	48	55	53	43	38	44	34	30	27	41	52
WASHINGTON	33	30	36	33	37	39	44	43	37	29	26	32
FORT YUKON	4	4	3	3	5	8	11	12	6	6	4	3
YUMA	4	4	3	1	1	1	2	6	4	3	2	5

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TABLE II

NORTH AMERICAN CLIMATIC REGIONS

Proportion of the Total Variance Accounted for by the First Six Principal Components

Princ. Comp. No.	Variance in the ith Princ. Comp.	Cumulative of the Total Variance in the First i Princ. Comp.'s
1	.60	.60
2	.22	.82
3	.11	.93
4	.03	.96
5	.01	.97
6	.01	.98

Note

The principal components referred to in Tables II, III, IV, and in Maps 2,3,4, were obtained by using the computer program BMD 02. These components are orthogonal but do not have unit variance. The components were later normalized in order to use them as input to the discriminant iterations program.

TABLE III

NORTH AMERICAN CLIMATIC REGIONS

Loadings of the Variables in the First Six Principal Components

Components:	1	2	3	4	5	6
PRECIPITATION						
Jan.	-0.18	-0.25	+0.28	-0.17	+0.02	+0.07
Feb.	-0.19	-0.23	+0.24	-0.24	-0.03	+0.18
Mar.	-0.20	-0.22	+0.14	-0.35	-0.10	+0.06
Apr.	-0.21	-0.21	-0.04	-0.27	-0.16	-0.24
May	-0.20	-0.15	-0.27	-0.04	-0.22	-0.54
June	-0.17	-0.10	-0.41	-0.04	-0.19	-0.34
July	-0.16	-0.15	-0.41	-0.08	-0.24	+0.46
Aug.	-0.15	-0.21	-0.36	+0.13	-0.05	+0.49
Sept.	-0.17	-0.25	-0.22	+0.33	+0.25	+0.02
Oct.	-0.16	-0.29	-0.00	+0.42	+0.43	-0.13
Nov.	-0.15	+0.31	+0.18	+0.02	-0.29	-0.09
Dec.	-0.16	-0.27	+0.28	-0.11	+0.09	+0.03
TEMPERATURE						
Jan.	-0.24	+0.11	+0.17	+0.22	-0.21	+0.06
Feb.	-0.24	+0.13	+0.17	+0.21	-0.17	+0.06
Mar.	-0.24	+0.15	+0.11	+0.14	-0.10	-0.01
Apr.	-0.24	+0.18	+0.04	+0.04	+0.03	-0.04
May	-0.23	+0.20	-0.04	-0.10	+0.19	+0.04
June	-0.21	+0.22	-0.12	-0.22	+0.29	+0.07
July	-0.20	+0.24	-0.15	-0.23	+0.31	-0.02
Aug.	-0.21	+0.22	-0.11	-0.16	+0.23	-0.03
Sept.	-0.23	+0.19	-0.04	-0.07	+0.11	+0.05
Oct.	-0.24	+0.17	+0.04	+0.09	-0.04	+0.01
Nov.	-0.24	+0.12	+0.00	+0.19	-0.20	-0.04
Dec.	-0.24	+0.11	+0.15	+0.24	-0.25	-0.01

TABLE IV

NORTH AMERICAN CLIMATIC REGIONS

Scores with respect to the first six Principal Components

YUMA	-0.2292	0.8644	0.2056	0.0942	0.1595	0.0663
BANFF	0.3680	0.0491	0.0168	0.0018	-0.0560	-0.0307
CALGARY	0.3008	0.1263	-0.0912	0.0531	-0.0764	-0.0581
MEDICINE HAT	0.2704	0.2591	-0.0191	0.0098	0.0407	-0.0363
BOISE	0.1082	0.3697	0.2331	0.0025	0.0606	-0.0386
DENVER	0.1059	0.3449	0.0254	0.0390	-0.0078	-0.0375
HELENA	0.2523	0.2622	0.0355	0.0488	-0.0180	-0.0972
PIKES PEAK	0.5889	-0.4450	-0.0701	0.0331	-0.0072	0.0023
SAN ANTONIO	-0.4525	0.4421	0.0009	0.0771	0.0331	-0.0618
SAN DIEGO	-0.0358	0.4962	0.4079	0.1382	-0.0837	0.0402
CHARLESTON	-0.6414	0.1103	-0.2615	0.0600	-0.0585	0.2537
GALVESTON	-0.6654	0.1873	-0.0421	0.1116	0.0763	0.0248
MONTGOMERY	-0.7038	0.0170	0.0360	-0.2204	-0.0705	0.0613
NASHVILLE	-0.5028	0.0210	-0.0221	-0.1608	-0.0400	0.0940
NEW ORLEANS	-0.8396	0.0012	-0.1504	-0.0559	-0.0879	0.0977
RALEIGH	-0.5298	0.0027	-0.1933	-0.0721	-0.1044	0.0490
VICKSBURG	-0.6997	0.0198	0.0503	-0.1985	-0.0505	-0.0130
WASHINGTON	-0.3566	0.0247	-0.1224	-0.0489	-0.0167	0.0394
VANCOUVER	-0.3729	-0.3743	0.4684	-0.0595	0.1091	-0.0526
PRINCE RUPER	-0.6971	-1.0639	0.2499	0.0461	0.1330	-0.0462
VICTORIA	0.0202	0.0717	0.4219	0.1035	-0.0010	0.0037
EUREKA	-0.1049	-0.1620	0.0623	-0.0034	-0.1212	-0.0314
SITKA	-0.5664	-0.9976	0.1191	0.2486	0.2024	0.0718
SACRAMENTO	-0.1423	0.3868	0.4325	-0.0291	0.0256	0.0212
SAN FRANCISC	-0.0702	0.2050	0.5596	0.0560	-0.1222	0.0366
CHICAGO	-0.1191	0.0866	-0.1159	-0.0117	0.0009	-0.0373
CLEVELAND	-0.0946	0.0676	-0.0359	-0.0057	0.0126	0.0145
DES MOINES	-0.1292	0.1166	-0.2040	0.0091	-0.0050	-0.1159
HARRISBURG	-0.2327	0.0458	-0.0938	-0.0201	0.0394	0.0392
INDIANAPOLIS	-0.2974	0.0096	-0.0928	-0.0985	-0.0004	-0.0439
NEW YORK	-0.3039	-0.0421	-0.0514	-0.0523	0.0036	0.0773
OMAHA	-0.1160	0.1864	-0.2951	0.0158	0.0041	-0.0640
SALT LAKE	0.0480	0.3330	0.1414	-0.0313	0.0769	-0.0711
ST LOUIS	-0.3664	0.0956	-0.1518	-0.0756	-0.0029	-0.1034
EDMONTON	0.3348	0.1123	-0.1116	-0.0041	-0.0420	0.0191
WINNIPEG	0.3024	0.1038	-0.1535	-0.0275	0.0707	0.0029
PORT ARTHUR	0.1733	-0.1143	-0.1497	0.0169	0.0003	-0.0226
LONDON	-0.1119	-0.0717	-0.0420	-0.0532	0.0197	-0.0115
TORONTO	-0.0424	0.0477	-0.0164	-0.0358	0.0081	-0.0057
OTTAWA	0.0246	-0.0763	-0.0906	-0.0569	0.0426	-0.0069
MONTREAL	-0.1100	-0.1523	-0.1070	-0.0813	0.0467	-0.0134
ATLIN	0.5399	0.0915	-0.1278	0.1102	0.0069	0.0297
QUEBEC	-0.0744	-0.2469	-0.1813	-0.0471	0.0194	-0.0022
HALIFAX	-0.2563	-0.3791	-0.0153	-0.0353	-0.0209	-0.0775
ST JOHN	-0.1508	-0.4482	0.1320	-0.0386	-0.0469	-0.0198
ALBANY, NY	-0.1206	0.0315	-0.1021	-0.0235	0.0255	0.0170
BOSTON	-0.2139	-0.0727	-0.0027	-0.0603	0.0078	0.0080
DULUTH	0.1747	-0.0301	-0.2374	0.0551	-0.0430	-0.0420
OSWEGO	-0.0540	-0.0171	-0.0001	-0.0019	0.0216	-0.0366
PITTSBURGH	-0.2212	0.0598	-0.0783	-0.0587	-0.0306	0.0199
PORTLAND	-0.2712	-0.0923	0.0925	0.0048	-0.1027	-0.0044
ST PAUL	0.0490	0.1050	-0.2427	-0.0066	0.0197	-0.0643
COPPERMINE	0.9562	-0.2008	-0.0368	-0.0153	0.0170	0.0272
F GOOD HOPE	0.7921	-0.0674	-0.1069	-0.1068	0.1553	0.0464
DAWSON	0.6544	0.0080	-0.0686	-0.0749	0.1368	0.0310
PRINCE GEORG	0.2601	0.0265	0.0421	0.0802	0.0033	0.0275
F VERMILLION	0.5547	0.0779	-0.0766	-0.0628	0.0779	0.0113
CHURCHILL	0.7650	-0.1153	-0.1077	0.0165	0.0318	0.0735
FORT YUKON	0.7968	0.0576	-0.0570	-0.1209	0.1675	0.0267
HEBRON	0.4861	-0.2212	-0.0128	0.0728	-0.1314	-0.0951
BARROW	1.0875	-0.1545	0.0659	0.0575	-0.0676	0.0700
NOME	0.5867	-0.1353	-0.0365	0.1304	-0.0516	0.1678
MOULD BAY	1.3099	-0.2837	0.0277	-0.0105	-0.0486	-0.0200

TABLE V

Final Table- Climatic Classification

Iterations no.		1	2	3	4
SUBSET	1				
1	YUMA	1	1	1	1
2	BANFF	1	1	1	1
3	CALGARY	1	1	5	5
4	MEDICINE HAT	1	1	1	1
5	BOISE	1	1	1	1
6	DENVER	1	1	1	1
7	HELENA	1	1	1	1
8	PIKES PEAK	8	8	8	8
9	SAN ANTONIO	1	1	1	1
10	SAN DIEGO	4	4	4	4
SUBSET	2				
11	CHARLESTON	2	2	2	2
12	GALVESTON	5	5	1	1
13	MONTGOMERY	2	2	2	2
14	NASHVILLE	2	2	2	2
15	NEW ORLEANS	2	2	2	2
16	RALEIGH	2	2	2	2
17	VICKSBURG	2	2	2	2
18	WASHINGTON	2	2	2	2
SUBSET	3				
19	VANCOUVER	3	3	3	3
20	PRINCE RUPER	3	3	3	3
21	VICTORIA	4	4	4	4
22	EUREKA	4	4	4	4
23	SITKA	3	3	3	3
SUBSET	4				
24	SACRAMENTO	4	4	4	4
25	SAN FRANCISC	4	4	4	4
SUBSET	5				
26	CHICAGO	5	5	5	5
27	CLEVELAND	6	6	6	6
28	DES MOINES	5	5	5	5
29	HARRISBURG	6	6	6	6

30	INDIANAPOLIS	5	6	6	6
31	NEW YORK	2	2	2	2
32	OHAHA	5	5	5	5
33	SALT LAKE	1	1	1	1
34	ST LOUIS	5	5	5	5
SUBSET	6				
35	EDMONTON	6	6	6	6
36	WINNIPEG	7	7	7	7
37	PORT ARTHUR	6	6	6	5
38	LONDON	6	6	6	6
39	TORONTO	6	6	6	6
40	OTTAWA	6	6	6	6
41	MONTREAL	6	6	6	6
42	ATLIN	1	1	1	1
43	QUEBEC	6	6	6	6
44	HALIFAX	6	6	6	6
45	ST JOHN	6	6	6	6
46	ALBANY NY	6	6	6	6
47	BOSTON	6	6	6	6
48	DULUTH	6	5	5	5
49	OSWEGO	6	6	6	6
50	PITTSBOURGH	6	6	6	6
51	PORTLAND	6	6	6	6
52	ST PAUL	5	5	5	5
SUBSET	7				
53	COPPERMINE	7	7	7	7
54	F GOOD HOPE	7	7	7	7
55	DAWSON	7	7	7	7
56	PRINCE GEORG	1	1	1	1
57	F WSCHILLION	7	7	7	7
58	CHURCHILL	7	7	7	7
59	FORT YUKON	7	7	7	7
SUBSET	8				
60	HEBRON	8	8	8	8
61	BARROW	8	8	8	8
62	NOME	8	8	8	8
63	MOULD BAY	8	8	8	8

TABLE VI

Final Table-Disordered Classifications

Iteration no.		1	2	3	4	5	6	7
SUBSET 1								
1	YUMA	1	1	1	1	1	1	1
2	RANGE	6	6	6	6	6	6	6
3	CALGARY	6	6	6	6	6	6	6
4	MEDICINE HAT	1	1	4	4	4	4	4
5	BOISE	1	1	1	1	1	1	1
6	DENVER	1	1	1	1	1	6	6
7	HELENA	1	1	1	4	4	4	4
SUBSET 2								
8	PIKES PEAK	6	6	6	6	6	6	6
9	SAN ANTONIO	1	1	1	1	1	1	1
10	SAN DIEGO	1	1	1	1	1	1	1
11	CHARLESTON	2	2	2	2	2	2	2
12	GALVESTON	3	1	1	1	1	1	1
13	MONTGOMERY	2	2	2	2	2	2	2
14	NASHVILLE	2	2	2	2	2	2	2
15	NEW ORLEANS	2	2	2	2	2	2	2
16	RALEIGH	2	2	2	2	2	2	2
17	VICKSBURG	2	2	2	2	2	2	2
18	WASHINGTON	2	2	2	2	2	2	2
19	VANCOUVER	3	3	3	3	3	3	3
20	PRINCE RUPER	3	3	3	3	3	3	3
21	VICTORIA	3	3	3	3	3	3	3
SUBSET 3								
22	EUREKA	3	3	3	3	3	3	3
23	SITKA	3	3	3	3	3	3	3
24	SACRAMENTO	3	1	1	1	1	1	1
25	SAN FRANCISC	3	3	3	3	3	3	3
26	CHICAGO	6	6	6	6	6	6	6
27	CLEVELAND	4	4	4	4	4	4	5
28	DES MOINES	6	4	4	4	6	4	6
29	HARRISBURG	2	2	2	2	2	2	5
SUBSET 4								
30	INDIANAPOLIS	6	6	6	6	5	5	5
31	NEW YORK	2	2	2	2	2	2	2
32	OMAHA	6	6	6	6	6	6	6
33	SALT LAKE	1	1	1	1	1	1	1
34	ST LOUIS	6	6	6	6	6	6	6
35	EDMONTON	6	6	6	6	6	6	6
36	WINNIPEG	6	6	6	6	6	6	6
37	PORT ARTHUR	6	4	4	4	4	4	4
38	LONDON	4	5	5	5	5	5	5
39	TORONTO	4	4	4	4	4	5	5
40	OTTAWA	4	4	4	4	5	5	5
41	MONTREAL	4	5	5	5	5	5	5

SUBSET	5							
42	ATLIN	8	8	8	8	8	8	8
43	QUEBEC	5	5	5	5	5	5	5
44	HALIFAX	5	5	5	5	5	5	5
45	ST JOHN	5	5	5	5	5	5	5
46	ALBANY NY	4	4	4	4	4	5	5
47	BOSTON	5	5	5	5	5	5	5
48	DULUTH	6	6	6	6	6	6	6
49	OSWEGO	5	4	4	4	4	4	4
50	PITTSBOURGH	2	2	2	2	2	2	5
SUBSET	6							
51	PORTLAND	2	5	5	5	5	5	5
52	ST PAUL	4	4	4	4	4	4	4
53	COPPERMINE	8	8	8	8	8	8	8
SUBSET	7							
54	F GOOD HOPE	7	7	7	7	7	7	7
SUBSET	8							
55	DAWSON	7	7	7	7	7	7	7
56	PRINCE GEORG	6	6	6	6	6	6	6
57	F VERMILLION	7	7	7	7	7	7	7
58	CHURCHILL	8	8	8	8	8	8	8
59	FORT YUKON	7	7	7	7	7	7	7
60	NEBRON	6	6	6	6	6	6	6
61	BARROW	8	8	8	8	8	8	8
62	NOME	8	8	8	2	8	8	8
63	NOULD BAY	8	8	8	8	8	8	8

TABLE VII

Final Table-Shuffled Classification

Iteration No.		1	2	3	4	5	6	7
SUBSET 1								
1	E VERMILION	1	1	1	1	1	1	1
2	VICKSBURG	4	4	4	4	4	4	4
3	CHURCHILL	0	1	1	1	1	1	1
4	FORT YUKON	1	1	1	1	1	1	1
5	WASHINGTON	4	4	4	4	4	4	4
SUBSET 2								
6	ST LOUIS	2	2	2	6	6	6	6
7	SALT LAKE	3	3	3	2	2	2	2
SUBSET 3								
8	BOISE	3	3	3	3	3	2	2
9	TORONTO	5	5	5	5	5	5	5
SUBSET 4								
10	HARRISBURG	4	4	5	5	5	5	5
SUBSET 5								
11	EDMONTON	5	5	5	5	5	5	5
12	INDIANAPOLIS	2	5	5	5	5	5	5
13	OTTAWA	1	5	5	5	5	5	5
14	MONTREAL	1	5	5	5	5	5	5
15	ATLIN	7	3	3	3	3	3	2
16	QUEBEC	4	5	5	5	5	5	5
17	DENVER	3	3	2	2	2	2	2
18	GALVESTON	4	2	2	2	2	2	2
19	NEW YORK	4	4	4	4	4	4	4
20	SAN FRANCISC	7	7	3	3	3	3	3
21	SACRAMENTO	3	3	3	3	3	3	3
22	WINNIPEG	1	1	5	5	5	5	5
23	BOSTON	5	5	5	5	5	5	5
24	PORT ARTHUR	5	5	5	5	5	5	5
25	DULUTH	6	6	6	6	6	6	6
26	PITTSBOURGH	4	4	4	5	5	5	5
27	PORTLAND	7	7	5	5	5	5	5
28	ST PAUL	6	6	6	6	6	6	6
SUBSET 6								
29	CHICAGO	6	5	5	5	5	5	5
30	CLEVELAND	5	5	5	5	5	5	5
31	DES MOINES	6	6	6	6	6	6	6
32	OMAHA	6	6	6	6	6	6	6

SUBSET 7

33	YUMA	3	3	3	3	2	2	2
34	BANFF	7	6	6	6	6	6	6
35	CALGARY	6	6	6	6	6	6	6
36	MEDICINE HAT	3	5	5	5	2	2	2
37	MONTGOMERY	6	6	6	6	6	6	6
38	F GOOD HOPE	1	1	1	1	1	1	1
39	NASHVILLE	4	6	6	6	3	3	3
40	DAWSON	1	1	1	1	1	1	1
41	BARROW	8	8	8	8	8	8	8
42	LONDON	5	5	5	5	5	5	5
43	VANCOUVER	7	7	7	7	7	7	7
44	NEW ORLEANS	4	4	4	4	4	4	4
45	PRINCE GEORG	7	5	5	5	5	5	5
46	SITKA	7	7	7	7	7	7	7
47	RALEIGH	6	6	6	6	6	6	6
48	PRINCE RUPER	7	7	7	7	7	7	7
49	VICTORIA	7	7	3	3	3	3	3
50	NOME	8	8	8	8	8	8	8
51	COPPERMINE	1	1	1	1	1	1	1
52	EUREKA	7	7	7	3	3	3	3
53	OSWEGO	5	5	5	5	5	5	5
54	HEBRON	7	6	6	6	6	6	6
55	HELENA	2	2	6	6	6	6	6
56	PIKES PEAK	8	8	8	8	8	8	8
57	SAN ANTONIO	2	2	2	2	2	2	2
58	HALIFAX	7	7	5	5	5	5	5
59	SAN DIEGO	3	3	3	3	3	3	3

SUBSET 8

60	ST JOHN	7	7	7	5	5	5	5
61	ALBANY NY	4	5	5	5	5	5	5
62	CHARLESTON	4	4	4	4	4	4	4
63	MOULD BAY	8	8	8	8	8	8	8

TABLE VIII

Ratio R of the Between to the Within Classes Variance

Classification	Iteration no.	Sum of Eigenvalues R
Climatic	0	1.84
	1	3.60
	2	3.62
	3	3.89
	4	3.97*
Disordered	0	0.70
	1	1.83
	2	2.11
	3	2.20
	4	2.22
	5	2.20*
	6	2.34
	7	2.56
Shuffled	0	0.23
	1	1.21
	2	1.96
	3	2.54
	4	3.09
	5	3.54*
	6	3.61
	7	3.82

TABLE IX

Results of Tests I and II

Classification	Test I	Test II
Climatic	$.50 > Pr > .30$	$.05 > Pr > .02$
Disordered	$.0008 > Pr > .0005$	$Pr = .30$
Shuffled	$.00002 > Pr > .00001$	$.80 > Pr > .70$

TABLE II

Vectors d, t, t*, and Matrix A required for Test II

Cigrette Classification

A =	.00	.15	.06	.10	.15	.31	.13	.10
	.20	.00	.05	.09	.14	.29	.13	.09
	.18	.13	.00	.03	.13	.27	.12	.03
	.19	.14	.05	.00	.14	.28	.12	.09
	.20	.14	.05	.09	.00	.29	.13	.09
	.23	.17	.06	.11	.17	.00	.15	.11
	.20	.14	.05	.09	.14	.29	.00	.09
	.19	.14	.05	.09	.14	.28	.12	.00

d =	3	1	2	0	5	5	1	0
t =	3.11	2.40	.83	1.64	1.84	3.50	2.16	1.64
t* =	4	1	0	3	4	3	1	1

Disordered Classification

A =	.00	.14	.11	.20	.25	.12	.07	.11
	.13	.00	.11	.20	.25	.13	.07	.11
	.12	.14	.00	.19	.25	.12	.07	.10
	.13	.15	.12	.00	.27	.13	.08	.12
	.14	.16	.12	.23	.00	.14	.08	.12
	.12	.14	.11	.20	.25	.00	.07	.11
	.12	.14	.10	.19	.24	.12	.00	.10
	.12	.14	.10	.19	.25	.12	.07	.00

d =	5	7	5	8	3	3	0	5
t =	3.93	4.20	3.47	5.59	8.49	4.17	2.63	3.47
t* =	5	1	3	7	8	7	3	2

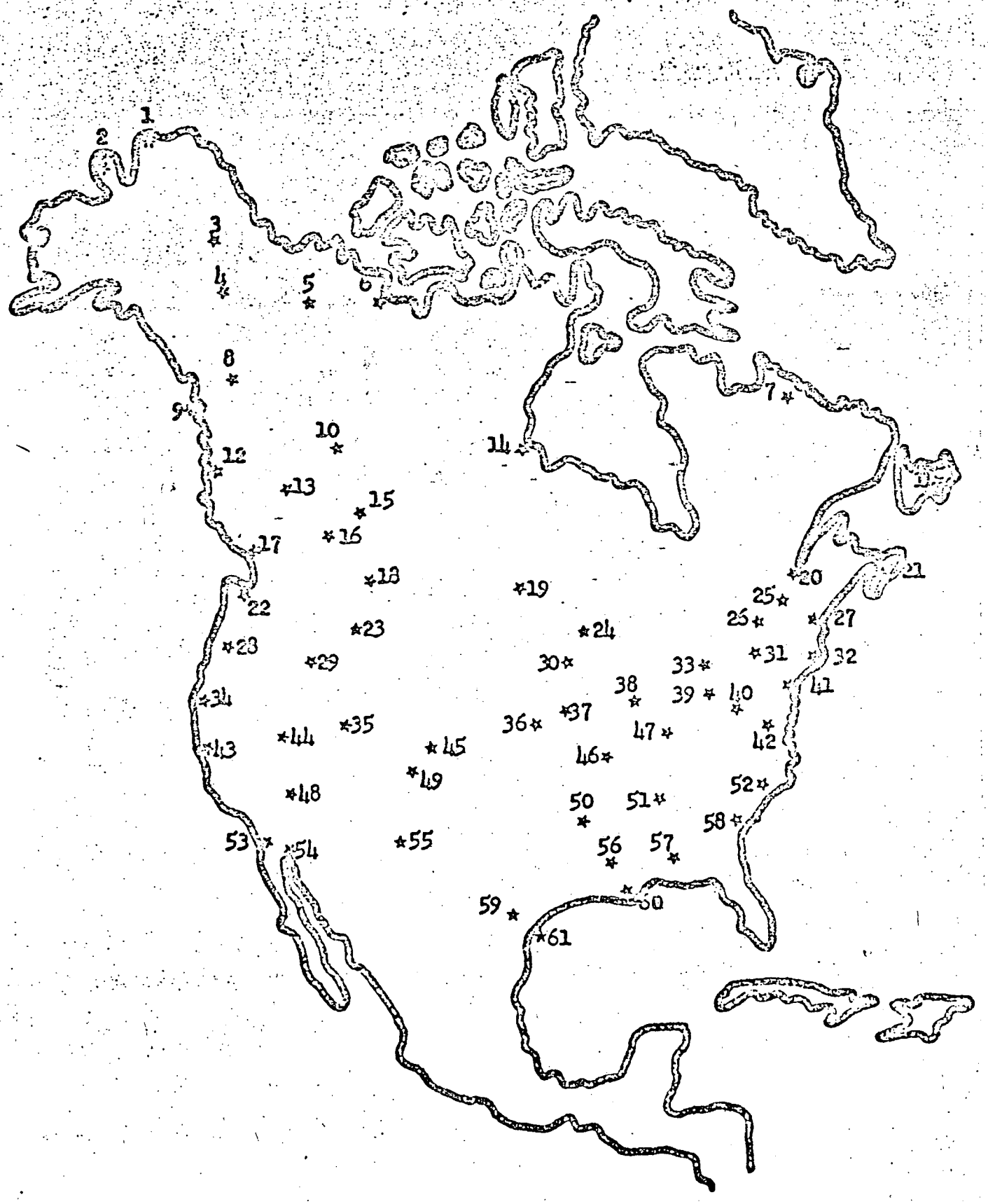
Sheffield Classification

A =	.09	.14	.09	.14	.35	.16	.05	.07
	.11	.09	.09	.14	.35	.16	.05	.07
	.10	.14	.09	.14	.35	.15	.05	.07
	.11	.14	.09	.09	.36	.16	.05	.07
	.14	.19	.12	.19	.09	.21	.07	.09
	.11	.15	.09	.15	.37	.09	.05	.07
	.10	.13	.08	.13	.33	.15	.09	.07
	.10	.14	.08	.14	.34	.15	.03	.09

d =	2	1	2	1	8	2	24	3
t =	4.46	6.04	3.66	6.04	11.76	6.67	1.11	2.96
t° =	3	7	5	8	10	7	0	3

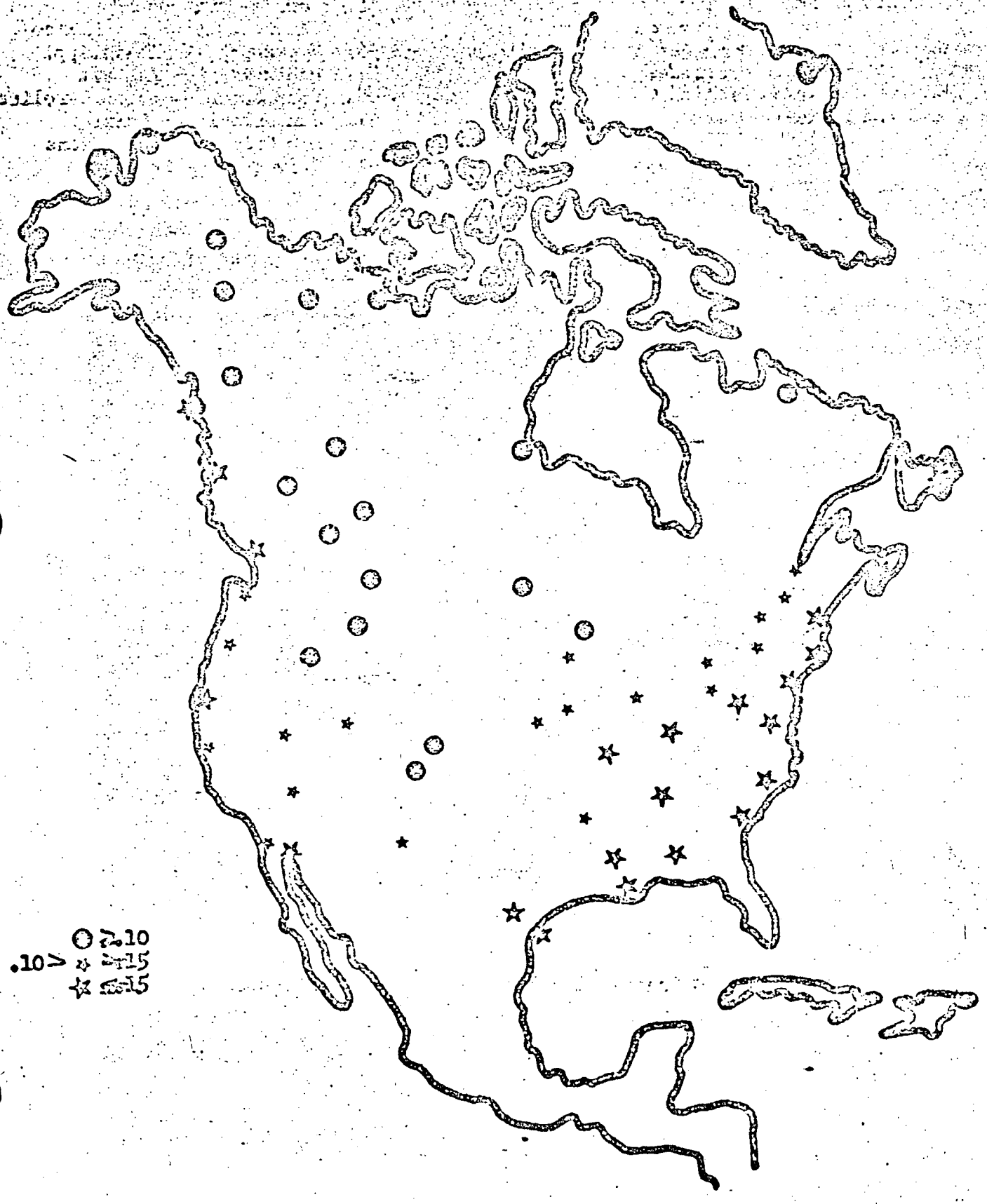
Map 1

Location of meteorologic stations

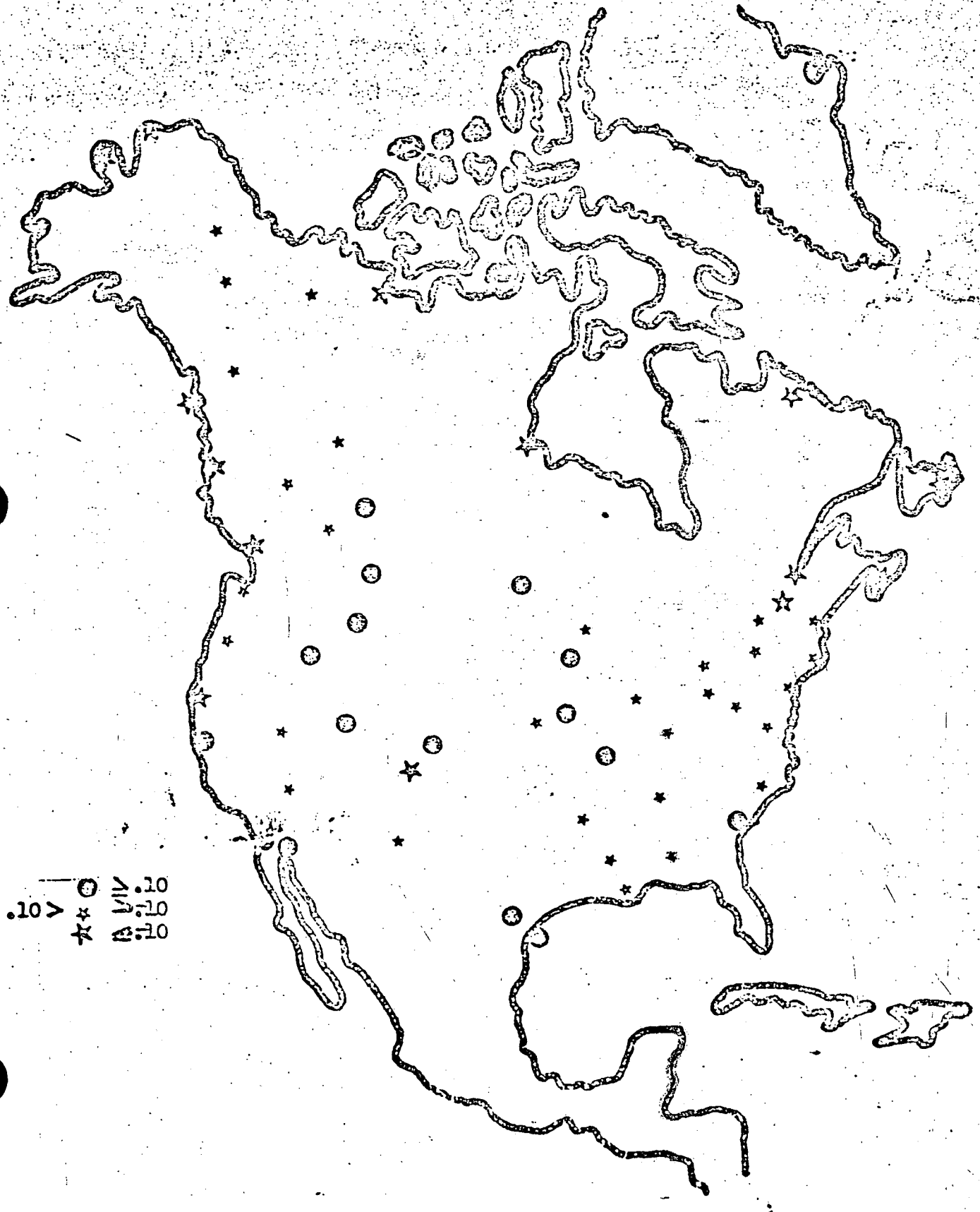


1. Barrow — Alaska
2. Nome — Alaska
3. Fort Yukon — Alaska
4. Dawson — Yukon
5. Good Hope — Northwest Territory
6. Coppermine — Northwest Territory
7. Nakvak — Labrador
8. Atlin — British Columbia
9. Sitka — Alaska
10. Fort Vermilion — Alberta
11. St. John — Newfoundland
12. Prince Rupert — British Columbia
13. Prince George — British Columbia
14. Churchill — Manitoba
15. Edmonton — Alberta
16. Banff — Alberta
17. Vancouver — British Columbia
18. Medicine Hat — Alberta
19. Winnipeg — Manitoba
20. Quebec — Quebec
21. Halifax — Nova Scotia
22. Seattle — Washington
23. Helena — Montana
24. Fort Arthur — Ontario
25. Montreal — Quebec
26. Ottawa — Ontario
27. Portland — Maine
28. Salem — Oregon
29. Boise — Idaho
30. Duluth — Minnesota
31. Toronto — Ontario
32. Boston — Massachusetts
33. London — Ontario
34. Eureka — California
35. Salt Lake — Utah
36. Omaha — Nebraska
37. Des Moines — Iowa
38. Chicago — Illinois
39. Cleveland — Ohio
40. Pittsburgh — Penna
41. New York — New York
42. Washington — District of Columbia
43. San Francisco — California
44. Austin — Nevada
45. Denver — Colorado
46. St. Louis — Missouri
47. Indianapolis — Indiana
48. Las Vegas — Nevada
49. Pikes Peak — Colorado
50. Pine — Arkansas
51. Nashville — Tennessee
52. Raleigh — North Carolina
53. San Diego — California
54. Yuma — Arizona
55. Albuquerque — New Mexico
56. Vicksburg — Mississippi
57. Montgomery — Alabama
58. Charleston — South Carolina
59. San Antonio — Texas
60. New Orleans — Louisiana
61. Galveston — Texas

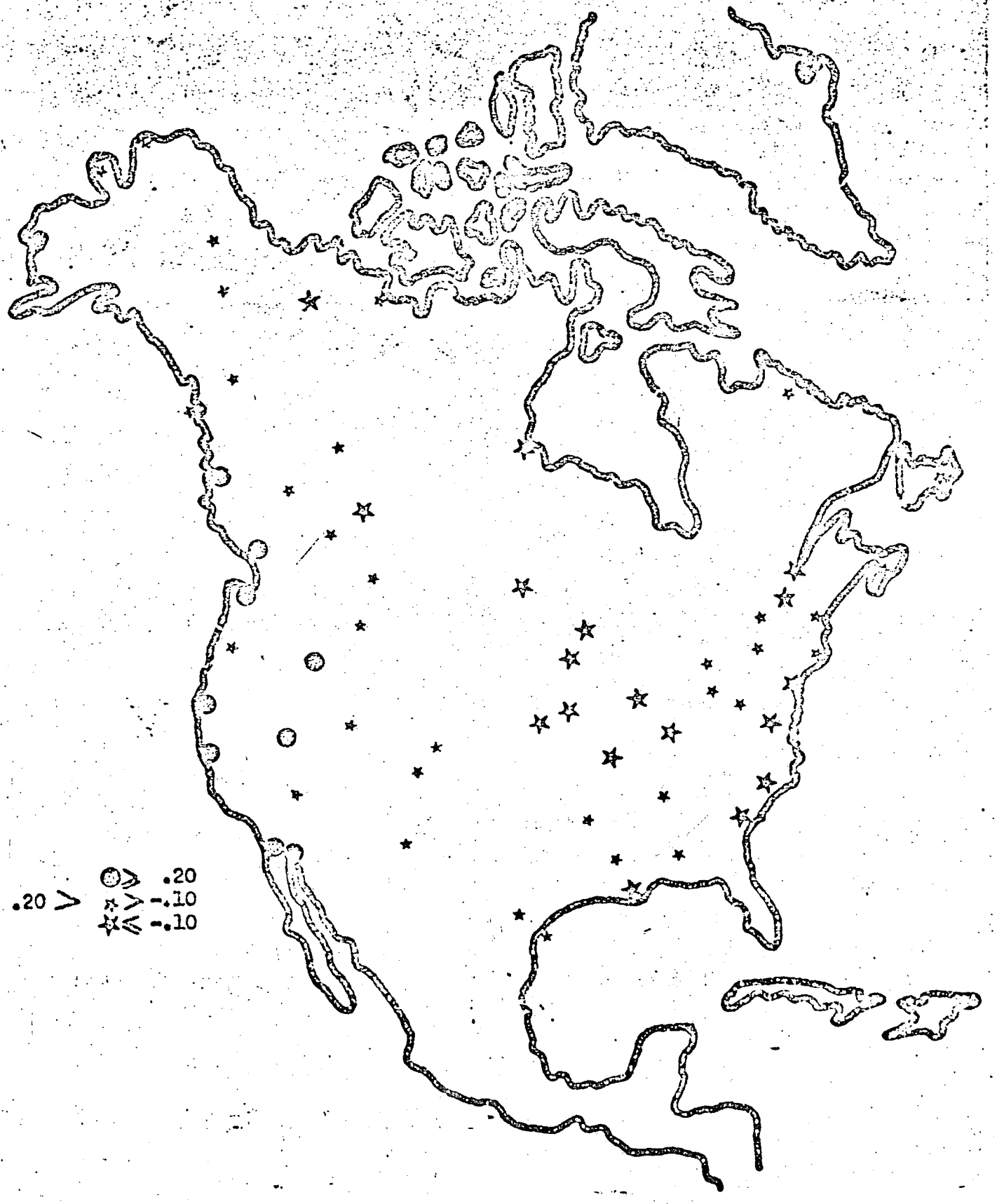
Map 2 First Component



Map 3 Second Component

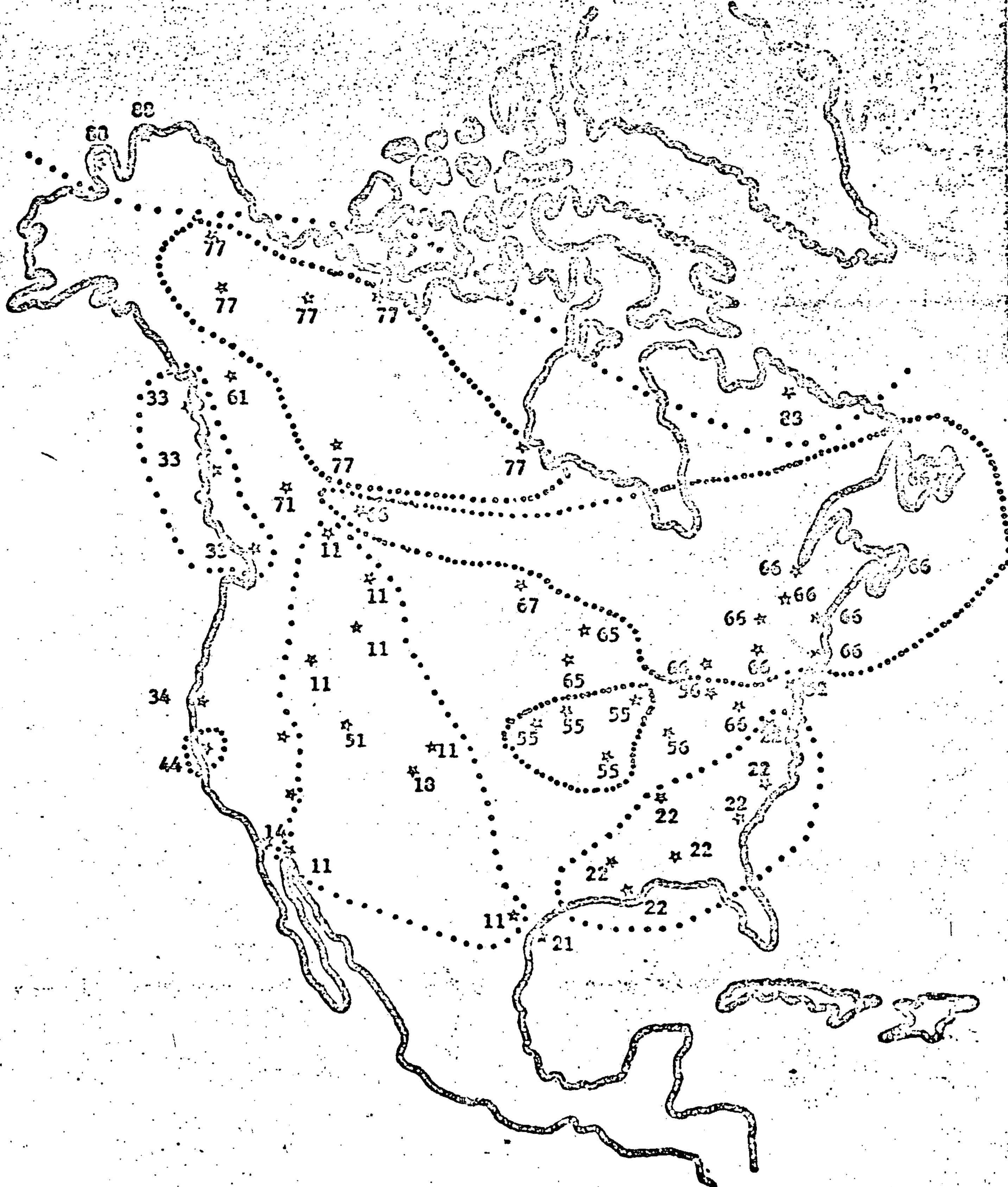


Map 4. Third Component



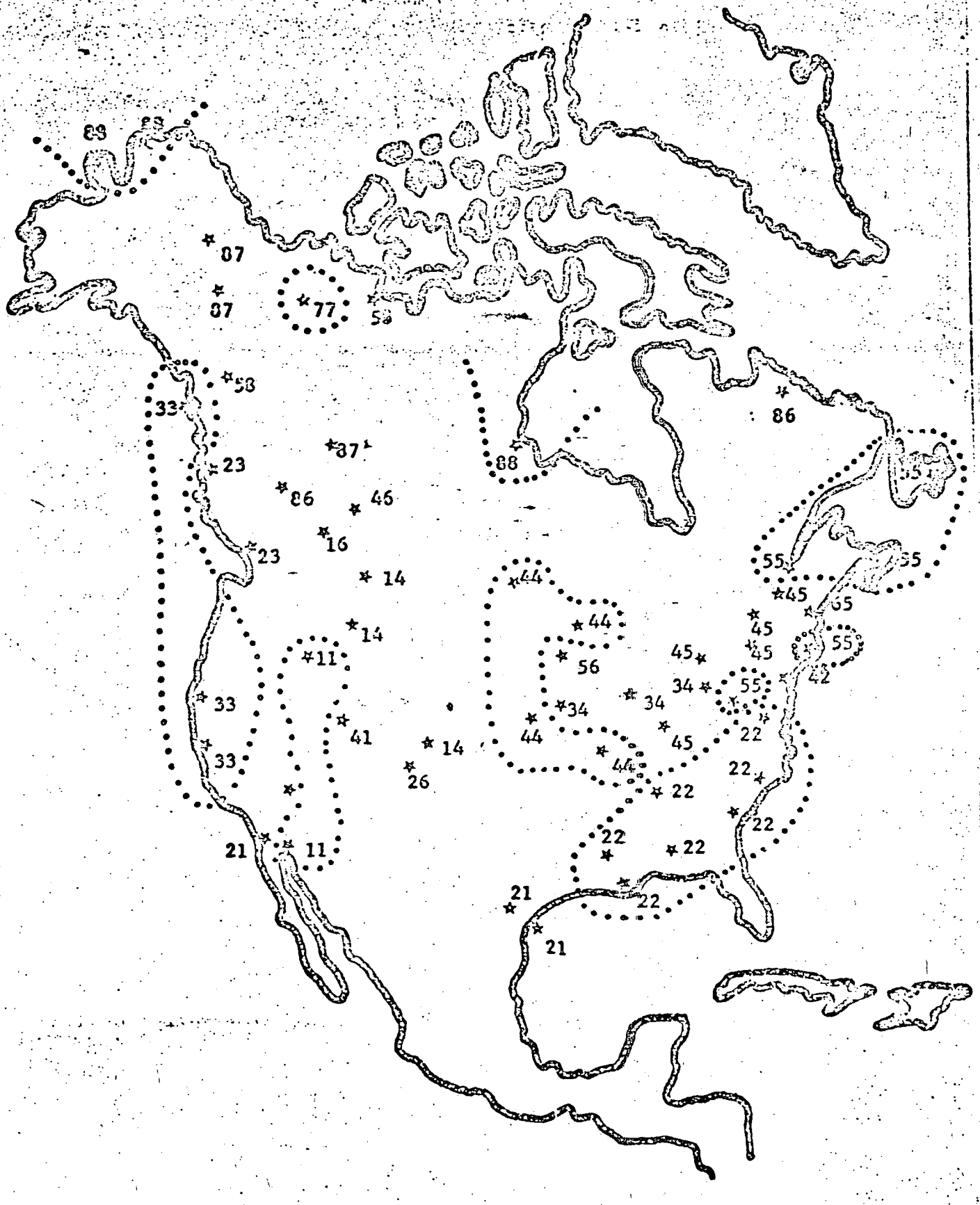
Map 5

Climatic Classification



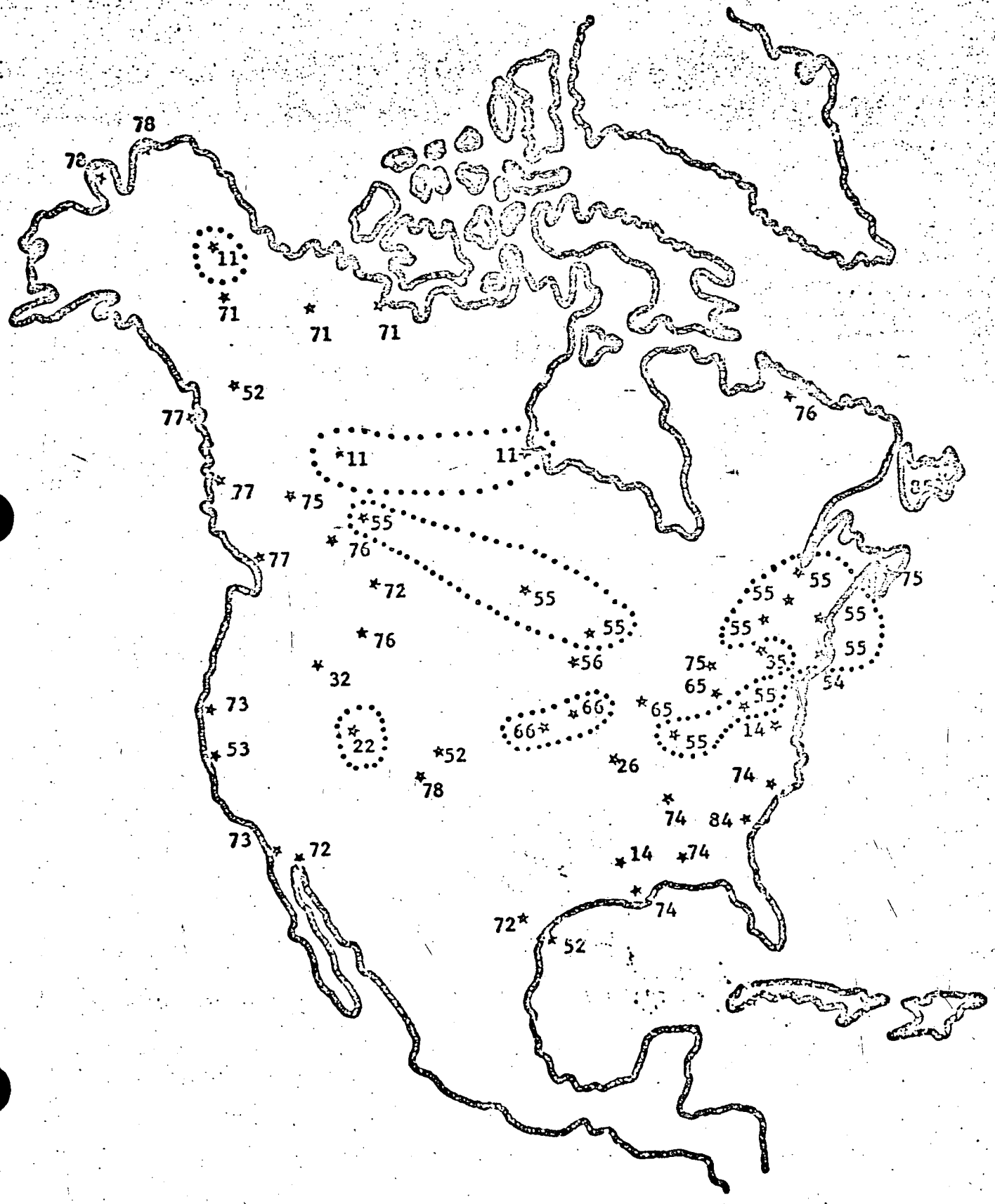
Map 6

Disordered Classification



Map 7

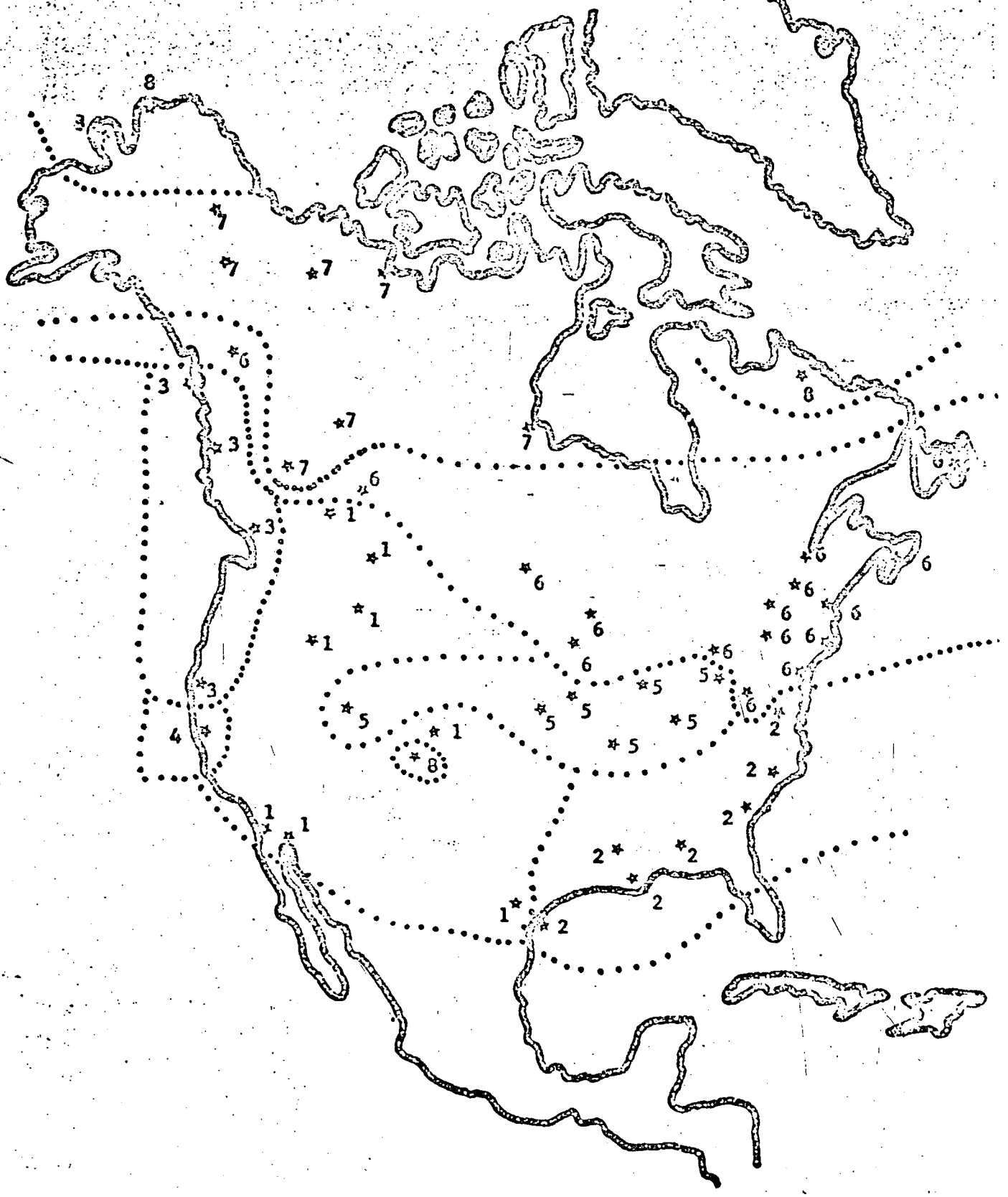
Shuffled Classification



Map 8

Climatic Classification

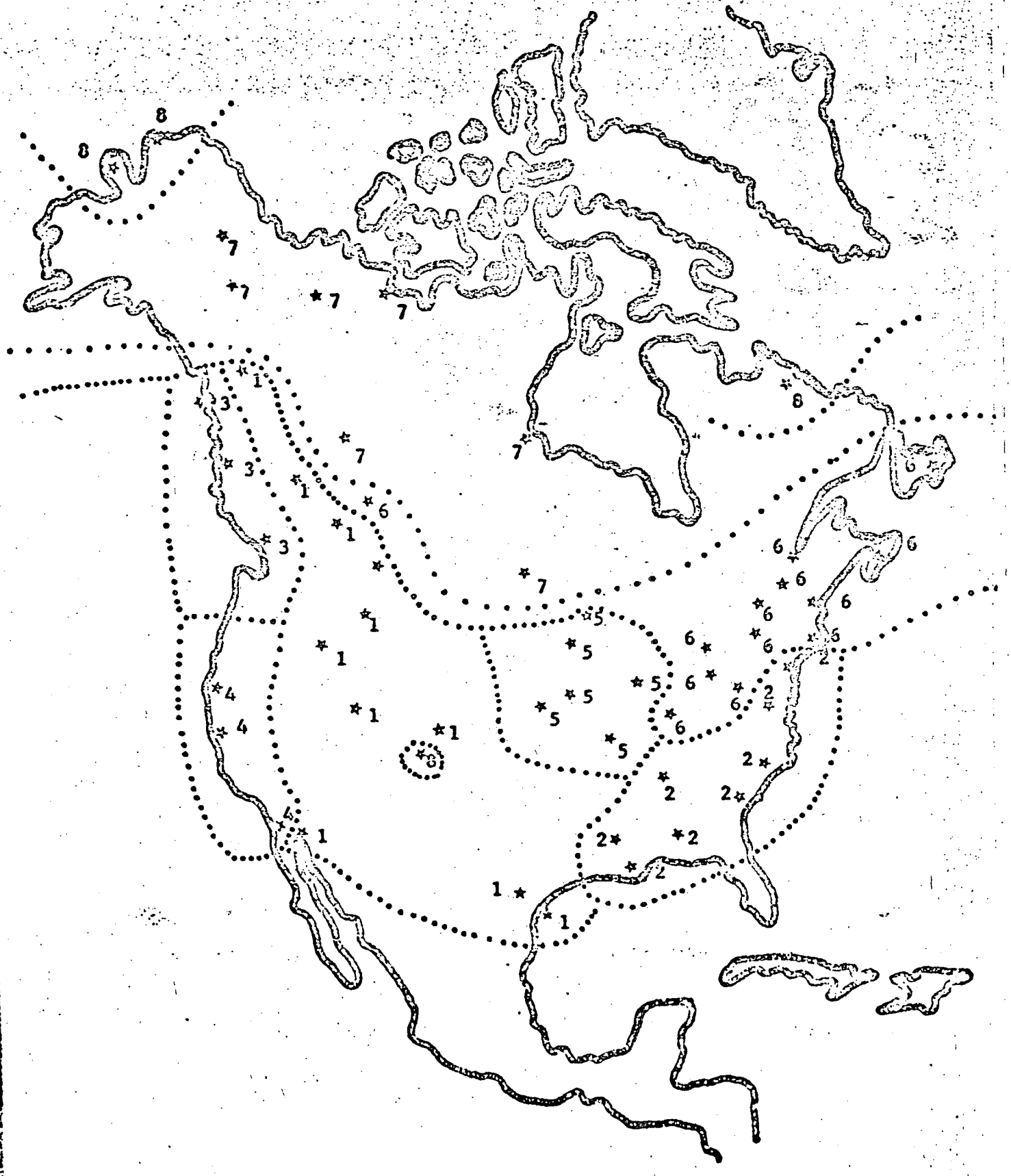
(Initial Classification)



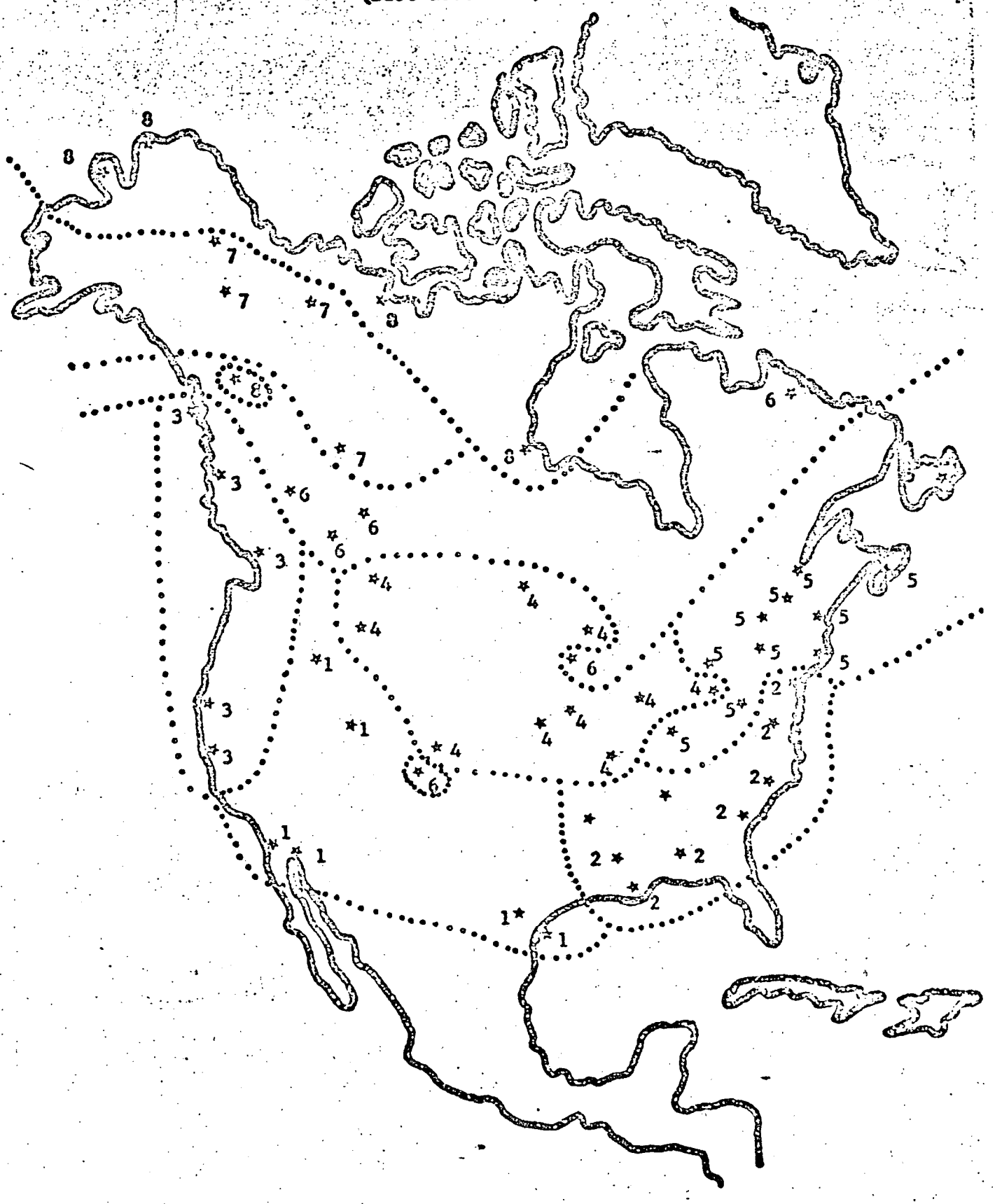
Map 9

Climatic Classification

(Last Iteration)



Map 11
Disordered Classification
(Last Iteration)



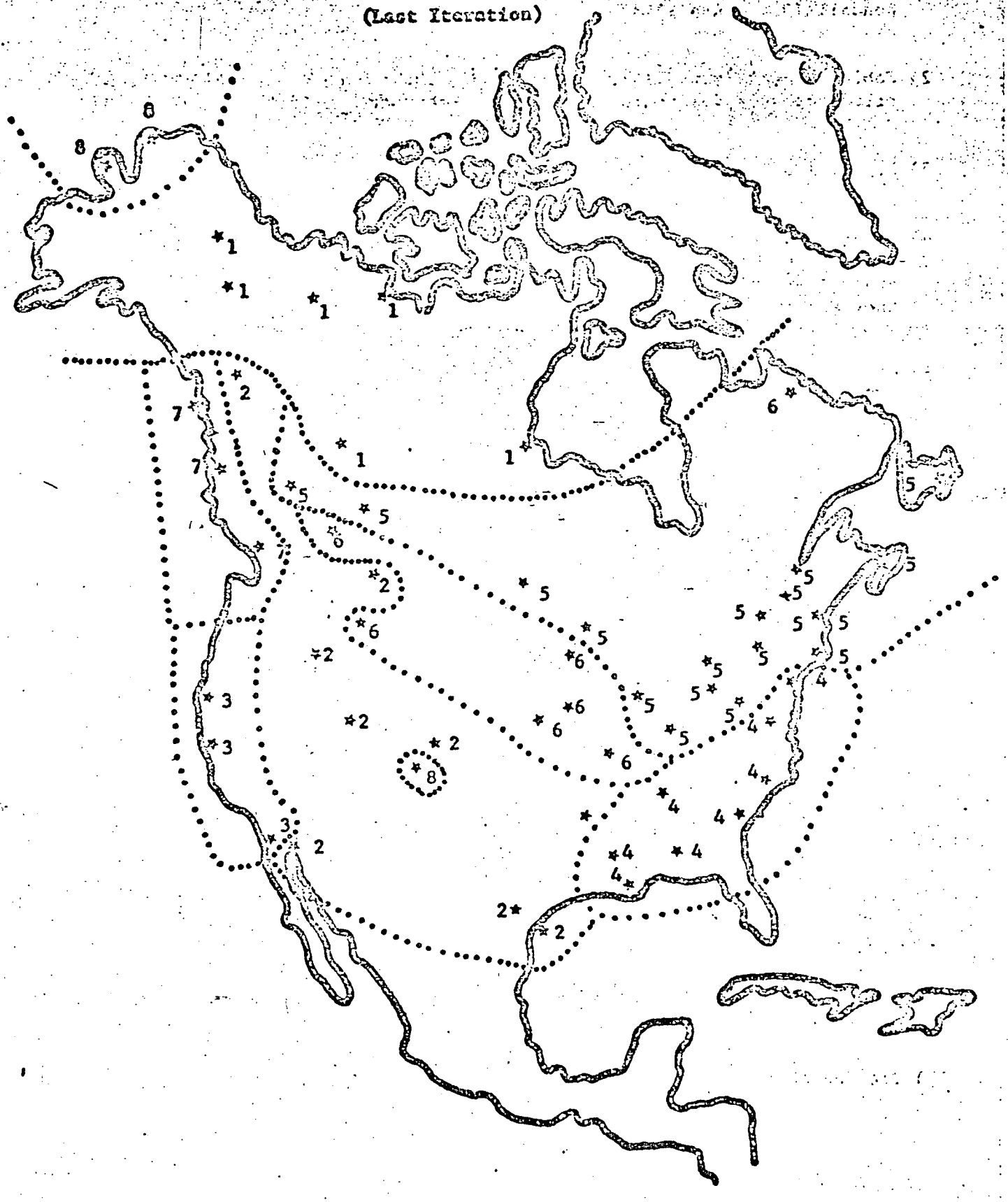
Map 12

Shuffled Classification

(Initial Classification)

Map 13

Shuffled Classification
(Last Iteration)



NOTES

1) Eagood et al. 1941, 1943; Berry 1960(a), 1960(b), 1961; Stone 1960; Kendall 1939; Rao 1948; Barnard 1935.

2) Zobler 1956; Brown 1947; Fisher 1936, 1938; Von Mises 1945; for a bibliography on discriminant functions see Hodges 1955.

3) Fisher 1953.

4) Geographical regions are an example of classifications based on optimal criteria subject to a constraint. The areal units more similar to each other (optimality criterion) are included in same regions provided that they are contiguous (constraint).

5) Clark and Evans 1954; Clark 1954,1956; Dacey 1958 a,b,c.

6) McQuitty 1959; Cattel 1944; Peters 1956; Tryon 1955; Fruchter 1954; Rao 1948; Olson and Miller 1958.

7) Cooley and Lohnes 1962,p.116 fgg.

8) Rao 1946, 1948, 1950; Berry 1959; Greig-Smith 1957; Tompson 1956.

9) The orthogonalization of the data can be obtained by a variety of methods, for instance by the Gram-Schmidt process (Birkoff and Mc Lane 1953,p. 192; Rao 1952, p.345; Mohn 1958, p.203), by the principal component method (Kendall 1957, p.10; Harman 1962, p.154), or by the "reduction" process (Rao 1952, p.347). Non orthogonal measures can be considered as coordinates with respect to axis forming to each other angles other than 90 (Berry 1959, 1960, p.114; Stone 1960, p.5). The orthogonalization is a transformation yielding coordinates with respect to orthogonal axis.

10) The functions satisfying the distance axioms are generally referred to as distance functions. If a distance from A to B is denoted by d(AB) the distance axioms can be written as follows:
$d(AA)=0$, $d(AB)\geq 0$, $d(AB)= d(BA)$, $d(AB)+d(BC)\geq d(AC)$. See for instance Birkhoof and Mc Lane 1962, p.190. A discussion of several distance functions can be found in Bellman 1961, p.99 fgg.; Kolmogorof and Fomin 1957, p.16 fgg.

11) The Euclidean distance between two points A and B in a t-dimensional space,

identified by the vectors $a=(a_1,\ldots,a_t)$ and $b=(b_1,\ldots,b_t)$ whose elements are coordinates of the points with respect to an orthogonal basis, is defined as

$$d^2(AB) = \sum_{i}^{t}(a_i-b_i)^2 = (a-b)^T(a-b)$$

If the vectors a and b contain the coordinates of A and B with respect to a non orthogonal basis, and S is the matrix of an orthogonalizing tranformation

$$d^2(AB) = (a-b)^T S^T S(a-b)$$

(see Stone 1960, p.5, and Mahalanobis 1927, 1930, 1940; Rao 1952, chapter 9 on Mahalanobis generalized distance D).

12) Casetti 1964.

13) Birkoff and Mc Lane 1962, p.25.

14) For a discussion of these points see Casetti 1964.

15) There is no absolute criterion for determining how similar two items or classes are. Similarity is relative to a view point. A view point consists in isolating certain properties and qualities of things and disregarding others. If variables are measures of these properties, the very fact of selecting some variables identifies a particular way of looking at the objects. Therefore the DP'S are justified when the classes of a classification appear different from the viewpoint identified by the set variables being used. In practice classes are considered different from each other if the null hypothesis that they are samples from a same population can be rejected at a convenient level of significance (see for instance Rao 1962, p.236 fgg.).

16) It can be easily proved that given a set of points in a t-dimensional space the quadratic average of the distance of any point from any other point is equal to twice the average of the t variances of the points with respect to the t (orthogonal) axis. Suppose that S is a set of points $X_1, X_2, \ldots, X_t$ in a t-dimensional space, each point being identified by a vector

$$X_i = (x_{i1}, x_{i2}, \ldots, x_{it})$$

Term
1) $\bar{X}$ the center of gravity of the points in S identified by a vector

$\bar{X} = (\bar{x}_{.1}, \bar{x}_{.1}, \ldots, \bar{x}_{.t})$ where $\bar{x}_{.j} = \frac{1}{p}\sum_i x_{ij}$

2) v the quadratic average of the variances of the points in S with respect to their t coordinates. That is

$$v^2 = \frac{1}{t}\sum_j v_j^2 \quad \text{where } v_j^2 = \frac{1}{p}\sum_i \hat{x}_{ij}^2 \quad \text{and } \hat{x}_{ij} = x_{ij} - \bar{x}_{.j}$$

3) D_q the quadratic average of the distances between X_q and all the points in S That is

$$D_q^2 = \frac{1}{p}\sum_{ij}(x_{qj} - x_{ij})^2$$

4) D the quadratic average of all D_q's that is

$$D^2 = \frac{1}{p}\sum_q D_q^2$$

THEOREM

$$D^2 = 2v^2$$

Proof: Take $\bar{X}$ as origin of the coordinates so that

$$\hat{x}_{ij} = x_{ij}$$

By definition

$$D_q^2 = \frac{1}{p}\sum_{ij}(x_{qj} - x_{ij})^2$$

$$= \frac{1}{p}(p\sum_j x_{qj}^2 + \sum_{ij} x_{ij}^2 - 2\sum_{ij} x_{qj}x_{ij})$$

$$\sum_{ij} x_{qj}x_{ij} = \sum_i(x_{qj}\sum_i x_{ij}) = 0 \quad \text{because } \sum_i x_{ij} = 0 \quad \text{for all } j\text{'s}$$

Therefore

$$D_q^2 = \sum_i x_{qj}^2 + \frac{1}{p}\sum x_{ij}^2$$

But

$$D^2 = \frac{1}{p}\sum_q D_q^2 = \frac{1}{p}\sum_q(\sum_j x_{qj}^2 + \frac{1}{p}\sum x_{ij}^2)$$

$$= \frac{1}{p}\sum_{qj}^{pt} x_{qj}^2 + \frac{p}{p}\sum_{ij} x_{ij}^2$$

$$= \frac{2}{p} \sum_{ij} n_{ij}^2$$

$$= 2v^2$$

For different statements of the theorem see M.Baldessari, Statistica, Milano, 1953, vol.I, p.[illegible] and M.G.Kendall and A.Stuart, The advanced theory of Statistics, Hafner, 1958, p.47.

APPENDIX

DISCRIMINANT ITERATIONS PROGRAM

LANGUAGE: Fortran II

OUTPUT:
1) Initial data
2) Subset averages
3) Matrix $D^T D$ (D is the matrix of deviations of subset averaged from grand averages)
4) Matrix $V^T V$ (V is the matrix of deviations of item measures from subset averages)
5) Eigenvalues of $(V^T V)^{-1} D^T D$
6) Eigenvectors of $(V^T V)^{-1} D^T D$ (in the print-out: RESULT MATRIX)
7) Discriminant scores for the items (in the print-out: MATRIX MR)
8) Discriminant scores for the subsets (in the print-out: MAVR)
9) Distances of each item from each class center of gravity (in the print-out: DISTANCE MATRIX)
10) Final Table (in the print-out: RESULT OF I ITERATIONS, where I is the number of the last iteration). This table indicates for each item the number of the class in which the item was located in the 1st, 2nd, ith iteration. The items are associated to the rows and the iterations to the columns of the Table

No.'s 1 and 10 are printed once for each problem, no.'s 2 through 9 are printed at each iteration.

No.'s 3, 4, 7, 8 are printed out only if a 1 is punched in the appropriate location in the control card.

The symbols in this program <u>do not</u> correspond to those used in the text.

RESTRICTIONS: This program handles up to 150 items divided into a maximum of 10 subsets containing one item or more. Each item can be associated with up to 10 observations (variables).

CARD PREPARATION

Title Card
Cols 1-72 Title

Control card
Cols 1-2 no. of observations (variables) per item
3 1 if full print-out is desired, 0 otherwise
4-5 maximum number of iterations
6-41 variable format statement defining the format of the card input. The first two fields should be in A-conversion and are to be used for the items' names. The subsequent fields can be numeric or blanc. For example: a statement

A6, A4, 1X, 2F6.2 reserves the first 10 cols for a name and cols 12-17, 18-23 for decimal numbers having the integer parts in cols 12-15 and 18-21 and the fractional portions in cols 16-17 and 22-23.

Data Cards: The data cards are punched in accordance with the variable format statement contained in the control card. The data are divided into subsets. The cards containing any subset but the last one should be followed by end of subset card(s) containing 999 in the first numeric field to be located by the variable format statement applicable to the data. The cards containing the last subset should be followed by end of the data card(s) containing 999 in the first two numeric fields, to be located as above. For example: if the format of the data cards is based on the statement A5, A6, 1X, 2F6.2 the end of subset cards should have a 9 punched in cols 13, 14, 15 and the end of data card should have a 9 in cols 13, 14, 15, 19, 20, 21.

Note: A variable format statement which instructs the computer to read the observations associated with each item from n cards requires that each end of subset card and the end of data card be followed by n-1 blank card.

DECK MAKE-UP:
1) program cards
2) title card
3) control card
4) data cards:
   - 1st subset cards
   - end of subset card(s)
   - 2nd subset cards
   - end of subset card(s)
   - .....
   - end of data card(s)

Note: Any number of problems may be consecutively executed by repeating steps 2 and 4 inclusive of above.

The assistance of Mrs. B. Benson, who wrote the first draft of this program, is gratefully acknowledged. The program uses the subroutines MDIAG and DIMM published in 1962 in Multivariate Procedures for the Behavioral Sciences by W.W. Cooley and P.R. Lohnes, pp. 200-202 and 205, and reprinted in Multiple Discriminant Functions by E.Casetti, Technical Report no.11, ONR Task no.389-135, Contract NONR 1228(26), Evanston 1964, at pages 58-61.

```
      *** DISCRIMINANT ITERATIONS PROGRAM
C
C     *** PROGRAM HANDLES UP TO 150 ITEMS DIVIDED INTO 10 SUBSETS.
C     *** 10 VARIABLES EACH OBSERVATION
C
      DIMENSION TITL(12),FMT(6),NROW(10),NORIG(10),ROOTR(10)
      DIMENSION NAME(151,2),NAMALT(151,2),ID(151),IDALT(151)
      DIMENSION DIST(151,10),X(151,10),XALT(151,10),XR(151,10)
      DIMENSION XAVR(10,10),SUMTOT(10),XBARDV(10),SUMSET(10,10)
      DIMENSION XBAR(10,10),IRANK(151,20),D(10,10),DT(10,10)
      DIMENSION V(151,10),VT(10,151),RES(10,10),DD(10,10),VV(10,10)
      DIMENSION IRTEMP(151)
      COMMON NVAR
C
C
C     *** READ TITLE CARD AND CONTROL CARD
    2 IT=1
      READ INPUT TAPE 5,100,TITL
  100 FORMAT (12A6)
      WRITE OUTPUT TAPE 6,100,TITL
      WRITE OUTPUT TAPE 6,127,IT
  127 FORMAT (/2X,9HITERATION, I3)
      READ INPUT TAPE 5,101,NVAR,PROPT,MAXIT,FMT
  101 FORMAT (I2,F1.0,I2,6A6)
C
C     *** READ AND PRINT DATA
      WRITE OUTPUT TAPE 6,103
  103 FORMAT (/40X,4HDATA/40X4H----)
      K=1
      N=1
    3 WRITE OUTPUT TAPE 6,104,N
  104 FORMAT (1X6HSUBSET, I3)
      KPREV=K
    4 READ INPUT TAPE 5,FMT,(NAME(K,J),J=1,2),(X(K,J),J=1,NVAR)
      IF (X  (K,1) -999.) 6,7,6
    6 WRITE OUTPUT TAPE 6,105,K,(NAME(K,J),J=1,2),(X(K,J),J=1,NVAR)
  105 FORMAT (3XI3,2X,2A6,1X,10F11.4)
      K=K+1
      GO TO 4
C     *** END OF DATA SUBSET
    7 WRITE OUTPUT TAPE 6,99,(NAME(K,J),J=1,2),(X(K,J),J=1,NVAR)
   99 FORMAT (8X,2A6,1X,10F11.4)
      NROW(N)= K-KPREV
      IF (X(K,2)-999.)   8,9,8
    8 N=N+1
      GO TO 3
C
C     *** END OF DATA
    9 MAXRO = K-1
      DO 10 K=1,MAXRO
   10 ID(K)=K
      DO 235 M=1,N
  235 NORIG(M)=NROW(M)
C
C
C     *** (REENTRY POINT SUCCESSIVE ITERATIONS)
```

```
C     *** COMPUTE SUMS AND AVERAGES
    5 DO 13 J=1,NVAR
      SUMTOT(J)=0.0
      K=0
      DO 12 M=1,N
      NR=NROW(M)
      SUMSET(M,J)=0.0
      IF (NR) 241,241,240
  240 DO 11 I=1,NR
      K=K+1
   11 SUMSET(M,J) = SUMSET(M,J) + X(K,J)
  241 XBAR(M,J) = SUMSET(M,J) / FLOATF(NR)
   12 SUMTOT(J) = SUMTOT(J) + SUMSET(M,J)
   13 XBAROV(J)=SUMTOT(J) / FLOATF(MAXRO)
C
C     **** PRINT AVERAGES
      WRITE OUTPUT TAPE 6,106
  106 FORMAT (//40X,8HAVERAGES/40X,8H--------//)
       DO 20 M=1,N
   20 WRITE OUTPUT TAPE 6,107,M,(XBAR(M,J) ,J=1,NVAR)
  107 FORMAT (8X,6HSUBSET,I3,4X,10F11.4)
      WRITE OUTPUT TAPE 6,108,(XBAROV(J),J=1,NVAR)
  108 FORMAT (8X,7HOVERALL,  6X,10F11.4)
C
C     *** DEVELOP D MATRIX
      DO 14 M=1,N
      DO 14 J=1,NVAR
   14 D(M,J) = XBAR(M,J) -XBAROV(J)
C     ***** DEVELOP V MATRIX
      K=0
      DO 45 M=1,N
      NR=NROW(M)
      IF (NR) 45,45,44
   44 DO 16 I=1,NR
      K=K+1
      DO 16 J=1,NVAR
   16 V(K,J) = X(K,J) - XBAR(M,J)
   45 CONTINUE
C     *** TRANSPOSE D AND V MATRICES
      DO 15 I=1,N
      DO 15 J=1,NVAR
   15 DT(J,I) = D(I,J)
      DO 17 I=1,MAXRO
      DO 17 J=1,NVAR
   17 VT(J,I) = V(I,J)
C
C     ***** DEVELOP DD, VV MATRICES, AND PRINT OUT IF
      DO 19 I=1,NVAR
      DO 19 J=1,NVAR
      DD(I,J) =0.0
      VV(I,J) =0.0
      DO 18 K=1,N
   18 DD(I,J) = DD(I,J) + DT(I,K) * D(K,J)
      DO 19 K=1,MAXRO
   19 VV(I,J) = VV(I,J) + VT(I,K) * V(K,J)
      IF (PROPT) 201,201,200
```

```
  200 WRITE OUTPUT TAPE 6,109
  109 FORMAT (//40X10HMATRIX DTD//)
      DO 21 I=1,NVAR
   21 WRITE OUTPUT TAPE 6,110,(DD(I,J) ,J=1,NVAR)
  110 FORMAT (10X,10F12.4)
      WRITE OUTPUT TAPE 6,111,
  111 FORMAT (//40X,10HMATRIX VTV//)
      DO 22 I=1,NVAR
   22 WRITE OUTPUT TAPE 6,110,(VV(I,J) ,J=1,NVAR )
C
  201 CALL DIRNM(DD,NVAR,VV,RES,ROOTR)
C     **** PRINT ROOTR
      DO 67 I=1,NVAR
   67 WRITE OUTPUT TAPE 6,117,I,ROOTR(I)
  117 FORMAT (5X I5,F20.8)
C     PRINT RESULT MATRIX
      WRITE OUTPUT TAPE 6,143
  143 FORMAT (//40X13HRESULT MATRIX//)
      DO 65 I=1,NVAR
   65 WRITE OUTPUT TAPE 6,110,(RES(I,J),J=1,NVAR)
C
C     *** COMPUTE XR
      DO 206 K=1,MAXRO
      DO 206 J=1,NVAR
      XR(K,J)=0.0
      DO 206 L=1,NVAR
  206 XR(K,J) = XR(K,J) + X(K,L) * RES(L,J)
C
C     *** PRINT XR IF
      IF (PROPT) 208,208,207
  207 WRITE OUTPUT TAPE 6,100,TITL
      WRITE OUTPUT TAPE 6,127,IT
      WRITE OUTPUT TAPE 6,144
  144 FORMAT (//40X9HMATRIX XR//)
      K=0
      DO 85 M=1,N
      WRITE OUTPUT TAPE 6,104,M
      NR=NROW(M)
      IF (NR) 85,85,84
   84 DO 81 I=1,NR
      K=K+1
   81 WRITE OUTPUT TAPE 6,105,K,(NAME(K,J) ,J=1,2),(XR(K,J),J=1,NVA
   85 CONTINUE
C
C     *** COMPUTE XAVR
  208 DO 82 M=1,N
      DO 82 J=1,NVAR
      XAVR(M,J)=0.0
      DO 82 L=1,NVAR
   82 XAVR(M,J) = XAVR(M,J) + XBAR(M,L) * RES(L,J)
C
C     *** PRINT XAVR IF
      IF (PROPT) 210,210,209
  209 WRITE OUTPUT TAPE 6,145
  145 FORMAT (//40X11HMATRIX XAVR//)
      DO 83 M=1,N
```

```
   83 WRITE OUTPUT TAPE 6,107,M,(XAVR(M,J) ,J=1,NVAR)
C
C     *** SET FORMAT CONTROL FOR THIS WIDTH
      MM=N
  210 IF (MM-4) 213,213,214
  213 IFMT=1
      GO TO 217
  214 IF (MM-7) 215,215,216
  215 IFMT=2
      GO TO 217
  216 IFMT=3
C
C     *** COMPUTE DISTANCE MATRIX
  217 DO 211 K=1,MAXRO
      DO 211 MM=1,N
      DIST(K,MM) =0.0
      DO 212 L=1,NVAR
  212 DIST(K,MM) = DIST(K,MM) + (XR(K,L)-XAVR(MM,L))**2
  211 DIST(K,MM) = SQRTF(DIST(K,MM))
C
C     *** COMPUTE RANKS (WHICH COL OF GIVEN ROW HAS LEAST VALUE)
C     *** STORE RANKS IN TEMP VECTOR
      DO 224 K=1,MAXRO
      DISTLO=DIST(K,1)
      IRTEMP(K)=1
      DO 224 MM=2,N
      IF (DIST(K,MM) -DISTLO) 223,224,224
  223 DISTLO=DIST(K,MM)
      IRTEMP(K)=MM
  224 CONTINUE
C
C     *** PRINT DISTANCE MATRIX, AND CURRENT RANKS
C     *** DO TITLES
      WRITE OUTPUT TAPE 6,100,TITL
      WRITE OUTPUT TAPE 6,127,IT
      WRITE OUTPUT TAPE 6,121,(MM,MM=1,N)
  121 FORMAT (//28X3THDISTANCE FROM AVERAGES OF SUBSETS....//
     1   1H+,20X,10(I8,2X))
      GO TO (218,219,220),IFMT
  218 WRITE OUTPUT TAPE 6,151,
      GO TO 221
  219 WRITE OUTPUT TAPE 6,152
      GO TO 221
  220 WRITE OUTPUT TAPE 6,153
  151 FORMAT (67X,4HRANK)
  152 FORMAT (92X,4HRANK)
  153 FORMAT (122X,4HRANK)
C     *** DO BODY
  221 K=0
      DO 229 M=1,N
      WRITE OUTPUT TAPE 6,104,M
      NR=NROW(M)
      IF (NR) 229,229,222
  222 DO 228 I=1,NR
      K=K+1
      WRITE OUTPUT TAPE 6,154,K,(NAME(K,J),J=1,2),(DIST(K,MM),MM=1,N)
```

```
154 FORMAT (3H0   ,I3,2X,2A6,1X,10F10.4)
    GO TO (225,226,227),IFNT
225 WRITE OUTPUT TAPE 6,161,IRTEMP(K)
    GO TO 228
226 WRITE OUTPUT TAPE 6,162,IRTEMP(K)
    GO TO 228
227 WRITE OUTPUT TAPE 6,163,IRTEMP(K)
161 FORMAT (68X,I2)
162 FORMAT (93X,I2)
163 FORMAT (123X,I2)
228 CONTINUE
229 CONTINUE
C
C       *** UNSCRAMBLE TEMP RANKS, STORE PERM FOR THIS ITER
        DO 50 K=1,MAXRO
        L=ID(K)
 50     IRANK(L,IT) = IRTEMP(K)
C
        IF (IT-1) 24,24,25
 25     IF (IT-MAXIT) 26,70,70
C
C       *** ARE RESULTS THIS ITER SAME AS PREVIOUS
 26     DO 27 K=1,MAXRO
        IF (IRANK(K,IT) - IRANK(K,IT-1))  24,27,24
 27     CONTINUE
        GO TO 70
C
C       *** REARRANGE DATA INTO NEW SUBSETS,IN ALTERNATE STORAGE
C       *** KEEP COUNT OF ROWS EACH NEW SUBSET.
 24     KNU=0
        DO 234 M=1,N
        NROW(M)=0
        DO 234 K=1,MAXRO
        IF (IRTEMP(K)-M) 234,231,234
231     NROW(M)=NROW(M)+1
        KNU=KNU+1
        DO 232 J=1,NVAR
232     XALT(KNU,J) = X(K,J)
        DO 233 J=1,2
233     NAMALT(KNU,J) = NAME(K,J)
        IDALT(KNU) = ID(K)
234     CONTINUE
C
C       *** COPY REARRANGED DATA BACK INTO WORKING LOCATIONS
        DO 35 K=1,MAXRO
        DO 34 J=1,NVAR
 34     X(K,J) = XALT(K,J)
        ID(K)=IDALT(K)
        DO 35 J=1,2
 35     NAME(K,J) = NAMALT(K,J)
C
C       *** PROCESS NEW DATA FROM SCRATCH
        IT=IT+1
        WRITE OUTPUT TAPE 6,100,TITL
        WRITE OUTPUT TAPE 6,127,IT
        GO TO 5
```

```
C
C
C
C     *** INTERRUPT ITERS (20 ITERS OR CONVERGING)
   70 WRITE OUTPUT TAPE 6,100,TITL
   71 WRITE OUTPUT TAPE 6,123,IT
  123 FORMAT (/5X10HRESULTS OF ,I3,11H ITERATIONS/5X,24(1H-))
      WRITE OUTPUT TAPE 6,124,(J,J=1,IT)
  124 FORMAT (42X,20I3)
C
C     *** SORT NAMES BACK INTO ORIGINAL ROWS
      DO 36 K=1,MAXRO
      L=ID(K)
      DO 36 J=1,2
   36 NAMALT(L,J) = NAME(K,J)
C
C     *** PRINT TABLE OF RANKS FOR ALL ITERATIONS
      K=0
      DO 73 M=1,N
      WRITE OUTPUT TAPE 6,164,M
  164 FORMAT (/20X,6HSUBSET,I3)
      NR=NORIG(M)
      DO 73 I=1,NR
      K=K+1
   73 WRITE OUTPUT TAPE 6,125,K,(NAMALT(K,J),J=1,2),(IRANK(K,J),J=1,IT)
  125 FORMAT (22X,I3,3X,2A6,2X,20I3)
      GO TO 2
      END(1,1,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

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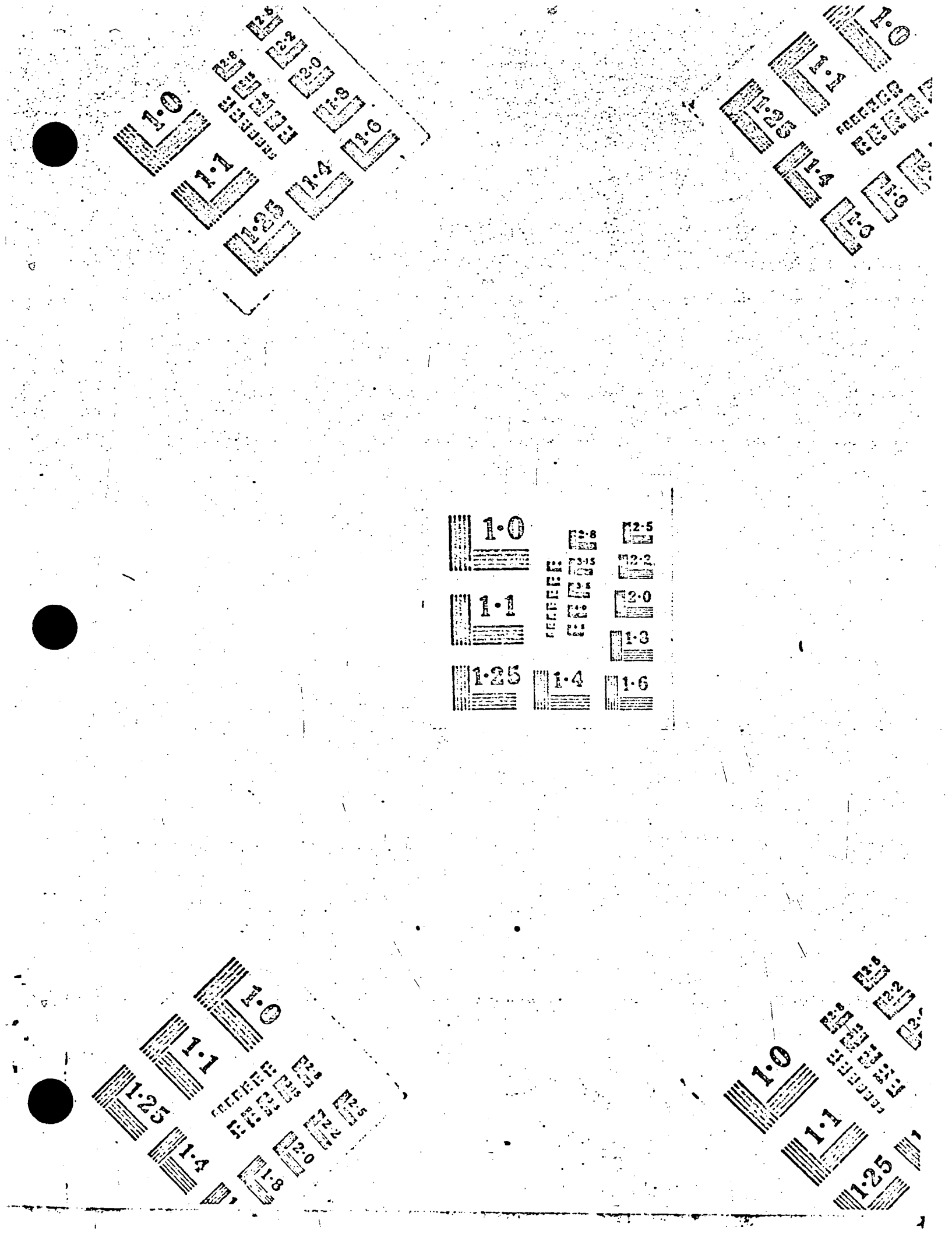
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A Criterion for Selecting Variables for the Linear Discriminant Function

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Summary

This paper considers the problem of selection of variables for the linear discriminant function (Anderson's classification statistic, W) in the case of two multivariate normal populations with different means and a common covariance matrix. The two conditional errors of allocation associated with the application of W are averaged over the prior distribution of the populations to form the conditional risk. A method for selecting variables is then developed on the basis of the conditional risk which is of central interest in evaluating the performance of the discriminant function formed from the selected variables. A tolerance interval on the increased conditional risk consequent to deleting a subset of variables from the linear discriminant function is presented. The confidence coefficient corresponding to no increase in risk is considered as an indicator of the additional discrimination value of the subset deleted. The proposed method can be used either as a step-down or a step-up type selection procedure.

1. Introduction

The selection of the most useful variables in discriminant analysis is an important and difficult problem in practice. For example, in the analysis of medical research data, it is usual for the investigator to attempt to reduce the number of variables measured on each individual. There may be several reasons for this. The investigator may wish to measure fewer variables in subsequent studies, to reduce cost or effort of measurement. He may wish to determine those variables which are most relevant in identifying the underlying biologic structure of the problem studied, or he may be essentially trying to reduce the complexity of the problem.

There are a number of statistical methods which have been suggested and used as rules for the selection of a subset of variables. Weiner and Dunn [1966] compared some intuitive selection procedures with a stepwise method and random selection for some medical data. Horton, Russell and Moore [1968] used a stepwise method described in Kendall [1957] to analyze some soil data, which has been analyzed further recently by McCabe [1975] who gave an algorithm for computing statistics for all possible subsets of variables. Urbakh [1971] proposed a criterion for eliminating a single variable and, in the context of an empirical problem, Eisenbeis, Gilbert and Avery [1973] examined several methods for selecting variable subsets. The situation where the variables fall into two subsets, those which are easy or inexpensive to measure and those which are difficult or expensive to measure, has been studied by Das Gupta and Perlman [1974] on the basis of Hotelling's T^2 and by Zielezny and Dunn [1975] who suggested a two-stage classification procedure.

In this study we shall present a tolerance interval on the increased conditional risk consequent to deleting a subset of variables from the linear discriminant function.

Key Words: Anderson's classification statistics; Conditional risk; Selection of variables.

2. *Statement of the Problem*

The allocation of a multivariate observation $\mathbf{x}$ into one of two normal populations Π_1, Π_2 with different means $\boldsymbol{\mu}_1$, $\boldsymbol{\mu}_2$, respectively, and common covariance matrix $\boldsymbol{\Sigma}$ is considered on the basis of Anderson's classification statistic

$$W = \{\mathbf{x} - \tfrac{1}{2}(\bar{\mathbf{x}}_1 + \bar{\mathbf{x}}_2)\}'\mathbf{S}^{-1}(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2),$$

where $\bar{\mathbf{x}}_1$, $\bar{\mathbf{x}}_2$ and $\mathbf{S}$ are the sample means and pooled sample covariance matrix, based on two samples of sizes n_1, n_2 from Π_1, Π_2, respectively. The observations $\mathbf{x}$ is allocated to Π_1 or Π_2 according as W is $>$ or is ≤ 0, and the conditional error of misallocation for $\mathbf{x}$ coming from Π_i is

$$P_i = G\left((-1)^i \frac{\{\boldsymbol{\mu}_i - \tfrac{1}{2}(\bar{\mathbf{x}}_1 + \bar{\mathbf{x}}_2)\}'\mathbf{S}^{-1}(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2)}{+\sqrt{\{(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2)'\mathbf{S}^{-1}\boldsymbol{\Sigma}\mathbf{S}^{-1}(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2)\}}}\right), \qquad (i = 1, 2),$$

where G denotes the standard normal distribution function. It is assumed that there are equal probabilities and equal costs of misallocation so that the conditional risk is

$$r = \tfrac{1}{2}(P_1 + P_2).$$

The observation vector is partitioned now into two subvectors, $\mathbf{x}' = (\mathbf{x}_1', \mathbf{x}_2')$, where $\mathbf{x}_i$ has P_i components $(i = 1, 2)$. The corresponding partitions of the parameters and their estimators are $\boldsymbol{\mu}_i' = (\boldsymbol{\mu}_{1i}', \boldsymbol{\mu}_{2i}')$ and $\bar{\mathbf{x}}_i' = (\bar{\mathbf{x}}_{1i}', \bar{\mathbf{x}}_{2i}')$ for $i = 1, 2$ and

$$\boldsymbol{\Sigma} = \begin{bmatrix} \boldsymbol{\Sigma}_{11} & \boldsymbol{\Sigma}_{12} \\ \boldsymbol{\Sigma}_{21} & \boldsymbol{\Sigma}_{22} \end{bmatrix}, \qquad \mathbf{S} = \begin{bmatrix} \mathbf{S}_{11} & \mathbf{S}_{12} \\ \mathbf{S}_{21} & \mathbf{S}_{22} \end{bmatrix}.$$

The conditional risk for the case where the allocation is performed on the basis of the subset of variables, $\mathbf{x}_1$, is denoted by r_1.

It is well known that deletion of variables can never decrease the risk when the parameters are known. However, when the parameters are estimated, the risk may indeed be reduced on elimination of variables, providing the simultaneous reduction of the Mahalanobis distance between Π_1 and Π_2 is small.

Since the difference in the conditional risks, $r - r_1$, contains the unknown parameters it must be estimated. We shall estimate r by the estimator

$$Q(D, p) = \tfrac{1}{2}\{Q_1(D, p) + Q_2(D, p)\},$$

where $Q_i(D, p)$ is the asymptotic unbiased estimator of P_i suggested by McLachlan [1974] and defined by

$$Q_i(D, p) = G(-\tfrac{1}{2}D) + g(-\tfrac{1}{2}D)[\{(p-1)/D\}n_i^{-1} + (D/32)\{4(4p-1) - D^2\}N^{-1}] + 0_2,$$

where $D = \{(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2)'\mathbf{S}^{-1}(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2)\}^{1/2}$, g denotes the standard normal density function, 0_i denotes the term of the ith order with respect to $(n_1^{-1}, n_2^{-1}, N^{-1})$, $N = n_1 + n_2 - 2$ and $p = p_1 + p_2$. The asymptotic bias of $Q_i(D, p)$ is of the third order, although the second order term in its definition has been omitted here since second or higher order terms are to be ignored in this study. The corresponding estimator of r_1 is $Q(D_1, p_1)$, where

$$D_1 = \{(\bar{\mathbf{x}}_{11} - \bar{\mathbf{x}}_{12})'\mathbf{S}_{11}^{-1}(\bar{\mathbf{x}}_{11} - \bar{\mathbf{x}}_{12})\}^{1/2}.$$

By deriving the asymptotic distribution of

$$d = Q(D, p) - Q(D_1, p_1) - (r - r_1),$$

we shall obtain a criterion for determining with an associated level of confidence whether the elimination of a subset of variables from the observation vector will not increase the conditional risk.

3. *Distribution of d*

Since r and r_1 are invariant under any nonsingular linear transformation of the form

$$\begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{0} \\ \mathbf{A}_{21} & \mathbf{A}_{22} \end{bmatrix} \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{B}_1 \\ \mathbf{B}_2 \end{bmatrix},$$

we may suppose that $\boldsymbol{\mu}_1 = \mathbf{0}$, $\boldsymbol{\mu}_2 = \boldsymbol{\mu}_0$ and $\boldsymbol{\Sigma} = \mathbf{I}$, where $\boldsymbol{\mu}_0$ is a vector with its first component Δ_1, its $(p+1)$ th component Δ_2, and all other components zero, and

$$\Delta^2 = (\boldsymbol{\mu}_1 - \boldsymbol{\mu}_2)'\boldsymbol{\Sigma}^{-1}(\boldsymbol{\mu}_1 - \boldsymbol{\mu}_2),$$

$$\Delta_1^2 = (\boldsymbol{\mu}_{11} - \boldsymbol{\mu}_{12})'\boldsymbol{\Sigma}_{11}^{-1}(\boldsymbol{\mu}_{11} - \boldsymbol{\mu}_{12}),$$

and

$$\begin{aligned} \Delta_2^2 &= \Delta^2 - \Delta_1^2 \\ &= \mathbf{b}'(\boldsymbol{\Sigma}_{22} - \boldsymbol{\Sigma}_{21}\boldsymbol{\Sigma}_{11}^{-1}\boldsymbol{\Sigma}_{12})^{-1}\mathbf{b}, \end{aligned}$$

where $\mathbf{b} = \boldsymbol{\mu}_{21} - \boldsymbol{\mu}_{22} - \boldsymbol{\Sigma}_{21}\boldsymbol{\Sigma}_{11}^{-1}(\boldsymbol{\mu}_{11} - \boldsymbol{\mu}_{12})$.

The asymptotic distribution of d may be obtained by the application of Theorem 1, given in the appendix of McLachlan [1975], where it was used for expanding the distribution of $P_1 - Q_1(D, p)$. Similarly, the distribution of d can be expanded to show that, on ignoring the term of the second order, d has a normal distribution with mean zero and variance

$$\sigma^2 = v(\Delta) + v(\Delta_1) - 2\{\Delta_1 g(-\tfrac{1}{2}\Delta)/\Delta g(-\tfrac{1}{2}\Delta_1)\}v(\Delta_1),$$

where

$$v(\Delta) = \{g(-\tfrac{1}{2}\Delta)\}^2(1/4n_1 + 1/4n_2 + \Delta^2/8N).$$

4. *Proposed Criterion*

Since the asymptotic distribution of d is $N(0, \sigma^2)$, it follows that

$$\Pr\{r - r_1 \geq Q(D, p) - Q(D_1, p_1 - z\sigma\} \approx \alpha \tag{4.1}$$

for $z = G^{-1}(\alpha)$, where Pr refers to the unconditional probability. Hence by setting

$$Q(D, p) - Q(D_1, p_1) - z\sigma \geq 0, \tag{4.2}$$

a criterion is obtained for deciding if $r \geq r_1$ with an associated confidence α equal to the asymptotic unconditional probability that $r - r_1$ exceeds the left-hand side of (4.2). On estimating Δ and Δ_1 by D and D_1, respectively, in σ, the criterion becomes

$$C = Q(D, p) - Q(D_1, p_1) - z\sigma(D, D_1) \geq 0. \tag{4.3}$$

Of course, one may wish to test whether $r - r_1 \geq \epsilon$ for $\epsilon < 0$ rather than $\epsilon = 0$. This variation can be easily accommodated by replacing zero with ϵ on the right-hand side of (4.3).

The criterion differs from other methods in that the selection procedure is defined directly in terms of the estimated conditional risk, which is of central interest in evaluating the

performance of the discriminant function formed from the selected variables. The criterion may be used as a step-down or a step-up type procedure.

By calculating the value of z, and hence α, for which the left-hand side of (4.3) is zero, we obtain the approximate confidence coefficient, α_0, corresponding to no increase in the conditional risk, which may be used as an indicator of the additional discrimination value of the subset deleted. Indeed, it is this last form of the criterion which would appear to be more useful in practice.

5. *Some Numerical Results*

We now consider the data of Zaslavski and Sycheva [1965] related to the diagnostics of stenocardia by means of 13 ballistocardiographical variables and described in Urbakh [1971]. By setting $\hat{\Delta}_1^2 - \hat{\Delta}^2 \geq 0$, Urbakh [1971] subsequently gave a criterion for the elimination of a single variable, where $\hat{\Delta}^2$ and $\hat{\Delta}_1^2$ are possible estimates of Δ^2 and Δ_1^2, respectively; for example,

$$\hat{\Delta}^2 = \{D^2 - p(1/n_1 + 1/n_2)\}\{(N - p - 1)/N\}$$

as suggested by Lachenbruch and Mickey [1968]. On applying his criterion to the data of Zaslavski and Sycheva and considering the 13 subsets of 12 variables obtained by successively excluding each of the variables, Urbakh [1971] suggested that any one of the variables 3, 4, 8 or 10 may be omitted.

We now consider the suggestions of Urbakh [1971] on the basis of the criterion proposed in the previous section. The criterion is applied to the same data (for which $D^2 = 10.90$ and $n_1 = 100$, $n_2 = 93$), and the purpose of the application of the criterion here is to report the significance values associated with the elimination of a single variable from the system. For each of the 13 possible values of D_1^2 formed by splitting the 13 variables into two subsets with $p_1 = 12$ and $p_2 = 1$, the value of α for which C is zero is computed from (4.3) to give the approximate confidence coefficient, α_0, corresponding to no increase in the conditional risk on deleting a single variable. The values of α_0 obtained can be interpreted as a measure of the relative value of the individual variables. They are displayed in Table 1 along with the corresponding values of D_1^2 and $Q(D, p) - Q(D_1, p_1)$. Note that as the initial samples are large in this example $[(n_1 + n_2 - p - 1)/p = 13.8]$, the approximate confidence coefficients in Table 1 should be fairly close to the exact values; see Lachenbruch [1965] for use of the expression $(n_1 + n_2 - p - 1)/p$ as an indicator of largeness of sample size.

We see from Table 1 that if any one of the variables 3, 4, 8 or 10 is deleted, one can be reasonably confident that there is no increase in the conditional risk; indeed, the confidence coefficient associated with the deletion of variable 8 is as high as 0.99.

Of course the criterion can be applied to the above data to give the confidence coefficient associated with the selection of any subset of variables. For example, following on from the results in Table 1, it is of interest to consider the simultaneous elimination of variables 3, 4, 8 and 10 from the system. On splitting the 13 variables into two subsets with $p_1 = 9$ and $p_2 = 4$ and applying the criterion, it is found that the approximate confidence coefficient corresponding to no increase in the conditional risk on eliminating variables 3, 4, 8 and 10 simultaneously is given by $\alpha_0 = 0.31$; the estimated difference in the conditional risks is given by $Q(D, p) - Q(D_1, p_1) = -0.0020$ and $D_1^2 = 10.17$.

Table 1

LEVEL OF CONFIDENCE THAT THE CONDITIONAL RISK IS NOT INCREASED ON DELETING A GIVEN VARIABLE

Variable	D_1^2	$Q(D,p) - Q(D_1,p_1)$	α_0
1	9.90	-0.0087	0.03
2	9.81	-0.0097	0.02
3	10.86	0.0008	0.83
4	10.87	0.0009	0.89
5	10.38	-0.0038	0.12
6	7.85	-0.0352	0.00
7	10.41	-0.0035	0.14
8	10.89	0.0011	0.99
9	10.72	-0.0005	0.40
10	10.85	0.0007	0.78
11	9.16	-0.0172	0.00
12	9.10	-0.0180	0.00
13	9.85	-0.0093	0.03

Un Critere de Selection de Variables Pour la Function Discriminante Lineaire

Résumé

Dans cet article on considère le problème de sélection de variables pour la fonction linéaire discriminante (avec la statistique de classement W d'Anderson). On présente un intervalle de tolérance de l'accroissement du risque conditionnel dû à la suppression d'un sous ensemble de variables de la fonction discriminante linéaire. Le coefficient de confiance correspondant au non accroissement du risque est pris comme un indicateur de la valeur additionnelle de discriminationdu sous ensemble supprimé.

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VI. Questions relating to: Texas Instruments, Indian Point Impingement Study Report for the Period 1 January 1975 through 31 December 1975 (November 1976)

VI:1 With respect to unscheduled screen washings to alleviate head loss due to high debris loading or impingement, the comment is made on page III-2 that: "When TI was notified of their occurrence, these additional washes and fish collections were treated in the same manner as the scheduled daily washes." Provide dates and units when TI was so notified. Provide dates and units when TI was not so notified.

Response: Dates on which there were unscheduled screen washes and Texas Instruments' Impingement collection crews were so notified are listed in Attachment A.

Dates on which there were unscheduled screen washes and Texas Instruments' Impingement collection crews could not be reached before the wash are listed in Attachment B. With respect to these latter incidences, it was sometimes necessary to immediately wash heavy loads of debris such as leaves and grass from the screens to prevent damage. If such corrective action is not taken immediately, screens can collapse. When this occurs, the associated circulator pump must be taken out of service, an action which would normally result in the derating of the plant.

Attachment A

Dates of Emergency (unscheduled) screen washes when impinged fish were collected in 1975

Month

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.					x		x		x	x	x	x
2.					x		x		x	x	x	x
3.							x		x	x	x	x
4.	x	x							x	x	x	x
5.						x			x	x	x	x
6.										x		x
7.									x	x		x
8.					x		x					
9.	x									x		
10.				x		x	x			x		
11.	x	x			x	x			x			
12.	x				x	x	x					
13.	x	x			x			x	x		x	
[illegible]	x				x					x		
[illegible]	x				x		x	x				
16.	x						x			x		
17.					x		x	x				
18.				x			x	x				x
19.				x				x	x			
20.				x		x	x	x			x	x
21.							x	x			x	x
22.							x	x			x	x
23.				x			x	x			x	
24				x								
25.		x		x				x	x			x
26.	x	x			x	x	x	x	x	x		
27.				x			x	x	x			
28.				x			x	x	x			
29	x			x	x	x	x					
30.	x			x	x	x	x	x				
31.	x							x		x		

Attachment B

Dates of Emergency (unscheduled) Screen Washes when impinged fish were not collected in 1975

Date
April 26, 1975
May 4, 1975
July 12, 1975
July 13, 1975
August 12, 1975
August 16, 1975
September 13, 1975
September 24, 1975
November 30, 1975
December 3, 1975

VI 2. Provide an explanation of why it is not possible to calculate the values in Tables A-6 and A-7 (number of fish impinged per 10^6 m^3 of water pumped) from the data in Tables A-4 and A-5 (number of fish impinged) and Tables C-1 and C-2 (total flow, in 10^6 m^3).

Response: Tables A-4 and A-5 of the 1975 Indian Point Impingement Study Report include all fish count data collected during 1975 from all the intake screens of Units Nos. 1 and 2 respectively. Tables C-1 and C-2 present the total daily flow for Units Nos. 1 and 2 respectively, based on the number of circulators operating and the daily operating time for each.

In calculating impingement rates, only those days for which data on the actual circulator operating times and the corresponding impingement counts were used. This was necessary as occasionally, one or more circulators were operated intermittently, making it impossible to correlate a specific impingement count with the volume circulated during the period of operation. In addition, occasional unscheduled emergency screen washes, resulting in the loss of impinged fish, also prevented the calculation of an impingement rate. Accordingly, the data used to calculate the rates of impingement presented in Tables A-6 and A-7 were selected to include only data that represented known flow volumes and associated impingement collections, and consequently, the values presented would differ from what might be calculated using all fish counts presented in Tables A-4 and A-5 and all circulator flows presented in Tables C-1 and C-2.

VI.3. With respect to the 1975 monthly estimates of impingement rate (number/10^6 m^3) for each of the six species in Tables A-6 and A-7, provide in a table the numerator and denominator used to calculate each impingement rate, and the impingement rate itself, rounded off to two decimal places (instead of no decimal places). Provide the same information for each of the six species for each month from 15 June 1972 through December 31, 1974.

Response: The data in Tables A-6 and A-7 have been updated since the printing of the Impingement Study Report for 1975. The data in Tables 8 and 9 attached contain the information, in a corrected format, per your request.

Tables 1 through 7 attached contain the requested information for the period 15 June 1972 through December 31, 1974.

Note that the number of each species collected in a given month is the numerator and the flow for that month (Column 2 in the tables) is the denominator in the calculation of the impingement rate for the species in that specific month.

Table 1

MONTHLY ESTIMATES OF IMPINGEMENT RATES (NUMBER/$10^6 m^3$): 1972 UNIT I

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JUN	19.555369	18	.92	1	.05	1	.05	5	.26	111	5.68	193	9.87
JUL	36.530043	6	.16	10	.27	5	.14	51	1.40	207	5.67	287	7.86
AUG	45.186185	859	19.01	5325	117.85	0	0	474	10.49	5447	120.55	1579	34.94
SEP	31.802516	433	13.62	4871	153.16	34	1.07	355	11.16	24991	785.82	1813	57.01
OCT	35.671181	182	5.10	1666	46.70	1373	38.49	405	11.35	6302	176.67	11964	335.40
NOV	20.395506	8	.39	15	.74	138	6.77	140	6.86	82	4.02	5218	255.84
DEC	20.603041	7	.34	24	1.16	8	.39	96	4.66	123	5.97	2609	126.63

Table 2

MONTHLY ESTIMATES OF IMPINGEMENT RATES (NUMBER/$10^6 m^3$): 1972 UNIT II

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JUN	22.623807	11	.48	1	.04	0	0	4	.18	4261	188.34	144	6.36
JUL	2.670977	0	0	0	0	0	0	0	0	0	0	0	0
AUG	8.876760	0	0	0	0	0	0	0	0	0	0	0	0
SEP	39.293564	11	.28	92	2.34	5	.13	44	1.12	4651	118.37	202	5.14
OCT	12.384499	1	.08	24	1.94	9	.73	20	1.61	2120	171.18	251	20.27
NOV		UNIT NOT OPERATING											
DEC		UNIT NOT OPERATING											

Table 3

MONTHLY ESTIMATES OF IMPINGEMENT RATES (NUMBER/$10^6 m^3$): 1973 UNIT I

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JAN	.960621	0	0	0	0	0	0	0	0	11	11.45	9	9.36
FEB		UNIT NOT OPERATING											
MAR		UNIT NOT OPERATING											
APR		UNIT NOT OPERATING											
MAY	16.087102	8	.50	0	0	0	0	9	.56	44	2.74	2137	132.84
JUN	4.403026	7	1.58	0	0	2	.45	8	1.82	10	2.27	123	27.94
JUL	1.319476	0	0	0	0	0	0	0	0	0	0	0	0
AUG	1.154812	0	0	0	0	0	0	0	0	0	0	2	1.73
SEP	1.396812	0	0	0	0	0	0	0	0	0	0	0	0
OCT		UNIT NOT OPERATING											
NOV		UNIT NOT OPERATING											
DEC		UNIT NOT OPERATING											

Table 4

MONTHLY ESTIMATES OF IMPINGEME[illegible]ATES (NUMBER/$10^6 m^3$): 1973 UNIT II

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERC[illegible] NO.	WHITE PERC[illegible] RATE
JAN	2.050929	0	0	0	0	0	0	49	23.89	971	473.44	1190	580.22
FEB	13.911866	0	0	5	.36	0	0	134	9.63	1120	80.51	9554	686.75
MAR	47.088670	7	.15	0	0	2	.04	502	10.66	400	8.49	30232	642.02
APR	25.059175	0	0	0	0	0	0	418	16.68	602	24.02	17652	704.41
MAY	18.097149	6	.33	0	0	0	0	9	.50	211	11.66	3084	170.41
JUN	46.219674	32	.69	5	.11	11	.24	25	.54	7918	171.31	679	14.69
JUL	65.810963	368	5.59	295	4.48	2	.03	28	.43	9188	139.61	381	5.79
AUG	81.163031	581	7.16	8421	103.75	12	.15	223	2.75	3390	41.77	2277	28.05
SEP	46.443205	51	1.10	2724	58.65	23	.50	21	.45	429	9.24	218	4.69
OCT	54.601137	67	1.23	413	7.56	67	1.23	14	.26	1	.02	43	.79
NOV	15.368618	58	3.77	12	.78	482	31.36	113	7.35	3	.20	630	41.00
DEC	9.640642	12	1.24	2	.21	204	21.16	101	10.48	43	4.46	1828	189.61

Table 5

MONTHLY ESTIMATES OF IMPINGEMENT RATES (NUMBER/$10^6 m^3$): 1974 UNIT I

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JAN	8.067330	0	0	0	0	0	0	67	8.31	192	23.80	4596	569.71
FEB	26.822815	0	0	0	0	2	.07	76	2.83	17	.63	6684	249.20
MAR	25.717551	1	.04	0	0	1	.04	128	4.98	9	.35	6482	252.05
APR	30.786502	0	0	0	0	24	.78	349	11.34	1	.03	8433	273.92
MAY	20.010298	135	6.75	20	1.00	75	3.74	33	1.65	469	23.44	1785	89.20
JUN	47.063151	184	3.91	1839	39.08	417	8.86	55	1.17	27771	590.08	1138	24.18
JUL	44.059160	254	5.76	5239	118.91	53	1.20	75	1.70	4702	106.72	236	5.36
AUG	50.423321	190	3.77	4963	98.43	91	1.80	104	2.06	11238	222.87	171	3.39
SEP	49.390965	225	4.56	3114	63.05	136	2.75	108	2.19	5090	103.06	446	9.03
OCT	47.836320	1306	27.30	1960	40.98	7619	159.27	154	3.22	996	20.82	4534	94.78
NOV	17.556911	123	7.01	2	.11	6947	395.68	45	2.56	21	1.20	2360	134.4
DEC	23.050243	163	7.07	8	.35	30	1.30	371	16.10	2941	127.59	21580	936.22

Table 6

MONTHLY ESTIMATES OF IMPINGEMENT RATES (NUMBER/$10^6 m^3$): 1974 UNIT II

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JAN	11.500782	1	.09	0	0	1	.09	386	33.56	26	2.26	22107	1922.22
FEB	11.933550	1	.08	0	0	16	1.34	414	34.69	9	.75	22954	1923.48
MAR	28.189285	2	.07	0	0	5	.18	253	8.98	4	.14	38982	1382.84
APR	55.492388	10	.18	0	0	337	6.07	377	6.79	2	.04	69740	1256.75
MAY	90.961079	409	4.50	154	1.69	1572	17.28	912	10.03	12824	140.98	59371	652.71
JUN	117.842025	313	2.66	7035	59.70	776	6.59	207	1.76	112926	958.28	7434	63.08
JUL	112.282260	574	5.11	25806	229.83	90	.80	313	2.79	75116	668.99	713	6.35
AUG	117.042844	478	4.08	23182	198.06	249	2.13	588	5.02	56252	480.61	1224	10.46
SEP	113.346937	288	2.54	18318	161.61	362	3.19	427	3.77	37831	333.76	3502	30.90
OCT	94.089405	1246	13.24	1917	20.37	6763	71.88	182	1.93	1754	18.64	11366	120.80
NOV	63.971424	237	3.70	31	.48	11480	179.46	252	3.94	152	2.38	18110	283.10
DEC	45.273062	2	.04	1	.02	9	.20	220	4.86	617	13.63	46094	1018.13

Table 7

MONTHLY ESTIMATES OF IMPINGEMENT RATES (NUMBER/$10^6 m^3$): 1974 UNIT III

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JAN		UNIT NOT OPERATING											
FEB		UNIT NOT OPERATING											
MAR	.146798	0	0	0	0	0	0	1	6.81	0	0	4	27.25
APR	4.372137	18	4.12	0	0	2	.46	20	4.57	1	.23	3060	699.89
MAY	1.335489	9	6.74	0	0	0	0	6	4.49	0	0	429	321.23
JUN	16.876433	185	10.96	576	34.13	332	19.67	84	4.98	20583	1219.63	1001	59.31
JUL	3.497710	11	3.14	713	203.85	2	.57	13	3.72	2866	819.39	14	4.00
AUG	4.578820	6	1.31	27	5.90	0	0	9	1.97	428	93.57	2	.44
SEP	5.834814	2	.34	8	1.37	0	0	11	1.89	183	31.36	9	1.54
OCT	4.706009	58	12.32	8	1.70	11	2.34	18	3.82	29	6.16	63	13.39
NOV		UNIT NOT OPERATING											
DEC		UNIT NOT OPERATING											

Table 8

MONTHLY ESTIMATES OF IMPINGEMENT [illegible]S (NUMBER/$10^6 m^3$): 1975 UNIT I

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JAN	14.572275	7	.48	1	.07	8	.55	152	10.43	584	40.08	9301	638.27
FEB	14.709126	51	3.47	0	0	30	2.04	693	47.11	449	30.53	15367	1044.73
MAR	15.939789	8	.50	0	0	7	.44	93	5.83	52	3.26	5882	369.01
APR	15.570711	11	.71	0	0	75	4.82	103	6.61	31	1.99	11111	713.58
MAY	10.980992	12	1.09	0	0	35	3.19	5	.46	49	4.46	777	70.76
JUN	14.185143	19	1.34	52	3.67	22	1.55	0	0	703	49.56	124	8.74
JUL	6.370336	10	1.57	121	18.99	17	2.67	10	1.57	119	18.68	61	9.58
AUG	4.539557	4	.88	74	16.30	2	.44	7	1.54	83	18.28	43	9.47
SEP		UNIT NOT OPERATING											
OCT		UNIT NOT OPERATING											
NOV		UNIT NOT OPERATING											
DEC		UNIT NOT OPERATING											

Table 9

MONTHLY ESTIMATES OF IMPINGEMENT [illegible]S (NUMBER/$10^6 m^3$): 1975 UNIT II

MONTH	FLOW	ALEWIFE NO.	ALEWIFE RATE	BAY ANCHOVY NO.	BAY ANCHOVY RATE	BLUEBACK HERRING NO.	BLUEBACK HERRING RATE	STRIPED BASS NO.	STRIPED BASS RATE	ATLANTIC TOMCOD NO.	ATLANTIC TOMCOD RATE	WHITE PERCH NO.	WHITE PERCH RATE
JAN	48.095075	2	.04	0	0	2	.04	162	3.37	429	8.92	31858	662.40
FEB	47.433706	34	.72	3	.06	11	.23	557	11.74	265	5.59	24875	524.42
MAR	28.205848	1	.04	1	.04	5	.18	59	2.09	23	.82	13417	475.68
APR	76.456711	6	.08	0	0	184	2.41	440	5.75	76	.99	67665	885.01
MAY	101.794942	71	.70	10	.10	241	2.37	59	.58	673	6.61	12322	121.05
JUN	134.945261	354	2.62	1559	11.55	149	1.10	34	.25	28351	210.09	1831	13.57
JUL	126.412975	2343	18.53	24793	196.13	1282	10.14	1289	10.20	15195	120.20	1757	13.90
AUG	87.074899	132	1.52	38286	439.69	1003	11.52	938	10.77	12425	142.69	13455	154.52
SEP	115.148780	184	1.60	23368	202.94	656	5.70	596	5.18	16818	146.05	11054	96.00
OCT	72.519671	179	2.47	7675	105.83	47308	652.35	220	3.03	283	3.90	7152	98.62
NOV	103.708610	715	6.89	2	.02	91232	879.70	198	1.91	333	3.21	26901	259.34
DEC	102.871084	89	.87	29	.28	10273	99.86	359	3.49	1609	15.64	43933	427.07

VII. Questions relating to: J. E. Baker, "Rearing of Hudson River striped bass at the Edenton National Fish Hatchery (1975)" (August 1976)

VII.1. Provide an estimate of the rearing cost per fingerling for the 270,961 fingerlings mentioned on page 27. Provide a second estimate of this rearing cost, including labor (i.e., the 441 Man-Days mentioned on page 28). In each case provide a step-by-step explanation of the derivation.

Response: a) In Table X of Baker's report (Attachment 1), materials and services costs (excluding labor) for Phase I and Phase II culture combined total $9,110.47.

Under this amount, Baker calculated the "Cost per Fish (Phase I and Phase II): $0.019 per Fish". It appears that this price excludes labor costs. Baker probably calculated this cost as follows (see Table IX, Attachment 1).

Total Phase I fingerlings disposed	517,727 fish
Phase I fingerlings restocked for Phase II	-331,243 fish
Phase I fingerlings distributed	186,484 fish

Total Phase II fingerlings distributed and restocked	270,961 fish
Phase I fingerling distributed (from above)	+ 186,484 fish
Total fingerlings distributed (Phase I and Phase II)	457,445 fish

$9,110.47 ÷ 457,445 fish = $0.0199 per fish

*(Note: Baker probably rounded off $0.0199 to 0.019, and erroneously added ¢ after the value instead of $ before it)

b) Baker stated in Table X, "Total Man-Days used in Phase I and Phase II = 441 Man-Days (eight-hour days)." No pay rates of employees were provided. However, in the "Statistical Appendix, Annual Report, Fiscal Year 1975, Division of Fish Hatcheries, USDI, F&WS," Table 5 lists Pondfish Production and Cost Data - fiscal year 1975 for Edenton and other federal hatcheries (see attachment 2). Table 1 lists Pounds of Fish Produced - Species (fiscal year 1974-75). From these tables, it is stated that at the Edenton Hatchery in fiscal year 1975:

a total of 8,295 lb fish were produced (Table 1)

3,153 lb fish were produced per Man-Year (Table 5)

Labor cost for this production was $39,606 (Table 5)

Assuming that the man-years of effort in the production of fish in 1975 can be calculated as follows:

8,295 lbs ÷ 3,153 lb/man-year = 2.63 man-years

and that the cost per man-day can be calculated as follows:

$39,606 ÷ 2.63 man-years = $15,059/man-year

or $57.92/man-day (1 man-year = 260 man-days)

then the labor costs for Phase I and Phase II rearing might be estimated as follows:

(441 man-days $57.92/man-day) = $25,542.72

c) Total production cost for Phase I and Phase II rearing might then be assumed to be approximately:

Materials/Services	$ 9,110.47
Labor	25,542.72
	$34,653.19

d) Cost per fish, based on 457,445 Phase I and Phase II fingerlings produced appears therefore to be approximately:

$34,653.19 ÷ 457,445 fish = $0.08 per fish

e) Cost per fish for the 270,961 Phase II fingerling mentioned in the NRC question can not be precisely estimated. Baker did not mention how many Man-Days applied to each phase, and the only materials that definitely can be divided between phases are fish food, peanut hay, some chemicals, saran filter tubes and brine shrimp eggs.

An estimate of the range of costs can be developed, however.

Estimate of lower range of costs might be:

Include the surplus Phase I fingerlings as above (d):

$34,653.19 ÷ 457,445 fish $0.08 per fish

Note: Phase I fingerlings are less costly to produce than Phase II fingerlings. Accordingly, this cost per fish can be assumed to be more than the actual cost for Phase I fingerlings and less than the actual cost for Phase II fingerlings.

Estimate of upper range of costs might be:

Exclude the surplus Phase I fingerlings from the estimate above (d):

$34,653.19 ÷ 270,961 fish $0.13 per fish

In this case, Phase II fingerlings are considered the only final product.

The above is largely theoretical yet provides an estimate of from $0.08 to $0.13 per fish as the cost to an experienced hatchery producing Phase II fingerlings of 5 inch mean total length.

Note: It is doubtful that capitol costs, the amortization of the hatchery facilities and equipment have been considered in any of these costs.

Attachment 1

THE REARING OF HUDSON RIVER STRIPED BASS AT THE EDENTON NATIONAL FISH HATCHERY 1975

Prepared for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
4 Irving Place
New York, New York 10003

Prepared by

James E. Baker,
Acting Manager
Edenton National Fish Hatche
Edenton, North Carolina

August, 1976

Table X

REARING COSTS AND MAN-DAYS

Materials/Services	Units	Quantity	Amount
Electricity (pumping, feeders, holding house, etc.)	kilowatts	53,440	$ 2,051.28
Fish Food (Phase I & II)	pounds	18,748	5,339.20
Peanut Hay (Phase I)	pounds	17,820	409.86
Superphosphate (I & II)	pounds	1,980	119.60
Chemicals (I & II):			
Copper Sulfate	pounds	146	70.81
Potassium permanganate	pounds	350	269.50
Malachite Green	pounds	10	65.00
Formalin	gallons	25	72.00
Salt (NaCl)	pounds	9,225	268.50
Miscellaneous	- -	- -	50.00
Saran Filter Tubes (10 ft.)	each	23	346.15
Brine Shrimp Eggs	can #10	2	48.57
		TOTAL	$ 9,110.47

should be $??

Cost per Fish (Phase I & Phase II) - 0.019 ¢ per Fish should be ¢?

Cost per Pound of Fish (Phase I & Phase II) - 0.589 ¢ per Pound

Total Man-Days used in Phase I and Phase II - 441 Man-Days (eight-hour days)

Table IX

DISPOSITION OF HUDSON RIVER STRIPED BASS FINGERLINGS

Phase I	Number	Weight
Harvest inventory:	533,243 fish	1,867 pounds
Mortality in holding house:	15,516	
Weight gain in holding house:		667
Total fingerlings available:	517,727 fish	2,534 pounds
Disposition of Phase I fingerlings		
Restocked for Phase II:	331,243 fish	1,468 pounds
Distributed:		
Con Edison, N.Y.	20,863	274
Fish & Game, Va.	164,971	789
Natal Parke, So. Africa	150	1
Oak Ridge, Tenn.	500	2
Total Phase I fingerlings disposed:	517,727 fish	2,534 pounds
Phase II		
Harvest inventory:	271,640 fish	14,059 pounds
Mortality in holding house:	679	
Weight gain in holding house:		350
Total Phase II fingerlings available:	270,961 fish	14,409 pounds
Disposition of Phase II fingerlings		
Distributed:		
Con Edison, N.Y.	179,348*	7,739
Game & Fish Comm., Ky.	91,363	6,635
Restocked for future broodstock:	250	35
Total Phase II distributed & restocked	270,961 fish	14,409 pounds

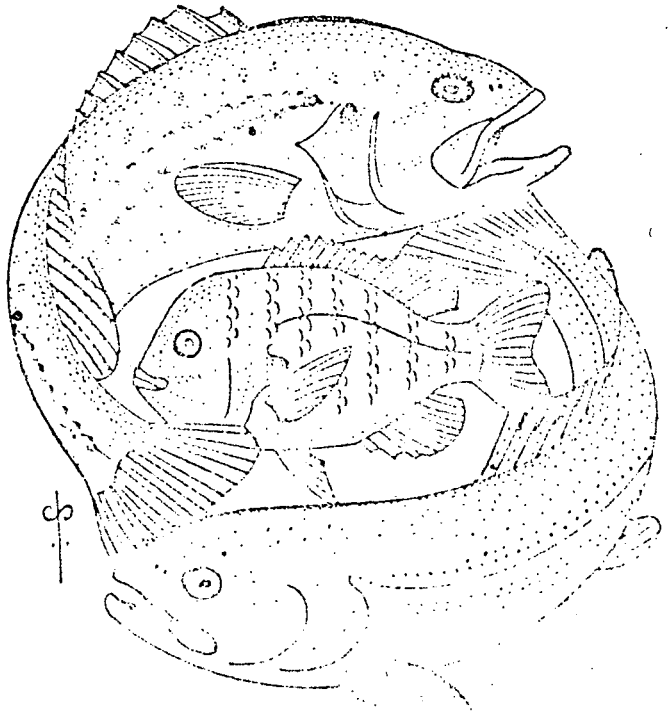
* Total distributed to Con Edison, N.Y. (Phase I & II) - 200,211 fish

Attachment 2

Statistical Appendix

ANNUAL REPORT FISCAL YEAR 1975

Division of Fish Hatcheries



United States Department of the Interior
Fish and Wildlife Service

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. Fish & Wildlife Service

Part B
Table 1.

Pounds of Fish Produced - Species (FY 1974-75)

Station	Warmwater		Trout		Anadromous		All Species		Average Production Per Total Man-Year	
	FY 1974	FY 1975	FY 1974	FY 1975	FY 1974	FY 1975	FY 1974	FY 1975	FY 1974	FY 1975
REGION 1										
Abernathy	--	--	--	--	31,207	29,811	31,207	29,811	2,769	2,429
Carson	--	--	6,837	6,570	98,922	95.163	105,759	101,733	19,954	17,360
Coleman	--	--	104,483	142,726	246,551	191,272	351,034	333,998	18,178	17,947
Dworshak	--	--	21,466	92,836	473,607	291,506	495,073	384,342	23,242	16,014
Eagle Creek	--	--	--	--	125,379	155,053	125,379	155,053	15,751	19,751
Entiat	--	--	53,817	37,378	--	12,505	53,817	49,883	10,614	9,537
Hagerman	--	--	199,478	185,287	--	--	199,478	185,287	28,993	27,696
Kooskia	--	--	--	--	19,585	45,238	19,585	45,238	4,266	7,552
Lahontan	--	--	72,987	72,104	--	--	72,987	72,104	10,670	11,161
Leavenworth	--	--	99	190	72,099	98,975	72,198	99,165	11,316	16,072
Little White Salmon	--	--	--	--	153,954	153,011	153,954	153,011	17,839	18,022
Quilcene	--	--	39,291	36,906	82,073	91,440	121,364	128,346	22,558	22,635
Quinault	--	--	--	--	142,594	183,509	142,594	183,509	27,689	27,973
Spring Creek	--	--	--	--	225,690	313,266	225,690	313,266	21,412	31,077
Tehama-Colusa	--	--	--	--	1,871	5,642	1,871	5,642	107	360
Willard	--	--	--	--	128,902	145,236	128,902	145,236	21,412	25,569
Winthrop	--	--	89,699	71,479	--	4,079	89,699	75,558	13,209	13,027
Subtotal	--	--	589,157	645,476	1,802,434	1,815,706	2,391,591	2,461,182	15,449	15,669
REGION 2										
Alchesay - Wms. Cr.	--	--	161,700	155,328	--	--	161,700	155,328	15,775	14,368
Dexter	8,000	3,901	--	--	--	--	8,000	3,901	1,415	926
Fort Worth	16,592	--	--	--	--	--	16,592	--	3,950	--
Inks Dam	32,302	45,546	--	--	--	--	32,302	45,546	5,937	7,921
Mescalero	--	--	62,727	60,959	--	--	62,727	60,959	12,323	13,576
San Marcos	--	--	--	--	--	--	--	--	--	--
Tishomingo	23,794	24,560	1,059	424	--	--	24,853	24,984	3,938	4,143
Uvalde	21,340	23,033	--	--	--	--	21,340	23,033	3,704	3,832
Willow Beach	--	--	158,054	152,426	--	--	158,054	152,426	22,482	21,652
Subtotal	102,028	97,040	383,540	369,137	--	--	485,568	466,177	9,509	10,365
REGION 3										
Genoa	3,096	2,876	2,338	4,208	--	--	5,434	7,084	1,229	1,602
Hebron	2,888	4,645	--	--	--	--	2,888	4,645	725	1,082
Hiawatha Forest	--	--	37,269	36,861	--	--	37,269	36,861	12,022	11,170
Jordan River	--	--	141,871	145,766	--	--	141,871	145,766	12,867	13,132
Lake Mills	1,710	892	2,487	9,749	--	--	4,197	10,641	1,299	3,005
New London	1,708	2,187	--	31	--	--	1,708	2,219	342	549
Pendills Creek	--	--	38,585	41,900	--	--	38,585	41,900	10,316	10,997
Senecaville	13,046	8,623	--	--	--	--	13,046	8,623	3,181	2,166
Subtotal	22,448	19,223	222,550	238,515	--	--	244,998	257,738	6,320	6,660
REGION 4										
Carbon Hill	1,471	2,583	--	--	--	--	1,471	2,583	454	909
Chattahoochee Fr.	--	--	108,133	107,190	--	--	108,133	107,190	20,287	19,595
Cheraw	5,177	7,107	--	--	--	--	5,177	7,107	1,334	2,277
Cohutta	4,816	6,546	--	--	--	--	4,816	6,546	1,152	1,669
Corning	5,057	7,336	--	--	--	--	5,057	7,336	1,377	2,610
Dale Hollow	--	--	202,204	213,734	--	--	202,204	213,734	31,893	32,781
Edenton	4,613	8,295	--	--	--	--	4,613	8,295	845	2,108
Erwin	--	--	70,876	66,279	--	--	70,876	66,279	14,855	13,553
Frankfort	15,767	12,728	--	--	--	--	15,767	12,728	4,238	3,104
Greers Ferry	--	--	150,448	120,175	--	--	150,448	120,175	25,327	22,462
Mammoth Spring	3,024	2,516	--	--	--	--	3,024	2,516	711	833
McKinney Lake	5,738	4,104	--	--	--	--	5,738	4,104	1,555	1,172
Meridian	7,232	2,584	--	--	--	--	7,232	2,584	1,025	567
Millen	8,172	10,960	--	--	--	--	8,172	10,960	1,408	1,953
Natchitoches	7,162	9,944	--	--	--	--	7,162	9,944	1,523	2,473
Norfork	--	--	377,733	385,320	--	--	377,733	385,320	38,426	38,378
Orangeburg	3,925	6,736	--	--	--	--	3,925	6,736	654	1,157
Pisgah Forest	--	--	201,621	193,884	--	--	201,621	193,884	22,730	22,703
Tupelo	6,773	8,527	--	--	--	--	6,773	8,527	1,616	2,126
Walhalla	--	--	122,044	125,134	--	--	122,044	125,134	20,897	21,537
Warm Springs	3,558	2,420	--	--	--	--	3,558	2,420	741	500
Welaka	10,782	10,100	--	--	--	1,040	10,782	11,140	1,623	1,670
Subtotal	114,133	102,485	1,233,059	1,211,716	--	1,040	1,347,192	1,315,242	10,923	12,004

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. Fish and Wildlife Service

Part B
Table 5.

Pondfish Production and Cost Data - FY 1975

	Avg. Production per acre		Production per Production Man-Year		Production Costs			
	No. (000's)	Lbs.	No.	Lbs.	Total	Labor	Per 000	Per Lb.
REGION 2								
Dexter	52.4	278	271,851	1,444	$ 53,386	$ 41,964	$ 72.73	$ 13.68
Inks Dam	28.6	1,423	329,496	16,383	55,967	34,298	61.09	1.22
Tishomingo	54.6	430	950,304	7,487	59,619	43,351	19.12	2.42
Uvalde	12.4	354	235,672	6,734	70,898	42,875	87.96	3.07
Subtotal	33.1	577	475,553	7,967	$239,760	$162,488	$ 43.04	$ 2.47
REGION 3								
Genoa	19.9	95	499,166	2,396	$ 28,876	$ 17,435	$ 48.20	$ 10.04
Hebron	80.3	94	1,718,777	2,028	36,538	29,552	9.28	7.86
Lake Mills	6.3	11	471,296	825	14,929	13,334	29.33	16.37
New London	8.1	20	935,164	2,403	23,066	13,960	27.10	10.54
Senecaville	86.6	344	1,031,428	4,106	41,778	27,142	19.28	4.84
Subtotal	27.8	66	1,063,456	2,536	$145,187	$101,423	$ 18.01	$ 7.55
REGION 4								
Carbon Hill	19.0	123	343,965	2,226	$ 22,781	$ 16,003	$ 57.09	$ 8.81
Cheraw	60.2	177	1,722,142	5,076	27,928	22,299	11.58	3.92
Cohutta	67.2	233	991,052	3,445	39,638	31,682	21.05	6.05
Corning	47.8	159	1,333,333	4,446	30,224	24,368	14.01	4.20
Edenton	14.8	267	174,804	3,153	58,732	39,606	127.67	7.68
Frankfort	59.8	318	1,119,158	5,947	46,467	37,928	19.40	3.85
Mammoth Springs	74.8	228	520,886	1,592	36,409	30,585	44.23	14.47
McKinney Lake	75.9	178	959,340	2,254	37,095	30,209	21.24	9.03
Meridian	71.9	83	1,143,076	1,325	31,277	28,077	14.03	12.10
Millen	78.1	304	1,000,711	3,900	49,177	42,238	17.48	4.48
Natchitoches	68.5	157	2,554,437	5,884	36,619	26,296	8.48	3.68
Orangeburg	75.2	143	812,881	1,559	69,739	59,091	19.71	10.35
Tupelo	78.9	284	1,246,842	4,487	35,876	28,346	15.14	4.20
Warm Springs	89.6	142	952,500	1,512	25,177	22,370	16.52	10.40
Welaka	64.2	155	2,119,781	5,126	56,493	40,234	13.53	5.59
Subtotal	62.9	193	1,090,432	3,357	$604,232	$479,312	$ 18.15	$ 5.89
REGION 5								
Bowden	1.5	14	50,000	466	$ 937	$ 767	$312.33	$ 33.46
Harrison Lake	95.6	446	1,177,005	5,489	30,450	24,733	13.83	2.96
Lamar	54.0	459	--	--	331	119	6.12	.72
Leetown	--	--	--	--	4,065	3,861	--	--
North Attleboro	6.7	119	740,000	13,180	2,609	1,750	35.25	1.97
White Sulphur Springs	3.0	10	600,000	2,000	184	184	30.66	9.20
Subtotal	59.9	310	956,497	5,101	$ 38,576	$ 31,414	$ 18.49	$ 3.19
REGION 6								
Cedar Bluff	74.5	248	563,573	1,877	$ 66,117	$ 41,117	$ 40.31	$ 12.10
Garrison Dam	50.2	40	1,684,931	1,360	29,249	18,370	11.81	14.72
Gavins Point	75.8	131	1,574,863	2,720	44,458	27,236	15.42	8.93
Miles City	10.1	25	70,629	174	27,429	18,950	271.57	109.71
Neosho	82.5	62	402,439	304	6,527	5,843	39.55	52.21
Valley City (Incl. Baldhill Dam)	--	69	1,082	809	60,660	45,339	12.17	16.26
Subtotal	41.4	94	572,906	1,306	$234,640	$156,855	$ 32.35	$ 14.18
TOTAL	47.0	206	865,151	3,787	$1,262,595	$931,492	$ 22.34	$ 5.10

VII 2. Provide an estimate of the total cost to Con Edison of the 179,348 fingerlings distributed to Con Edison from the Edenton National Fish Hatchery. Include in this estimate not only the rearing costs (including labor) requested in the preceding question, but also include all other costs incurred, starting with the collection of female and male adults in the Hudson River by Texas Instruments to the restocking of fingerlings of Texas Instruments in the Hudson River. Provide a step-by-step explanation of the derivation of this estimate.

Response: The cost to Con Edison of the 1975 striped bass hatchery rearing and stocking program is estimated to be $136,839.00 Table 1, attached provides a listing of costs to Con Edison related to producing striped bass larvae and shipping, marking and stocking fingerlings.

It is important to note that costs incurred by the Edenton National Fish Hatchery were not charged to Con Edison.

It should be recognized that the Con Edison striped bass hatchery rearing and stocking program represents an experimental study. Accordingly, cost estimates of a hatchery rearing and stocking program as a mitigation measure may be substantially different per unit of production from the costs per unit of production which might be calculated (erroneously) from the data provided herein.

Table 1

Costs Related to Producing Striped Bass Larvae and Shipping, Marking and Stocking Fingerlings, 1975 TI Hatchery Program

1. Reimbursable Materials

a) Production of Larvae

Haul seine, gill nets, netting	$ 1,571
Brood fish purchase (from commercial fisherman)	250
Chorionic gonadotropin and misc. lab supplies	300
	$ 2,121
Overhead @ 10%	212
Subtotal	$ 2,333

b) Shipping Fingerlings from Edenton, N.C. to Verplanck, N.Y.

Trucking (7 trips)	$14,000
Travel expenses, oxygen	780
Misc.	200
	$14,980
Overhead @ 10%	1,498
Subtotal	$16,478

c) Marking Fingerlings

Micro-magnetic nose-tagging equipment (4 mo. rental + shipping)	$ 3,054
Nose tags (200,000)	3,000
Replacement parts	1,139
Salt	1,019
Antibiotic and misc. supplies	500
	$ 8,712
Overhead @ 10%	871
Subtotal	$ 9,583

d) Stocking Fingerlings in Hudson River

Diesel fuel for Con Edison's Monarch "Torque-Wagon"	$ 200
Misc. supplies	50
	$ 250
Overhead @ 10%	25
Subtotal	$ 275

e) General Program, Facilities Modification and Expansion

Office/lab trailer (9 mo. rental)	$ 2,250
Van rental (9 mo.)	3,150
12 ft. diameter steel tanks (15) (fiscal year 1974)	5,870
Hardware, plumbing, pump repair, shelters, paint	4,220
Fuel, misc.	3,000
	$18,490
Overhead @ 10%	1,849
Subtotal	$20,339

Table 1 cont'd.

2. Labor

Month	Man-Days	Cost($)
March	117	$ 4,845
April	144	5,845
May	416	14,127
September	240	9,248
October	273	10,391
November	103	4,516
		$48,972
	Overhead @ 69%	33,791
	Subtotal	$82,763

3. Consultant for Induced Spawning of Striped Bass

Consultant's fee @ $250/day plus expenses	$ 4,137
Overhead @22.5%	931
	$ 5,068

TOTAL $136,839

VIII. Additional questions and requests for information

VIII.1 Provide a three-dimensional drawing or a two-dimensional contour map with no larger than 5-ft contours of the near-field bottom morphometry of the Hudson River at Indian Point and Roseton. Consider a semicircular area with a radius of 1000 ft, centered at the Roseton intake structure and the Indian Point Unit 1 intake structure.

Response:

A) Indian Point
Attachment A is a Hydrographic chart of the 5 foot depth contours in the vicinity of the Indian Point Generating Station.

B) Roseton
Attachment B (Figure 3.1-4, in Roseton Generating Station. Nearfield Effects of Once-Through Cooling System Operation On Hudson River Biota. July 1977.) is a map of the bottom contours in the vicinity of the Roseton Generating Station.

Attachment A

Hydrographic Chart of the Hudson River
in the Vicinity of the Indian Point Generating Station

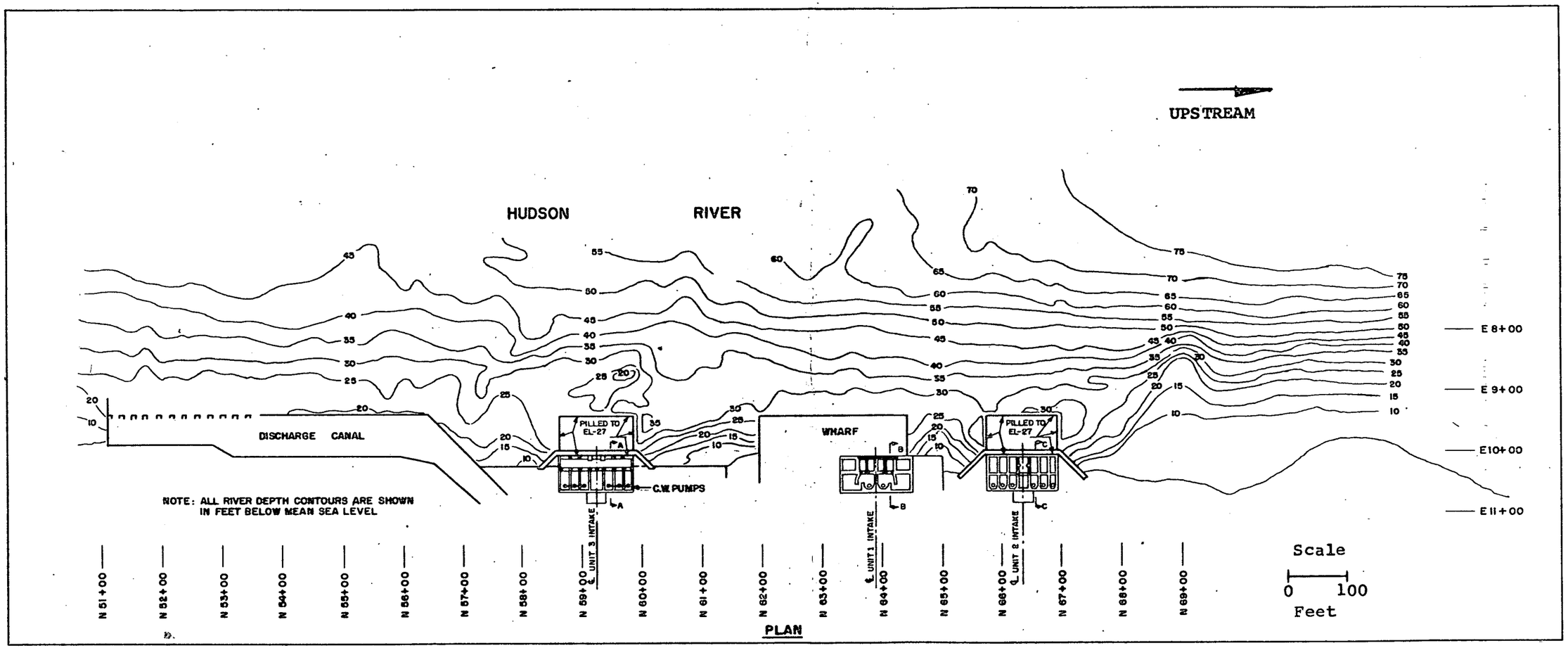


Figure 1-11. BOTTOM CONTOURS NEAR INDIAN POINT INTAKES AND DISCHARGE

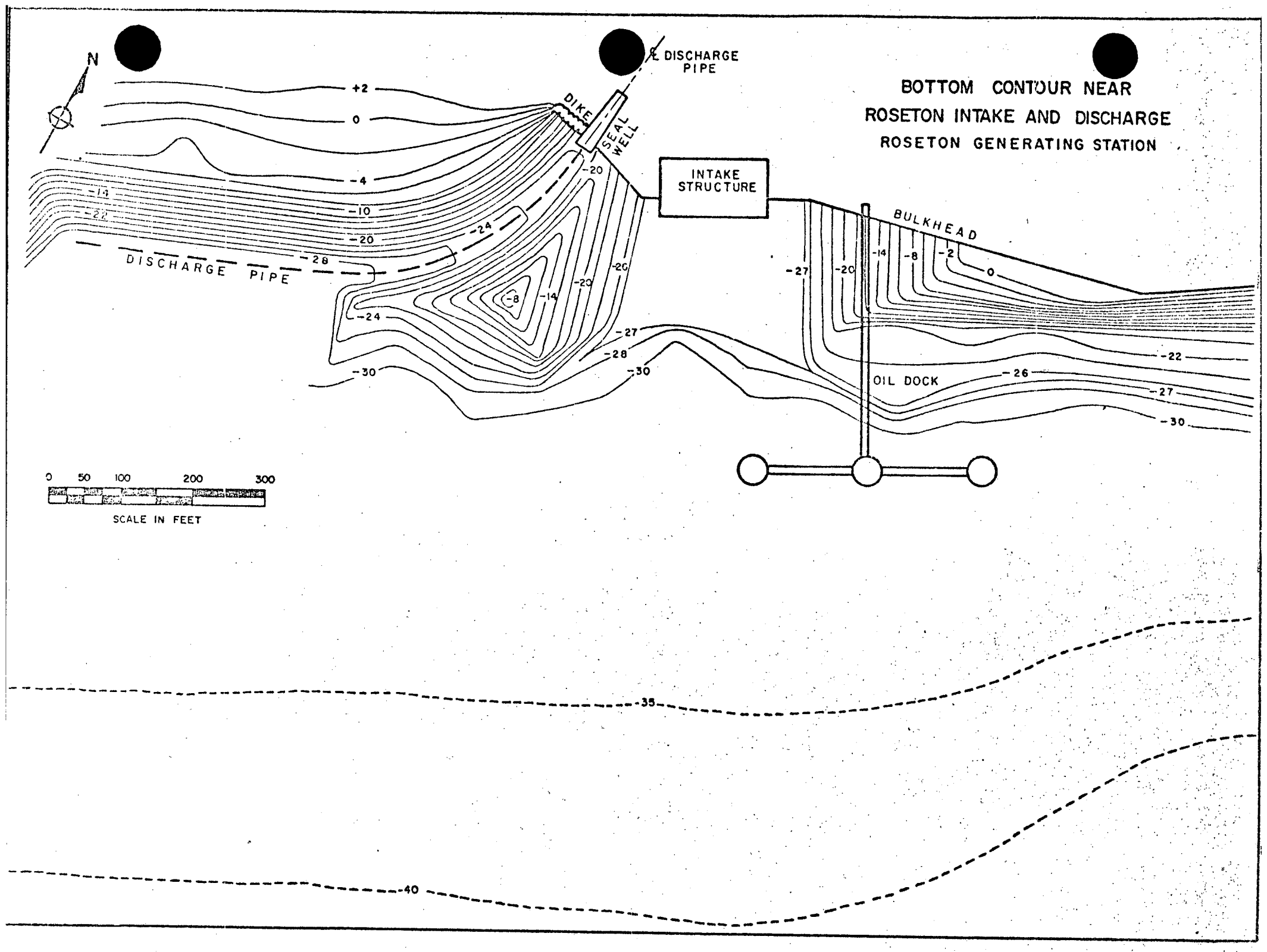
Source: Stone & Webster 1976

Reference

Stone and Webster Engineering Corporation. 1976. Final Report Indian Point Flume Study. Report prepared for Consolidated Edison Company of New York, Inc.

Attachment B

Bottom Contours Near the Intake and
Discharge-Roseton Generating Station


BOTTOM CONTOUR NEAR
ROSETON INTAKE AND DISCHARGE
ROSETON GENERATING STATION
N
℄ DISCHARGE PIPE
DIKE
SEAL WELL
INTAKE STRUCTURE
BULKHEAD
OIL DOCK
DISCHARGE PIPE
+2
0
-4
-10
-14
-20
-22
-24
-28
-8
-30
-27
-26
-2
35
40
0 50 100 200 300
SCALE IN FEET

VIII.2 Explain why the "adjusted" estimates of contribution to the Atlantic striped bass fishery on page 4-61 of the Environmental Report (March 1977) do not sum to 100%.

Response: The adjusted estimate for the contribution of the Chesapeake to the NRC Outer Zone, Table 4-15, page 4-61 of the Environmental Report, was typed incorrectly. The correct value is 96% rather than 94%. (See Table 7.10-6, page 7.218, FRR. The mean for the Chesapeake Adjusted Contribution is 96.4%).

IX. Questions for Central Hudson

IX 1. Provide monthly estimates of impingement rate (number of fish impinged per 10^6 cubic meters of water withdrawn) as follows:

a. for each of the following six species: white perch, striped bass, tomcod, blueback herring, alewife, and bay anchovy;

b. for each unit at Roseton and each unit at Danskammer;

c. for each month during 1972, 1973, 1974, 1975, and 1976, for which the necessary data are available.

In addition to each impingement rate (which is to be given to two decimal places), provide the value for the numerator (i.e.,number of fish of that species actually collected during the sampling periods during that month) and the value of the denominator (i.e., power-plant intake flow during the sampling periods during the given month).

Response: Enclosed are impingement data for the Roseton Generating Station for the period 1973-1976, and for the Danskammer Generating Station for the period 1972-1976. These data are for the species white perch, striped bass, tomcod, blueback herring, alewife and bay anchovy.

Impingement estimates are not calculated for individual Units at Roseton and Danskammer. Monthly rates are calculated by averaging weekly values for each month.

Form No. 405

1973
Roseton Impingement
White Perch

Date	# Fish	C.W Flow (MG)	# Fish / (MG)
7/10-11	11	313.6	0.0351
8/7-8	137	602.4	0.2274
21-22	338	652.6	0.5179
			0.3726
9/18-19	976	602.4	1.6202
10/3-4	357	366.4	0.9743
17-19	5739	940.8	6.1001
31-11/1	232	652.5	0.3556
			2.4767
11/15-16	911	652.6	1.3960
28-29	26	257.4	0.1018
			0.7489
12/11-12	40	340.4	0.1175
26-27	31	340.6	0.0910
			0.1042

1 f2

Form NCT 406

1974

Roseton Impingement

White Perch

Date	# Fish Collected	CW Flow (MG)	# Fish / MG
1/8-9	3	340.08	0.6088
22-23	0	348.80	—
			0.0044
3/5-6	1	313.92	0.0032
19	0	78.48	—
			0.0016
4/2-3	3	183.12	0.0164
15-16	134	313.92	0.4269
30-5/1	391	313.92	1.2455
			0.5629
5/14-15	1034	601.92	1.7178
21	360	189.66	1.8981
28-29	651	601.92	1.0815
			1.5658
6/4-5	826	614.46	1.3443
13-14	73	601.68	0.1213
19-20	63	601.92	0.1047
25-26	26	601.92	0.0432
			0.4634
7/2-3	2	613.96	0.0033
9-10	2	595.65	0.0050
16-17	0	614.46	—
23-24	0	601.92	0.0022
30-31	2	320.46 92.38	
			0.0026
8/6-7	1	601.92	0.0017
13-14	24	320.46	0.0749
20-23	279	601.92	0.4635
27-28	171	615.06	0.2780
			0.2045
9/3-4	48	601.92	0.0797
17-18	99	601.92	0.1645
24-25	11	459.90	0.0239
			0.0894

Form No. 406

1974
Roseton Impingement

White Perch

Date	# Fish	Flow (MG)	Fish / MG
10/1-2	80	451.44	0.1772
8-9	10	105.63	0.6947
15-16	51	235.44	0.2166
			0.1628
11/5-6	5	137.94	0.0362
12-13	114	451.44	0.2525
19-20	63	50.16	1.2560
26-27	544	413.82	1.3146
			0.7148
12/5-6	71	125.40	0.5662
10-11	276	451.44	0.6114
17-18	162	589.38	0.2749
26-27	74	601.52	0.1229
			0.3938

Form No. 405

1975

Roseton Impingement

White Perch

Date	# Fish Collected	CW Flow (MG)	#Fish/MG
1/8-9	66	600.53	0.1099
15-16	9	313.92	0.0287
22-23	51, 93	755.08 1357	0.0685
29-30	36	601.92	
			0.0690
2/4-5	77	807.84	0.0953
11-12	44	799.42	0.0550
18-19	10	601.92	0.0166
25-26	30	601.92	0.0498
			0.0542
3/4-5	9	300.96	0.0299
11-12	66	601.92	0.1096
18-19	18	602.35	0.0299
			0.0565
4/1-2	218	326.04	0.6686
8-9	94	401.28	0.2343
17-18	507	288.42	1.7579
23-24	1243	286.33	2.4890
30-5/1	222	302.25	
			1.2874
5/6-7	260	526.35	0.4940
13-14	164	300.96	0.5449
20-21	625	521.73	1.1979
27-28	203	807.84	0.2513
			0.6220
6/3-4	116	807.84	0.1436
10-11	63	601.92	0.1047
17-19	21	601.92	0.0349
24-25	12	782.60	0.0153
			0.0746

2

Form No. 405

1975

Roseton Impingement

White Perch

Date	# Fish Collected	CW Flow (MG)	# Fish / MG
7/1-2	8	807.84	0.0099
8-9	35	807.84	0.0433
16-17	59	756.79	0.0780
24-26	132 → 838	807.84 → 1615.68	0.5187
30-31	706	807.84	
			0.1625
8/5-6	279	648.94	0.4299
12-13	602	595.65	1.0107
21-22	42	578.18	0.0726
27-28	260	602.92	0.4312
			0.4861
9/4-5	455	601.92	0.7559
9-10	309	601.92	0.5134
18-19	119	601.92	0.1977
23-24	52 → 391	601.92 → 1203.84	0.3248
30-10/1	339	601.92	
			0.4480
10/7-8	456	451.44	1.0101
15-16	211	653.78	0.3227
22-23	1802 → 4445	601.92 → 1202.17	3.6975
29-30	2643	600.25	
			1.6768
11/5-6	2583	601.92	4.2913
12-13	963	576.84	1.6694
19-20	1313	601.92	2.1814
25-26	711	601.92	1.1812
			2.3308
12/2-3	29	313.92	0.0924
10-11	28	313.92	0.0892
17-18	11	313.92	0.0350
23-24	24 → 95	319.92 → 922.27	0.1030
30-31	71	602.35	
			0.0799

Page 1 of 2

Form No. 405

1976

Roseton Impingement

White Perch

Date	#Fish Collected	C.W. Flow (MG)	#Fish/MG			
1/6-7	44	313.92	0.1402			
13-14	6	313.92	0.0191			
22-23	19	601.92	0.0631			
29-30	57	601.92				
Total			0.0741			
2/5-6	151	597.74	0.2526			
12-13	27	601.92	0.0449			
17-18	18	593.56	0.0303			
24-25	119	601.92	0.1977			
Total			0.1314			
3/2-3	46	593.56	0.0775			
9-10	9	363.66	0.0247			
16-17	12	313.50	0.0383			
23-24	31	301.96	0.1286			
30-31	28	156.96				
Total			0.0673			
4/6-7	1056	601.92	1.7544			
13-14	896	338.58	2.6463			
20-21	548	495.33	1.1063			
28-29	1155	764.08	1.5116			
Total			1.7546			
5/4-5	260	601.92	0.4320			
11-12	1405	807.84	1.7392			
18-19	432	807.84	0.5348			
25-26	783	808.08	0.9690			
Total			0.9188			
6/2-3	183	601.09	0.3044			
8-9	472	807.84	0.5843			
15-16	144	807.54	0.1783			
22-23	73	807.84	0.0819			
29-30	58	790.73				
Total			0.2872			

Form No. 405

1976

Roseton Impingement

White Perch

Date	# Fish collected	CW Flow (MG)	# Fish/MG			
7/6-7	17	808.08	0.0210			
13-14	3	807.84	0.0037			
20-21	18	807.85	0.0223			
27-28	4	897.76	0.0045			
			0.0129			
8/3-4	14	807.84	0.0173			
10-11	192	807.84	0.2377			
17-18	35	807.84	0.0433			
24-25	18 → 64	809.52 → 1.73	0.0453			
31-9/1	46	602.21 14				
			0.0859			
9/7-8	178	808.16	0.2203			
14-15	138	782.59	0.1763			
21-22	8	601.92	0.0133			
28-29	17	601.92	0.0282			
			0.1095			
10/5-6	16	601.92	0.0266			
12-13	402	601.92	0.6679			
20-21	216	599.83	0.3601			
27-28	480	497.68	1.0722			
			0.5317			
11/2-3	1609	601.92	2.6731			
9-10	1811 → 2401	313.92 → 4.7	3.7462			
12-13	590	327.00 6				
16-17	469	313.92	1.4940			
23-24	294 → 3	307.58 → 1.30	0.6164			
30-12/1	89 3	313.92 6				
			2.1324			
12/7-8	68	313.92	0.2166			
16-17	78 196	317.19 → 13	0.2164			
21-22	115	588.54				
28-29	176	601.92	0.2924			
			0.2418			

Form No. 406

Weekly Intervals
1-7 15-21
8-14 22-31

Central Hudson Gas & Electric Corporation
Danskammer Point Generating Station
1977
Impingement: White Perch

Date	# Fish	Flow (MG)	# Fish/MG
1/12	10	173.46	
1/13	35	292.74	
1/14	54	337.12	
	99	803.32	.1232
1/15	46	294.28	
1/16	19	176.97	
1/19	2	93.69	
1/20	6	147.49	
1/21	3	93.59	
	76	806.02	.0943
1/22	8	56.49	
1/23	—	111.43	
1/25	7	245.02	
1/26	15	300.77	
1/27	14	276.34	
1/28	2	164.70	
	46	1154.75	.0398
Jan Avg			.0858
2/4	7	121.94	
2/5	7	137.25	
2/7	8	166.71	
	22	425.90	.0517
2/8	5	168.90	
2/10	3	100.08	
2/11	3	146.48	
2/13	2	98.82	
2/14	3	64.47	
	16	577.75	.0277
2/16	5	137.76	
2/17	7	131.76	
2/19	2	89.43	
2/20	—	32.94	
	14	385.89	.0363

Form No. 405

1972 Dan Hammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish/MG			
2/22	5	89.86				
2/23	7	135.18				
2/25	4	31.50				
2/26	2	74.34				
	18	330.88	.0544			
Feb Avg.			.0425			
3/2	7	128.34				
3/3	4	113.82				
3/5	7	131.76				
3/6	8	146.88				
	26	520.80	.0499			
3/8	10	146.88				
3/9	9	47.88				
3/11	33	119.76				
3/12	34	139.32				
3/14	16	48.05				
	102	501.89	.2032			
3/15	7	94.50				
3/17	17	81.90				
3/18	12	95.76				
3/20	9	71.82				
3/21	11	95.76				
	56	439.74	.1273			
3/23	6	119.28				
3/24	6	88.20				
3/26	13	110.88				
3/27	4	95.76				
3/29	5	95.76				
3/30	8	131.76				
	42	641.64	.0655			
March Avg			.1115			
4/4	2	21.96				
4/5	8	131.76				
4/7	2	81.00				
	12	234.72	.0511			

Form No. 406

1972 Dan Kammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish / MG			
4/8	9	131.76				
4/10	–	146.88				
4/11	–	146.88				
4/13	2	146.88				
4/14	2	96.12				
	13	668.52	.0194			
4/17	–	36.72				
4/19	8	146.88				
4/20	21	162.00				
	29	345.60	.0839			
4/22	571	162.00				
4/23	147	146.88				
4/25	386	162.00				
4/26	209	131.76				
4/28	123	131.76				
4/29	258	145.62				
	1694	880.02	1.9250			
April Avg.			.5198			
5/1	122	162.00				
5/2	85	162.00				
5/4	91	94.19				
5/5	114	159.48				
5/7	98	162.00				
	510	739.67	.6895			
5/8	486	162.00				
5/10	553	162.00				
5/11	825	162.00				
5/13	1129	154.44				
5/14	240	121.50				
	3233	761.94	4.2431			
5/16	1165	136.62				
5/17	104	162.00				
5/19	742	146.88				
5/20	63	146.89				
	2074	592.39	3.5011			

Form No. 406

1972 Dam-Kammer Impingement

White perch

Date	# Fish	Flow (MG)	# Fish/MG			
5/22	750	145.50				
5/23	332	191.52				
5/25	404	187.74				
5/26	287	191.52				
5/28	304	176.76				
5/29	265	162.00				
5/31	889	158.76				
	3231	1213.80	2.6619			
May	Average		2.8189			
6/1	94	128.52				
6/3	770	144.00				
6/4	312	137.32				
6/6	633	158.76				
6/7	314	191.52				
	2123	760.12	2.7930			
6/9	680	158.76				
6/10	839	143.64				
6/12	369	110.88				
6/13	193	158.76				
	2081	572.04	3.6379			
6/15	174	191.52				
6/16	101	158.76				
6/18	353	191.52				
6/19	169	191.52				
6/21	252	158.76				
	1049	892.08	1.1759			
6/24	74	176.40				
6/25	61	176.40				
6/27	117	158.76				
6/28	84	191.52				
6/30	212	126.00				
	548	829.08	0.6610			
June	Average		2.0670			

Form No. 405

1972 Danskammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish/MG			
7/1	66	143.64				
7/4	104	134.40				
7/6	143	172.90				
	313	450.94	.6941			
7/9	188	147.00				
7/10	159	191.52				
7/12	272	198.24				
7/13	262	135.66				
	881	672.42	1.3102			
7/15	93	176.40				
7/16	125	83.16				
7/18	78	191.52				
7/19	208	191.52				
7/21	70	191.52				
	574	834.12	.6882			
7/22	88	208.56				
7/24	17	227.52				
7/25	64	227.52				
7/27	91	227.52				
7/28	128	227.52				
7/30	111	227.52				
7/31	182	208.87				
	681	1555.03	.4379			
July	Average		.7826			
8/2	353	232.58				
8/3	313	227.52				
8/5	43	131.27				
8/6	193	177.00				
	902	768.37	1.1739			
8/8	149	170.64				
8/9	187	227.52				
8/11	144	162.37				
8/12	263	191.52				
8/14	1016	227.52				
	1759	979.57	1.7957			

Form No. 405

1972 Danskammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish/MG			
8/15	243	212.40				
8/17	62	170.64				
8/20	21	212.40				
8/21	32	212.40				
	358	807.84	.4432			
8/23	16	170.64				
8/24	60	218.52				
8/26	38	194.52				
8/27	257	155.52				
8/29	61	227.52				
8/30	53	155.52				
	475	1122.24	.4233			
August	Average		.9590			
9/1	40	132.30				
9/2	47	191.52				
9/4	133	132.30				
9/5	80	191.52				
9/7	89	191.52				
	389	839.16	.4636			
9/10	94	191.52				
9/11	45	191.52				
9/13	112	191.52				
9/14	40	191.52				
	291	766.08	.3799			
9/16	44	191.52				
9/17	45	176.40				
9/19	76	191.52				
9/20	58	158.76				
	233	718.20	.3244			

1972 Dawskammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish / MG
9/22	366	184.59	
9/23	272	155.52	
9/25	263	116.64	
9/26	261	179.52	
9/28	161	191.52	
9/29	154	191.52	
	1477	1019.31	1.4490
September	Average		0.6542
10/1	212	191.52	
10/2	314	191.52	
10/4	519	196.98	
10/5	622	158.76	
10/7	455	191.52	
	2122	930.30	2.2810
10/8	181	176.40	
10/10	1118	191.52	
10/11	240	143.64	
10/13	304	191.52	
10/14	125	176.40	
	1968	879.48	2.2377
10/16	200	176.40	
10/17	231	176.40	
10/19	328	132.30	
10/20	252	167.96	
	1011	653.06	1.5481
10/22	185	160.02	
10/23	128	146.16	
10/25	183	161.28	
10/26	231	161.28	
10/28	103	153.72	
10/29	366	128.52	
10/31	45	153.72	
	1241	1064.70	1.1656
October	Average		1.8081

1972 Danskammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish / MG
11/1	62	161.28	
11/3	82	161.28	
11/4	91	161.28	
11/6	38	120.96	
11/7	131	161.28	
	404	766.08	.5274
11/10	99	131.04	
11/12	359	162.00	
11/13	357	191.52	
	815	484.56	1.6819
11/15	357	191.52	
11/16	219	191.52	
11/18	124	191.52	
11/19	94	191.52	
	794	766.08	1.0364
11/25	107	191.52	
11/27	280	133.75	
11/28	69	88.20	
11/30	55	161.28	
	511	574.75	.8891
November	Average		1.0337
12/1	145	153.72	
12/3	102	138.60	
12/4	129	161.28	
12/6	137	161.28	
12/7	80	138.60	
	593	753.48	0.7870
12/9	60	153.72	
12/10	47	113.40	
12/12	36	146.16	
12/13	96	161.28	
	239	574.56	0.4160

No. 405

1972 Dan. Kammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish/MG			
12/15	58	131.76				
12/16	34	131.76				
12/18	84	131.76				
12/19	58	106.38				
12/20	50	164.70				
12/21	23	106.38				
	307	772.74	0.3973			
12/28	18	175.68				
12/29	1	87.84				
	19	263.52	0.0721			
December	Average		0.4181			

Form No. 406

1973

Danskammer Impingement

White Perch

Date	# Fish	C.W. Flow (MG)	# Fish/(MG)
1/4-5	10	252.54	0.0396
10-11	13	258.04	0.0504
17-18	10	263.52	0.0379
24-25	4	256.20	0.0098
31-2/1	0	153.72	
Mean			0.0344
2/7-8	0	191.52	0.0000
14-15	3	222.64	0.0135
21	4	172.93	0.0231
27-28	3	241.56	0.0124
Mean			0.0122
3/6-7	6	261.40	0.0230
21-22	22	137.16	0.1604
mean			0.0917
4/3-4	97	263.51	0.3681
18-19	104	242.55	0.4288
25	164	108.00	1.5185
mean			0.7718
5/2-3	380	291.11	1.3031
17-18	468	316.19	1.4801
30-31	449	367.08	1.2232
mean			1.3355
6/13-14	249	455.04	0.5472
26-27	328	455.04	0.7208
mean			0.6340
7/10-11	1377	455.04	3.0261
24-25	589	910.08	0.6472
Mean			1.8366
8/7-8	75	455.04	0.1648
21-22	250	492.96	0.5071
mean			0.3360

1973
Danskammer Impingement
White Perch

Date	# Fish	C.W. Flow (MG)	# Fish / (MG)
9/5-6	147	455.04	0.3230
18-19	429	440.82	0.9732
mean			0.6481
10/3-4	313	336.96	0.9289
17-18	531	414.96	1.2796
31-11/1	1354	382.20	3.5426
mean			1.9170
11/15-16	1081	382.20	2.8284
28-29	225	382.20	0.5887
mean			1.7086
12/11-12	110	313.20	0.3512
26-27	59	252.72	0.2335
mean			0.2924

Form No. 405

1978

Danskammer Impingement

White Perch

Date	#Fish	Flow (MG)	#Fish/MG
1/8-9	42	315.71	0.1330
22-23	6	285.48	0.0210
			0.0770
2/5-6	2	316.98	0.0063
19-20	1	285.48	0.0035
			0.0049
3/5-6	5	263.52	0.0190
25-26	5	263.52	0.0190
			0.0190
4/2-3	22	248.52	0.0885
15-16	321	242.10	1.3259
30-5/1	1814	293.76	6.1751
			2.5300
5/14-15	130	293.76	0.4425
21-22	986	361.10	2.7305
28-29	459	352.80	1.3010
			1.4913
6/4-5	801	311.85	2.5685
11-12	238	252.00	0.9444
18-19	411	306.95	1.3390
25-26	300	324.00	0.9259
			1.4444
7/2-3	392	394.17	0.9945
9-10	89	381.00	0.2336
16-17	133	303.87	0.4377
23-24	126, 365	458.42, 931.16	0.3920
30-31	239	472.74	
			0.5144
8/6-7	87	436.14	0.1995
13-14	242	405.51	0.5968
20-21	352	415.35	0.8475
27-28	75	434.60	0.1726
			0.4541

1974

Dansk No. 405

Danskammer Impingement

White Perch

Date	# Fish	Flow (MG)	# Fish / MG
9/3-4	81	439.16	0.1844
10-13	60	442.16	0.1357
17-18	132	329.05	0.4012
24-25	30.	357.72	0.0839
			0.2013
10/1-2	256	424.80	0.6026
8-9	129	458.67	0.2812
15-16	295	455.04	0.6483
22-23	232, 388	392.28, 769.79	0.5040
29-30	156	377.51	
			0.5090
11/5-6	173	392.28	0.4410
12-13	236	383.04	0.6161
19-20	132	392.28	0.3365
26-27	265	383.04	0.6918
			0.5214
12/3-4	158	162.69	0.9712
* 10-11	433	383.04	1.1304
17-18	273	392.28	0.6959
26-27	77	322.56	0.2387
			0.7590

Form No. 406

1979

Danskammer Impingement

White Perch

Date	#Fish	Flow (MG)	#Fish/MG			
1/8-9	34	263.52	0.1290			
15-16	44	287.52	0.1530			
22-23	19, 42	532.45	0.0789			
29-30	23	mean	0.1203			
2/4-5	35	293.75	0.1191			
11-12	9	190.59	0.0472			
18-19	3	139.00	0.0216			
25-26	5	91.76	0.0545			
			0.0606			
3/4-5	6	119.52	0.0502			
11-12	6	119.52	0.0502			
18-19	5	120.56	0.0415			
27-28	12	120.77	0.0994			
			0.0603			
4/1-2	24	119.52	0.2008			
8-9	36	119.52	0.3012			
17-18	132	119.52	1.1044			
23-24	235, 735	328.32	2.2387			
30-5/1	500					
			0.9613			
5/6-7	79	239.04	0.3305			
13-14	228	239.04	0.9538			
20-21	130	239.04	0.5438			
27-28	63	216.06	0.2916			
			0.5299			
6/3-4	216	380.56	0.5676			
10-11	1306	397.20	3.2880			
17-18	293	416.30	0.7038			
24-25	141	455.04	0.3099			
			1.2173			

No. 406

Danskammer Impingement

White Perch

Date	#Fish	Flow (MG)	#Fish / MG
7/1-2	42	428.77	0.0980
8-9	87	311.04	0.2797
16-17	310	342.56	0.9050
24-25	149, 226	796.52	0.2837
30-31	77		
			0.3916
8/5-6	349	451.56	0.7729
12-13	253	394.34	0.6416
21-22	470	394.56	1.1912
27-28	61	443.36	0.1376
			0.6858
9/4-5	364	394.56	0.9225
9-10	209	394.56	0.5297
18-19	245	394.56	0.6209
23-24	23, 159	787.60	0.2019
30-10/1	136		
			0.5688
10/7-8	741	311.64	2.3823
15-16	249	335.22	0.7428
22-23	642, 2585	717.12	3.6047
29-30	1943		
			2.2433
11/5-6	2264	394.56	5.7380
12-13	787	394.56	1.9946
19-20	796	379.73	2.0962
25-26	68	245.10	0.2774
			2.5266
12/2-3	192	233.28	0.8230
10-11	24	226.94	0.1058
17-18	38	233.28	0.1629
23-24	20, 49	466.56	0.1050
30-31	29		
			0.2992

Form No. 405

1976

Danskammer Impingement

White Perch

Date	#Fish	Flow (MG)	#Fish/MG
1/6-7	63	213.84	0.2946
13-14	12	230.53	0.0521
22-23	14 → 67	227.27 → 460.55	0.1455
29-30	53	233.28	
			0.1641
2/5-6	16	161.28	0.0992
12-13	28	212.19	0.1320
17-18	15	221.53	0.0677
24-25	40	203.04	0.1970
			0.1240
3/2-3	32	203.04	0.1576
9-10	9	203.04	0.0443
16-17	27	198.81	0.1358
23-24	24 → 210	204.27 → 407.31	0.5156
30-31	186	203.04	
			0.2133
4/6-7	1648	253.51	6.5007
13-14	1655	233.28	7.0945
20-21	312	230.03	1.3563
28-29	348	299.52	1.1619
			4.0284
5/4-5	91	306.72	0.2967
11-12	610	306.72	1.9888
18-19	188	306.72	0.6129
25-26	275	307.32	0.8948
			0.9483
6/2-3	336	277.53	1.2107
8-9	292	276.48	1.0561
15-16	288	335.54	0.8583
22-23	179 → 265	334.42 → 662.52	0.4000
29-30	86	328.10	
			0.8813

No. 405

1976

Danskammer Impingement

White Perch

Date	# Fish	Flow (MG)	# Fish / MG			
7/6-7	85	306.72	0.2771			
13-14	49	290.75	0.1685			
20-21	7	305.45	0.0229			
27-28	37	246.11	0.1503			
			0.1547			
8/3-4	8	306.72	0.0208			
10-11	29	306.72	0.0945			
17-18	8	306.72	0.0261			
24-25 →	112 → 110	335.08 → 672.04	0.2530			
31-9/1	58	336.96				
			0.0986			
9/7-8	274	365.76	0.7491			
14-15	9	396.00	0.0227			
21-22	100	455.04	0.2198			
28-29	246	394.56	0.6235			
			0.4038			
10/5-6	298	334.08	0.8920			
12-13	132	331.76	0.3979			
20-21	1285	334.08	3.8464			
24-25 →	598 → 1626	203.04 → 500.59	3.2482			
27-28	1028	297.55				
			2.0961			
11/2-3 →	1648 → 3193	233.28 → 466.88	6.8390			
5-6	1545	233.60				
9-10	1375	233.28	5.8942			
16-17	1461	258.91	5.6429			
23-24 →	732 → 1018	293.76 → 581.40	1.7509			
30-12/1	286	287.64				
			5.0318			
12/7-8	152	285.70	0.5320			
16-17 →	230 → 392	263.60 → 559.99	0.7000			
21-22	162	296.39				
28-29	94	263.52	0.3567			
			0.5300			

9-12-77

Form No. 406

1973

Roseton Generating Station

Impingement: Striped Bass

Date	# Fish Collected	C. W. Flow (mg)	# Fish/mg
7/10-11	1	313.6	0.0032
8/7-8	33	602.4	0.0548
21-22	7	652.6	0.0107
			0.0328
9/18-19	20	602.4	0.0332
10/3-4	7	366.4	0.0191
17-19	294	940.8	0.3125
31-11/1	8	652.5	0.0123
			0.1146
11/15-16	30	652.6	0.0460
28-29	4	255.4	0.0157
			0.0308
12/11-12	6	340.4	0.0176
26-27	6	340.6	0.0176
			0.0176

orm No. 405

1974 Roseton Impingement
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	1	340.08	.0029
1/22-23	—	348.80	—
			.0014
3/5-6	—	313.92	—
3/19	—	78.48	—
4/2-3	—	183.12	—
4/15-16	1	313.92	.0032
4/30-5/1	—	313.92	—
			.0011
5/14-15	2	601.92	.0033
5/21	—	189.66	—
5/28-29	9	601.92	.0150
			.0061
6/4-5	6	614.46	.0098
6/13-14	1	601.68	.0017
6/19-20	6	601.92	.0100
6/25-26	2	601.92	.0033
			.0062
7/2-3	3	613.96	.0049
7/9-10	—	595.65	—
7/16-17	—	614.46	—
7/23-24	3 → 5	→ 922.38	.0054
7/30-31	2		
			.0026
8/6-7	—	601.92	—
8/13-14	1	320.46	.0031
8/20-23	6	601.92	.0100
8/27-28	1	615.06	.0016
			.0037
9/3-4	4	601.92	.0066
9/17-18	2	601.92	.0033
9/24-25	2	459.90	.0043
			.0047

1974 Roseton Impinge
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG			
9/3-4	[illegible]	[illegible]				
9/17-18	[illegible]	[illegible]				
9/24-25	[illegible]	[illegible]				
10/1-2	2	451.44	.0044			
10/8-9	—	105.63	—			
10/15-16	3	235.44	.0127			
			.0057			
11/5-6	—	137.94	—			
11/12-13	1	451.44	.0022			
11/19-20	—	50.16	—			
11/26-27	34	413.82	.0822			
			.0211			
12/5-6	—	125.40	—			
12/10-11	4	451.44	.0089			
12/17-18	—	589.38	—			
12/26-27	2	601.92	.0033			
			.0030			

orm No. 405

1975 Roseton Impin.

Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	3	600.53	.0050
1/15-16	—	313.92	—
1/22-23 →	3 → 5	→ 1357.00	.0037
1/29-30	2		
			.0029
2/4-5	—	807.84	—
2/11-12	1	799.42	.0012
2/18-19	—	601.92	—
2/25-26	1	601.92	.0017
			.0007
3/4-5	—	300.96	—
3/11-12	2	601.92	.0033
3/18-19	—	602.35	—
			.0011
4/1-2	—	326.04	—
4/8-9	1	401.28	.0025
4/17-18	1	288.42	.0035
4/23-24 →	— → 2	→ 588.58	.0034
4/30-5/1	2		
			.0024
5/6-7	—	526.35	—
5/13-14	—	300.96	—
5/20-21	2	521.73	.0038
5/27-28	1	807.84	.0012
			.0012
6/3-4	1	807.84	.0012
6/10-11	1	601.92	.0017
6/17-19	1	601.92	.0017
6/24-25	—	782.60	—
			.0012

1975 Roseton Impingement
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/1-2	—	807.84	—
7/8-9	18	807.84	.0223
7/16-17	22	756.79	.0291
7/24-26 →	11 → 24	→ 1615.68	.0149
7/30-31	13		
			.0166
8/5-6	20	648.94	.0308
8/12-13	5	595.65	.0084
8/21-22	—	578.18	—
8/27-28	1	602.92	.0017
			.0102
9/4-5	2	601.92	.0033
9/9-10	2	601.92	.0033
9/18-19	1	601.92	.0017
9/23-24 →	— → 3	→ 1203.84	.0025
9/30-10/1	3		
			.0027
10/7-8	3	451.44	.0066
10/15-16	—	653.78	—
10/22-23 →	21 → 50	→ 1202.17	.0416
10/29-30	29		
			.0161
11/5-6	12	601.92	.0199
11/12-13	6	576.84	.0104
11/19-20	3	601.92	.0050
11/25-26	6	601.92	.0100
			.0113
12/2-3	—	313.92	—
12/10-11	1	313.92	.0032
12/17-18	2	313.92	.0064
12/23-24 →	1 → 5	→ 922.27	.0054
12/30-31	4		.0038

orm No. 405

1976 Roseton Impingem
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/6-7	–	313.92	–
1/13-14	–	313.92	–
1/22-23 →	–	→ 1203.84	–
1/29-30	–		
2/5-6	1	597.74	.0017
2/12-13	–	601.92	–
2/17-18	–	593.56	–
2/24-25	–	601.92	–
			.0004
3/2-3	1	593.56	.0017
3/9-10	–	363.66	–
3/16-17	–	313.50	–
3/23-24 →	– → –	→ 458.92	–
3/30-31			
			.0004
4/6-7	1	601.92	.0017
4/13-14	–	338.58	–
4/20-21	–	495.33	–
4/28-29	1	764.08	.0013
			.0008
5/4-5	2	601.92	.0033
5/11-12	2	807.84	.0025
5/18-19	1	807.84	.0012
5/25-26	3	808.08	.0037
			.0027
6/2-3	1	601.09	.0017
6/8-9	5	807.84	.0062
6/15-16	3	807.84	.0037
6/22-23 →	1 → 2	1598.57	.0012
6/29-30	1		
			.0032

1976 Roseton Impingement
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/6-7	—	808.08	—
7/13-14	3	807.84	.0037
7/20-21	2	807.85	.0025
7/27-28	—	897.76	—
			.0016
8/3-4	3	807.84	.0037
8/10-11	5	807.84	.0062
8/17-18	—	807.84	—
8/24-25 → 8/31-9/1	— → 2	→ 1411.73	.0014
			.0028
9/7-8	3	808.16	.0037
9/14-15	1	782.59	.0013
9/21-22	—	601.92	—
9/28-29	1	601.92	.0017
			.0017
10/5-6	—	601.92	—
10/12-13	1	601.92	.0017
10/20-21	1	599.83	.0017
10/27-28	11	447.68	.0246
			.0070
11/2-3	13	601.92	.0216
11/9-10 → 11/12-13	8 → 5 → 13	→ 640.92	.0203
11/16-17	4	313.92	.0127
11/23-24 → 11/30-12/1	1 → 1 → 2	→ 621.30	.0032
			.0144
12/7-8	1	313.92	.0032
12/16-17 → 12/21-22	— → — → —	→ 905.73	—
12/28-29	—	601.92	—
			.0011

Form No. 405

Weekly Intervals
[illegible] 15-21
22-31

Central Hudson G & E Electric Corporation
Dunkirk Fossil Generating Station
1972
Impingement Stepped Bars

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg
Jan 12	1	173.46	
13	10	292.74	
14	22	337.12	
	33	803.32	0.0411
15	12	294.28	
16	3	176.97	
19	11	93.69	
20	10	147.49	
21	1	93.59	
	37	806.02	0.0459
22	0	56.49	
23	1	111.43	
25	6	245.02	
26	5	300.77	
27	2	276.34	
28	0	164.70	
	14	1154.75	0.0121
January Avg. #/mg			0.0230
Feb. 4	0	121.94	
5	1	137.25	
7	1	166.71	
	2	425.90	0.0047
8	0	168.90	
10	0	100.08	
11	1	145.48	
13	0	98.82	
14	0	64.47	
	1	577.75	0.0017

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg
Feb 16	0	131.76	
17	0	131.76	
19	2	89.43	
20	0	32.94	
	2	385.89	0.0052
22	3	89.86	
23	1	135.18	
25	0	31.50	
26	0	74.34	
	4	330.88	0.0121
February Avg. #/mg			0.0059
March 2	0	128.34	
3	0	113.82	
5	0	131.76	
6	1	146.88	
	1	520.80	0.0019
8	2	146.88	
9	1	47.88	
11	2	119.76	
12	1	137.32	
14	2	48.05	
	8	501.89	0.0159
15	8	94.50	
17	10	81.90	
18	6	95.76	
20	7	71.82	
21	1	95.76	
	32	479.74	0.0667

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
March 23	0	119.28				
24	2	88.20				
26	1	110.88				
27	0	95.76				
29	2	95.76				
30	1	131.76				
	6	641.64	0.0094			
March Avg. #/mg			0.0235			
April 4	0	21.96				
5	1	131.76				
7	0	81.00				
	1	234.72	0.0043			
8	0	131.76				
10	0	146.88				
11	0	146.88				
13	0	146.88				
14	0	96.12				
	0	668.52	0.0000			
17	0	36.72				
19	0	146.88				
20	0	162.00				
	0	345.60	0.0000			
22	1	162.00				
23	2	146.88				
25	0	162.00				
26	2	131.76				
28	0	131.76				
29	2	145.62				
	7	880.02	0.0080			
April Avg. #/mg			0.0031			

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
May 1	0	162.00				
2	0	162.00				
4	0	194.19				
5	0	159.48				
7	1	162.00				
	1	739.67	0.0014			
8	4	162.00				
10	1	162.00				
11	10	162.00				
13	2	154.44				
14	1	121.50				
	18	761.94	0.0236			
16	3	136.62				
17	1	162.00				
19	2	146.88				
20	0	146.79				
	6	592.39	0.0101			
22	2	145.50				
23	0	191.52				
25	0	187.74				
26	0	191.52				
28	1	176.76				
29	1	162.00				
31	13	158.76				
	17	1213.80	0.0140			
May Avg. # /mg			0.0123			
June 1	7	128.52				
3	15	144.00				
4	15	137.32				
6	18	158.76				
7	32	191.52				
	87	760.12	0.1145			

Area No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
June 9	46	158.76				
10	43	143.64				
12	25	110.88				
13	26	158.76				
	140	572.04	0.2447			
15	29	191.52				
16	9	158.76				
18	35	191.52				
19	35	191.52				
21	28	158.76				
	136	892.08	0.1525			
24	27	176.40				
25	20	176.40				
27	31	158.76				
28	15	191.52				
30	25	126.00				
	118	829.08	0.1423			
June Avg. #/mg			0.1635			
July 1	17	143.64				
4	17	134.40				
6	25	172.90				
	59	450.94	0.1308			
9	16	147.00				
10	17	191.52				
12	16	198.24				
13	0	135.66				
	49	672.42	0.0729			

Form No. 406

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg
July 15	19	176.40	
16	21	83.16	
18	21	191.52	
19	44	191.52	
21	18	191.52	
	123	834.12	0.1475
22	26	208.56	
24	7	227.52	
25	37	227.52	
27	52	227.52	
28	45	227.52	
30	43	227.52	
31	49	208.27	
	259	1555.03	0.1666
July Avg. #/mg			0.1294
Aug. 2	50	232.58	
3	100	227.52	
5	12	131.27	
6	55	177.00	
	217	768.37	0.2824
8	21	170.64	
9	35	227.52	
11	41	162.37	
12	19	191.52	
14	103	227.52	
	219	979.57	0.2236
15	36	212.40	
17	14	170.64	
20	18	212.40	
21	26	212.40	
	94	807.84	0.1164

Date	# Fish Collected	C.W. Flow (mio)	Weekly Fish/mio			
Aug. 23	14	170.64				
24	20	217.52				
26	12	194.52				
27	29	155.52				
29	40	227.52				
30	16	155.52				
	131	1122.24	0.1167			
August Avg. #/mio			0.1248			
Sept. 1	14	132.30				
2	24	191.52				
4	28	132.30				
5	22	191.52				
7	33	191.52				
	121	839.16	0.1442			
10	17	191.52				
11	15	191.52				
13	26	191.52				
14	12	191.52				
	70	766.08	0.0914			
16	10	191.52				
17	8	176.40				
19	28	191.52				
20	9	158.76				
	55	718.20	0.0766			
22	12	184.59				
23	8	155.52				
25	21	116.64				
26	13	179.52				
28	22	191.52				
29	16	191.52				
	92	1019.31	0.0903			

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
September						
Avg. #/mg			0.1006			
Oct. 1	11	191.52				
2	23	191.52				
4	17	196.98				
5	88	158.76				
7	14	191.52				
	153	930.30	0.1645			
8	13	176.40				
10	27	191.52				
11	23	143.64				
13	14	191.52				
14	13	176.40				
	90	879.48	0.1023			
16	9	176.40				
17	10	176.40				
19	31	132.30				
20	22	167.96				
	72	653.06	0.1102			
22	29	160.02				
23	16	146.16				
25	10	161.28				
26	14	161.28				
28	3	153.72				
29	27	128.52				
31	1	153.72				
	100	1064.70	0.0939			
October						
Avg. #/mg			0.1177			

Form No. 406

Date	# Fish Collected	C.W. Flow (mg)	Weekly #/mg			
Nov. 1	1	161.28				
3	5	161.28				
4	0	161.28				
6	0	120.96				
7	9	161.28				
	15	766.08	0.0196			
10	2	131.04				
12	0	162.00				
13	12	191.52				
	14	484.56	0.0289			
15	18	191.52				
16	3	191.52				
18	6	191.52				
19	9	191.52				
	36	766.08	0.0470			
25	6	191.52				
27	2	133.75				
28	0	88.20				
30	0	161.28				
	8	574.75	0.0139			
November						
Avg. #/mg			0.0274			
Dec 1	1	153.72				
3	0	138.60				
4	0	161.28				
6	8	161.28				
7	1	138.60				
	10	753.48	0.0133			

Form No. 405

	Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
*K	Dec 9	2	153.72				
	10	0	113.40				
	12	0	146.16				
	13	3	161.28				
		5	574.56	0.0087			
	15	2	131.76				
	16	1	131.76				
	18	7	131.76				
	19	9	106.38				
	20	13	164.70				
	21	0	106.38				
		32	772.74	0.0414			
	28	1	175.68				
	29	0	87.84				
		1	263.52	0.0038			
	December						
	Avg. #/mg			0.0168			

Form No. 405

1973
Dans Kammer Impingement
Striped Bass

C.L.L.
9-13-77

Revised 10-17-77
MWD

Date	# Fish	C.W. Flow (MG)	# Fish / MG
1/4-5	0	252.54	—
10-11	0	256.04	—
17-18	0	263.52	—
24-25	0	256.20	—
31-2/1	0	153.72	
mean			
2/7-8	0	192.52	—
14-15	5	222.64	0.0225
21	0	172.93	—
27-28	0	241.56	—
mean			0.0056
3/6-7	0	261.40	—
21-22	0	137.16	—
mean			
4/3-4	1	263.51	0.0038
18-19	0	242.55	—
25	0	108.00	—
mean			0.0013
5/2-3	1	291.61	0.0034
17-18	5	316.19	0.0158
30-31	4	367.08	0.0109
mean			0.0100
6/13-14	7	455.04	0.0154
26-27	22	455.04	0.0483
mean			0.0318
7/10-11	90	455.04	0.1978
24-25	44	910.08	0.0483
mean			0.1230
8/7-8	23	455.04	0.0505
21-22	39	492.96	0.0791
mean			0.0648

Form No. 405

1973

Dauskammer Impingement

Striped Bass

C.H.L.
7-13-77

Date	# Fish	C.W. Flow (MG)	# Fish / MG.
9/5-6	16	455.04	0.0352
18-19	93	440.82	0.2110
mean			0.1231
10/3-4	74	336.96	0.2196
17-18	212	414.96	0.5109
31-11/1	870	382.20	2.2763
mean			1.0023
11/15-16	162	382.20	0.4239
28-29	34	382.20	0.0890
mean			0.2564
12/11-12	36	313.20	0.1149
26-27	33	252.72	0.1306
mean			0.1228

Form No. 405

1974 Danskammer Impingement
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	12	315.71	.0380
1/22-23	—	285.48	—
			.0190
2/5-6	2	316.98	.0063
2/19-20	—	285.48	—
			.0032
3/5-6	—	263.52	—
3/25-26	—	263.52	—
4/2-3	2	248.52	.0080
4/15-16	2	242.10	.0083
4/30-5/1	19	293.76	.0647
			.0270
5/14-15	—	293.76	—
5/21-22	16	361.10	.0443
5/28-29	17	352.80	.0482
			.0308
6/4-5	18	311.85	.0577
6/11-12	10	252.00	.0397
6/18-19	27	306.95	.0880
6/25-26	31	324.00	.0957
			.0703
7/2-3	56	394.17	.1421
7/9-10	31	381.00	.0814
7/16-17	39	303.87	.1283
7/23-24 →	107 → 200	→ 931.16	.2148
7/30-31	93		
			.1416
8/6-7	35	436.14	.0802
8/13-14	37	405.51	.0912
8/20-21	57	415.35	.1372
8/27-28	34	434.60	.0782
			.0967

No. 405

1974 Dawskammer Impingement
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG			
9/3-4	25	439.16	.0569			
9/10-13	36	442.16	.0814			
9/17-18	23	329.05	.0699			
9/24-25	13	357.72	.0363			
			.0611			
10/1-2	18	424.80	.0424			
10/8-9	18	458.67	.0392			
10/15-16	20	455.04	.0440			
10/22-23	5 → 15	→ 769.79	.0195			
10/29-30	10					
			.0363			
11/5-6	9	392.28	.0229			
11/12-13	6	383.04	.0157			
11/19-20	3	392.28	.0076			
11/26-27	19	383.04	.0496			
			.0240			
12/3-4	10	162.69	.0615			
12/10-11	14	383.04	.0365			
12/17-18	31	392.28	.0790			
12/26-27	3	322.56	.0093			
			.0466			

Form No. 405

1/21/77 CM

1975 DANSKAMMER I IMPINGEMENT
Striped bass

Date	# Fish Collected	C.W. Flows (MG)	# Fish/MG
1/8-9	—	263.52	—
1/15-16	7	287.52	.0243
1/22-23	—	532.45	.0038
1/29-30	2		
			.0094
2/4-5	5	293.75	.0170
2/11-12	—	190.59	—
2/18-19	1	139.00	.0072
2/25-26	—	91.76	—
			.0060
3/4-5	1	119.52	.0084
3/11-12	1	119.52	.0084
3/18-19	1	120.56	.0083
3/27-28	2	120.77	.0166
			.0104
4/1-2	2	119.52	.0167
4/8-9	—	119.52	—
4/17-18	—	119.52	—
4/23-24	—	328.32	—
4/30-5/1			.0042
5/6-7	1	239.04	.0042
5/13-14	1	239.04	.0042
5/20-21	1	239.04	.0042
5/27-28	—	216.06	—
			.0032
6/3-4	4	380.56	.0105
6/10-11	26	397.20	.0655
6/17-18	13	416.30	.0312
6/24-25	15	455.04	.0330
			.0350

9/21/77 [illegible]

orm No. 405

1975 Dans Kammer Impingement
Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/1-2	3	428.77	.0070
7/8-9	5	311.04	.0161
7/16-17	11	342.56	.0321
7/24-25 → 7/30-31	10 → 7	→ 796.52	.0213
			.0191
8/5-6	12	451.56	.0266
8/12-13	10	394.34	.0254
8/21-22	11	394.56	.0279
8/27-28	2	443.36	.0045
			.0211
9/4-5	10	394.56	.0253
9/9-10	7	394.56	.0177
9/18-19	11	394.56	.0279
9/23-24 → 9/30-10/1	0 → 5	→ 787.60	.0063
			.0193
10/7-8	14	311.04	.0450
10/15-16	3	335.22	.0089
10/22-23 → 10/29-30	6 → 53	717.12	.0823
			.0454
11/5-6	24	394.56	.0608
11/12-13	18	394.56	.0456
11/19-20	7	379.73	.0184
11/25-26	8	245.10	.0326
			.0394
12/2-3	30	233.28	.1286
12/10-11	6	226.94	.0264
12/17-18	3	233.28	.0129
12/23-24 → 12/30-31	1 → 2	→ 466.56	.0064
			.0436

Form No. 405

4/21/77 CM

1976 Danskammer Impingement

Striped bass

Date	# Fish Collected	C.W. Flow (M.G)	# Fish/MG
1/6-7	2	213.84	.0094
1/13-14	5	230.53	.0217
1/22-23 >	5 > 11	460.55	.0239
1/29-30	6		
			.0183
2/5-6	—	161.28	—
2/12-13	14	212.19	.0660
2/17-18	2	221.53	.0090
2/24-25	3	203.04	.0148
			.0224
3/2-3	—	203.04	—
3/9-10	1	203.04	.0049
3/16-17	—	198.81	—
3/23-24 >	— > —	407.31	—
3/30-31			
			.0012
4/6-7	—	253.51	—
4/13-14	—	233.28	—
4/20-21	—	230.03	—
4/28-29	1	299.52	.0033
			.0008
5/4-5	—	306.72	—
5/11-12	1	306.72	.0033
5/18-19	—	306.72	—
5/25-26	7	307.32	.0228
			.0065
6/2-3	5	277.53	.0180
6/8-9	3	276.48	.0108
6/15-16	1	335.54	.0030
6/22-23 >	2 > 4	662.52	.0060
6/29-30	2		
			.0094

9/21/77 CTH

orm No. 405

1976 Dans Kammer Impingement

Striped bass

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/6-7	1	306.72	.0033
7/13-14	3	290.75	.0103
7/20-21	—	305.45	—
7/27-28	1	246.11	.0041
			.0044
8/3-4	—	306.72	—
8/10-11	4	306.72	.0130
8/17-18	2	306.72	.0065
8/24-25	4	672.04	.0164
8/31-9/1	7		
			.009
9/7-8	4	365.76	.0109
9/14-15	—	396.00	—
9/21-22	2	455.04	.0044
9/28-29	—	394.56	—
			.0038
10/5-6	3	334.08	.0090
10/12-13	—	331.76	—
10/20-21	13	334.08	.0389
10/24-25	18	500.59	.0819
10/27-28	23		
			.0324
11/2-3	14	466.88	.0621
11/5-6	15		
11/9-10	12	233.28	.0514
11/16-17	15	258.91	.0579
11/23-24	6	581.40	.0189
11/30-12/1	5		
			.0476
12/7-8	7	285.70	.0245
12/16-17	1	559.99	.0071
12/21-22	3		
12/28-29	1	263.52	.0038
			.0118

rm No. 405

1973

Roseton Generating Station

Impingement: Atlantic Tomcod

Date	# Fish Collected	C. W. Flow (MG)	# Fish/MG
7/10-11	2	313.6	0.0064
8/7-8	15	602.4	0.0249
21-22	1	652.6	0.0015
			0.0132
9/18-19	9	602.4	0.0149
10/3-4	2	366.4	0.0055
17-19	15	940.8	0.0159
31-11/1	1	652.5	0.0015
			0.0076
11/15-16	8	652.6	0.0123
28-29	0	255.4	0.0000
			0.0062
12/11-12	1	340.4	0.0029
26-27	24	340.6	0.0705
			0.0367

rm No. 406

1974 Roseton Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish / MG
1/8-9	46	340.08	.1353
1/22-23	45	348.80	.1290
			.1322
3/5-6	—	313.92	—
3/19	—	78.48	—
4/2-3	—	183.12	—
4/15-16	—	313.92	—
4/30-5/1	—	313.92	—
5/14-15	—	601.92	—
5/21	1	189.66	.0053
5/28-29	67	601.92	.1113
			.0389
6/4-5	67	614.46	.1090
6/13-14	34	601.68	.0565
6/19-20	27	601.92	.0449
6/25-26	91	601.92	.1512
			.0904
7/2-3	35	613.96	.0570
7/9-10	1	595.65	.0017
7/16-17	2	614.46	.0036
7/23-24 > 7/30-31	2/3 > 5	> 922.38	.0054
			.0169
8/6-7	—	601.92	—
8/13-14	5	320.46	.0156
8/20-23	40	601.92	.0665
8/27-28	17	615.06	.0276
			.0274
9/3-4	27	601.92	.0449
9/17-18	8	601.92	.0133
9/24-25	—	459.90	—

1974 Roseton Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
10/1-2	1	451.44	.0022
10/8-9	1	105.63	.0095
10/15-16	1	235.44	.0042
			.0053
11/5-6	—	137.94	—
11/12-13	—	451.44	—
11/19-20	—	50.16	—
11/26-27	33	413.82	.0797
			.0199
12/5-6	7	125.40	.0558
12/10-11	8	451.44	.0177
12/17-18	22	589.38	.0373
12/26-27	269	601.92	.4469
			.1394

rm No. 405

1975 Roseton Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	88	600.53	.1465
1/15-16	24	313.92	.0765
1/22-23 → 1/29-30	47 → 22 → 69	→ 1357.00	.0508
			.0913
2/4-5	49	807.84	.0607
2/11-12	16	799.42	.0200
2/18-19	1	601.92	.0017
2/25-26	2	601.92	.0033
			.0214
3/4-5	—	300.96	—
3/11-12	3	601.92	.0050
3/18-19	—	602.35	—
			.0016
4/1-2	7	326.04	.0215
4/8-9	3	401.28	.0075
4/17-18	1	288.42	.0035
4/23-24 → 4/30-5/1	—	588.58	—
			.0081
5/6-7	—	526.35	—
5/13-14	—	300.96	—
5/20-21	1	521.73	.0019
5/27-28	5	807.84	.0062
			.0020
6/3-4	2	807.84	.0025
6/10-11	4	601.92	.0066
6/17-19	7	601.92	.0116
6/24-25	4	782.60	.0051
			.0064

1975 Roseton Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG			
7/1-2	2	807.84	.0025			
7/8-9	22	807.84	.0272			
7/16-17	72	756.79	.0951			
7/24-26 →	11 → 28	→ 1615.68	.0173			
7/30-31	17					
			.0355			
8/5-6	3	648.94	.0046			
8/12-13	11	595.65	.0185			
8/21-22	–	578.18	—			
8/27-28	4	602.92	.0066			
			.0074			
9/4-5	1	601.92	.0017			
9/9-10	6	601.92	.0100			
9/18-19	1	601.92	.0017			
9/23-24 →	3 → 7	→ 1203.84	.0058			
9/30-10/1	4					
			.0048			
10/7-8	8	451.44	.0177			
10/15-16	4	653.78	.0061			
10/22-23 →	15 → 67	→ 1202.17	.0557			
10/29-30	52					
			.0265			
11/5-6	53	601.92	.0880			
11/12-13	13	576.84	.0225			
11/19-20	8	601.92	.0133			
11/25-26	4	601.92	.0066			
			.0326			
12/2-3	1	313.92	.0032			
12/10-11	3	313.92	.0096			
12/17-18	—	313.92	—			
12/23-24 →	2 → 9	922.27	.0098			
12/30-31	7					
			.0056			

Form No. 405

1976 Roseton Impingement

Atlantic tomcod

Date	# Fish Collected	C.W. Flow (M.G)	# Fish/MG
1/6-7	1	313.92	.0032
1/13-14	4	313.92	.0127
1/22-23 >	6 > 8	> 1203.84	.0066
1/29-30	2		
			.0075
2/5-6	4	597.74	.0067
2/12-13	0	601.92	—
2/17-18	3	593.56	.0051
2/24-25	1	601.92	.0017
			.0034
3/2-3	7	593.56	.0118
3/9-10	1	363.66	.0027
3/16-17	2	313.50	.0064
3/23-24 >	— > 1	458.92	.0022
3/30-31	1		
			.0058
4/6-7	2	601.92	.0033
4/13-14	—	338.58	—
4/20-21	—	495.33	—
4/28-29	—	764.08	—
			.0008
5/4-5	—	601.92	—
5/11-12	1	807.84	.0012
5/18-19	9	807.84	.0111
5/25-26	6	808.08	.0074
			.0049
6/2-3	52	601.09	.0865
6/8-9	296	807.84	.3664
6/15-16	50	807.84	.0619
6/22-23 >	2 > 5	> 1598.57	.0031
6/29-30	3		
			.1295

Form No. 405

1/21/77 CTH

1976 Roseton Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/6-7	—	808.08	—
7/13-14	—	807.84	—
7/20-21	—	807.85	—
7/27-28	—	897.76	—
8/3-4	2	807.84	.0025
8/10-11	2	807.84	.0025
8/17-18	2	807.84	.0025
8/24-25 →	4 → 5	→ 1411.73	.0035
8/31-9/1	1.		
			.0028
9/7-8	2	808.16	.0025
9/14-15	3	782.59	.0038
9/21-22	—	601.92	—
9/28-29	—	601.92	—
			.0016
10/5-6	—	601.92	—
10/12-13	—	601.92	—
10/20-21	—	599.83	—
10/27-28	11	447.68	.0246
			.0062
11/2-3	66	601.92	.1096
11/9-10 →	131 → 175	→ 640.92	.2730
11/12-13	44		
11/16-17	31	313.92	.0988
11/23-24 →	17 → 57		
11/30-12/1	40	621.30	.0917
			.1433
12/7-8	37	313.92	.1179
12/16-17 →	48 → 188	→ 905.73	.2076
12/21-22	140		
12/28-29	92	601.92	.1528
			.1594

Form No. 405

Weekly Intervals
1-7 15-21
14 22-31

Central Hudson Gas & Electric Corporation
Danskammer Point Generating Station
1972
Impingement: Atlantic Tomcod

Date	# Fish	Flow (MG)	# Fish / MG			
1/12	31	173.46				
1/13	834	292.74				
1/14	1477	337.12				
	2342	803.32	2.9154			
1/15	1879	294.28				
1/16	1158	176.97				
1/19	22	93.69				
1/20	1069	147.49				
1/21	46	93.59				
	4174	806.02	5.1785			
1/22	67	56.49				
1/23	160	111.43				
1/25	1904	245.02				
1/26	2072	300.77				
1/27	1147	276.34				
1/28	454	164.70				
	5804	1154.75	5.0262			
January	Average		4.3734			
2/4	572	121.94				
2/5	419	137.25				
2/7	182	166.71				
	1173	425.90	2.7542			
2/8	69	168.90				
2/10	34	100.08				
2/11	91	145.48				
2/13	15	98.82				
2/14	14	64.47				
	223	577.45	.3862			
2/16	68	131.76				
2/17	116	131.76				
2/19	22	89.43				
2/20	10	32.94				
	216	385.89	.5597			

Form No. 405

CTH

1972 Danskammer Impingement
Atlantic tomcod

Date	# Fish	Flow (MG)	# Fish/MG			
2/22	14	89.86				
2/23	35	135.18				
2/25	10	31.50				
2/26	16	74.34				
	75	330.88	.2267			
February	Average		.9817			
3/2	19	128.34				
3/3	9	113.82				
3/5	19	131.76				
3/6	99	146.88				
	146	520.80	.2803			
3/8	77	146.88				
3/9	68	47.88				
3/11	25	119.76				
3/12	10	139.32				
3/14	2	48.05				
	182	501.89	.3626			
3/15	21	94.50				
3/17	29	181.90				
3/18	3	95.76				
3/20	—	71.82				
3/21	—	95.76				
	53	439.74	.1205			
3/23	1	119.28				
3/24	2	88.20				
3/26	4	110.88				
3/27	5	95.76				
3/29	4	95.76				
3/30	4	131.76				
	20	641.64	.0312			
March	Average		.1986			
4/4	2	21.96				
4/5	1	131.76				
4/7	2	81.00				
	5	234.72	.0213			

1972 Danskammer Impingement
Atlantic tomcod

Date	# Fish	Flow (MG)	# Fish/MG			
4/8	-	131.76				
4/10	3	146.88				
4/11	-	146.88				
4/13	-	146.88				
4/14	-	96.12				
	3	668.52	.0045			
4/17	-	36.72				
4/19	-	146.88				
4/20	-	162.00				
	-	345.60	0			
4/22	1	162.00				
4/23	-	146.88				
4/25	-	162.00				
4/26	1	131.76				
4/28	-	131.76				
4/29	1	145.62				
	3	880.02	.0034			
April	Average		.0073			
5/1	-	162.00				
5/2	-	162.00				
5/4	-	94.19				
5/5	-	159.48				
5/7	-	162.00				
	0	739.67	0			
5/8	0	162.00				
5/10	0	162.00				
5/11	-	162.00				
5/13	-	154.44				
5/14	-	121.50				
	-	761.94	0			
5/16	-	136.62				
5/17	-	162.00				
5/19	-	146.88				
5/20	-	146.89				
	-	592.39	0			

CTH

1972 Dawskummer Impingement
Atlantic tomcod

Date	# Fish	Flow (MG)	# Fish/MG			
5/22	-	145.50				
5/23	-	191.52				
5/25	-	187.74				
5/26	-	191.52				
5/28	-	176.76				
5/29	-	162.00				
5/31	-	158.76				
	-	1213.80	0			
May	Average		0			
6/1	0	128.52				
6/3	0	144.00				
6/4	0	137.32				
6/6	0	158.76				
6/7	0	191.52				
	0	760.12	0.0000			
6/9	0	158.76				
6/10	0	143.64				
6/12	0	110.88				
6/13	0	158.76				
	0	572.04	0.0000			
6/15	0	191.52				
6/16	0	158.76				
6/18	0	191.52				
6/19	0	191.52				
6/21	0	158.76				
	0	892.08	0.0000			
6/24	0	176.40				
6/25	0	176.40				
6/27	0	158.76				
6/28	0	191.52				
6/30	0	126.00				
	0	829.08	0.0000			
June	Average		0.0000			

No. 405

1972 Danskammer Impingement
Atlantic tomcod

Date	# Fish	Flow (MG)	# Fish/MG			
7/1	–	143.64				
7/4	–	134.40				
7/6	–	172.90				
	–	450.94	0			
7/9	1	147.00				
7/10	–	191.52				
7/12	18	198.24				
7/13	7	135.66				
	26	672.42	0.0387			
7/15	9	176.40				
7/16	–	83.16				
7/18	–	191.52				
7/19	–	191.52				
7/21	1	191.52				
	10	834.12	.0120			
7/22	–	208.56				
7/24	–	227.52				
7/25	3	227.52				
7/27	1	227.52				
7/28	–	227.52				
7/30	–	227.52				
7/31	–	208.87				
	4	1555.03	.0026			
July	Average		.0133			
8/2	–	232.58				
8/3	–	227.52				
8/5	–	131.27				
8/6	1	177.00				
	1	768.37	.0013			
8/8	–	170.64				
8/9	1	227.52				
8/11	–	162.37				
8/12	1	191.52				
8/14	1	227.52				
	3	979.57	.0031			

No. 405

1972 Dans Karm r Impingement
Atlantic tomcod

Date	# Fish	Flow (MG)	# Fish/MG			
8/15	–	212.40				
8/17	–	170.64				
8/20	–	212.40				
8/21	–	212.40				
	–	807.84	0			
8/23	1	170.64				
8/24	–	218.52				
8/26	2	194.52				
8/27	–	155.52				
8/29	4	227.52				
8/30	1	155.52				
	7	1122.24	.0062			
August	Average		.0026			
9/1	5	132.30				
9/2	–	191.52				
9/4	9	132.30				
9/5	4	191.52				
9/7	29	191.52				
	47	839.16	0.0560			
9/10	30	191.52				
9/11	9	191.52				
9/13	20	191.52				
9/14	11	191.52				
	70	766.08	.0914			
9/16	24	191.52				
9/17	5	176.40				
9/19	40	191.52				
9/20	47	158.76				
	116	718.20	.1615			

10/4/77 CTH

No. 405

1972 Dansammer Impingement

Date	# Fish	Flow (MG)	# Fish / MG
9/22	724	184.59	
9/23	41	155.52	
9/25	88	116.64	
9/26	114	179.52	
9/28	37	191.52	
9/29	88	191.52	
	1092	1019.31	1.0713
September	Average		.3450
10/1	124	191.52	
10/2	73	191.52	
10/4	131	196.98	
10/5	174	158.76	
10/7	82	191.52	
	584	930.30	.6278
10/8	15	176.40	
10/10	55	191.52	
10/11	19	143.64	
10/13	10	191.52	
10/14	11	176.40	
	110	879.48	.1251
10/16	15	176.40	
10/17	6	176.40	
10/19	45	132.30	
10/20	35	167.96	
	101	653.06	.1547
10/22	36	160.02	
10/23	13	146.16	
10/25	83	161.28	
10/26	21	161.28	
10/28	3	153.72	
10/29	25	128.52	
10/31	8	153.72	
	189	1064.70	.1775
October	Average		.2713

10/4/77 CTH

No. 405

1972 Dans Kammer Impingement
Atlantic tomcod

Date	# Fish	Flow (MG)	# Fish / MG			
11/1	7	161.28				
11/3	10	161.28				
11/4	–	161.28				
11/6	–	120.96				
11/7	16	161.28				
	33	766.08	.0431			
11/10	5	131.04				
11/12	1	162.00				
11/13	21	191.52				
	27	484.56	.0557			
11/15	84	191.52				
11/16	37	191.52				
11/18	100	191.52				
11/19	187	191.52				
	408	766.08	.5326			
11/25	492	191.52				
11/27	252	133.75				
11/28	34	88.20				
11/30	29	161.28				
	807	574.75	1.4041			
November	Average		.5089			
12/1	77	153.72				
12/3	73	138.60				
12/4	200	161.28				
12/6	174	161.28				
12/7	65	138.60				
	589	753.48	0.7817			
12/9	129	153.72				
12/10	63	113.40				
12/12	157	146.16				
12/13	358	161.28				
	707	574.56	1.2305			

No. 405

1972 Dans Kammer Impingement
White perch

Date	# Fish	Flow (MG)	# Fish / MG			
12/15	258	131.76				
12/16	952	131.76				
12/18	1175	131.76				
12/19	1269	106.38				
12/20	4642	164.70				
12/21	3261	106.38				
	11557	774.72	14.9176			
12/28	2824	175.68				
12/29	1466	87.84				
	4290	263.52	16.2796			
December						
Avg. #/MG			8.3024			

Form No. 405

1973

Dunskammer Point Generating station

Impingement: Atlantic Tomcod

Revised 10-17-77 mwo

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg			
1/4-5	3443	252.54	13.6335			
10-11	11465	258.04	44.4311			
17-18	11290	263.52	42.8430			
24-25	43492 > 53060	256.20 > 409.92	129.4399			
31-2/1	9568	153.72				
			57.5869			
2/7-8	2961	191.52	15.4605			
14-15	10073	222.64	45.2434			
21	2128	172.93	12.3056			
27-28	1775	241.56	7.3481			
			20.0894			
3/6-7	1388	261.40	5.3099			
21-22	627	137.16	4.5713			
			4.9406			
4/3-4	39	263.51	0.1480			
18-19	2	242.55	0.0082			
25	0	108.00	0.0000			
			0.0521			
5/2-3	3	291.61	0.0103			
17-18	1	316.19	0.0032			
30-31	69	367.08	0.1880			
			0.0672			
6/13-14	4	455.04	0.0088			
26-27	4	455.04	0.0088			
			0.0088			
7/10-11	6	455.04	0.0132			
24-26	25	910.08	0.0275			
			0.0204			
8/7-8	5	455.04	0.0110			
21-22	1	492.96	0.0020			
			0.0065			

No. 405

1973
Dauskammer
Atlantic Tomcod

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg			
9/5-6	0	455.04	0.0000			
18-19	2	440.82	0.0045			
			0.0022			
10/3-4	0	336.96	0.0000			
17-18	1	414.96	0.0024			
31-11/1	18	382.20	0.0471			
			0.0165			
11/15-16	1	382.20	0.0026			
28-29	1	382.20	0.0026			
			0.0026			
12/11-12	11	313.20	0.0351			
26-27	506	252.72	2.0022			
			1.0186			

9/23/7[illegible]

rm No. 405

1974 Danskammer Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	3939	315.71	12.4766
1/22-23	2549	285.48	8.9288
			10.7027
2/5-6	3249	316.98	10.2499
2/19-20	498	285.48	1.7444
			5.9972
3/5-6	257	263.52	.9753
3/25-26	7	263.52	.0266
			.5010
4/2-3	9	248.52	.0362
4/15-16	1	242.10	.0041
4/30-5/1	5	293.76	.0170
			.0191
5/14-15	1	293.76	.0034
5/21-22	0	361.10	—
5/28-29	0	352.80	—
			.0011
6/4-5	3	311.85	.0096
6/11-12	0	252.00	—
6/18-19	21	306.95	.0684
6/25-26	6	324.00	.0185
			.0241
7/2-3	53	394.17	.1345
7/9-10	1	381.00	.0026
7/16-17	2	303.87	.0066
7/23-24	1 4	931.16	.0043
7/30-31	3		
			.0370
8/6-7	3	436.14	.0069
8/13-14	4	405.51	.0099
8/20-21	13	415.35	.0313
8/27-28	1	434.60	.0023
			.0126

No. 405

1974 Dans Kammer Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
9/3-4	2	439.16	.0046
9/10-13	0	442.16	—
9/17-18	0	329.05	—
9/24-25	0	357.72	—
			.0012
10/1-2	0	424.80	—
10/8-9	1	458.67	.0022
10/15-16	6	455.04	.0132
10/22-23 → 10/29-30	0 → 5	→ 769.79	.0065
			.0055
11/5-6	2	392.28	.0051
11/12-13	2	383.04	.0052
11/19-20	0	392.28	—
11/26-27	4	383.04	.0104
			.0052
12/3-4	177	162.69	1.0880
12/10-11	117	383.04	.3055
12/17-18	186	392.28	.4742
12/26-27	1501	322.56	4.6534
			1.6303

7/23/77 CTH

m No. 405

1975 Danskammer Impingement
Atlantic Tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	1015	263.52	3.8517
1/15-16	968	287.52	3.3667
1/22-23	748 → 1231	→ 532.45	2.3120
1/29-30	483		
			3.1768
2/4-5	447	293.75	1.5217
2/11-12	171	190.59	.8972
2/18-19	200	139.00	1.4388
2/25-26	137	91.76	1.4930
			1.3377
3/4-5	217	119.52	1.8156
3/11-12	242	119.52	2.0248
3/18-19	217	120.56	1.7999
3/27-28	308	120.77	2.5503
			2.0476
4/1-2	215	119.52	1.7989
4/8-9	46	119.52	.3849
4/17-18	5	119.52	.0418
4/23-24	6 → 6	328.32	.0183
4/30-5/1	0		
			.5610
5/6-7	0	239.04	—
5/13-14	0	239.04	—
5/20-21	0	239.04	—
5/27-28	0	216.06	—
6/3-4	3	380.56	.0079
6/10-11	5	397.20	.0126
6/17-18	4	416.30	.0096
6/24-25	2	455.04	.0044
			.0086

9/25/77 CTH

405

1975 Dans Kammer Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/1-2	1	428.77	.0023
7/8-9	1	311.04	.0032
7/16-17	1	342.56	.0029
7/24-25 > 7/30-31	0 > 0	796.52	–
			.0021
8/5-6	0	451.56	–
8/12-13	0	394.34	–
8/21-22	0	394.56	–
8/27-28	1	443.36	.0023
			.0006
9/4-5	0	394.56	–
9/9-10	1	394.56	.0025
9/18-19	0	394.56	–
9/23-24 > 9/30-10/1	0 > 0	> 787.60	–
			.0006
10/7-8	4	311.04	.0129
10/15-16	0	335.22	–
10/22-23 > 10/29-30	0 > 70	> 717.12	.0976
			.0368
11/5-6	84	394.56	.2129
11/12-13	11	394.56	.0279
11/19-20	18	379.73	.0474
11/25-26	1	245.10	.0041
			.0731
12/2-3	50	233.28	.2143
12/10-11	29	226.94	.1278
12/17-18	95	233.28	.4072
12/23-24 > 12/30-31	4 > 43 39	> 466.56	.0922
			.2104

9/22/77 CHF

orm No. 405

1976 Dans Kammer Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (M.G.)	# Fish / MG
1/6-7	31	213.84	.1450
1/13-14	16	230.53	.0694
1/22-23	19	460.55	.0999
1/29-30	21		
			.1048
2/5-6	0	161.28	—
2/12-13	38	212.19	.1791
2/17-18	5	221.53	.0226
2/24-25	13	203.04	.0640
			.0664
3/2-3	15	203.04	.0739
3/9-10	4	203.04	.0197
3/16-17	17	198.81	.0855
3/23-24	2	407.31	.0098
3/30-31	2		
			.0472
4/6-7	7	253.51	.0276
4/13-14	2	233.28	.0086
4/20-21	0	230.03	—
4/28-29	0	297.52	—
			.0090
5/4-5	0	306.72	—
5/11-12	0	306.72	—
5/18-19	0	306.72	—
5/25-26	2	306.32	.0065
			.0016
6/2-3	6	277.53	.0216
6/8-9	25	276.48	.0904
6/15-16	2	335.54	.0060
6/22-23	0	662.52	.0015
6/29-30	1		
			.0299

1976 Danskammer Impingement
Atlantic tomcod

Date	# Fish Collected	C.W. Flow (MG)	# Fish / MG
7/6-7	0	306.72	–
7/13-14	0	290.75	–
7/20-21	0	305.45	–
7/27-28	0	246.11	–
8/3-4	0	306.72	–
8/10-11	0	306.72	–
8/17-18	0	306.72	–
8/24-25 → 8/31-9/1	0 → 0	→ 672.04	–
9/7-8	0	365.76	–
9/14-15	0	396.00	–
9/21-22	0	455.04	–
9/28-29	1	394.56	.0025
			.0006
10/5-6	5	334.08	.0150
10/12-13	0	331.76	–
10/20-21	19	334.08	.0569
10/24-25 → 10/27-28	34 → 154 120	→ 500.59	.3076
			.0949
11/2-3	322 → 858	→ 466.88	1.8377
11/5-6	536		
11/9-10	329	233.28	1.4103
11/16-17	149	258.91	.5755
11/23-24	66 → 554	→ 581.40	.9529
11/30-12/1	488		
			1.1941
12/7-8	190	285.70	.6650
12/16-17	341 → 6874	→ 559.99	12.2752
12/21-22	6533		
12/28-29	463	263.52	1.7570
			4.8991

Form No. 405

1973

Roseton Generating Station

Impingement: Blueback Herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG			
7/10-11	0	313.6	0.0000			
8/7-8	73	602.4	0.1212			
21-22	58	652.6	0.0889			
			0.1050			
9/18-19	340	602.4	0.5644			
10/3-4	53	366.4	0.1447			
17-19	6194	940.8	6.5838			
31-11/1	324	652.5	0.4966			
			2.4084			
11/15-16	610	652.6	0.9347			
28-29	23	255.4	0.0901			
			0.5124			
12/11-12	1	340.4	0.0029			
26-27	0	340.6	0.0000			
			0.0014			

9/15/77 CTH

Form No. 405

1974 Roseton Impingement
Blueback herring

Date	# Fish collected	C.W Flow (mg)	# Fish/mg
1/8-9	—	340.08	—
1/22-23	1	348.80	.0029
AVG			.0014
3/5-6	—	313.92	—
3/19	—	78.48	—
AVG			
4/2-3	—	183.12	—
4/15-16	—	313.92	—
4/30-5/1	26	313.92	.0828
AVG			.0276
5/14-15	21	601.92	.0349
5/21	1	189.66	.0053
5/28-29	37	601.92	.0615
Avg			.0339
6/4-5	78	614.46	.1269
6/13-14	7	601.68	.0116
6/19-20	11	601.92	.0183
6/25-26	7	601.92	.0116
Avg			.0421
7/2-3	—	613.96	—
7/9-10	—	595.65	—
7/16-17	3	614.46	.0049
7/23-24 >	— > 3	601.92 > 922.38	> .0032
7/30-31	3	320.46	
Avg			.0020
8/6-7	2	601.92	.0033
8/13-14	—	320.46	—
8/20-23	84	601.92	.1396
8/27-28	55	615.06	.0894
Avg			.0581
9/3-4	46	601.92	.0764
9/17-18	49	601.92	.0814
9/24-25	7	459.90	.0152

9/15/77 CTH

No. 405

1974 Roseton Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg
10/1-2	25	451.44	.0554
10/8-9	2	105.63	.0189
10/15-16	11	235.44	.0467
Avg			.0403
11/5-6	1	137.94	.0072
11/12-13	5	451.44	.0111
11/19-20	3	50.16	.0598
11/26-27	—	413.82	—
Avg			.0195
12/5-6	—	125.40	—
12/10-11	—	451.44	—
12/17-18	—	589.38	—
12/26-27	—	601.92	—

9/15/77 CTH

Form No. 405

1975 Roseton Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (M.G.)	# Fish/MG
1/8-9	—	600.53	—
1/15-16	—	313.92	—
1/22-23 >	—	755.08 > 1357	—
1/29-30	—	601.92	—
Avg			
2/4-5	—	807.84	—
2/11-12	—	799.42	—
2/18-19	—	601.92	—
2/25-26	—	601.92	—
Avg			
3/4-5	—	300.96	—
3/11-12	—	601.92	—
3/18-19	1	602.35	.0017
Avg			.0006
4/1-2	—	326.04	—
4/8-9	—	401.28	—
4/17-18	—	288.42	—
4/23-24 >	3 > 10	286.33 > 588.58	> .0170
4/30-5/1	7	302.25	
Avg			.0042
5/6-7	37	526.35	.0703
5/13-14	84	300.96	.2791
5/20-21	14	521.73	.0268
5/27-28	26	807.84	.0322
Avg			.1021
6/3-4	9	807.84	.0111
6/10-11	15	601.92	.0249
6/17-19	12	601.92	.0199
6/24-25	2	782.60	.0026
Avg			.0146

9/15/77 CTH

Form No. 405

1975 Roseton Impingement

Date	# Fish Collected	C.W. Flow (M.G)	# Fish/MG
7/1-2	1	807.84	.0012
7/8-9	1	807.84	.0012
7/16-17	22	756.79	.0291
7/24-26	77 > 593	807.84 > 1615.68	.3670
7/30-31	516	807.84	
			.0996
8/5-6	35	648.94	.0539
8/12-13	227	595.65	.3811
8/21-22	22	578.18	.0380
8/27-28	267	602.92	.4428
			.2290
9/4-5	109	601.92	.1811
9/9-10	83	601.92	.1379
9/18-19	45	601.92	.0748
9/23-24	56 > 361	601.92 > 1203.84	.2999
9/30-10/1	305	601.92	
			.1734
10/7-8	2002	451.44	4.4347
10/15-16	691	653.78	1.0569
10/22-23	2992 > 3478	601.92 > 1202.17	2.8931
10/29-30	486	600.25	
			2.7949
11/5-6	484	601.92	.8041
11/12-13	124	576.84	.2150
11/19-20	207	601.92	.3439
11/25-26	582	601.92	.9669
			.5825
12/2-3	5	313.92	.0159
12/10-11	–	313.92	
12/17-18	–	313.92	
12/23-24	–	319.92 > 922.27	
12/30-31	–	602.35	
			.0040

rm No. 405

1976 Roseton Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/6-7	—	313.92	—
1/13-14	—	313.92	—
1/22-23	—	601.92 → 1203.84	—
1/29-30	—	601.92	—
2/5-6	—	597.74	—
2/12-13	—	601.92	—
2/17-18	—	593.56	—
2/24-25	—	601.92	—
3/2-3	—	593.56	—
3/9-10	—	363.66	—
3/16-17	—	313.50	—
3/23-24 →	—	301.96 → 458.92	—
3/30-31	—	156.96	—
4/6-7	—	601.92	—
4/13-14	—	338.58	—
4/20-21	4	495.33	.0081
4/28-29	36	764.08	.0471
			.0138
5/4-5	6	601.92	.0100
5/11-12	22	807.84	.0272
5/18-19	14	807.84	.0173
5/25-26	39	808.08	.0483
			.0257
6/2-3	22	601.09	.0366
6/8-9	11	807.84	.0136
6/15-16	13	807.84	.0161
6/22-23 →	3 → 13	807.84 → 1598.57	.0081
6/29-30	10	790.73	
			.0186

9/15/77 CTH

Form No. 405

1976 Roseton Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/6-7	1	808.08	.0012
7/13-14	3	807.84	.0037
7/20-21	2	807.85	.0025
7/27-28	5	897.76	.0056
			.0032
8/3-4	11	807.84	.0136
8/10-11	29	807.84	.0359
8/17-18	36	807.84	.0446
8/24-25	18 → 34	809.52 → 1411.73	.0241
8/31-9/1	16	602.21	.0266
			.0296
9/7-8	52	808.16	.0643
9/14-15	138	782.59	.1763
9/21-22	5	601.92	.0083
9/28-29	7	601.92	.0116
			.0651
10/5-6	15	601.92	.0249
10/12-13	493	601.92	.8190
10/20-21	380	599.83	.6335
10/27-28	8	447.68	.0179
			.3738
11/2-3	3	601.92	.0050
11/9-10 →	1 → 1	313.92 → 640.92	.0016
11/12-13	—	327.00	—
11/16-17	1	313.92	.0032
11/23-24 →	— → —	307.38 → 621.30	—
11/30-12/1	—	313.92	
			.0024
12/7-8	—	313.92	—
12/16-17 →	—	317.19 → 905.73	—
12/21-22	—	588.54	—
12/28-29	—	601.92	—

10/4/77

Form No. 405

Weekly Intervals

1-7 15-21

8-14 22-31

Central Hudson Gas & Electric Corporation

Danskammer Point Generating Station

1972

Impingement: Gizzard Herring

Date	# Fish	Flow (MG)	Flow (MG)	# Fish/MG		
1/12	-	173.46				
1/13	-	292.74				
1/14	-	337.12				
	-	803.32	0			
1/15	-	294.28				
1/16	-	176.97				
1/19	-	93.69				
1/20	-	147.49				
1/21	-	93.59				
	-	806.02	0			
1/22	-	56.49				
1/23	-	111.43				
1/25	-	245.02				
1/26	-	300.77				
1/27	-	276.34				
1/28	-	164.70				
	-	1154.75	0			
January	Average					
2/4	-	121.94				
2/5	-	137.25				
2/7	-	166.71				
	-	425.90	0			
2/8	-	168.90				
2/10	-	100.08				
2/11	-	145.48				
2/13	-	98.82				
2/14	-	64.47				
	-	577.75	0			
2/16	-	131.76				
2/17	-	131.76				
2/19	-	89.42				
2/20	-	32.94				
	-	385.89	0			

Form No. 405

1972 Dans Skimmer Impingement
Blueback herring

Date	# Fish	Flow (MG)	# Fish / MG			
2/22	-	89.86				
2/23	-	135.18				
2/25	-	31.50				
2/26	-	74.34				
	-	330.88	0			
February	Average		0			
3/2	-	128.34				
3/3	-	113.82				
3/5	-	131.76				
3/6	-	146.88				
	-	520.80	0			
3/8	-	146.88				
3/9	-	47.88				
3/11	-	119.76				
3/12	-	139.32				
3/14	-	48.05				
	-	501.89	0			
3/15	-	94.50				
3/17	-	81.90				
3/18	-	95.76				
3/20	-	71.82				
3/21	-	95.76				
	-	439.74	0			
3/23	-	119.28				
3/24	-	88.20				
3/26	-	110.88				
3/27	-	95.76				
3/29	-	95.76				
3/30	-	131.76				
	-	641.64	0			
March	Average		0			
4/4	-	21.96				
4/5	-	131.76				
4/7	-	81.00				
	-	234.72	0			

Form No. 405

1017177 CTH

1972 Dans Kammer Impingement
Blueback herring

Date	# Fish	Flow (MG)	# Fish/MG			
4/8	-	131.76				
4/10	-	146.88				
4/11	-	146.88				
4/13	-	146.88				
4/14	-	96.12				
	-	668.52	0			
4/17	-	36.72				
4/19	-	146.88				
4/20	-	162.00				
	-	345.60	0			
4/22	-	162.00				
4/23	-	146.88				
4/25	-	162.00				
4/26	-	131.76				
4/28	2	131.76				
4/29	3	145.62				
	5	880.02	.0057			
April	Average		.0014			
5/1	4	162.00				
5/2	1	162.00				
5/4	1	94.19				
5/5	-	159.48				
5/7	-	162.00				
	6	739.67	.0081			
5/8	2	162.00				
5/10	-	162.00				
5/11	1	162.00				
5/13	-	154.44				
5/14	1	121.50				
	4	761.94	.0052			
5/16	6	136.62				
5/17	-	162.00				
5/19	3	146.88				
5/20	-	146.89				
	9	592.39	.0152			

1972 Danskammer Impingement
Blueback herring

Date	# Fish	Flow (MG)	# Fish/MG
5/22	5	145.50	
5/23	10	191.52	
5/25	–	187.74	
5/26	–	191.52	
5/28	1	176.76	
5/29	1	162.00	
5/31	13	158.76	
	30	1213.80	.0247
May	Average		.0133
6/1	3	128.52	
6/3	16	144.00	
6/4	8	137.32	
6/6	21	158.76	
6/7	23	191.52	
	71	760.12	0.0934
6/9	114	158.76	
6/10	69	143.64	
6/12	43	110.88	
6/13	57	158.76	
	283	572.04	0.4947
6/15	55	191.52	
6/16	26	158.76	
6/18	60	191.52	
6/19	52	191.52	
6/21	35	158.76	
	228	892.08	0.2556
6/24	7	176.40	
6/25	18	176.40	
6/27	17	158.76	
6/28	3	191.52	
6/30	5	126.00	
	50	829.08	0.0603
June	Average		0.2260

Form No. 405

1972 Dans Kammer Impingement
Blueback herring

Date	# Fish	Flow (MG)	# Fish / MG			
7/1	1	143.64				
7/4	2	134.40				
7/6	2	172.90				
	5	450.94	.0111			
7/9	–	147.00				
7/10	1	191.52				
7/12	12	198.24				
7/13	–	135.66				
	13	672.42	.0193			
7/15	2	176.40				
7/16	2	83.16				
7/18	1	191.52				
7/19	2	191.52				
7/21	–	191.52				
	7	834.12	.0084			
7/22	1	208.56				
7/24	–	227.52				
7/25	1	227.52				
7/27	–	227.52				
7/28	–	227.52				
7/30	–	227.52				
7/31	–	208.87				
	2	1555.03	.0013			
July	Average		.0100			
8/2	–	232.58				
8/3	–	227.52				
8/5	–	131.27				
8/6	1	177.00				
	1	768.37	.0013			
8/8	–	170.64				
8/9	1	227.52				
8/11	1	162.37				
8/12	2	191.52				
8/14	11	227.52				
	15	979.57	.0153			

Form No. 405

1972 Danskammer Impingement
Blueback Herring

Date	# Fish Collected	Flow (MG)	# Fish/MG			
8/15	1	212.40				
8/17	1	170.64				
8/20	24	212.40				
8/21	6	212.40				
	32	807.84	0.0396			
8/23	13	170.64				
8/24	6	218.52				
8/26	9	194.52				
8/27	12	155.52				
8/29	118	227.52				
8/30	15	155.52				
	173	1122.24	0.1542			
August						
Avg. #/MG			0.0526			
9/1	29	132.30				
9/2	1	191.52				
9/4	36	132.30				
9/5	1	191.52				
9/7	47	191.52				
	114	839.16	0.1359			
9/10	60	191.52				
9/11	7	191.52				
9/13	56	191.52				
9/14	10	191.52				
	133	766.08	0.1736			
9/16	20	191.52				
9/17	7	176.40				
9/19	17	191.52				
9/20	5	158.76				
	49	718.20	0.0682			

Form No. 405

1972 Davis Kammer Impingement
Blueback herring

Date	# Fish.	Flow (mg)	# Fish/mg			
9/22	84	184.59				
9/23	18	155.52				
9/25	75	116.64				
9/26	30	179.52				
9/28	51	191.52				
9/29	39	191.52				
	297	1019.31	0.2914			
September	Average		0.1673			
10/1	98	191.52				
10/2	241	191.52				
10/4	185	196.98				
10/5	55	152.76				
10/7	233	191.52				
	812	930.30	.8728			
10/8	20	176.40				
10/10	1345	191.52				
10/11	102	143.64				
10/13	696	191.52				
10/14	117	176.40				
	2280	879.48	2.5924			
10/16	242	176.40				
10/17	162	176.40				
10/19	191	132.30				
10/20	82	167.96				
	677	653.06	1.0367			
10/22	116	160.02				
10/23	21	146.16				
10/25	99	161.28				
10/26	42	161.28				
10/28	70	153.72				
10/29	31	129.52				
10/31	79	153.72				
	458	1064.70	.4302			
October	Average		1.2330			

Form No. 405

C7H

1972 Danskammer Impingement
Blue back herring

Date	# Fish	Flow (MG)	# Fish/MG
11/1	32	161.28	
11/3	52	161.28	
11/4	5	161.28	
11/6	11	120.96	
11/7	15	161.28	
	115	766.08	.1501
11/10	54	131.04	
11/12	226	162.00	
11/13	80	191.52	
	360	484.56	.7429
11/15	52	191.52	
11/16	22	191.52	
11/18	33	191.52	
11/19	7	191.52	
	114	766.08	.1488
11/25	18	191.52	
11/27	15	133.75	
11/28	4	88.20	
11/30	3	161.28	
	40	574.75	.0696
November	Average		.2778
12/1	14	153.72	
12/3	7	138.60	
12/4	4	161.28	
12/6	1	161.28	
12/7	0	138.60	
	26	753.48	0.0345
12/9	0	153.72	
12/10	0	113.40	
12/12	0	146.16	
12/13	0	161.28	
	0	574.56	0.0000

Form No. 406

1972 Danskammer Impingement
Blueback herring

Date	# Fish	Flow (MG)	# Fish / MG			
12/15	0	131.76				
12/16	0	131.76				
12/18	0	131.76				
12/19	0	106.38				
12/20	0	164.70				
12/21	0	106.38				
	0	772.24	0.0000			
12/28	0	175.68				
12/29	0	87.84				
	0	263.52	0.0000			
December	Average		0.0086			

Form No. 406

9-13-77

1973

Dunkammer Point Generating Station

Impingement: Blueback Herring

Revised 10-17-77 mwo

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/4-5	0	252.54	0.0000
10-11	1	258.04	0.0039
17-18	0	263.52	0.0000
24-25	0 > 0	256.20 > 409.92	0.0000
31-2/1	0	153.72	
			0.0010
2/7-8	0	191.52	0.0000
14-15	0	222.64	0.0000
21	0	172.93	0.0000
27-28	0	241.56	0.0000
			0.0000
3/6-7	0	261.40	0.0000
21-22	0	137.16	0.0000
			0.0000
4/3-4	0	263.51	0.0000
18-19	0	242.55	0.0000
25	0	108.00	0.0000
			0.0000
5/2-3	2	291.61	0.0069
17-18	8	316.19	0.0253
30-31	55	367.08	0.1498
			0.0607
6/13-14	31	455.04	0.0681
26-27	49	455.04	0.1077
			0.0879
7/10-11	11	455.04	0.0242
24-25	20	910.08	0.0220
			0.0231
8/7-8	62	455.04	0.1363
21-22	32	492.96	0.0649
			0.1006

1973
Dawskammer
Blueback Herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG			
9/5-6	48	455.04	0.1055			
18-19	106	440.82	0.2405			
			0.1730			
10/3-4	112	336.96	0.3324			
17-18	1177	414.96	2.8364			
31-11/1	573	382.20	1.4992			
			1.5560			
11/15-16	439	382.20	1.1486			
28-29	71	382.20	0.1858			
			0.6672			
12/11-12	4	313.20	0.0128			
26-27	0	252.72	0.0000			
			0.0064			

Form No. 405

1974 Dans Kammer Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	—	351.71	—
1/22-23	—	285.48	—
2/5-6	—	316.98	—
2/19-20	—	285.48	—
3/5-6	—	263.52	—
3/25-6	—	263.52	—
4/2-3	0	248.52	—
4/15-16	1	242.10	.0041
4/30-5/1	64	293.76	.2179
			.0740
5/14-15	4	293.76	.0136
5/21-22	11	361.10	.0305
5/28-29	26	352.80	.0737
			.0393
6/4-5	49	311.85	.1571
6/11-12	13	252.00	.0516
6/18-19	39	306.95	.1271
6/25-26	54	324.00	.1667
			.1256
7/2-3	57	394.17	.1459
7/9-10	1	381.00	.0026
7/16-17	2	303.87	.0066
7/23-24 →	1 → 5	458.42 → 931.16	.0054
7/30-31	4	472.74	.0401
8/6-7	8	436.14	.0183
8/13-14	13	405.51	.0321
8/20-21	99	415.35	.2384
8/27-28	98	434.60	.2249
			.1284

Form No. 405

1974 Danskammer Impingement
Bluebnck herring

Date	# Fish Collected	C.W Flow (MG)	# Fish/MG
9/3-4	10	439.16	.0228
9/10-13	96	442.16	.2171
9/17-18	45	329.05	.1368
9/24-25	21	357.72	.0587
			.1088
10/1-2	45	424.80	.1059
10/8-9	270	458.67	.5887
10/15-16	338	455.04	.7428
10/22-23 >	77 > 145	> 769.79	.1884
10/29-30	68.		
			.4064
11/5-6	248	392.28	.6322
11/12-13	68	383.04	.1775
11/19-20	26	392.28	.0663
11/26-27	12	383.04	.0313
			.2268
12/3-4	1	162.69	.0061
12/10-11	—	383.04	—
12/17-18	—	392.28	-
12/26-27	—	322.56	-
			.0015

Form No. 405

1975 Dans Kammer Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	0	263.52	–
1/15-16	0	287.52	–
1/22-23	0	532.45	–
1/29-30			–
2/4-5	0	293.75	–
2/11-12	0	190.59	–
2/18-19	0	139.00	–
2/25-26	0	91.76	–
3/4-5	0	119.52	–
3/11-12	0	119.52	–
3/18-19	0	120.56	–
3/27-28	0	120.77	–
4/1-2	0	119.52	–
4/8-9	0	119.52	–
4/17-18	4	119.52	.0335
4/23-24	4	328.32	.0122
4/30-5/1	2		
			.0114
5/6-7	1	239.04	.0042
5/13-14	3	239.04	.0126
5/20-21	6	239.04	.0251
5/27-28	10	216.06	.0463
			.0220
6/3-4	16	380.56	.0420
6/10-11	82	397.20	.2064
6/17-18	44	416.30	.1057
6/24-25	27	455.04	.0593
			.1034

9/19/77 CTH

m No. 405

1975 Dans Kammer Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/1-2	10	428.77	.0233
7/8-9	4	311.04	.0129
7/16-17	9	342.56	.0263
7/24-25 >	53 > 68	> 796.52	.0854
7/30-31	15		
			.0370
8/5-6	20	451.56	.0443
8/12-13	255	394.34	.6466
8/21-22	41	394.56	.1039
8/27-28	40	443.36	.0902
			.2212
9/4-5	76	394.56	.1926
9/9-10	148	394.56	.3751
9/18-19	101	394.56	.2560
9/23-24	41 > 157	> 787.60	.1993
9/30-10/1	116		
			.2558
10/7-8	6694	311.04	21.5213
10/15-16	142	335.22	.4236
10/22-23 >	921 > 990	> 717.12	1.3805
10/29-30	69		
			7.7751
11/5-6	252	394.56	.6387
11/12-13	249	394.56	.6311
11/19-20	112	379.73	.2949
11/25-26	112	245.10	.4570
			.5054
12/2-3	34	233.28	.1457
12/10-11	0	226.94	—
12/17-18	0	233.28	—
12/23-24 >	0 > 0	466.56	—
12/30-31	0		
			.0364

9/20/77 [illegible]

Form No. 405

1976 Dans Kammer Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/6-7	0	213.84	—
1/13-14	0	230.53	—
1/22-23	0	460.55	—
1/29-30	0		—
2/5-6	0	161.28	—
2/12-13	0	212.19	—
2/17-18	0	221.53	—
2/24-25	0	203.04	—
3/2-3	0	203.04	—
3/9-10	0	203.04	—
3/16-17	0	198.81	—
3/23-24	0	407.31	—
3/30-31	0		
4/6-7	0	253.51	—
4/13-14	0	233.28	—
4/20-21	1	230.03	.0043
4/28-29	3	299.52	.0100
			.0036
5/4-5	7	306.72	.0228
5/11-12	9	306.72	.0293
5/18-19	6	306.72	.0196
5/25-26	60	307.32	.1952
			.0667
6/2-3	22	277.53	.0793
6/8-9	8	276.48	.0289
6/15-16	17	335.54	.0507
6/22-23	17	662.52	.0257
6/29-30	5		
			.0462

9/20/77 CTH

No. 405

1976 Dans Kammer Impingement
Blueback herring

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/6-7	3	306.72	.0098
7/13-14	7	290.75	.0241
7/20-21	4	305.45	.0131
7/27-28	22	246.11	.0894
			.0341
8/3-4	5	306.72	.0163
8/10-11	26	306.72	.0848
8/17-18	2	306.72	.0065
8/24-25 >	21 > 31	> 672.04	.0461
8/31-9/1	10		
			.0384
9/7-8	58	365.76	.1586
9/14-15	17	396.00	.0429
9/21-22	24	455.04	.0527
9/28-29	113	394.56	.2864
			.1352
10/5-6	140	334.08	.4191
10/12-13	101	331.76	.3044
10/20-21	1249	334.08	3.7386
10/24-25 >	11 > 14	> 500.59	.0280
10/27-28	3		
			1.1225
11/2-3 >	5 > 11	> 466.88	.0236
11/5-6	6		
11/9-10	8	233.28	.0343
11/16-17	5	258.91	.0193
11/23-24 >	6 > 7	> 581.40	.0120
11/30-12/1	1		
			.0223
12/7-8	0	285.70	—
12/16-17 >	— 0	> 559.99	—
12/21-22	—		—
12/28-29	0	263.52	—

orm No. 405

1973

Roseton Generating Station

Impingement: Alewife

Date	# Fish Collected	C.W. Flow (MG)	# Fish / MG			
7/10-11	13	313.6	0.0415			
8/7-8	362	602.4	0.6009			
21-22	64	652.6	0.0981			
			0.3495			
9/18-19	263	602.4	0.4366			
10/3-4	19	366.4	0.0519			
17-19	641	940.8	0.6813			
31-11/1	30	652.5	0.0460			
			0.2597			
11/15-16	42	652.6	0.0644			
28-29	1	255.4	0.0039			
			0.0342			
12/11-12	0	340.4	0.0000			
26-27	0	340.6	0.0000			
			0.0000			

4-15-7

orm No. 405

1974

Roseton Generating Station

Impingement: Alewife

101 2

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	0	340.08	0.0000
22-23	0	348.80	0.0000
			0.0000
3/5-6	0	313.92	0.0000
19	0	78.48	0.0000
			0.0000
4/2-3	0	183.12	0.0000
15-16	0	313.92	0.0000
30-5/1	1	313.92	0.0032
			0.0011
5/14-15	2	601.92	0.0033
21	11	189.66	0.0580
28-29	8	601.92	0.0133
			0.0249
6/4-5	6	614.46	0.0098
13-14	0	601.68	0.0000
19-20	3	601.92	0.0050
25-26	4	601.92	0.0066
			0.0054
7/2-3	0	613.96	0.0000
9-10	0	595.65	0.0000
16-17	24	614.46	0.0391
23-24	39 > 53	601.92 > 922.38	0.0575
30-31	14	320.46	
			0.0242
8/6-7	0	601.92	0.0000
13-14	2	320.46	0.0062
20-23	86	601.92	0.1429
27-28	8	615.06	0.0130
			0.0405

9-15-77

orm No. 405

1974
Roseton
Alewife

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg
9/3-4	18	601.92	0.0299
17-18	12	601.92	0.0199
24-25	2	459.90	0.0043
			0.0180
10/1-2	4	451.44	0.0089
8-9	0	105.63	0.0000
15-16	1	235.44	0.0042
			0.0044
11/5-6	0	137.94	0.0000
12-13	2	451.44	0.0044
19-20	3	50.16	0.0598
26-27	4	413.82	0.0097
			0.0185
12/5-6	0	125.40	0.0000
10-11	0	451.44	0.0000
17-18	0	589.38	0.0000
26-27	0	601.92	0.0000
			0.0000

rm No. 405

1975
Roseton Generating Station
Impingement: Alewife

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	0	600.53	0.0000
15-16	0	313.92	0.0000
22-23	0 > 0	755.08 > 1357.00	0.0000
29-30	0	601.92	
			0.0000
2/4-5	0	807.84	0.0000
11-12	0	799.42	0.0000
18-19	0	601.92	0.0000
25-26	0	601.92	0.0000
			0.0000
3/4-5	0	300.96	0.0000
11-12	0	601.92	0.0000
18-19	1	602.35	0.0017
			0.0006
4/1-2	0	326.04	0.0000
8-9	1	401.28	0.0025
17-18	1	288.42	0.0035
23-24	1 > 5	286.33 > 588.58	0.0085
30-5/1	4	302.25	
			0.0036
5/6-7	3	526.35	0.0057
13-14	4	300.96	0.0133
20-21	2	521.73	0.0038
27-28	3	807.84	0.0037
			0.0066
6/3-4	1	807.84	0.0012
10-11	3	601.92	0.0050
17-19	0	601.92	0.0000
24-25	0	782.60	0.0000
			0.0016

Form No. 405

1975
Roseton
Alewife

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg
7/1-2	3	807.84	0.0037
8-9	176	807.84	0.2179
16-17	352	756.79	0.4651
24-26	227 > 597	807.84 > 1615.68	0.3695
30-31	370	807.84	
			0.2640
8/5-6	113	648.94	0.1741
12-13	32	595.65	0.0537
21-22	8	578.18	0.0138
27-28	17	602.92	0.0282
			0.0674
9/4-5	14	601.92	0.0233
9-10	13	601.92	0.0216
18-19	10	601.92	0.0166
23-24	5 > 10	601.92 > 1203.84	0.0083
30-10/1	5	601.92	
			0.0174
10/7-8	9	451.44	0.0199
15-16	10	653.78	0.0153
22-23	112 > 261	601.92 > 1202.17	0.2171
29-30	149	600.25	
			0.0841
11/5-6	125	601.92	0.2077
12-13	28	576.84	0.0485
19-20	69	601.92	0.1146
25-26	89	601.92	0.1479
			0.1297
12/2-3	7	313.92	0.0223
10-11	0	313.92	0.0000
17-18	0	313.92	0.0000
23-24	0 > 0	319.92 > 922.27	0.0000
30-31	0	602.35	
			0.0056

rm No. 405

1976

Roseton Generating Station

Impingement: Alewife

2

Date	# Fish collected	C.W. Flow (MG)	# Fish/MG
1/6-7	0	313.92	0.0000
13-14	0	313.92	0.0000
22-23	0 > 0	601.92 > 1203.84	0.0000
29-30	0	601.92	
			0.0000
2/5-6	0	597.74	0.0000
12-13	0	601.92	0.0000
17-18	0	593.56	0.0000
24-25	0	601.92	0.0000
			0.0000
3/2-3	0	593.56	0.0000
9-10	0	363.66	0.0000
16-17	0	313.50	0.0000
23-24	0 > 0	301.96 > 458.92	0.0000
30-31	0	156.96	
			0.0000
4/6-7	0	601.92	0.0000
13-14	0	338.58	0.0000
20-21	8	495.33	0.0162
28-29	14	764.08	0.0183
			0.0086
5/4-5	0	601.92	0.0000
11-12	9	807.84	0.0111
18-19	6	807.84	0.0074
25-26	8	808.08	0.0099
			0.0071
6/2-3	1	601.09	0.0017
8-9	7	807.84	0.0087
15-16	0	807.84	0.0000
22-23	0 > 1	807.84 > 1598.57	0.0006
29-30	1	790.73	
			0.0028

orm No. 405

2 2

1976
Roseton
Alewife

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg			
7/6-7	1	808.08	0.0012			
13-14	9	807.84	0.0111			
20-21	62	807.85	0.0767			
27-28	15	897.76	0.0167			
			0.0264			
8/3-4	12	807.84	0.0149			
10-11	50	807.84	0.0619			
17-18	6	807.84	0.0074			
24-25	17 > 24	809.52 > 1411.73	0.0170			
31-9/1	7	602.21				
			0.0253			
9/7-8	31	808.16	0.0384			
14-15	2	782.59	0.0026			
21-22	0	601.92	0.0000			
28-29	0	601.92	0.0000			
			0.0102			
10/5-6	2	601.92	0.0033			
12-13	10	601.92	0.0166			
20-21	3	599.83	0.0050			
27-28	36	447.68	0.0804			
			0.0263			
11/2-3	10	601.92	0.0166			
9-10	1 > 2	313.92 > 640.92	0.0031			
12-13	1	327.00				
16-17	0	313.92	0.0000			
23-24	0 > 0	307.38 > 621.30	0.0000			
30-12/1	0	313.92				
			0.0049			
12/7-8	0	313.92	0.0000			
16-17 >	0 > 0	317.19 > 905.73	0.0000			
21-22	0	588.54				
28-29	0	601.92	0.0000			
			0.0000			

Form No. 405

Weekly Intervals

1-7 15-21

8-14 22-31

Central Hudson Gas & Electric Corporation

Danskammer Point Generating Station

1972

Impingement: Alewife

Date		# Fish Collected	C.W. Flow (mg)	Weekly #/mg
Jan.	12	0	173.46	
	13	0	292.74	
	14	0	337.12	
		0	803.32	0.0000
	15	0	294.28	
	16	0	176.97	
	19	0	93.69	
	20	0	147.49	
	21	0	93.59	
		0	806.02	0.0000
	22	0	56.49	
	23	0	111.43	
	25	0	245.02	
	26	0	300.77	
	27	0	276.34	
	28	0	164.70	
		0	1154.75	0.0000
January Avg. #/mg				0.0000
Feb.	4	0	121.94	
	5	0	137.25	
	7	0	166.71	
		0	425.90	0.0000
	8	0	168.90	
	10	0	100.08	
	11	0	145.43	
	13	0	98.82	
	14	0	64.47	
		0	577.75	0.0000

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
Feb. 16	0	131.76				
17	0	131.76				
19	0	89.43				
20	0	32.94				
	0	325.89	0.0000			
22	0	89.86				
23	0	135.18				
25	0	31.50				
26	0	74.34				
	0	330.88	0.0000			
February Avg. # /mg			0.0000			
March 2	0	128.34				
3	0	113.82				
5	0	131.76				
6	0	146.88				
	0	520.80	0.0000			
8	0	146.88				
9	0	47.88				
11	0	119.76				
12	0	139.32				
14	0	48.05				
	0	506.89	0.0000			
15	0	94.50				
17	0	81.90				
18	0	95.76				
20	0	71.82				
21	0	95.76				
	0	479.74	0.0000			

Form No. 406

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
March 23	0	119.28				
24	0	88.20				
26	0	110.88				
27	0	95.76				
29	0	95.76				
30	1	131.76				
	1	641.64	0.0016			
March Avg. #/mg			0.0004			
April 4	0	21.96				
5	2	131.76				
7	0	81.00				
	2	234.72	0.0085			
8	0	131.76				
10	0	146.88				
11	0	146.88				
13	0	146.88				
14	0	96.12				
	0	668.52	0.0000			
17	0	36.72				
19	0	146.88				
20	0	162.00				
	0	345.60	0.0000			
22	12	162.00				
23	6	146.88				
25	35	162.00				
26	62	131.76				
28	12	131.76				
29	47	145.62				
	174	880.02	0.1977			
April Avg. #/mg			0.0516			

Form No. 406

Date	# Fish Collected	C.W. Flow (mo)	Weekly Fish/mo			
May 1	26	162.00				
2	24	162.00				
4	12	94.19				
5	32	159.48				
7	43	162.00				
	137	739.67	0.1852			
8	127	162.00				
10	51	162.00				
11	130	162.00				
13	68	154.44				
14	25	121.50				
	401	761.94	0.5263			
16	44	136.62				
17	12	162.00				
19	36	146.88				
20	10	146.89				
	102	592.39	0.1722			
22	30	145.50				
23	6	191.52				
25	39	187.74				
26	16	191.52				
28	29	176.76				
29	26	162.00				
31	3	158.76				
	149	1213.80	0.1228			
May Avg. #/mo			0.2516			
June 1	2	128.52				
3	4	144.00				
4	4	137.32				
6	5	158.76				
7	4	191.52				
	19	760.12	0.0250			

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
June 9	4	158.76				
10	5	143.64				
12	8	110.88				
13	9	158.76				
	26	572.04	0.0455			
15	6	191.52				
16	0	158.76				
18	10	191.52				
19	0	191.52				
21	8	158.76				
	24	892.08	0.0269			
24	15	176.40				
25	23	176.40				
27	39	158.76				
28	9	191.52				
30	51	126.00				
	137	829.08	0.1652			
June Avg. #/mg			0.0656			
July 1	9	143.64				
4	3	134.40				
6	63	172.90				
	75	450.94	0.1663			
9	15	147.00				
10	41	191.52				
12	33	198.24				
13	9	135.66				
	98	672.42	0.1457			

Form No. 406

Date		# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
July	15	27	176.40				
	16	5	83.16				
	18	7	191.52				
	19	3	191.52				
	21	3	191.52				
		45	834.12	0.0539			
	22	2	208.56				
	24	3	227.52				
	25	1	227.52				
	27	4	227.52				
	28	4	227.52				
	30	20	227.52				
	31	4	208.87				
		38	1555.03	0.0244			
July Avg. #/mg				0.0976			
Aug.	2	18	232.58				
	3	30	227.52				
	5	8	131.27				
	6	16	177.00				
		72	768.37	0.0937			
	8	23	170.64				
	9	52	227.52				
	11	77	162.37				
	12	78	191.52				
	14	263	227.52				
		493	979.57	0.5033			
	15	90	212.40				
	17	43	170.64				
	20	119	212.40				
	21	35	212.40				
		287	807.84	0.3553			

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg
Aug. 23	75	170.64	
24	16	218.52	
26	58	194.52	
27	36	155.52	
29	225	227.52	
30	85	155.52	
	495	1122.24	0.4411
August Avg. #/mg			0.3484
Sept. 1	94	132.30	
2	19	191.52	
4	129	132.30	
5	27	191.52	
7	120	191.52	
	389	839.16	0.4636
10	98	191.52	
11	52	191.52	
13	62	191.52	
14	18	191.52	
	230	766.08	0.3003
16	62	191.52	
17	3	176.40	
19	50	191.52	
20	13	158.76	
	128	718.20	0.1782
22	151	184.59	
23	52	155.52	
25	125	116.64	
26	95	179.52	
28	181	191.52	
29	135	191.52	
	739	1019.31	0.7250

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
September						
Avg. #/mg			0.4168			
Oct. 1	308	191.52				
2	163	191.52				
4	393	196.98				
5	119	158.76				
7	306	191.52				
	1289	930.30	1.3856			
8	57	176.40				
10	437	191.52				
11	100	143.64				
13	308	191.52				
14	82	176.40				
	984	879.48	1.1188			
16	297	176.40				
17	188	176.40				
19	398	132.30				
20	32	167.96				
	915	653.06	1.4011			
22	143	160.02				
23	36	146.16				
25	116	161.28				
26	97	161.28				
28	52	153.72				
29	66	128.52				
31	26	153.72				
	536	1064.70	0.5034			
October						
Avg. #/mg			1.1022			

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
Nov 1	30	161.28				
3	62	161.28				
4	23	161.28				
6	30	120.96				
7	5	161.28				
	150	766.08	0.1958			
10	11	131.04				
12	53	162.00				
13	17	191.52				
	81	484.56	0.1672			
15	4	191.52				
16	5	191.52				
18	1	191.52				
19	2	191.52				
	12	766.08	0.0157			
25	1	191.52				
27	0	133.75				
28	0	88.20				
30	0	161.28				
	1	574.75	0.0017			
November						
Avg. #/mg			0.0951			
Dec 1	1	153.72				
3	0	138.60				
4	0	161.28				
6	0	161.28				
7	0	138.60				
	1	753.48	0.0013			

Form No. 405

Date	# Fish Collected	C.W. Flow (mg)	Weekly Fish/mg			
Dec. 9	0	153.72				
10	0	113.40				
12	0	146.16				
13	0	161.28				
	0	574.56	0.0000			
15	0	131.76				
16	0	131.76				
18	0	131.76				
19	0	106.38				
20	0	164.70				
21	0	106.38				
	0	772.74	0.0000			
28	0	175.68				
29	0	87.84				
	0	263.52	0.0000			
December						
Avg. #/mg			0.0003			

orm No. 405

7-13-77

1973

Dunkirk Point Generating Station

Impingement: Alewife

Revised 10-17-77
mwD

f 2

Date	# Fish Collected	C.W. Flow (mg)	# Fish/mg			
1/4-5	0	252.54	0.0000			
10-11	1	258.04	0.0039			
17-18	0	263.52	0.0000			
24-25	0 > 0	256.20 > 409.92	0.0000			
31-2/1	0	153.72				
			0.0010			
2/7-8	0	191.52	0.0000			
14-15	0	222.64	0.0000			
21	0	172.93	0.0000			
27-28	0	241.56	0.0000			
			0.0000			
3/6-7	0	261.40	0.0000			
21-22	0	137.16	0.0000			
			0.0000			
4/3-4	3	263.51	0.0114			
18-19	23	242.55	0.0948			
25	59	108.00	0.5463			
			0.2175			
5/2-3	7	291.61	0.0240			
17-18	82	316.19	0.2593			
30-31	90	367.08	0.2452			
			0.1762			
6/13-14	23	455.04	0.0505			
26-27	27	455.04	0.0593			
			0.0549			
7/10-11	117	455.04	0.2571			
24-26	343	910.08	0.3769			
			0.3170			
8/7-8	1161	455.04	2.5514			
21-22	847	492.96	1.7182			
			2.1348			

No. 405

9-13-71

1973
Dowskammer
Alewife

Date	# Fish Collected	C.W. Flow (mb)	# Fish/mb			
9/5-6	475	455.04	1.0439			
18-19	3804	440.82	8.6294			
			4.8366			
10/3-4	366	336.96	1.0862			
17-18	2438	414.96	5.8753			
31-11/1	1164	382.20	3.0455			
			3.3357			
11/15-16	687	382.20	1.7975			
28-29	65	382.20	0.1701			
			0.9838			
12/11-12	0	313.20	0.0000			
26-27	0	252.72	0.0000			
			0.0000			

Form No. 405

1974 Danskammer Impingement
Alewife

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/8-9	—	315.71	—
1/22-23	—	285.48	—
2/5-6	—	316.98	—
2/19-20	—	285.48	—
3/5-6	—	263.52	—
3/25-26	2	263.52	.0076
			.0038
4/2-3	1	248.52	.0040
4/15-16	6	242.10	.0248
4/30-5/1	86	293.76	.2928
			.1072
5/14-15	95	293.76	.3234
5/21-22	116	361.10	.3212
5/28-29	78	352.80	.2211
			.2886
6/4-5	90	311.85	.2886
6/11-12	31	252.00	.1230
6/18-19	14	306.95	.0456
6/25-26	14	324.00	.0432
			.1251
7/2-3	21	394.17	.0533
7/9-10	4	381.00	.0105
7/16-17	5	303.87	0.0165
7/23-24 → 7/30-31	25 → 415	440 →	931.16 → .4725
			.1382
8/6-7	56	436.14	.1284
8/13-14	214	405.51	.5277
8/20-21	225	415.35	.5417
8/27-28	241	434.60	.5545
			.4381

No. 405

10-12-77
mwD

1974 Danskammer Impingement

Alewife

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
9/3-4	92	439.16	0.2095
10-13	250	442.16	0.5654
17-18	133	329.05	0.4042
24-25	107	357.72	0.2991
			0.3696
10/1-2	408	424.80	0.9605
8-9	646	458.97	1.4075
15-16	584	455.04	1.2834
22-23	224 364	392.28 767.79	0.4741
29-30	140	377.51	
			1.0314
11/5-6	106	392.28	0.2702
12-13	48	383.04	0.1253
19-20	32	392.28	0.0816
26-27	7	383.04	0.0183
			0.1238
12/3-4	0	162.69	0.0000
10-11	3	383.04	0.0078
17-18	0	392.28	0.0000
26-27	0	322.56	0.0000
			0.0020

Form No. 405

1975

Danskammer Impingement

Alewife

9-25-77

Date	# Fish	Flow (MG)	Fish / MG			
1/8-9	0	263.52	—			
15-16	0	287.52	—			
22-23	0 1	532.45	0.0019			
29-30	1					
			0.0006			
2/4-5	0	293.75	—			
11-12	0	190.59	—			
18-19	0	137.00	—			
25-26	0	91.76	—			
3/4-5	1	119.52	0.0084			
11-12	0	119.52	—			
18-19	2	120.56	0.0166			
27-28	2	120.77	0.0166			
			0.0164			
4/1-2	5	119.52	0.0418			
8-9	3	119.52	0.0251			
17-18	5-3	119.52	0.4183			
23-24	14 127	328.32	0.3868			
30-5/1	113					
			0.2180			
5/5-7	32	239.04	0.1339			
13-14	66	239.04	0.2761			
20-21	16	239.04	0.0669			
27-28	14	216.06	0.0648			
			0.1354			
6/3-4	49	380.56	0.1288			
10-11	10	397.20	0.0252			
17-18	9	416.30	0.0216			
24-25	7	455.04	0.0176			
			0.0483			

No. 405

1975

Daskammer Impingement

9-24-77

Alewife

Date	# Fish	Flow (MG)	Fish / MG
7/1-2	11	428.77	0.0257
8-9	45	311.04	0.1447
16-17	118	342.56	0.3445
24-25	141, 144	796.52	0.2436
30-31	53		
			0.1896
8/5-6	152	451.56	0.3366
12-13	177	394.39	0.4539
21-22	212	394.56	0.5373
27-28	159	443.36	0.3586
			0.4216
9/4-5	120	394.56	0.3041
9-10	106	394.56	0.2687
18-19	131	394.56	0.3320
23-24	43, 187	787.60	0.2374
30-10/1	144		
			0.2856
10/7-8	184	311.09	0.5916
15-16	133	335.22	0.3968
22-23	556, 726	717.12	1.0138
29-30	170		
			0.6674
11/5-6	434	394.56	1.1000
12-13	282	394.56	0.7147
19-20	503	379.73	1.3246
25-26	37	245.10	0.1510
			0.8226
12/2-3	4	233.28	0.0171
10-11	0	226.94	—
17-18	2	233.28	0.0086
23-24	0	466.56	—
30-31	0		
			0.0064

orm No. 405

C74

1976 Dans Kammer Impingement
Alewife

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
1/6-7	–	213.84	–
1/13-14	–	230.53	–
1/22-23	–	460.55	–
1/29-30	–		–
2/5-6	–	161.28	–
2/12-13	–	212.19	–
2/17-18	–	221.53	–
2/24-25	–	203.04	–
3/2-3	–	203.04	–
3/9-10	–	203.04	–
3/16-17	8	198.81	.0402
3/23-24	2	407.31	.0049
3/30-31	–		
			.0113
4/6-7	56	253.51	.2209
4/13-14	52	233.28	.2229
4/20-21	53	230.03	.2304
4/25-29	17	299.52	.0568
			.1828
5/4-5	129	306.72	.4206
5/11-12	71	306.72	.2315
5/18-19	128	306.72	.4173
5/25-26	28	307.32	.0911
			.2901
6/2-3	99	277.53	.3567
6/8-9	52	276.48	.1881
6/15-16	20	335.54	.0596
6/22-23	11	662.52	.0166
6/29-30	3		
			.1552

9/28/77 CH

orm No. 405

1976 Dawskammer Impingement
Alewife

Date	# Fish Collected	C.W Flow (MG)	# Fish/MG
7/6-7	+	306.72	—
7/13-14	5	290.75	.0172
7/20-21	3	305.45	.0098
7/27-28	3	246.11	.0122
			.0098
8/3-4	10	306.72	.0326
8/10-11	29	306.72	.0945
8/17-18	7	306.72	.0228
8/24-25 → 8/31-9/1	21 → 51 30	→ 672.04	.0759
			.0564
9/7-8	74	365.76	.2023
9/14-15	21	396.00	.0530
9/21-22	23	455.04	.0505
9/28-29	24	394.56	.0608
			.0916
10/5-6	52	334.08	.1557
10/12-13	41	331.76	.1236
10/20-21	65	334.08	.1946
10/24-25 → 10/27-28	135 → 202 67	→ 500.59	.4035
			.2194
11/2-3 → 11/5-6	48 → 116 68	→ 466.88	.2485
11/9-10	17	233.28	.0729
11/16-17	7	258.91	.0270
11/23-24 → 11/30-12/1	1 → 1 —	581.40	.0017
			.0875
12/7-8	—	285.70	—
12/14-17 → 12/21-22	1 → 1 —	554.99	.0018
12/28-29	0	263.52	—
			.0006

9-13-77

orm No. 405

1973

Roseton Generating Station

Impingement: Bay Anchovy

Date	# Fish Collected	C.W. Flow (MG)	# Fish/MG
7/10-11	0	313.6	0.0000
8/7-8	0	602.4	0.0000
21-22	25	652.6	0.0383
			0.0192
9/18-19	434	602.4	0.7205
10/3-4	53	366.4	0.1447
17-19	714	940.8	0.7589
31-11/1	22	652.5	0.0337
			0.3124
11/15-16	0	652.6	0.0000
28-29	0	255.4	0.0000
			0.0000
12/11-12	0	340.4	0.0000
26-27	0	340.6	0.0000
			0.0000

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Form No. 405

1974
Roseton Impingement

Bay Anchovy

CTC
9.28-77

Date	#Fish	Flow (MG)	#Fish/MG
1/8-9	—	340.08	0
22-23	—	348.80	0
3/5-6	—	313.92	0
19	—	78.48	0
4/2-3	—	183.12	0
15-16	—	313.92	0
30-5/1	—	313.92	0
5/14-15	—	601.92	0
21	—	189.66	0
28-29	2	601.92	0.0033
			0.0011
6/4-5	3	614.46	0.0049
13-14	2	601.68	0.0033
19-20	1	601.92	0.0017
25-26	—	601.92	0
			0.0025
7/2-3	3	613.96	0.0049
9-10	1	595.65	0.0017
16-17	—	614.46	0
23-24	— 6	601.92, 922.38	0.0065
30-31	6	320.86	
			0.0033
8/6-7	1	601.92	0.0017
13-14	16	320.46	0.0499
20-23	300	601.92	0.4984
27-28	100	615.06	0.1626
			0.1782
9/3-4	65	601.92	0.1080
17-18	12	601.92	0.0199
24-25	1	459.90	0.0022

0.0434

1974
Roseton Impingement

Bay Anchovy

9-28-77

Date	# Fish	Flow (MG)	# Fish / MG			
10/1-2	1	451.44	0.0022			
8-9	1	105.63	0.0095			
15-16	0	235.44	0			
			0.0039			
11/5-6	—	137.94	0			
12-13	—	451.44	0			
19-20	—	50.16	0			
26-27	—	413.82	0			
			0.0000			
12/5-6	—	135.40	0			
10-11	—	451.44	0			
17-18	—	589.38	0			
26-27	—	601.92	0			
			0.0000			

Page 17.2

Form No. 405

1975

Roseton Impingement

Bay Anchovy

CTC
9-28-76

Date	# Fish	Flow (MG)	Fish / MG
1/8-9	—	600.53	0
15-16	—	313.92	0
22-23	—	755.08, 1357	0
29-30	—	601.92	
2/4-5	—	807.84	0
11-12	—	799.42	0
18-19	—	601.92	0
25-26	—	601.92	0
3/4-5	—	300.96	0
11-12	—	601.92	0
18-19	—	602.35	0
4/1-2	—	326.04	0
8-9	1	401.28	0.0025
17-18	—	288.42	0
23-24	—	286.33, 588.58	0
30-5/1	—	302.25	
			0.0066
5/6-7	—	526.35	0
13-14	—	300.96	0
20-21	—	521.73	0
27-28	—	807.84	0
6/3-4	1	807.84	0.0012
10-11	—	601.92	0
17-18	—	601.92	0
24-25	1	782.60	0.0013
			0.0006

1975
Roseton Impingement
Bay Anchovy

CTC
9-25-77

Date	# Fish	Flow (MG)	# Fish / MG
7/1-2	—	807.84	0
8-9	—	807.84	0
16-17	21	756.77	0.0277
24-26	72 → 193	807.84 → 1615.68	0.1195
30-31	121	807.84	
			0.0368
8/5-6	29	648.94	0.0447
12-13	16	595.65	0.0269
21-22	16	578.18	0.0277
27-28	22	602.92	0.0365
			0.0340
9/4-5	38	601.92	0.0631
9-10	31	601.92	0.0515
18-19	36	601.92	0.0598
23-24	2 → 2	601.92 → 1203.84	0.0017
30-10/1	0	601.92	
			0.0440
10/7-8	—	451.44	0.
15-16	1	653.78	0.0015
22-23	—	601.92 → 1202.17	0
29-30	—	600.25	
			0.0005
11/5-6	—	601.92	0
12-13	—	576.84	0
19-20	—	601.92	0
25-26	—	601.92	0
12/2-3	—	313.92	0
10-11	—	313.92	0
17-18	—	313.92	0
23-24	—	313.92 → 922.27	0
30-31	—	602.35	

Form No. 405

1976

Roseton Impingement

Bay Anchovy

9-27-77

Date	# Fish	Flow (MG)	# Fish / MG
1/6-7	—	313.92	—
13-14	—	313.92	—
22-23	—	601.92, 1203.84	—
29-3	—	601.92	
2/5-6	—	597.74	—
12-13	—	601.92	—
17-18	—	593.56	—
24-25	—	601.92	—
3/2-3	—	593.56	—
9-10	—	363.66	—
16-17	—	313.50	—
23-24	—	301.96, 458.92	—
30-31	—	156.96	
4/6-7	—	601.92	—
13-14	—	338.58	—
20-21	—	495.33	—
28-29	—	769.08	—
5/4-5	—	601.92	—
11-12	—	807.84	—
18-19	—	807.84	—
25-26	—	808.08	—
6/2-3	—	601.09	—
9-9	—	807.84	—
1[illegible]-16	—	807.84	—
22-23	—	807.84, 1598.57	—
29-30	—	795.73	

1976

C.T.L.
9-27-77

405

Roseton Impingement

Bay Archway

Date	# Fish	Flow (MG)	# Fish / MG
7/6-7	14	808.08	0.0173
13-14	3	807.84	0.0037
20-21	1	807.85	0.0012
27-28	—	877.76	—
			0.0056
8/3-4	4	807.84	0.0050
10-11	184	807.84	0.2278
17-18	8	807.84	0.0099
24-25	15, 21	809.52, 1411.73	0.0149
31-9/1	6	602.21	
			0.0644
9/7-8	42	808.16	0.6520
14-15	49	782.59	0.0626
21-22	—	601.92	—
28-29	2	601.92	0.0033
			0.0295
10/5-6	5	601.92	0.0083
12-13	—	601.92	—
20-21	—	599.83	—
27-28	—	447.68	—
			0.0021
11/2-3	—	601.92	—
9-10	—	313.92, 640.92	—
12-13	—	327	
16-17	—	313.92	—
23-24	—	307.38, 621.30	—
30-12/1	—	313.92	
12/7-8	—	313.92	—
16-17	—	317.19, 905.73	—
21-22	—	588.54	
28-29	—	601.92	—

Form No. 405

Weekly Intervals
1-7 15-21
8-14 22-31

Central Hudson Gas & Electric Corporation
Danskammer Point Generating Station
1972
Impingement: Bay Anchovy

Date	# Fish	Flow (MG)	# Fish/MG
1/12	-	173.46	
1/13	-	292.74	
1/14	-	337.12	
	-	803.32	0
1/15	-	294.28	
1/16	-	176.97	
1/19	-	93.69	
1/20	-	147.49	
1/21	-	93.59	
	-	806.02	0
1/22	-	56.49	
1/23	-	111.43	
1/25	-	245.02	
1/26	-	300.77	
1/27	-	276.34	
1/28	-	164.70	
	-	1154.75	0
January	Average		0
2/4	-	121.94	
2/5	-	137.25	
2/7	-	166.71	
	-	425.90	0
2/8	-	168.90	
2/10	-	100.08	
2/11	-	145.48	
2/13	-	98.82	
2/14	-	64.57	
	-	577.75	0
2/16	-	131.76	
2/17	-	131.76	
2/19	-	89.43	
2/20	-	32.94	
	-	385.89	0

Form No. 405

1972 Dans Kammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish/MG			
2/22	-	89.86				
2/23	-	135.18				
2/25	-	31.50				
2/26	-	74.34				
	-	330.88	0			
February	Average					
3/2	-	128.34				
3/3	-	113.82				
3/5	-	131.76				
3/6	-	146.88				
	-	520.80	0			
3/8	-	146.88				
3/9	-	47.88				
3/11	-	119.76				
3/12	-	139.32				
3/14	-	48.05				
	-	501.89	0			
3/15	-	94.50				
3/17	-	81.90				
3/18	-	95.76				
3/20	-	71.82				
3/21	-	95.76				
	-	439.74	0			
3/23	-	119.28				
3/24	-	88.20				
3/26	-	110.88				
3/27	-	95.76				
3/29	-	95.76				
3/30	-	131.76				
	-	641.64	0			
March	Average		.0000			
4/4	-	21.96				
4/5	-	131.76				
4/7	-	81.00				
	-	234.72	0			

Form No. 405

1972 Danskammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish / MG			
4/8	-	131.76				
4/10	-	146.88				
4/11	-	146.88				
4/13	-	146.88				
4/14	-	96.12				
	-	668.52	0			
4/17	-	36.72				
4/19	-	146.88				
4/20	-	162.00				
	-	345.60	0			
4/22	-	162.00				
4/23	-	146.88				
4/25	-	162.00				
4/26	-	131.76				
4/28	-	131.76				
4/29	-	145.62	0			
	-	800.02				
April	Average		0			
5/1	-	162.00				
5/2	-	162.00				
5/4	-	94.19				
5/5	-	159.48				
5/7	-	162.00				
	-	739.67	0			
5/8	-	162.00				
5/10	-	162.00				
5/11	-	162.00				
5/13	-	154.44				
5/14	-	121.50				
	-	761.94	0			
5/16	-	136.62				
5/17	-	162.00				
5/19	-	146.88				
5/20	-	146.89				
	-	592.39	0			

Form No. 405

1972 Dan. Kammer Impingement
Bay Anchovy

Date	# Fish	Flow (mg)	# Fish/mg			
5/22	-	145.50				
5/23	-	191.52				
5/25	-	187.74				
5/26	-	191.52				
5/28	-	176.76				
5/29	-	162.00				
5/31	-	158.76				
	-	1213.80	0			
May	average		.0000			
6/1	0	128.52				
6/3	0	144.00				
6/4	0	137.32				
6/6	0	158.76				
6/7	0	191.52				
	0	760.12	0.0000			
6/9	0	158.76				
6/10	0	143.64				
6/12	0	110.88				
6/13	1	158.76				
	1	572.04	0.0017			
6/15	0	191.52				
6/16	0	158.76				
6/18	1	191.52				
6/19	0	191.52				
6/21	1	158.76				
	2	892.08	0.0022			
6/24	0	176.40				
6/25	0	176.40				
6/27	0	158.76				
6/28	1	191.52				
6/30	0	126.00				
	1	829.08	0.0012			
June	Average		0.0013			

Page No. 405

1972 Dawskammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish / MG			
7/1	-	143.64				
7/4	-	134.40				
7/6	-	172.90				
	-	450.94	0			
7/9	-	147.00				
7/10	-	191.52				
7/12	1	198.24				
7/13	-	135.66				
	1	672.42	.0015			
7/15	-	176.40				
7/16	-	83.16				
7/18	-	191.52				
7/19	-	191.52				
7/21	-	191.52				
	-	834.12	0			
7/22	-	208.56				
7/24	-	227.52				
7/25	-	227.52				
7/27	-	227.52				
7/28	-	227.52				
7/30	-	227.52				
7/31	-	208.87				
	-	1555.03	0			
July	Average		.0004			
8/2	-	232.58				
8/3	-	227.52				
8/5	-	131.27				
8/6	1	177.00				
	1	768.37	.0013			
8/8	-	170.64				
8/9	-	227.52				
8/11	-	162.37				
8/12	41	191.52				
8/14	131	227.52				
	172	979.57	.1756			

CTH

1972 Danskammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish / MG			
8/15	24	212.40				
8/17	7	170.64				
8/20	12	212.40				
8/21	–	212.40				
	43	807.84	.0532			
8/23	–	170.64				
8/24	–	218.52				
8/26	11	194.52				
8/27	3	155.52				
8/29	33	227.52				
8/30	18	155.52				
	65	1122.24	.0579			
August	Average		.0720			
9/1	27	132.30				
9/2	–	191.52				
9/4	20	132.30				
9/5	1	191.52				
9/7	32	191.52				
	80	839.16	.0953			
9/10	34	191.52				
9/11	4	191.52				
9/13	69	191.52				
9/14	17	191.52				
	124	766.08	.1619			
9/16	118	191.52				
9/17	5	176.40				
9/19	10	191.52				
9/20	3	158.76				
	136	718.20	.1894			

Form No. 405

1972 Danskammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish/MG			
9/22	58	184.59				
9/23	14	155.52				
9/25	41	116.64				
9/26	10	179.52				
9/28	21	191.52				
9/29	25	191.52				
	169	1019.31	.1658			
September	Average		.1531			
10/1	33	191.52				
10/2	38	191.52				
10/4	16	196.98				
10/5	10	158.76				
10/7	33	191.52				
	130	930.30	.1397			
10/8	8	176.40				
10/10	61	191.52				
10/11	4	143.64				
10/13	17	191.52				
10/14	24	176.40				
	114	879.48	.1296			
10/16	2	176.40				
10/17	2	176.40				
10/19	2	132.30				
10/20	—	167.96				
	6	653.06	.0092			
10/22	—	160.02				
10/23	—	146.16				
10/25	—	161.28				
10/26	2	161.28				
10/28	1	153.72				
10/29	—	128.52				
10/31	—	153.72				
	3	1064.70	.0028			
October	Average		.0703			

Page No. 405

1972 Dans Kammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish/MG			
11/1	–	161.28				
11/3	–	161.28				
11/4	–	161.28				
11/6	–	120.96				
11/7	–	161.28	0			
		766.08	0			
11/10	–	131.04				
11/12	–	162.00				
11/13	–	191.52				
	–	484.56	0			
11/15	–	191.52				
11/16	–	191.52				
11/18	–	191.52				
11/19	–	191.52				
	–	766.08	0			
11/25	–	191.52				
11/27	–	133.75				
11/28	–	88.20				
11/30	–	161.28				
	–	574.75	0			
November	Average		0			
12/1	0	153.72				
12/3	0	138.60				
12/4	0	161.28				
12/6	0	161.28				
12/7	0	138.60				
	0	753.48	0.0000			
12/9	0	153.72				
12/10	0	113.40				
12/12	0	146.16				
12/13	0	161.28				
	0	574.56	0.0000			

Form No. 405

1972 Danskammer Impingement
Bay Anchovy

Date	# Fish	Flow (MG)	# Fish/MG			
12/15	0	131.76				
12/16	0	131.76				
12/18	0	131.76				
12/19	0	106.38				
12/20	0	164.70				
12/21	0	106.38				
	0	772.74	0.0000			
12/28	0	175.68				
12/29	0	87.84				
	0	263.52	0.0000			
December						
Avg. #/MG			0.0000			

10-17-77
mwo

Form No. 405

1973 Danskammer Impingement
Bay Anchovy

Date	# Fish Collected	C.W. Flow (mg)	Fish/mg
1/4-5	—	252.54	—
10-11	—	258.04	—
17-18	—	263.52	—
24-25	—	256.20 > 409.92	—
31-2/1	—	153.72	-
			0.0000
2/7-8	—	191.52	—
14-15	—	222.64	—
21	—	172.93	—
27-28	—	241.56	—
			0.0000
3/6-7	—	261.40	—
21-22	—	137.16	—
			0.0000
4/3-4	—	263.51	—
18-19	—	242.55	—
25	—	108.00	—
			0.0000
5/2-3	—	291.61	—
17-18	—	316.19	—
30-31	—	367.08	—
			0.0000
6/13-14	1	455.04	0.0022
26-27	—	455.04	0.0000
			0.0011
7/10-11	6	455.04	0.0132
24-26	—	910.08	0.0000
			0.0066
8/7-8	1	455.04	0.0022
21-22	18	492.96	0.0365
			0.0194

orm No. 405

Date	# Fish Collected	C.W. Flow (MG)	Fish/MG			
9/5-6	143	455.04	0.3143			
18-19	711	440.82	1.6129			
			0.9636			
10/3-4	615	336.96	1.8251			
17-18	225	414.96	0.5422			
31-11/1	77	382.20	0.2015			
			0.8563			
11/15-16	1	382.20	0.0026			
28-29	—	382.20	0.0000			
			0.0013			
12/11-12	—	313.20	—			
26-27	—	252.72	—			
			0.0000			

Form No. 405

1974

Danskammer Impingement

Bay Anchovy

CTC
9-25-77

Date	# Fish	Flow (MG)	Fish/MG
1/8-9	0	351.71	—
22-23	0	285.48	—
2/5-6	0	316.98	—
19-20	0	285.48	—
3/5-6	0	263.54	—
25-26	0	252.52	—
4/2-3	0	248.52	—
15-16	0	242.10	—
30-5/1	0	293.76	—
5/14-15	0	293.76	—
21-22	1	361.10	0.0028
28-29	0	352.80	—
			0.0009
6/4-5	1	311.85	0.0032
11-12	0	252.00	—
18-19	1	306.95	0.0033
25-26	0	324.00	—
			0.0016
7/2-3	6	399.17	0.0152
9-10	5	381.00	0.0131
16-17	0	303.87	—
23-24	0 14	931.16	0.0150
30-31	14	472.04	
			0.0108
8/6-7	11	436.14	0.0252
13-14	36	405.51	0.0888
20-21	66	415.35	0.1589
27-28	84	434.60	0.1933
			0.1166

2 of 2

rm No. 405

1979

Daustromer Impingement

Bay Hackey

CPC

7-25-77

Date	# Fish	Flow (MG)	Fish/MG
9/3-4	10	439.16	0.0228
10-13	9	442.16	0.0204
17-18	10	329.05	0.0304
24-25	22	357.72	0.0615
			0.0338
10/1-2	7	424.80	0.0165
8-9	18	458.57	0.0392
15-16	0	455.04	—
22-23	0	769.79	—
29-30	0		
			0.0139
11/5-6	0	372.28	—
12-13	0	383.04	—
19-20	0	392.28	—
26-27	0	383.04	—
12/3-4	0	162.69	—
10-11	0	383.04	—
17-18	0	392.28	—
26-27	0	322.56	—

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Form No. 405

1975

9-25-77

Dan Skanner Impingement

Bay Anchovy

Date	# Fish	Flow MG	Fish/MG			
1/8-9	0	263.52	—			
15-16	0	287.52	—			
22-23	0	262.50	—			
29-30	0	269.95	—			
2/4-5	0	293.75	—			
11-12	0	190.59	—			
18-19	0	139.00	—			
25-26	0	91.76	—			
3/4-5	0	119.52	—			
11-12	0	119.52	—			
18-19	0	120.56	—			
27-28	0	120.77	—			
4/1-2	0	119.52	—			
8-9	0	119.52	—			
17-18	0	119.52	—			
23-24	0	119.52, 328.32	—			
30-5/1	0	209.8	—			
5/6-7	0	239.04	—			
13-14	0	239.04	—			
20-21	0	239.04	—			
27-28	0	216.06	—			
6/3-4	0	380.56	—			
10-11	0	297.20	—			
17-18	1	416.30	0.0024			
24-25	0	455.04	—			
			0.0006			

Form No. 405

1975

Danskammer - Impingement

Bay Anchovy

CTC
9-25-77

Date	# Fish	Flow (MG)	# Fish / MG
7/1-2	0	428.77	—
8-9	0	311.04	—
16-17	2	392.56	0.0058
24-25	5 → 7	424.80 → 796.52	0.0088
30-31	2	371.72	
			0.0036
8/5-6	6	451.56	0.0133
12-13	20	394.34	0.0507
21-22	10	394.56	0.0253
27-28	52	443.36	0.1173
			0.0516
9/4-5	30	394.56	0.0760
9-10	65	394.56	0.1647
18-19	70	394.56	0.1774
23-24	14 → 15	373.04 → 787.60	0.0190
30-10/1	1	394.56	
			0.1093
10/7-8	1	311.04	0.0032
15-16	0	335.22	—
22-23	0	717.12	—
29-30	0		
			0.0011
11/5-6	0	394.56	—
12-13	0	394.56	—
19-20	0	379.73	—
25-26	0	245.10	—
12/2-3	0	233.28	—
10-11	0	226.94	—
17-18	0	233.28	—
23-24	0	233.28 → 466.56	—
30-31	0	233.28	

Form No. 405

1976

Danskammer Impingement

Bay Anchovy

9-28-77

Date	# Fish	Flow (MG)	# Fish / MG
1/6-7	0	213.84	—
13-14	0	230.53	—
22-23	0	460.55	—
29-30	0		
2/5-6	0	161.28	—
12-13	0	212.19	—
19-18	0	221.53	—
24-25	0	203.04	—
3/2-3	0	203.04	—
9-10	0	203.04	—
16-17	0	198.81	—
23-24	0	407.31	—
30-31	0		
4/6-7	0	253.51	—
13-14	0	233.28	—
20-21	0	230.03	—
28-29	0	229.52	—
5/4-5	0	306.72	—
11-12	0	306.72	—
18-19	0	306.72	—
25-26	0	307.32	—
6/2-3	0	277.53	—
9-9	0	276.48	—
15-16	0	335.54	—
22-23	0	662.52	—
29-30	0		

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Form No. 406

1976
Danskammer Impingement

Bay Anchovy

CTC
9-28-77

Date	# Fish	Flow (MG)	# Fish / MG			
7/6-7	1	306.72	0.0033			
13-14	0	290.75	0			
20-21	0	305.45	0			
27-28	0	246.11	0			
			0.0008			
8/3-4	0	306.72	0			
10-11	0	306.72	0			
17-18	0	306.72	0			
24-25	1	672.09	0.0015			
31-9/1	0					
			0.0004			
9/7-8	1	365.76	0.0027			
14-15	2	396.00	0.0051			
21-22	2	455.09	0.0044			
28-29	2	394.56	0.0051			
			0.0043			
10/5-6	1	334.08	0.0030			
12-13	0	331.76	0			
20-21	0	334.08	0			
24-25	0	500.59	0			
27-28	0					
			0.0008			
11/2-3	0	466.88	0			
5-6	0					
9-10	0	233.28	0			
16-17	0	258.91	0			
23-24	0	581.40	0			
30-12/1	0					
12/1-8	0	285.70	0			
16-17	0	559.99	0			
21-22	0					
28-29	0	263.52	0			

IX 2. Provide an estimate (and associated variance and 95% confidence interval) of impingement collection efficiency. Provide a thorough discussion of data used and assumptions made.

Response: Central Hudson has only recently initiated impingement collection efficiency tests at the Roseton Generating Station. Results of these tests are not yet available.

No impingement collection efficiency tests have been made or are planned for the Danskammer Generating Station.

X. Questions for Orange and Rockland

X.1 Provide monthly estimates of impingement rate (number of fish impinged per 10^6 cubic meters of water withdrawn) as follows:

a. for each of the following six species: white perch, striped bass, tomcod, blueback herring, alewife, and bay anchovy;

b. for each unit at Bowline and each unit at Lovett;

c. for each month during 1972, 1973, 1974, 1975, and 1976 for which the necessary data are available.

In addition to each impingement rate (which is to be given to two decimal places, provide the value for the numerator (i.e., number of fish of that species actually collected during the sampling periods during the given month) and the value of the denominator (i.e., power-plant intake flow during the sampling periods during the given month).

Response: Enclosed are monthly impingement rate data for the Bowline and the Lovett Generating stations for the period November 1972 through December 1976.

KEY

#/MG x 263.99 = #/MCM
MG x 0.003788 = MCM

MG	=	Million Gallons
MCM	=	Million Cubic Meters
MO	=	Month
Est. of Impinge.	=	Best Estimate of Impingement
SB	=	Striped Bass
WP	=	White Perch
ATC	=	Atlantic Tomcod
ASD	=	American Shad
AW	=	Alewife
BBH	=	Blueback Herring
BA	=	Bay Anchovy

BOWLINE IMPINGEMENT: 1976
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
January	SB	0.050	12601.3	630
	WP	0.233	12601.3	2,936
	ATC	0.005	12601.3	63
	ASD	*	12601.3	0
	AW	0.073	12601.3	920
	BBH	0.001	12601.3	13
	BA	*	12601.3	0
February	SB	0.147	10600.2	1,558
	WP	0.359	10600.2	3,805
	ATC	0.008	10600.2	85
	ASD	*	10600.2	0
	AW	0.105	10600.2	1,113
	BBH	*	10600.2	0
	BA	*	10600.2	0
March	SB	0.210	14074.6	2,956
	WP	0.988	14074.6	13,906
	ATC	0.006	14074.6	84
	ASD	0.001	14074.6	14
	AW	0.009	14074.6	127
	BBH	*	14074.6	0
	BA	*	14074.6	0
April	SB	0.413	21939.9	9,061
	WP	2.604	21939.9	57,131
	ATC	0.001	21939.9	22
	ASD	*	21939.9	0
	AW	0.032	21939.9	702
	BBH	0.134	21939.9	2,940
	BA	0.029	21939.9	636
May	SB	0.002	22945.0	46
	WP	0.087	22945.0	1,996
	ATC	0.012	22945.0	275
	ASD	*	22945.0	0
	AW	0.004	22945.0	92
	BBH	0.010	22945.0	229
	BA	0.006	22945.0	138
June	SB	0.001	23201.3	23
	WP	0.035	23201.3	812
	ATC	0.112	23201.3	2,599
	ASD	0.001	23201.3	23
	AW	0.008	23201.3	186
	BBH	0.007	23201.3	162
	BA	0.003	23201.3	70

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
July	SB	0.003	28011.7	84
	WP	0.011	28011.7	308
	ATC	0.009	28011.7	252
	ASD	0.009	28011.7	252
	AW	0.015	28011.7	420
	BBH	0.002	28011.7	56
	BA	0.015	28011.7	420
August	SB	0.011	25238.0	278
	WP	0.431	25238.0	10,878
	ATC	0.026	25238.0	656
	ASD	0.033	25238.0	833
	AW	0.066	25238.0	1,666
	BBH	0.024	25238.0	606
	BA	0.091	25238.0	2,297
September	SB	0.003	26063.6	78
	WP	0.058	26063.6	1,512
	ATC	0.005	26063.6	130
	ASD	0.002	26063.6	52
	AW	0.009	26063.6	235
	BBH	0.024	26063.6	626
	BA	0.008	26063.6	209
October	SB	*	12139.9	0
	WP	0.004	12139.9	49
	ATC	0.001	12139.9	12
	ASD	*	12139.9	0
	AW	*	12139.9	0
	BBH	0.008	12139.9	97
	BA	0.001	12139.9	12
November	SB	0.047	14265.0	670
	WP	2.311	14265.0	32,966
	ATC	0.001	14265.0	14
	ASD	*	14265.0	0
	AW	0.003	14265.0	43
	BBH	0.048	14265.0	685
	BA	*	14265.0	0
December	SB	0.446	23061.8	10,286
	WP	6.477	23061.8	149,371
	ATC	0.016	23061.8	369
	ASD	*	23061.8	0
	AW	0.002	23061.8	46
	BBH	0.002	23061.8	46
	BA	*	23061.8	0

*Note: Less than 0.001 fish/million gallons

BOWLINE IMPINGEMENT: 1975
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
January	SB	0.989	24541.8	24,272
	WP	7.187	24541.8	176,382
	ATC	0.142	24541.8	3,485
	ASD	0.004	24541.8	98
	AW	0.008	24541.8	196
	BBH	0.016	24541.8	393
	BA	*	24541.8	0
February	SB	0.247	19984.4	4,936
	WP	0.368	19984.4	7,354
	ATC	0.076	19984.4	1,519
	ASD	0.001	19984.4	20
	AW	0.008	19984.4	160
	BBH	0.026	19984.4	520
	BA	*	19984.4	0
March	SB	0.604	21491.7	12,981
	WP	1.147	21491.7	24,651
	ATC	0.026	21491.7	559
	ASD	*	21491.7	0
	AW	0.008	21491.7	172
	BBH	0.010	21491.7	215
	BA	0.001	21491.7	21
April	SB	1.436	22200.0	31,879
	WP	5.113	22200.0	113,509
	ATC	0.005	22200.0	111
	ASD	0.007	22200.0	155
	AW	0.050	22200.0	1,110
	BBH	0.358	22200.0	7,948
	BA	*	22200.0	0
May	SB	0.010	14420.0	144
	WP	0.658	14420.0	9,488
	ATC	0.009	14420.0	130
	ASD	*	14420.0	0
	AW	0.012	14420.0	173
	BBH	0.013	14420.0	187
	BA	0.001	14420.0	14
June	SB	0.001	21535.5	22
	WP	0.057	21535.5	1,228
	ATC	0.452	21535.5	9,734
	ASD	0.001	21535.5	22
	AW	0.021	21535.5	452
	BBH	0.010	21535.5	215
	BA	0.018	21535.5	388

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
July	SB	0.006	24783.9	149
	WP	0.073	24783.9	1,809
	ATC	0.020	24783.9	496
	ASD	0.030	24783.9	744
	AW	0.184	24783.9	4,560
	BBH	0.026	24783.9	644
	BA	0.116	24783.9	2,875
August	SB	0.001	27893.2	28
	WP	0.016	27893.2	446
	ATC	0.002	27893.2	56
	ASD	0.001	27893.2	28
	AW	0.007	27893.2	195
	BBH	0.001	27893.2	28
	BA	0.006	27893.2	167
September	SB	0.001	27153.0	27
	WP	0.007	27153.0	190
	ATC	0.001	27153.0	27
	ASD	0.001	27153.0	28
	AW	0.006	27153.0	163
	BBH	0.002	27153.0	54
	BA	0.004	27153.0	109
October	SB	*	14741.4	0
	WP	0.009	14741.4	133
	ATC	0.001	14741.4	15
	ASD	0.001	14741.4	27
	AW	0.004	14741.4	59
	BBH	0.023	14741.4	339
	BA	0.001	14741.4	15
November	SB	*	13651.2	0
	WP	0.077	13651.2	1,051
	ATC	*	13651.2	0
	ASD	0.004	13651.2	55
	AW	0.008	13651.2	109
	BBH	0.875	13651.2	11,945
	BA	*	13651.2	0
December	SB	0.327	23304.6	7,621
	WP	2.356	23304.6	54,906
	ATC	0.002	23304.6	47
	ASD	*	23304.6	0
	AW	0.048	23304.6	1,119
	BBH	0.132	23304.6	3,076
	BA	0.002	23304.6	47

*Note: Less than 0.001 fish/million gallons

BOWLINE IMPINGEMENT: 1974
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
January	SB	0.495	14122.6	6,991
	WP	4.137	14122.6	58,425
	ATC	0.014	14122.6	198
	ASD	0.020	14122.6	282
	AW	0.131	14122.6	1,850
	BBH	0.046	14122.6	650
	BA	0.001	14122.6	14
February	SB	0.982	10179.4	9,996
	WP	4.618	10179.4	47,008
	ATC	0.022	10179.4	224
	ASD	*	10179.4	0
	AW	0.004	10179.4	41
	BBH	*	10179.4	0
	BA	*	10179.4	0
March	SB	0.718	14092.0	10,118
	WP	3.668	14092.0	51,689
	ATC	0.012	14092.0	169
	ASD	*	14092.0	0
	AW	0.007	14092.0	99
	BBH	0.038	14092.0	535
	BA	*	14092.0	0
April	SB	2.090	16296.5	34,060
	WP	3.492	16296.5	56,907
	ATC	0.003	16296.5	49
	ASD	*	16296.5	0
	AW	0.009	16296.5	147
	BBH	0.067	16296.5	1,092
	BA	*	16296.5	0
May	SB	0.075	8384.0	629
	WP	0.346	8384.0	2,901
	ATC	0.001	8384.0	8
	ASD	*	8384.0	0
	AW	0.007	8384.0	59
	BBH	0.040	8384.0	335
	BA	0.002	8384.0	17
June	SB	0.003	20328.1	61
	WP	0.070	20328.1	1,423
	ATC	0.312	20328.1	6,342
	ASD	*	20328.1	0
	AW	0.018	20328.1	366
	BBH	0.009	20328.1	183
	BA	0.048	20328.1	976

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
July	SB	0.008	26674.1	213
	WP	0.020	26674.1	533
	ATC	0.233	26674.1	6,215
	ASD	0.007	26674.1	187
	AW	0.018	26674.1	480
	BBH	0.003	26674.1	80
	BA	0.042	26674.1	1,120
August	SB	0.006	28639.0	172
	WP	0.013	28639.0	372
	ATC	0.010	28639.0	286
	ASD	0.004	28639.0	115
	AW	0.032	28639.0	916
	BBH	0.004	28639.0	115
	BA	0.037	28639.0	1,060
September	SB	0.010	31142.6	311
	WP	0.017	31142.6	529
	ATC	0.006	31142.6	187
	ASD	0.003	31142.6	93
	AW	0.067	31142.6	2,087
	BBH	0.004	31142.6	125
	BA	0.033	31142.6	1,028
October	SB	0.084	33308.5	2,798
	WP	0.111	33308.5	3,697
	ATC	0.003	33308.5	100
	ASD	0.085	33308.5	2,831
	AW	0.185	33308.5	6,162
	BBH	0.927	33308.5	30,877
	BA	0.025	33308.5	833
November	SB	0.085	23039.4	1,958
	WP	1.882	23039.4	43,360
	ATC	0.005	23039.4	115
	ASD	0.049	23039.4	1,129
	AW	0.395	23039.4	9,101
	BBH	0.452	23039.4	10,414
	BA	0.003	23039.4	69
December	SB	0.530	28163.4	14,927
	WP	3.199	28163.4	90,095
	ATC	0.060	28163.4	1,690
	ASD	0.001	28163.4	28
	AW	0.035	28163.4	986
	BBH	0.019	28163.4	535
	BA	0.005	28163.4	141

*Note: Less than 0.001 fish/million gallons

BOWLINE IMPINGEMENT: 1973
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
January	SB	0.094	15183.4	1,427
	WP	1.121	15183.4	17,021
	ATC	0.562	15183.4	8,533
	ASD	*	15183.4	0
	AW	0.002	15183.4	30
	BBH	*	15183.4	0
	BA	*	15183.4	0
February	SB	0.174	12077.4	2,101
	WP	1.340	12077.4	16,184
	ATC	0.151	12077.4	1,824
	ASD	*	12077.4	0
	AW	0.002	12077.4	24
	BBH	*	12077.4	0
	BA	*	12077.4	0
March	SB	0.073	4095.4	299
	WP	1.093	4095.4	4,476
	ATC	0.005	4095.4	20
	ASD	*	4095.4	0
	AW	*	4095.4	0
	BBH	*	4095.4	0
	BA	*	4095.4	0
April	SB	0.170	13651.2	2,321
	WP	1.751	13651.2	23,903
	ATC	0.023	13651.2	314
	ASD	*	13651.2	0
	AW	*	13651.2	0
	BBH	*	13651.2	0
	BA	*	13651.2	0
May	SB	0.032	16504.6	528
	WP	0.893	16504.6	14,739
	ATC	0.027	16504.6	446
	ASD	0.001	16504.6	16
	AW	0.004	16504.6	66
	BBH	0.004	16504.6	66
	BA	0.005	16504.6	83
June	SB	*	10927.9	0
	WP	0.074	10927.9	809
	ATC	0.014	10927.9	153
	ASD	*	10927.9	0
	AW	0.006	10927.9	66
	BBH	0.002	10927.9	22
	BA	*	10927.9	0

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
July	SB	0.028	13304.7	373
	WP	0.052	13304.7	692
	ATC	0.027	13304.7	359
	ASD	0.007	13304.7	93
	AW	0.715	13304.7	9,513
	BBH	0.012	13304.7	160
	BA	0.051	13304.7	679
August	SB	0.015	15837.3	238
	WP	0.172	15837.3	2,724
	ATC	0.058	15837.3	919
	ASD	0.003	15837.3	48
	AW	0.356	15837.3	5,638
	BBH	0.059	15837.3	934
	BA	0.188	15837.3	2,977
September	SB	0.004	15858.5	63
	WP	0.018	15858.5	285
	ATC	0.001	15858.5	16
	ASD	*	15858.5	0
	AW	0.026	15858.5	412
	BBH	*	15858.5	0
	BA	0.022	15858.5	349
October	SB	0.005	17141.8	86
	WP	0.019	17141.8	326
	ATC	*	17141.8	0
	ASD	0.003	17141.8	51
	AW	0.024	17141.8	411
	BBH	0.037	17141.8	634
	BA	0.011	17141.8	189
November	SB	0.018	13900.3	250
	WP	0.036	13900.3	500
	ATC	0.001	13900.3	14
	ASD	0.008	13900.3	111
	AW	0.169	13900.3	2,349
	BBH	1.044	13900.3	14,512
	BA	0.004	13900.3	56
December	SB	0.090	12790.1	1,151
	WP	1.412	12790.1	18,060
	ATC	0.001	12790.1	13
	ASD	0.002	12790.1	26
	AW	0.132	12790.1	1,688
	BBH	0.193	12790.1	2,468
	BA	0.001	12790.1	13

*Note: Less than 0.001 fish per million gallons

BOWLINE IMPINGEMENT: 1972

ESTIMATED IMPINGEMENT RATES

MONTH	SPECIES	#/MG	MG/MO	EST. OF IMPINGEMENT
December	SB	0.100	16,879.9	1,688
	WP	3.545	16,879.9	59,839
	ATC	0.514	16,879.9	8,676
	ASD	*	16,879.9	*
	AW	0.016	16,879.9	270
	BBH	0.008	16,879.9	135
	BA	*	16,879.9	*

*NOTE: Less than 0.001 fish/million gallons

KEY

#/MG x 263.99 = #/MCM
MG x 0.003788 = MCM

MG	=	Million Gallons
MCM	=	Million Cubic Meters
MO	=	Month
Est. of Impinge.	=	Best Estimate of Impingement
SB	=	Striped Bass
WP	=	White Perch
ATC	=	Atlantic Tomcod
ASD	=	American Shad
AW	=	Alewife
BBH	=	Blueback Herring
BA	=	Bay Anchovy

LOVETT IMPINGEMENT: 1976
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
January	SB	0.036	8649.9	311
	WP	1.373	8649.9	11,876
	ATC	0.040	8649.9	346
	ASD	0.001	8649.9	9
	AW	0.008	8649.9	69
	BBH	*	8649.9	0
	BA	*	8649.9	0
February	SB	0.026	7905.8	206
	WP	0.160	7905.8	1,265
	ATC	0.042	7905.8	332
	ASD	*	7905.8	0
	AW	*	7905.8	0
	BBH	*	7905.8	0
	BA	*	7905.8	0
March	SB	0.056	7561.7	423
	WP	0.356	7561.7	2,692
	ATC	0.015	7561.7	113
	ASD	*	7561.7	0
	AW	0.002	7561.7	15
	BBH	0.004	7561.7	30
	BA	*	7561.7	0
April	SB	0.013	6749.7	88
	WP	0.706	6749.7	4,765
	ATC	*	6749.7	0
	ASD	*	6749.7	0
	AW	0.014	6749.7	94
	BBH	0.004	6749.7	27
	BA	0.005	6749.7	34
May	SB	0.003	2890.1	9
	WP	0.031	2890.1	90
	ATC	*	2890.1	0
	ASD	*	2890.1	0
	AW	0.006	2890.1	17
	BBH	0.003	2890.1	9
	BA	*	2890.1	0
June	SB	0.001	6041.9	6
	WP	0.101	6041.9	610
	ATC	0.004	6041.9	24
	ASD	*	6041.9	0
	AW	0.005	6041.9	30
	BBH	0.010	6041.9	60
	BA	*	6041.9	0

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
July	SB	0.003	5660.0	17
	WP	0.039	5660.0	221
	ATC	0.001	5660.0	6
	ASD	0.001	5660.0	6
	AW	0.006	5660.0	34
	BBH	0.003	5660.0	17
	BA	0.010	5660.0	57
August	SB	0.006	8268.7	50
	WP	0.067	8268.7	554
	ATC	0.006	8268.7	50
	ASD	0.001	8268.7	8
	AW	0.019	8268.7	157
	BBH	0.012	8268.7	99
	BA	0.025	8268.7	207
September	SB	0.004	6124.8	24
	WP	0.084	6124.8	514
	ATC	0.003	6124.8	18
	ASD	*	6124.8	0
	AW	0.008	6124.8	49
	BBH	0.010	6124.8	61
	BA	0.013	6124.8	80
October	SB	0.020	3560.4	71
	WP	0.047	3560.4	167
	ATC	*	3560.4	0
	ASD	0.007	3560.4	25
	AW	*	3560.4	0
	BBH	0.013	3560.4	46
	BA	*	3560.4	0
November	SB	0.042	4726.4	199
	WP	2.158	4726.4	10,200
	ATC	0.002	4726.4	9
	ASD	*	4726.4	0
	AW	0.002	4726.4	9
	BBH	0.005	4726.4	24
	BA	*	4726.4	0
December	SB	0.024	6501.7	156
	WP	2.025	6501.7	13,166
	ATC	0.057	6501.7	371
	ASD	*	6501.7	0
	AW	0.014	6501.7	91
	BBH	0.001	6501.7	7
	BA	*	6501.7	0

*Note: <0.001 fish/million gallons

LOVETT IMPINGEMENT: 1975
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
January	SB	0.148	11236.0	1,663
	WP	3.219	11236.0	36,169
	ATC	0.222	11236.0	2,494
	ASD	0.004	11236.0	45
	AW	0.004	11236.0	45
	BBH	0.004	11236.0	45
February	SB	0.084	9402.4	790
	WP	0.460	9402.4	4,325
	ATC	0.036	9402.4	338
	ASD	0.008	9402.4	75
	AW	0.014	9402.4	132
	BBH	0.002	9402.4	19
March	SB	0.096	6649.8	638
	WP	0.639	6649.8	4,249
	ATC	0.012	6649.8	80
	ASD	*	6649.8	0
	AW	0.009	6649.8	60
	BBH	0.007	6649.8	47
April	SB	0.157	5736.9	901
	WP	2.068	5736.9	11,864
	ATC	0.006	5736.9	34
	ASD	*	5736.9	0
	AW	0.008	5736.9	46
	BBH	0.124	5736.9	711
May	SB	*	7936.3	0
	WP	0.099	7936.3	786
	ATC	*	7936.3	0
	ASD	*	7936.3	0
	AW	0.022	7936.3	175
	BBH	0.017	7936.3	135
June	SB	0.010	9485.1	95
	WP	0.101	9485.1	958
	ATC	0.024	9485.1	228
	ASD	*	9485.1	0
	AW	0.018	9485.1	171
	BBH	0.014	9485.1	133

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
July	SB	0.004	9735.9	39
	WP	0.028	9735.9	273
	ATC	0.079	9735.9	769
	ASD	0.004	9735.9	39
	AW	0.040	9735.9	389
	BBH	0.002	9735.9	19
August	SB	0.027	10134.2	274
	WP	0.162	10134.2	1,642
	ATC	0.038	10134.2	385
	ASD	0.001	10134.2	10
	AW	0.088	10134.2	892
	BBH	0.002	10134.2	20
September	SB	0.014	6973.2	98
	WP	0.092	6973.2	642
	ATC	0.005	6973.2	35
	ASD	0.004	6973.2	28
	AW	0.032	6973.2	223
	BBH	0.011	6973.2	77
October	SB	0.005	8491.5	42
	WP	0.115	8491.5	977
	ATC	*	8491.5	0
	ASD	0.014	8491.5	119
	AW	0.021	8491.5	178
	BBH	0.390	8491.5	3,312
November	SB	0.051	8124.3	414
	WP	2.046	8124.3	16,622
	ATC	0.002	8124.3	16
	ASD	0.014	8124.3	114
	AW	0.304	8124.3	2,470
	BBH	0.320	8124.3	2,600
December	SB	0.046	8179.0	376
	WP	0.545	8179.0	4,458
	ATC	0.006	8179.0	49
	ASD	0.002	8179.0	16
	AW	0.019	8179.0	155
	BBH	0.030	8179.0	245

*Note: Less than 0.001 fish/million gallons

LOVETT IMPINGEMENT: 1974
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
January	SB	0.286	11560.8	3,306
	WP	1.735	11560.8	20,058
	ATC	0.740	11560.8	8,555
	ASD	*	11560.8	0
	AW	0.005	11560.8	58
	BBH	0.032	11560.8	370
February	SB	0.227	8401.7	1,907
	WP	1.511	8401.7	12,695
	ATC	0.076	8401.7	639
	ASD	*	8401.7	0
	AW	0.041	8401.7	344
	BBH	0.004	8401.7	34
March	SB	NS	7887.3	NEA
	WP	NS	7887.3	NEA
	ATC	NS	7887.3	NEA
	ASD	NS	7887.3	NEA
	AW	NS	7887.3	NEA
	BBH	NS	7887.3	NEA
April	SB	0.259	9527.1	2,468
	WP	1.977	9527.1	18,835
	ATC	*	9527.1	0
	ASD	*	9527.1	0
	AW	0.026	9527.1	248
	BBH	0.070	9527.1	667
May	SB	0.019	10102.3	192
	WP	0.618	10102.3	6,243
	ATC	*	10102.3	0
	ASD	*	10102.3	0
	AW	0.019	10102.3	192
	BBH	0.077	10102.3	778
June	SB	0.029	9860.7	286
	WP	0.154	9860.7	1,519
	ATC	0.442	9860.7	4,358
	ASD	*	9860.7	0
	AW	0.036	9860.7	355
	BBH	0.030	9860.7	296

	SPECIES	#/MG	MG/MO.	EST. OF IMPINGE.
July	SB	0.007	5419.7	38
	WP	0.034	5419.7	184
	ATC	0.412	5419.7	2,233
	ASD	0.003	5419.7	16
	AW	0.014	5419.7	76
	BBH	0.010	5419.7	54
August	SB	0.017	10703.1	182
	WP	0.046	10703.1	492
	ATC	0.285	10703.1	3,050
	ASD	0.013	10703.1	139
	AW	0.026	10703.1	278
	BBH	0.002	10703.1	21
September	SB	0.012	9888.6	119
	WP	0.040	9888.6	396
	ATC	0.044	9888.6	435
	ASD	0.003	9888.6	30
	AW	0.038	9888.6	376
	BBH	0.007	9888.6	69
October	SB	0.039	7090.6	277
	WP	0.412	7090.6	2,921
	ATC	*	7090.6	0
	ASD	0.062	7090.6	440
	AW	0.153	7090.6	1,085
	BBH	0.954	7090.6	6,764
November	SB	0.038	10256.1	390
	WP	1.146	10256.1	11,753
	ATC	0.001	10256.1	10
	ASD	0.036	10256.1	369
	AW	0.044	10256.1	451
	BBH	0.456	10256.1	4,677
December	SB	0.048	10229.4	491
	WP	1.180	10229.4	12,071
	ATC	0.018	10229.4	184
	ASD	*	10229.4	0
	AW	*	10229.4	0
	BBH	0.006	10229.4	61

NS - no sampling
NEA - no estimate available

*Note: Less than 0.001 fish/million gallons

LOVETT IMPINGEMENT: 1973
ESTIMATED IMPINGEMENT RATES

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
January	SB	0.010	13192.8	132
	WP	0.268	13192.8	3,536
	ATC	2.222	13192.8	29,314
	ASD	*	13192.8	0
	AW	*	13192.8	0
	BBH	*	13192.8	0
	BA	*	13192.8	0
February	SB	0.035	11601.3	406
	WP	0.309	11601.3	3,585
	ATC	1.882	11601.3	21,834
	ASD	*	11601.3	0
	AW	0.002	11601.3	23
	BBH	*	11601.3	0
	BA	*	11601.3	0
March	SB	0.050	13129.8	656
	WP	0.842	13129.8	11,055
	ATC	0.382	13129.8	5,016
	ASD	0.004	13129.8	53
	AW	0.001	13129.8	13
	BBH	0.002	13129.8	26
	BA	*	13129.8	0
April	SB	0.061	11517.8	703
	WP	0.744	11517.8	8,569
	ATC	0.033	11517.8	380
	ASD	*	11517.8	0
	AW	0.012	11517.8	138
	BBH	0.001	11517.8	12
	BA	0.001	11517.8	12
May	SB	0.002	10813.8	22
	WP	0.250	10813.8	2,703
	ATC	0.003	10813.8	32
	ASD	*	10813.8	0
	AW	0.016	10813.8	173
	BBH	0.004	10813.8	43
	BA	0.006	10813.8	65
June	SB	0.014	12018.0	168
	WP	0.187	12018.0	2,247
	ATC	0.006	12018.0	72
	ASD	*	12018.0	0
	AW	0.008	12018.0	96
	BBH	0.004	12018.0	48
	BA	0.014	12018.0	168

	SPECIES	#/MG.	MG/MO.	EST. OF IMPINGE.
July	SB	0.007	13181.1	92
	WP	0.062	13181.1	817
	ATC	0.018	13181.1	237
	ASD	*	13181.1	0
	AW	0.118	13181.1	1,555
	BBH	0.001	13181.1	13
	BA	0.026	13181.1	343
August	SB	0.070	13590.2	951
	WP	0.325	13590.2	4,417
	ATC	0.190	13590.2	2,582
	ASD	0.008	13590.2	109
	AW	0.291	13590.2	3,955
	BBH	0.008	13590.2	109
	BA	0.168	13590.2	2,283
September	SB	0.016	11544.4	185
	WP	0.052	11544.4	600
	ATC	*	11544.4	0
	ASD	*	11544.4	0
	AW	0.044	11544.4	508
	BBH	*	11544.4	0
	BA	0.018	11544.4	208
October	SB	0.012	9276.0	111
	WP	0.010	9276.0	93
	ATC	0.002	9276.0	19
	ASD	0.002	9276.0	19
	AW	0.002	9276.0	19
	BBH	0.015	9276.0	139
	BA	0.008	9276.0	74
November	SB	0.076	11220.3	853
	WP	0.538	11220.3	6,037
	ATC	*	11220.3	0
	ASD	0.010	11220.3	112
	AW	0.157	11220.3	1,762
	BBH	0.593	11220.3	6,654
	BA	0.004	11220.3	45
December	SB	0.102	11723.7	1,196
	WP	1.475	11723.7	17,292
	ATC	*	11723.7	0
	ASD	0.006	11723.7	70
	AW	0.038	11723.7	446
	BBH	0.170	11723.7	1,993
	BA	0.002	11723.7	23

*Note: Less than 0.001 fish per million gallons

LOVETT IMPINGEMENT: 1972

ESTIMATED IMPINGEMENT RATES

MONTH	SPECIES	#/MG	MG/MO	EST. OF IMPINGEMENT
December	SB	0.056	13,252.7	742
	WP	2.540	13,252.7	33,662
	ATC	0.944	13,252.7	12,511
	ASD	*	13,252.7	*
	AW	0.001	13,252.7	13
	BBH	0.021	13,252.7	278
	BA	*	13,252.7	*

X.2 Provide an estimate (and associated variance and 95% confidence interval) of impingement collection efficiency. Provide a thorough discussion of data used and assumption made.

Response: Impingement collection efficiency studies were described in Section 10.2.3.1.3 pages 10.2-10-10.2-12 of the Bowline Generating Station Nearfield Effects of Once-through Cooling System Operation On Hudson River Biota dated July, 1977. Table 10.2-4 of the report provided the data obtained in a series of efficiency tests conducted in January-March 1977. The efficiency of collection ranged from 81 to 98% and averaged 89.4%

The attached document titled

Screen Collection Efficiency Studies
Bowline Point Generating Station
October 1976-June 1977

also discusses the impingement collection efficiency tests and presents the data collected.

SCREEN COLLECTION EFFICIENCY STUDIES
BOWLINE POINT GENERATING STATION
OCTOBER 1976 - JUNE 1977

The special study was initiated on 27 October 1976 to investigate the collection efficiency of the traveling screens for tagged dead fish released directly in front of an operating screen. The study was performed once a week in conjunction with a regularly scheduled impingement survey.

Up to 100 dead fish, primarily Morone spp. (<10cm), were removed from the discard wash, tagged with a latex dye injection, and lengthed. Release of the fish was performed at a randomly chosen operating screen.

The fish were released by hand between the bar rack and the traveling screen. At screens 2 (Unit 2, B) and 5 (Unit 1, B) access was through service manholes in the floor, approximately 0.3m from the screen face. Access to the remaining screens was through service manholes on the outside walkway, approximately 1 or 2m from the screen face.

Two modes of screenwash operation were used, continuous and intermittant. During an intermittant wash mode, screen rotation and wash was not performed until 4 hours after the release of the tagged fish. Sample collections were made after 12 or 24 hours. Any pertinent observations were recorded on the field data sheets.

Collection efficiency was the number recovered divided by the number released, expressed as a percentage.

A loss on a small initial population could result in a substantial percentage loss. For the analysis of the data, only sample sizes greater than 50 fish were used. The majority of the samples consisted of 100 fish, an average sample size during normal impingement surveys. An additional survey (2 May 1977) was also deleted from the data analysis due to clear aberrations in the sampling procedure. The malfunction of the screenwash pumps combined with heavy debris provided for a non-quantitative estimate of recovery efficiency.

A summary of all the surveys is presented in Table 1 and 2. Using the data that meets the prescribed criteria, a mean collection efficiency of 83% with a 95% confidence interval of from 76-89% (Table 3) was demonstrated.

Attachment 1

IMPINGEMENT MARK-RECAPTURE SPECIAL STUDY
BOWLINE GENERATING STATION - 1976-1977

DATE	OPERATING PUMPS (a,b)	OPERATING SCREENS (c)	RELEASE LOCATION	SPECIES RELEASED	NUMBER RELEASED	RELEASE TIME	NUMBER RECAPTURED 12 HRS UNIT 1	12 HRS UNIT 2	24 HRS UNIT 1	24 HRS UNIT 2	TOTAL	COMMENTS
27 OCT 1976	4,5	$4,5_{1,2,3}$	Screen 3	RH	18	1000	No collection				0	Unit 2 off line
				SB	1				1*		1	
				WP	4						0	
3 NOV 1976	4,5	$4,5_{1,2,3}$	Screen 4	WP	9	1000	No collection		1*		1	
				SB	1						0	
				BBH	7				1*		1	
10 NOV 1976	4,5	$4,5_{1,2,3}$	Random	WP	70	1130	No collection		38*		38	
				RH	20				9*		9	
17 NOV 1976	4,5	$4,5_{1,2,3}$	Screen 4	WP	13	1000	No collection	5		0	5	
24 NOV 1976	$4,5_{2,3}$	$4,5_{2,3}$	Screen 3	WP	40	1330	No collection	0		29	29	
				SB	40			0		36	36	
				GSD	19			0		9	9	
				AW	1			0		1	1	
				BKL	1			0		1	1	
				PS	1			0		1	1	
8 DEC 1976	$4,5_{2,3}$	$4,5_{2,3}$	Screen 5	SB	50	1000	No collection	18		0	18	
				WP	50			20		0	20	
				GSD	9			2		0	2	
				AW	1						0	
15 DEC 1976	$4,5_{2,3}$	$4,5_{1,2,3}$	Screen 2	ATC	1	1150	No collection	0		1	1	
				SB	50			6		34	40	
				WP	50			2		46	48	
22 DEC 1976	$4,5_{2,3}$	$4,5_{1,2,3}$	Screen 2	WP	50	1150	No collection	1		48	49	
				SB	50			0		50	50	
				ATC	5			0		4	4	
				AW	1			0		0	0	
29 DEC 1976	$4,5_{2,3}$	$4,5_{1,2,3}$	Manhole at Screen 2	WP	70	1130	No collection	0		67	67	
				SB	28			0		27	27	

a) Number = specific pump; pump Nos. 4,5,6 serve Unit 1; pump Nos. 1,2,3 serve Unit 2
b) Flow data during tests is contained in response to EPA Oct. 12, 1977 Motion Attachment C, Question No. 7, (9/27/77)
c) Number = specific screen; screens 4,5,6 are opposite pumps 4,5,6; screen 1,2,3 are opposite

IMPINGEMENT MARK-RECAPTURE SPECIAL STUDY
BOWLINE GENERATING STATION - 1976-1977

DATE	OPERATING PUMPS	OPERATING SCREENS	RELEASE LOCATION	SPECIES RELEASED	NUMBER RELEASED	RELEASE TIME	NUMBER RECAPTURED 12 HRS UNIT 1	12 HRS UNIT 2	24 HRS UNIT 1	24 HRS UNIT 2	TOTAL	COMMENTS
27 OCT 1976	4,5	$4,5_{1,2,3}$	Screen 3	RH	18	1000	No collection				0	Unit 2 off line
				SB	1				1*		1	
				WP	4						0	
3 NOV 1976	4,5	$4,5_{1,2,3}$	Screen 4	WP	9	1000	No collection		1*		1	
				SB	1						0	
				BBH	7				1*		1	
10 NOV 1976	4,5	$4,5_{1,2,3}$	Random	WP	70	1130	No collection		38*		38	
				RH	20				9*		9	
17 NOV 1976	4,5	$4,5_{1,2,3}$	Screen 4	WP	13	1000	No collection		5	0	5	
24 NOV 1976	$4,5_{2,3}$	$4,5_{2,3}$	Screen 3	WP	40	1330	No collection		0	29	29	
				SB	40				0	36	36	
				GSD	19				0	9	9	
				AW	1				0	1	1	
				BKL	1				0	1	1	
				PS	1				0	1	1	
8 DEC 1976	$4,5_{2,3}$	$4,5_{2,3}$	Screen 5	SB	50	1000	No collection		18	0	18	
				WP	50				20	0	20	
				GSD	9				2	0	2	
				AW	1						0	
15 DEC 1976	$4,5_{2,3}$	$4,5_{1,2,3}$	Screen 2	ATC	1	1150	No collection		0	1	1	
				SB	50				6	34	40	
				WP	50				2	46	48	
22 DEC 1976	$4,5_{2,3}$	$4,5_{1,2,3}$	Screen 2	WP	50	1150	No collection		1	48	49	
				SB	50				0	50	50	
				ATC	5				0	4	4	
				AW	1				0	0	0	
29 DEC 1976	$4,5_{2,3}$	$4,5_{1,2,3}$	Manhole at Screen 2	WP	70	1130	No collection		0	67	67	
				SB	28				0	27	27	

TABLE VII (CONTINUED)

IMPINGEMENT MARK-RECAPTURE SPECIAL STUDY
BOWLINE GENERATING STATION - 1976-1977

DATE	OPERATING PUMPS	OPERATING SCREENS	RELEASE LOCATION	SPECIES RELEASED	NUMBER RELEASED	RELEASE TIME	NUMBER RECAPTURED 12 HRS UNIT 1	12 HRS UNIT 2	24 HRS UNIT 1	24 HRS UNIT 2	TOTAL	COMMENTS
24 JAN 1977	$4,5_{2,3}$	$4_{1,2,3}$	Screen 3	WP	49	1045	0	35	0	0	35	Basket Overflow
				SB	50		3	29	0	0	32	
31 JAN 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 5	WP	65	1000	53	0	2	0	55	
				SB	37		37	0	0	0	37	
7 FEB 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 2	WP	50**	1020	0	47	0	0	47	
				SB	50**		0	51	0	0	51	
14 FEB 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 5	WP	50	1020	45*		0*		45	
				SB	50		47*		0*		47	
21 FEB 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 1	WP	50	1025	39*		0*		39	
				SB	50		42*		0*		42	
28 FEB 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 5	WP	50	1010	48*		0*		48	Run 1-Blockage in Screen Wash Housing
				SB	50		46*		0*		46	
7 MAR 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 1	WP	50	1010	48*		0*		48	
				SB	50		38*		2*		40	
14 MAR 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 6	WP	82	1030	70	0	0	0	70	
				SB	18		14	0	1	0	15	
21 MAR 1977	$4,5_{2,3}$	$4,5,6_{1,2,3}$	Screen 4	WP	83	1010	71	0	0	0	71	
				SB	17		16	0	0	0	16	

* Units 1 & 2 Combined
** Field identification of 1 WP probably in error; number released most likely 49 WP and 51 SB

WP: White Perch
SB: Striped Bass
RH: River Herring
ATC: Atlantic Tomcod
AW: Alewife
PS: Pumpkinseed
GSD: Gizzard Shad
BBH: Blueback Herring

XI. Questions on LMS "1974 Hudson River Aquatic Ecology Studies - Bowline Point and Lovett Generating Stations (December 1975

XI.1 Tables X-27 and X-29 have the same numbers in the body of the table, although the headings for columns (3), (4), and (5) are different. Which is correct?

Response: Table X-29 is the correct table. Table X-27 is a duplicate with erroneous headings. It should be disregarded.

XI. 2. What equation was used to calculate the impingement rates in column (3) of Table X-29, and where in the report are the values for number of fish impinged and associated plant flows used to calculate these impingement rates. If these values are not in the report, please provide.

Response: The values presented in Table X-29 for white perch impingement at Lovett have become obsolete in light of the data update and improved procedures for the impingement estimate. The updated impingement estimate for white perch at Lovett is given in the data package provided in response to Question X.1-"Questions for Orange & Rockland." The same estimate procedures described in Section 3-IV.D.4 of Supplement I for striped bass at Bowline and Roseton were used. In essence, each month was divided into four periods (1st-7th, 8th-14th, 15-21st, and the remainder of the month) and impingement rate (number per million gallons, No./MG) for each period was calculated as the ratio of the total fish collected during the sampling period(s) to the total volume (MG) of water sampled. The impingement rates for the four periods were then averaged to obtain the monthly average impingement rate (No./MG). Estimates of the monthly fish impingement (No./month) were determined by multiplying the monthly average impingement rates by the total monthly flows (MG/month).

The number of fish impinged and associated plant flows from which the above impingement rates (No./MG) and monthly impingement estimates (No./month) were calculated are provided in the data package prepared in response to Question X.1-"Questions for Orange & Rockland."

XII. Questions relating to the Texas Instruments' First Annual Report of the Multiplant Impact Study of the Hudson River Estuary (July 1975)

XII 1. Provide the raw data from which the estimates of July-August CPUA and July-August growth increment in Figure VIII-4 were calculated. For each sample used in the calculations, include the date, time of day, location at which the sample was taken, the gear type, and the numbers and lengths of striped bass and white perch collected. For the 1969 data, indicate which samples were collected by NYU and which by Raytheon. Provide maps showing the stations from which data were used as well as any other stations at which samples were collected.

Response: Raw data from which the estimates of July-August CPUA and July-August growth increments as depicted in figure 10.5-1 of the McFadden 1977 Report which was an update of material utilized to develop figure VIII-4 of the Multiplant Impact Report have been provided to the NRC's consultants members of the Oak Ridge National Laboratory staff on magnetic tapes pursuant to a request for all data by the Environmental Protection Agency (October 12, 1977 Motion To Specify Area Of Requestors' Testimony To Be Cross-Examined During Initial Phase Of Hearing)

Further, Section 10.5.1 of the McFadden 1977 Report has been revised since its release in February 1977. The following information pertains to the revised version of Section 10.5.1 which appeared in Supplement I to the McFadden 1977 Report (dated July 1977). Table 1 (attached) contains data used in the analysis of juvenile striped bass density collected in the Area of Indian Point, Hudson River.

Figures 1 through 7 are maps of the locations of the sampling stations at which the data in table 1 were obtained.

Table 1 contains two sets of data for the year 1969. One set was collected by New York University and the second set was collected by Raytheon. Note that the weighted mean CPUA of these two sets is 71.4.

Table 2 contains a listing of the growth indices by year in addition to the abundance indices provided as CPUA values in Table 1. In addition Table 3 contains length information used in the calculation of the growth indices in Table 2.

This analysis has been updated by information contained in the document titled

> Relationship Between Population Density and Growth for Juvenile Striped Bass in the Hudson River

This document was submitted into evidence in the EPA Hudson River case as Exhibit UT 49. A copy of this exhibit is attached.

Table 1. Data used in the Analysis of Juvenile Striped bass Density Collected in the Area of Indian Point, Hudson River.

Year	Collector/ Survey	Sample Dates Used	# Caught	Area Swept (ft^2)	CPUA
1965	NYU	7/19 - 8/16	11	15,750	7.0
1966	NYU	7/18 - 8/24	0	50,275	0.0
1967	NYU	7/17 - 8/21	37	30,000	12.3
1968	NYU	7/15 - 8/19	12	54,700	2.2
1969	NYU	7/17 - 8/13	93	14,000	66.4
				weighted mean =	71.4
1969	RAY	7/13 - 8/30	338	46,325	73.0
1970	RAY	7/12 - 8/29	986	266,420	37.0
1972	TI	7/16 - 9/2	447	208,292	21.5
1973	TI	7/15 - 9/1	1,803	174,384	103.4
1974	TI	7/14 - 8/31	313	130,788	23.9
1975	TI	7/13 - 8/30	282	125,944	22.4

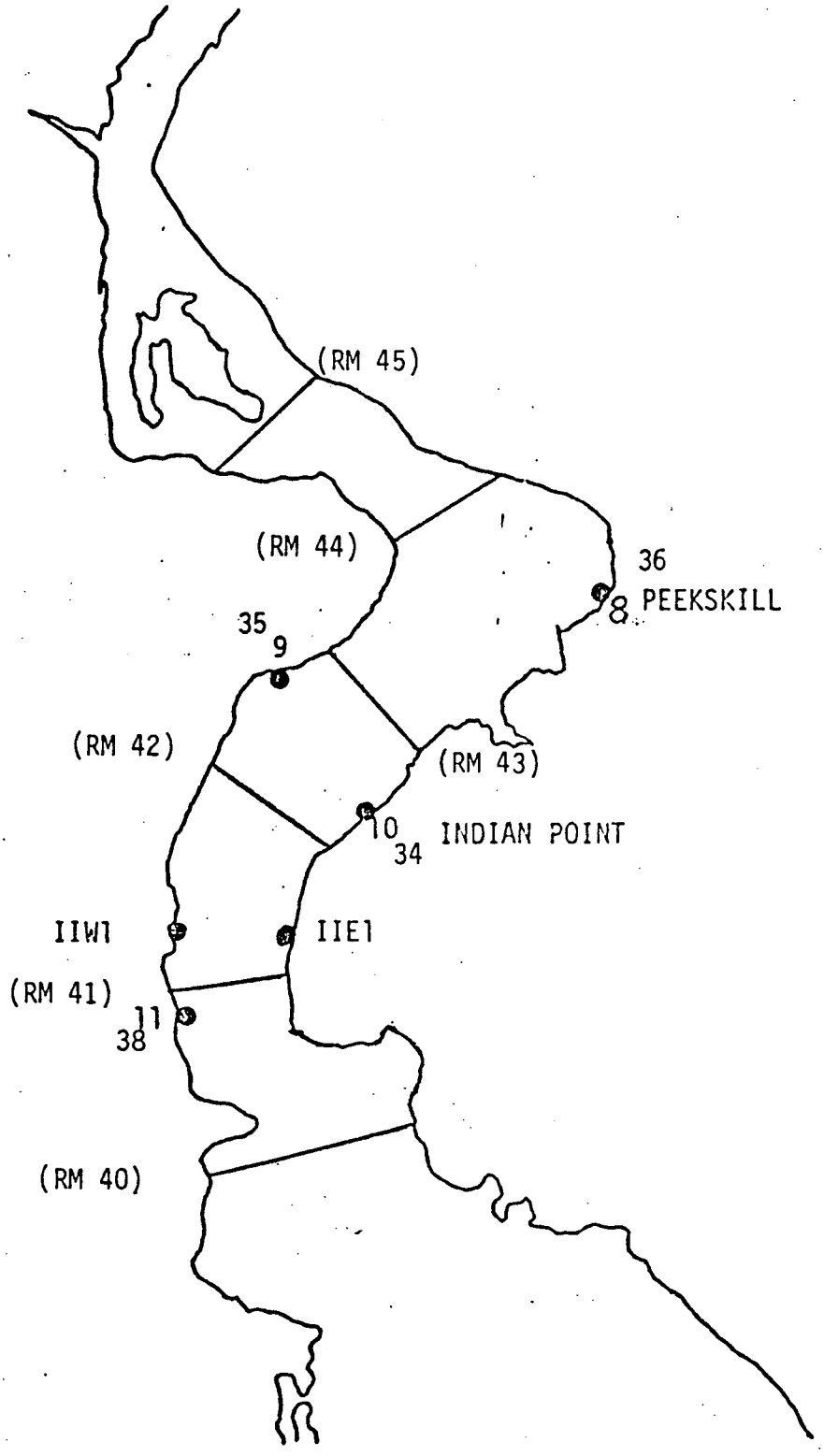

Figure Indian Point area of the Hudson River showing sampling stations from which data was used for the growth vs. density analysis on juvenile striped bass.

NYU Stations : II W1, IIE1
RAY Stations : 34, 35, 36, 38
TI Stations : 8, 9, 10, 11

RM = River Mile

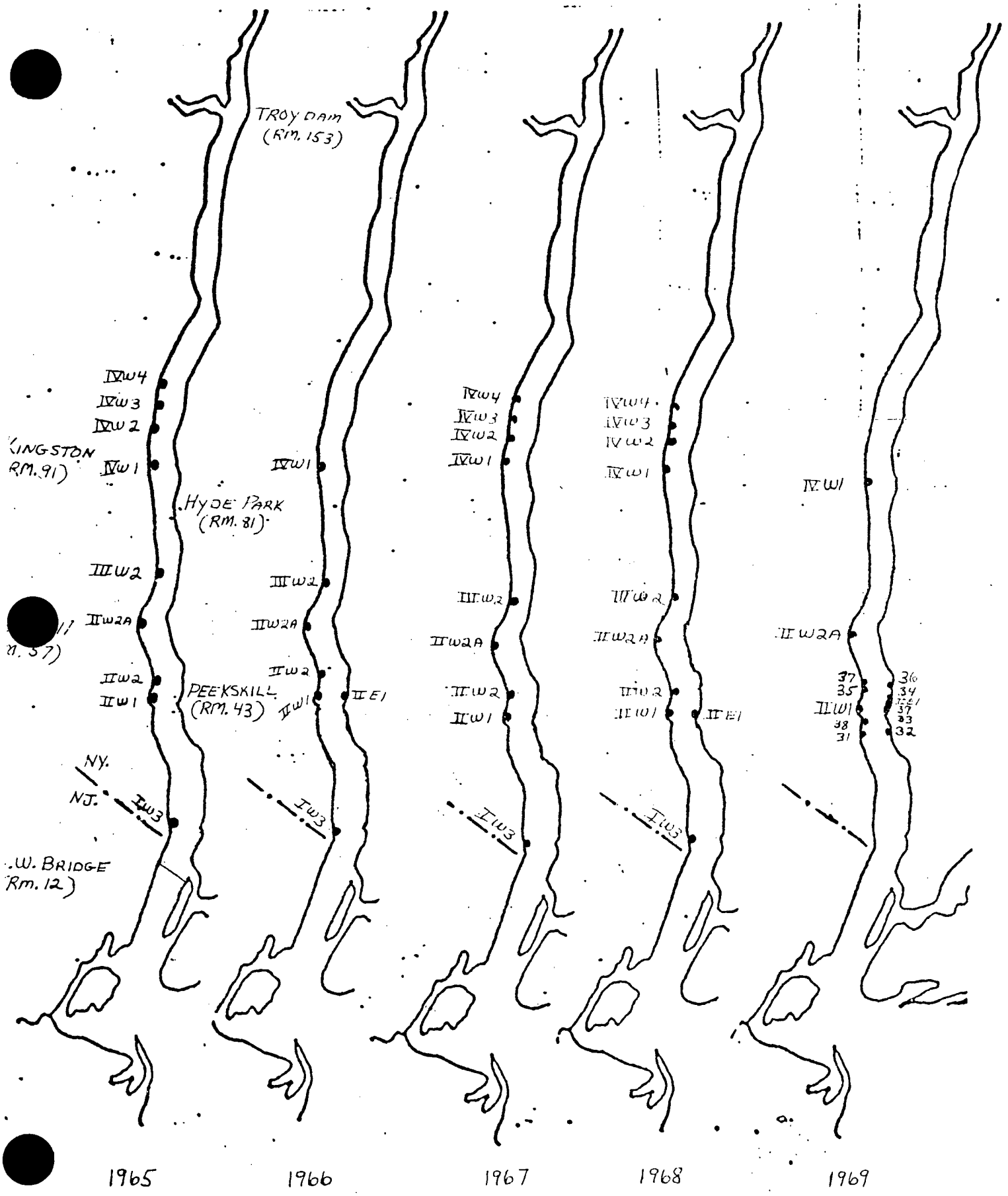

Figure 2. NYU and Raytheon beach seine stations sampled from 1965-1969. Raytheon sampled during 1969 at the stations 31-39. NYU Station preceded by Roman numbers, Raytheon Stations are in arabic numbers.

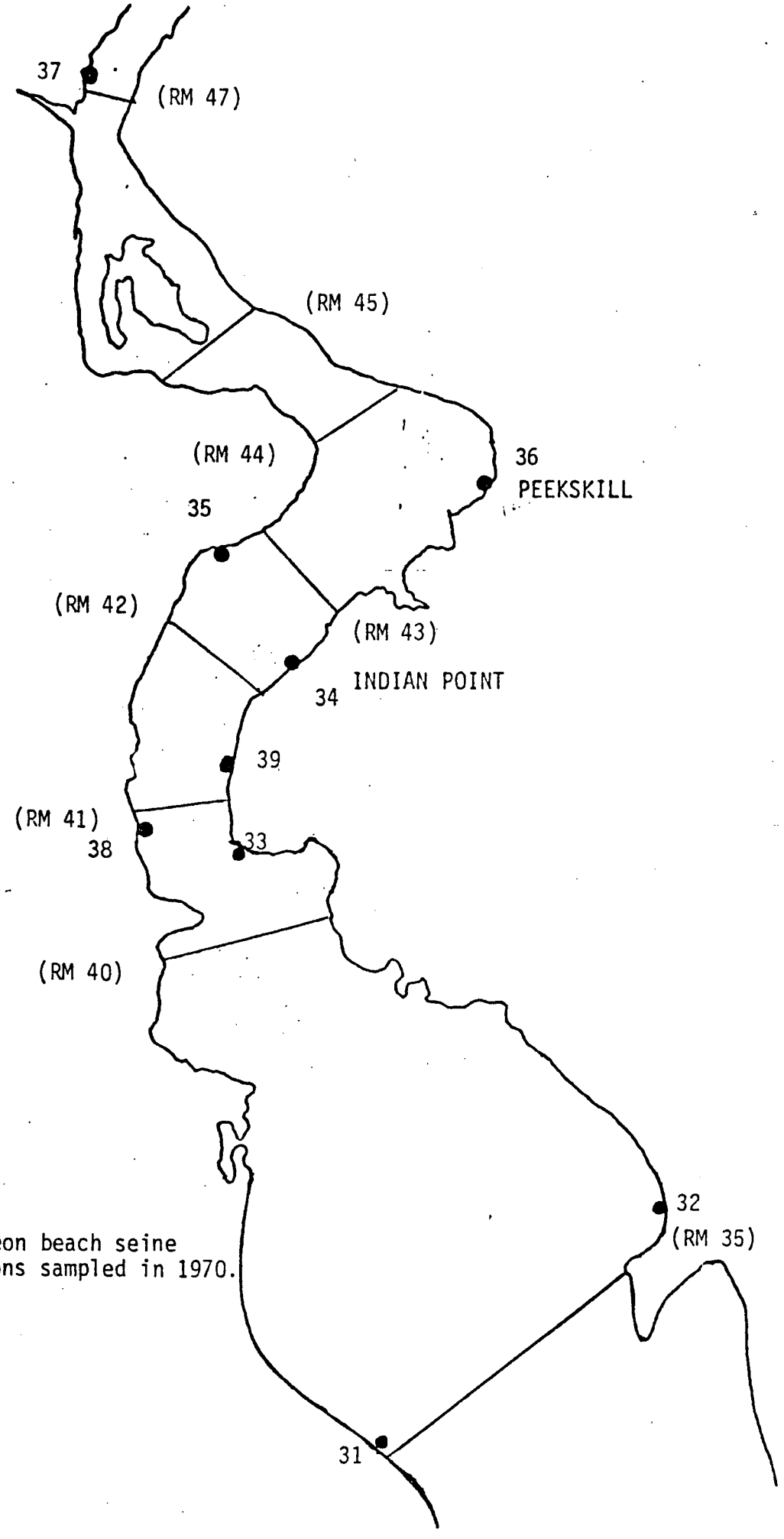

Figure 3. Raytheon beach seine stations sampled in 1970.

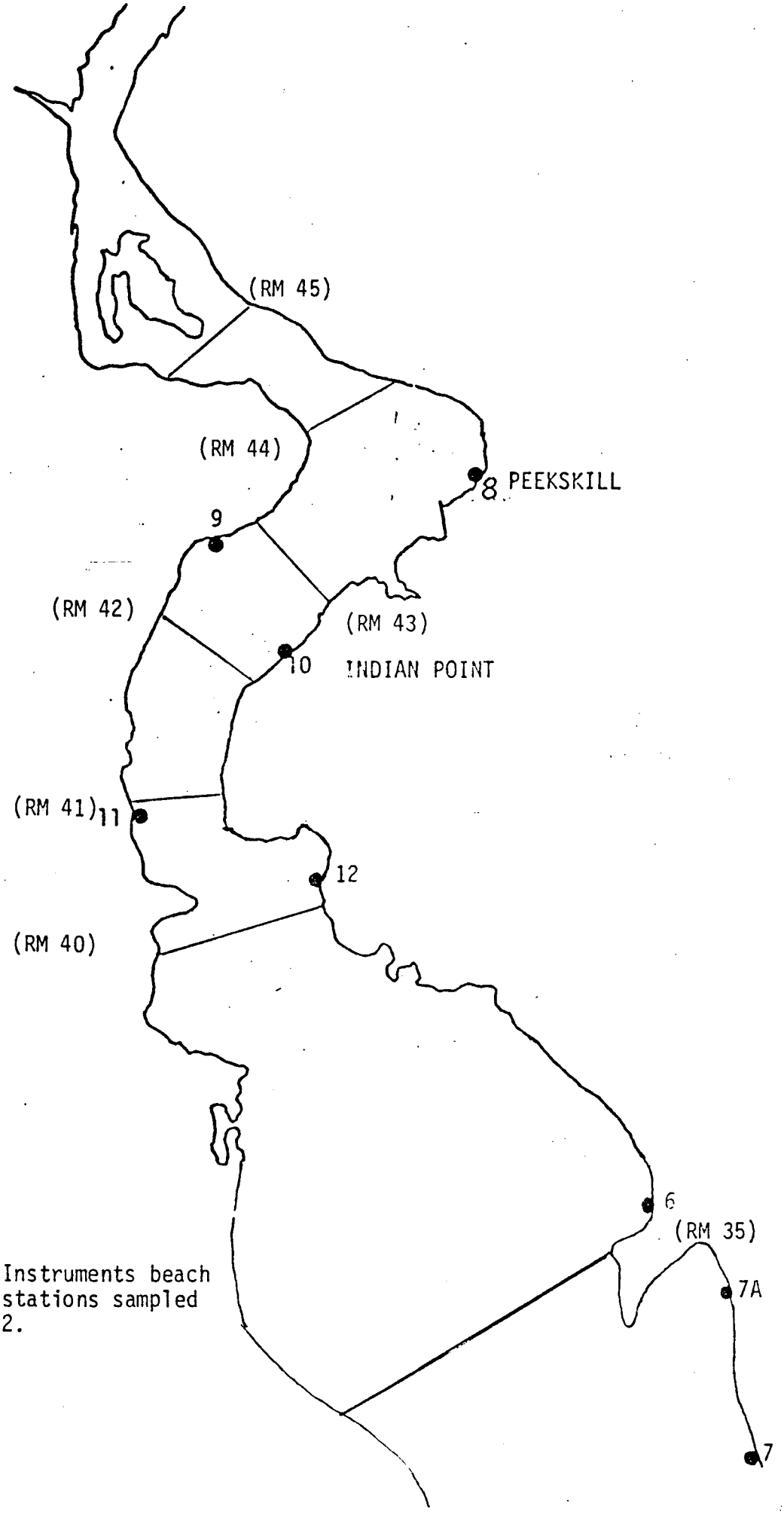

Figure 4. Texas Instruments beach seine stations sampled in 1972.

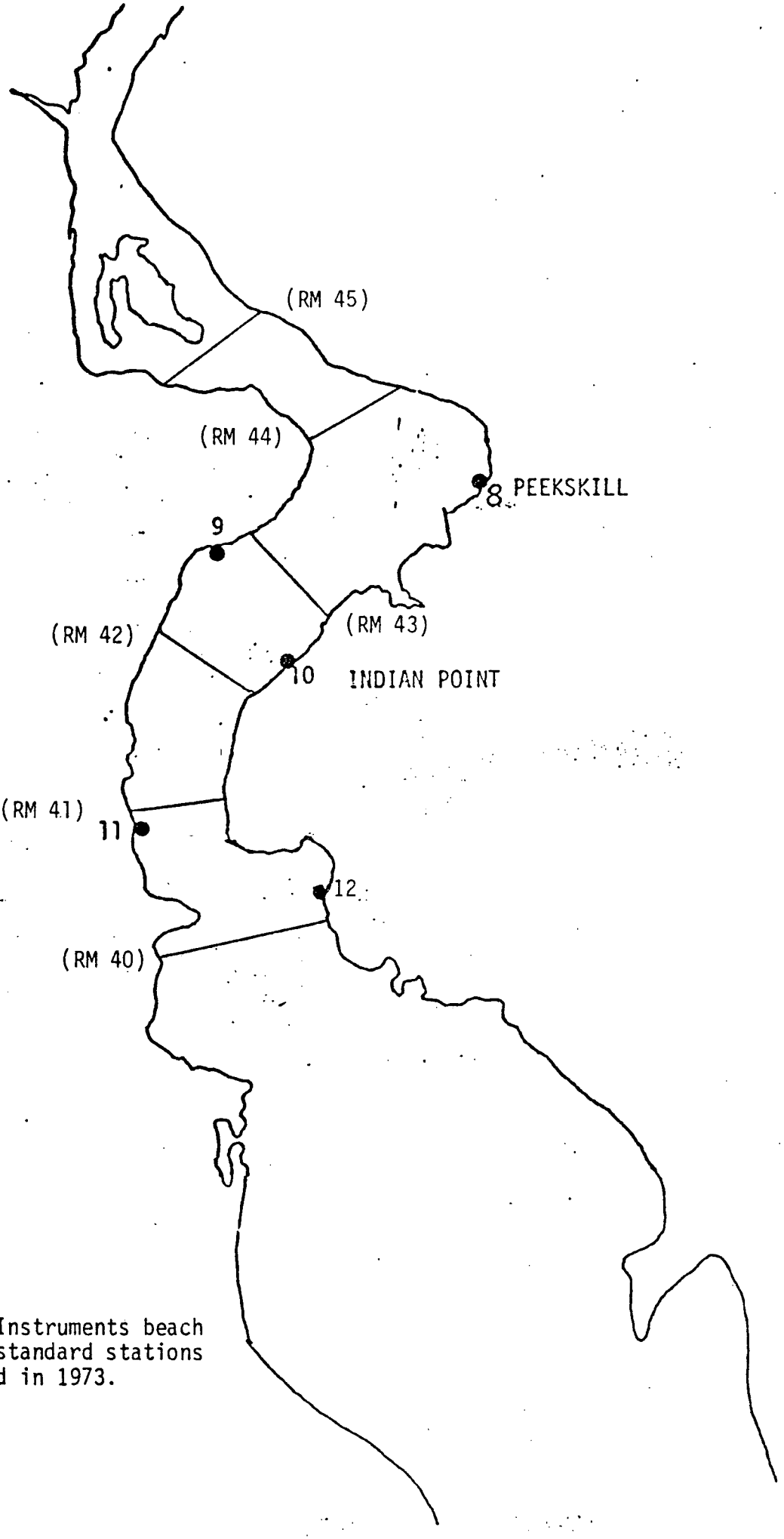

Figure 5. Texas Instruments beach seine standard stations sampled in 1973.

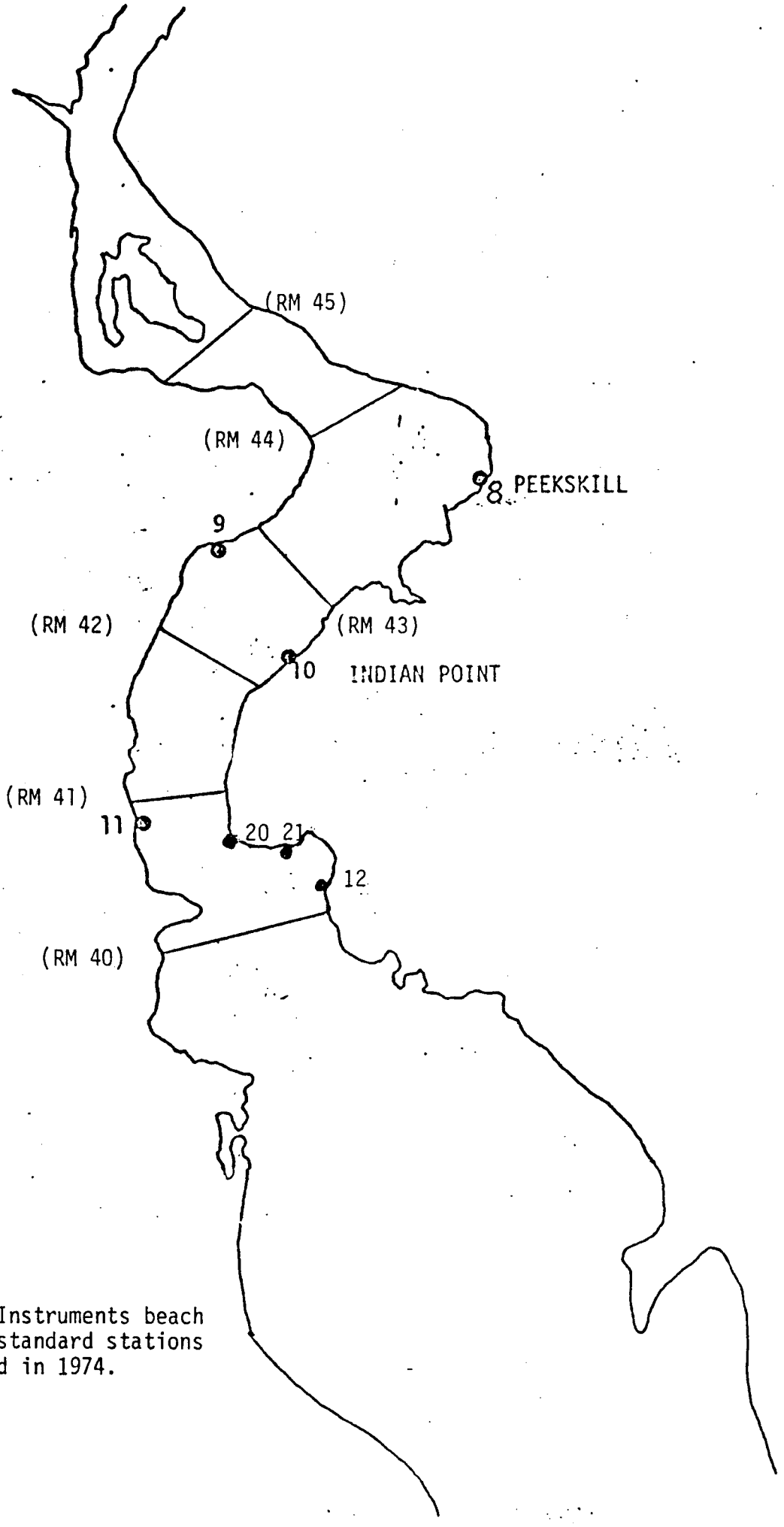

Figure 6. Texas Instruments beach seine standard stations sampled in 1974.

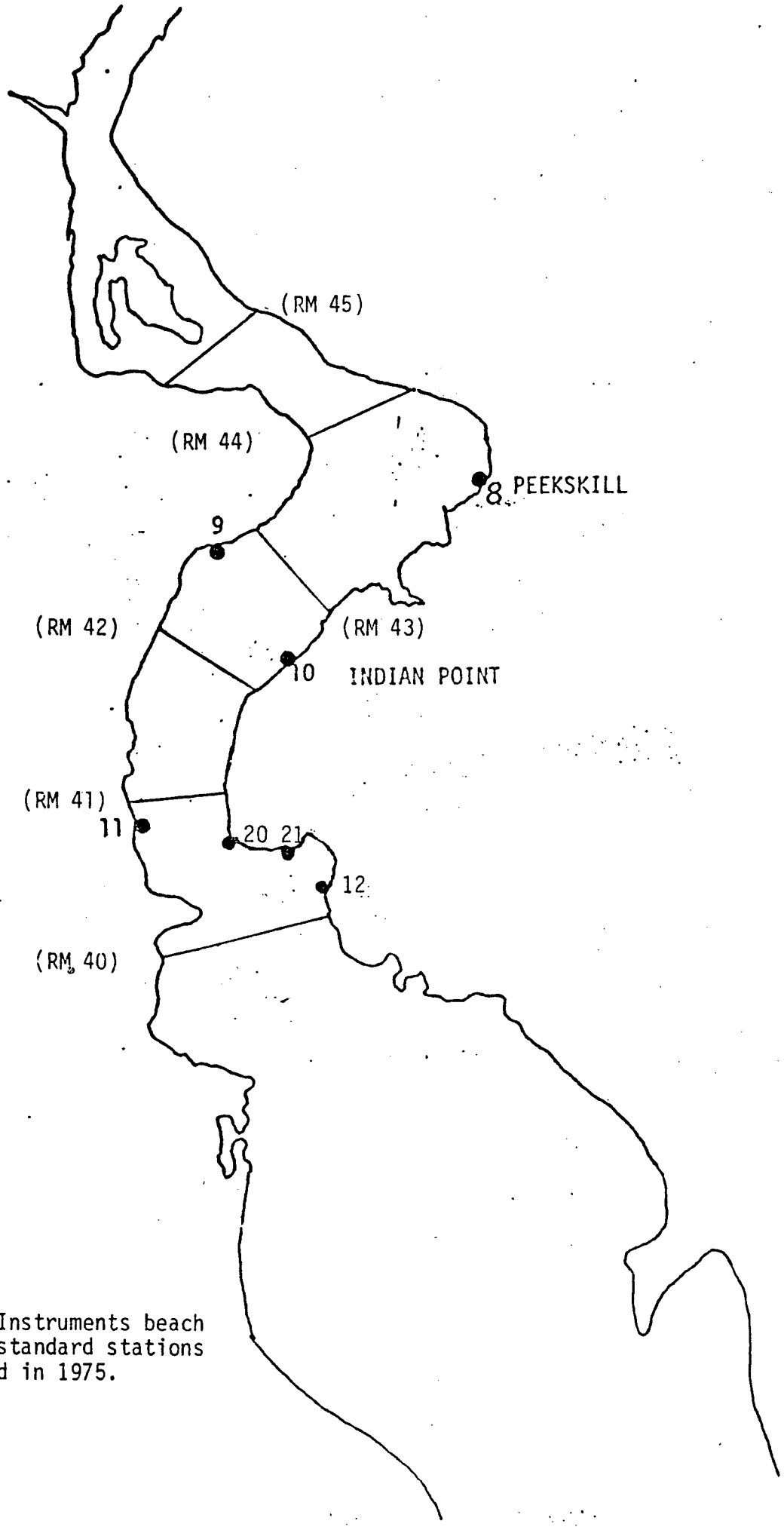

Figure 7. Texas Instruments beach seine standard stations sampled in 1975.

Table 2. Abundance (CPUA) and Growth (TL) Indices for Juvenile Striped Bass during July-August, 1965-1975 (1971 excluded), in Hudson River, Used in the Density-Dependent Growth Analyses.

YEAR	INDIAN POINT AREA	
	ABUNDANCE INDEX (CPUA)[1]	GROWTH INDEX (TL)[2]
1965	7.0	27.4
1966	0	----
1967	12.3	26.3
1968	2.2	23.6
1969	71.4	7.9
1970	37.0	15.3
1972	21.5	21.2
1973	103.4	31.8
1974	23.9	20.1
1975	22.4	23.1

[1]Catch-per-unit-area swept by beach seines from mid-July through August.

[2]Mean total length (mm) for fish captured in last half of August minus mean total length (mm) for fish captured in last half of July.

Table 3. Data used in the analysis of density vs. growth in juvenile striped bass collected in the area of Indian Point (Indian Point Area Version), Hudson River.

Year	Collector/ Survey	Sample Stations (river miles)	Seine Dimensions: Length (ft)	Seine Dimensions: Mesh Size (in)	Sample Dates Used	Number Caught	Length Information (mm): Min.	Max.	Mean Stand. Length	Mean Total Length	Standard Error	Δ Total Length (Aug minus Jul)	Year
1965	NYU	IIW1(41)	50		7/19	3	30.4	33.5	32.17	43.99	0.92[a]	27.41	1965
				0.38 in. stretch mesh	8/16	3	53.4	58.2	55.20	70.90	1.51[a]		
1966	NYU	IIW1(41),IIE1(41)	50		7/18-7/27	0							1966
				0.38 in. stretch mesh	8/15-8/24	0							
1967	NYU	IIW1(41)	50		7/17-7/31	24	14.0	48.6	25.45	35.50	2.15[a]	26.26	1967
				0.38 in. stretch mesh	8/14-8/21	12	16.4	65.3	47.52	61.76	4.02[a]		
1968	NYU	IIW1(41), IIE1(41)	50		7/15-7/29	5	28.6	37.0	33.80	45.43	1.50[a]	23.56	1968
				0.38 in. stretch mesh	8/12-8/19	7	40.0	71.0	53.61	68.99	4.57[a]		
1969	NYU	IIW1(41), IIE1(41)	50		7/17	55	29	52	41.02	54.02	0.70[a]	2.80	
				0.38 in. stretch mesh	8/13	38	34	76	43.37	56.82	1.30[a]	7.87	1969
1969	RAY	34(42),35(43), 36(44), 38(40)	75		7/13-8/2	182	22	74		48.74		9.39	
				0.25 in. bar mesh	8/17-8/30	29	42	94		58.13			
1970	RAY	34(42), 35(43), 36(44), 38(40)	100		7/12-8/1	604	25	76		46.80		15.34	1970
				0.38 in. bar(wings)	8/16-8/29	185	25	98		62.14			
				0.25 in. bar(bag) mesh									
1972	TI	8(43), 9(42), 10(42), 11(40)	100		7/16-7/29	148	29	62		46.14	0.83	21.18	1972
				0.38 in. bar(wings)	8/20-9/2	66	35	94		67.32	2.00		
				0.19 in. bar(bag) mesh									
1973	TI	8(43), 9(42) 10(42), 11(40)	100		7/15-7/28	88	30	57		42.03	0.84	31.79	1973
				0.38 in. bar(wing)	8/19-9/1	582	51	97		73.82	1.09		
				0.19 in. bar(bag) mesh									
1974	TI	8(43), 9(42), 10(42), 11(40)	100		7/14-8/3	121	27	64		48.00	0.87	20.11	1974
				0.38 in. bar(wing)	8/18-8/31	128	44	100		68.11	1.16		
				0.19 in. bar(bag) mesh									
1975	TI	8(43), 9(42), 10(42), 11(40)	100		7/13-8/2	124	29	80		52.68	1.22	22.67	1975
				0.38 in. bar(wing)	8/17-8/30	46	52	111		75.35	2.26		
				0.19 in. bar(bag) mesh									

[a]these standard errors are based on standard lengths measured by New York University (NYU). Mean standard lengths converted to mean total lengths for 1965-1969 NYU data by equation: Total Length = 1.19 x standard length +5.21

NYU = New York University
RAY = Raytheon Company
TI = Texas Instruments Incorporated

Exhibit Ut 49

2/2/78

Relationship Between Population Density and Growth for Juvenile Striped Bass in the Hudson River

Introduction

Many investigators have observed an inverse relationship between population density and growth rate in fishes, although the mechanisms involved may be complex and difficult to identify (Backiel and LeCren 1967). Beverton and Holt (1957) concluded that 'the variation of growth with density in fish populations is perhaps the best established of the density dependent effects which we consider in this paper ...'. The importance of density-dependent relationships between density and growth is emphasized by Backiel and LeCren (1967) who conclude that there are two main density effects operating on fish populations: density-dependent mortality and density-dependent growth.

Texas Instruments (TI) has examined the relationship between population density and growth juvenile striped bass in the Hudson River. A significant inverse relationship ($r = -0.866$, $p<.05$) between density and growth, (1965-74), holding constant the effects of mean daily water temperature in June on growth, was presented in an earlier report (TI 1975). The density and growth indices were calculated from data collected in the area of the Indian Point power plant during July and August. The results of a similar analysis for the period 1965-75 were presented in McFadden (1977). Subsequent examination of the raw data inputs to this analysis revealed some errors which required several corrections including: (a) the density index for 1973 had not included all juveniles that were collected. Therefore, the negative correlation between density and growth ($r = -0.85$, $p<.01$) reported in McFadden (1977) was altered; (b) the index of density and growth presented in McFadden (1977) and TI (1975) used catch and effort data collected near Indian Point in seines during all

of July and August. Since few juvenile striped bass were collected in seines prior to mid-July, a better index of density would include only data collected from mid- July through August. Similarly, a better index of growth would be the mean total length (mm) of fish caught during the last half of August minus the mean total length of fish caught during the last half of July. These modifications revised the indices of growth and density and changed the negative correlation between density and growth from $r = -.85$ ($p<.01$) to $r = -0.08$ ($p>.80$). Density and growth were still inversely related but only weakly and not significantly.

The purpose of this document is to describe the recent analyses that TI has completed to assess the influence of population density on growth in juvenile striped bass. The current relationship is based on a more "river-wide" data base rather than a data base restricted to the area near Indian Point. We feel that a riverwide data base should more accurately reflect annual variations in the abundance and growth of young striped bass. When the effects of water temperature on growth are considered, our recent analyses indicate a significant inverse relationship between density and growth in young striped bass during July and August for 1965 through 1976.

Methods and Materials

1. Sampling Stations

The riverwide data sets for population density and growth analyses in juvenile striped bass include seine samples collected from river mile (RM) 27 to 105 in 1965, 1966, 1967 and 1968 in New York University (NYU); from RM 41 to 87 by NYU and from RM 31 to 39 by Raytheon (RAY) in 1969; from RM 35 to 47 by RAY in 1970; and from RM 32 to 43 by TI in 1972; and from RM 12-152 by TI in 1973 through 1976. The locations of the sampling stations in 1965 to 1972 (excluding 1971 when no samples were taken) are given in Figures 1 through 3. TI sampled with seines throughout the estuary between RM 12 and 152 in 1973 through 1976 using a stratified random design.

In the years 1969, 1970 and 1972, sampling with seines was generally restricted to the area of Indian Point. A riverwide density was approximated for juvenile striped bass in 1969, 1970 and 1972 by adjustment with a ratio between a riverwide area (RM 12-152) density index and an Indian Point area density index during three years when comparable catch and effort data for both areas were available - 1973, 1974 and 1975. The four comparable TI and RAY Indian Point area stations for 1969, 1970 and 1972-75 are shown in Figure 4. The density index calculated from these four stations in 1969, 1970 and 1972 was multiplied times the geometric mean of the riverwide area to Indian Point area ratios from 1973, 1974 and 1975 to approximate riverwide densities for juvenile striped bass (see Table 3 for details).

Water temperatures were measured by the Water Works Department of Poughkeepsie, New York. The intake is located just north of Marist College approximately 1000 ft from the west shoreline. The water is withdrawn from a depth of about 45 ft, near the bottom; temperature measurements are taken as the water enters the treatment plant. TI received permission to use these temperature data.

2. Sampling Techniques

The data used to calculate population density and growth indices were collected by NYU with a 50 ft seine in 1965-69, by RAY with a 75 ft seine in 1969, by RAY with a 100 ft seine in 1970, and by TI with a 100 ft seine in 1972-76. Detailed descriptions of gear dimensions, deployment procedures, and gear comparability are presented in Section IV of TI's 1974 Year Class Report (Texas Instruments 1976).

3. Sampling Times

Seine samples collected during the day in July and August were used to generate annual density and growth indices for juvenile striped bass. The density indices were based on samples collected between approximately

mid-July through late August-early September (Table 1). Juvenile striped bass begin to migrate to the shorezone in late June-early July; shoreward movement increases sharply in late July-early August. Annual growth indices were calculated from differences between mean total length during the last half of August and mean total length during the last half of July (Table 1).

The water temperature indices used were derived from daily temperature measured from mid-May through August.

4. Sampling Effort

Effort was expressed in a comparable unit, area swept (ft^2). NYU measured the area swept for each tow of their 50 ft seines. Therefore, total effort for the 50 ft seine was simply the sum of all individual area per tow measurements.

The average area swept per haul for the 75 ft seine used by RAY in 1969 was estimated at 2725 ft^2, based on the assumption that the 75 ft seine swept an area similar in shape to the 100 ft seine. Thus the area swept for the 75 ft seine was calculated as

$$\frac{75^2}{100^2} \times 4844 \text{ ft}^2 = 2725 \text{ ft}^2$$

The value 4844 ft^2 is the mean area swept by the 100 ft beach seine as measured by TI. Effort for the 75 ft and 100 ft seines was 2725 ft^2 and 4844 ft^2, respectively, multiplied times the number of tows (see Table 2).

5. Density Index

Daytime catches of juvenile striped bass in seines from approximately mid-July through late August of each year were divided by the total effort (area swept in ft^2 times 10^{-4}) to yield annual density indices. Thus, each annual density index represented the number of juvenile striped bass caught per 10,000 ft^2 swept. For 1969, when both NYU and RAY sampled

the river, a density index was calculated from both data sets, then a single index was calculated by weighting the individual density indices by total area swept and combining the results (Table 3).

6. Growth Index (Incremental)

Daytime catches in seines were also used to generate annual indices of growth in juvenile striped bass. The sum of the lengths (mm) of all juveniles caught was divided by the total number caught to generate a mean length. These mean lengths were calculated separately for the second half of July and the second half of August of each year. The difference between the July and August means is the incremental growth index. In those cases where only a subsample of juveniles was measured rather than the entire catch, the average length of the measured fish was calculated and multiplied by the total catch for the sample. For the NUY length data (1965-1969), which was taken in standard as opposed to total length, the mean of individual standard lengths, for each time period considered, was converted by TI to a mean total length using the formula:

$$\text{total length} = \text{standard length } (1.19) + 5.21$$

For 1969 when both NYU and RAY sampled the river, mean total lengths for NYU and RAY data (for July and for August) were combined by weighting on total area swept (Table 4).

Another index of growth, relative growth, was also in the density-dependent growth analysis (Table 4). Relative growth is simply the incremental growth index divided by the mean total length during the last half of July.

No adjustments of the 1969, 1970 and 1972 growth indices were made to "approximate" riverwide growth indices. The geometric means of the ratios of riverwide/Indian Point growth (in 1973, 1974 and 1975) were 0.94 and 0.99 for the incremental growth index and relative growth index, respectively.

7. Water Temperature Index

Water temperature can have a strong influence on growth rate in fishes, so selected indices of water temperature which occurred between peak egg deposition for striped bass (mid to late May) and the end of August were included in the growth versus density analysis. This time period includes the important larval stages through the summer months when juvenile density and growth were measured.

Selection of a water temperature index was based, in part, on the results of earlier TI analyses designed to determine the relationships between the density of juvenile striped bass and several biotic and abiotic factors. The rate of temperature increase between 16 and 20°C (degree rise per day) was shown to be an important factor explaining variation in juvenile density and may be important in growth also. In addition, the growth indices were correlated with mean daily water temperatures for several time intervals from mid May through the end of August. Those time intervals for which the mean daily temperatures were relatively strongly associated with the growth indices were considered for the growth versus density analysis.

Except for degree rise per day, 16-20°C, no other water temperature index was strongly correlated with incremental growth (Table 5), so this temperature index was the only temperature index used in the analysis of population density effects on incremental growth.

Degree rise per day, 16-20°C, was also used in the analysis of density versus relative growth, but several other water temperature indices were also relatively strongly associated with relative growth (Table 5). A biological rationale for further selecting temperature indices was lacking, therefore, mean daily temperature for the interval 16 May - 31 August was selected as a second temperature index for incremental growth since the correlation coefficient was among the highest ($r = -0.59$) and the probability value was the lowest ($p = 0.056$

8. Analyses

Multiple regression analyses were performed to determine the amount of variation in each growth index (incremental and relative) which was explained by population density and water temperature.

Results

Incremental growth was inversely (-) related to population density of juvenile striped bass ($R = -0.537$, $p < .10$) (Table 6). The selected water temperature index (degree rise per day, 16-20°C) was directly (+) related to incremental growth. In combination, density and temperature explained 66.9 per cent of the annual variation in incremental growth and the regression equation was significant at $\alpha = .05$.

Relative growth was also inversely (-) related to population density ($R = -0.408$, $p < .10$) (Tables 7 and 8). In the first multiple regression analysis, the selected water temperature index (degree rise per day, 16-20°C) was directly (+) related to incremental growth (Table 7). In combination, density and temperature explained 52.1 per cent of the annual variation in incremental growth. The regression equation was significant at $\alpha = .10$ but not at $\alpha = .05$. In the second multiple regression analysis, the selected water temperature index (mean daily temperature, 16 May - 31 August) was inversely (-) related to incremental growth (Table 8). In combination, density and temperature explained only 42.6 per cent of the annual variation in incremental growth. The regression equation was not significant, however, either at $\alpha = .10$ or $\alpha = .05$.

Discussion

Growth rates in juvenile striped bass during July and August are influenced by water temperatures as one would predict, but population density also influences growth. The relative magnitude of temperature or

density effects on growth during any given year could not be assessed with the data set for 1965-76, although one would predict that it is variable among years. Major fluctuations in temperature may strongly influence growth rates in young striped bass during one year, while in another year, when temperatures were relatively normal, population density may be a major factor determining growth rates.

The inverse relationship between population density and growth for juvenile striped bass, with temperature effects on growth taken into consideration, offers empirical support for a compensatory mechanism in Hudson River striped bass. During years of high juvenile abundance, competition for resources may be intensified and growth rate declines. Competition for food and reduced growth rates may have an indirect effect on mortality by lengthening the time taken for the juvenile striped bass to grow to a size that makes them less vulnerable to predation. This size-related disadvantage may continue as the fish get older and relatively low survival rates may persist. Conversely, during years of low juvenile striped bass abundance, competion may be greatly reduced. As a result, food may be more readily available so growth rates increase along with survival rates. The detrimental effects of natural or man-related environmental perturbations which reduce the number of juvenile striped bass in a given year can be offset by the inverse relationship between density and growth, an example of a compensatory mechanism.

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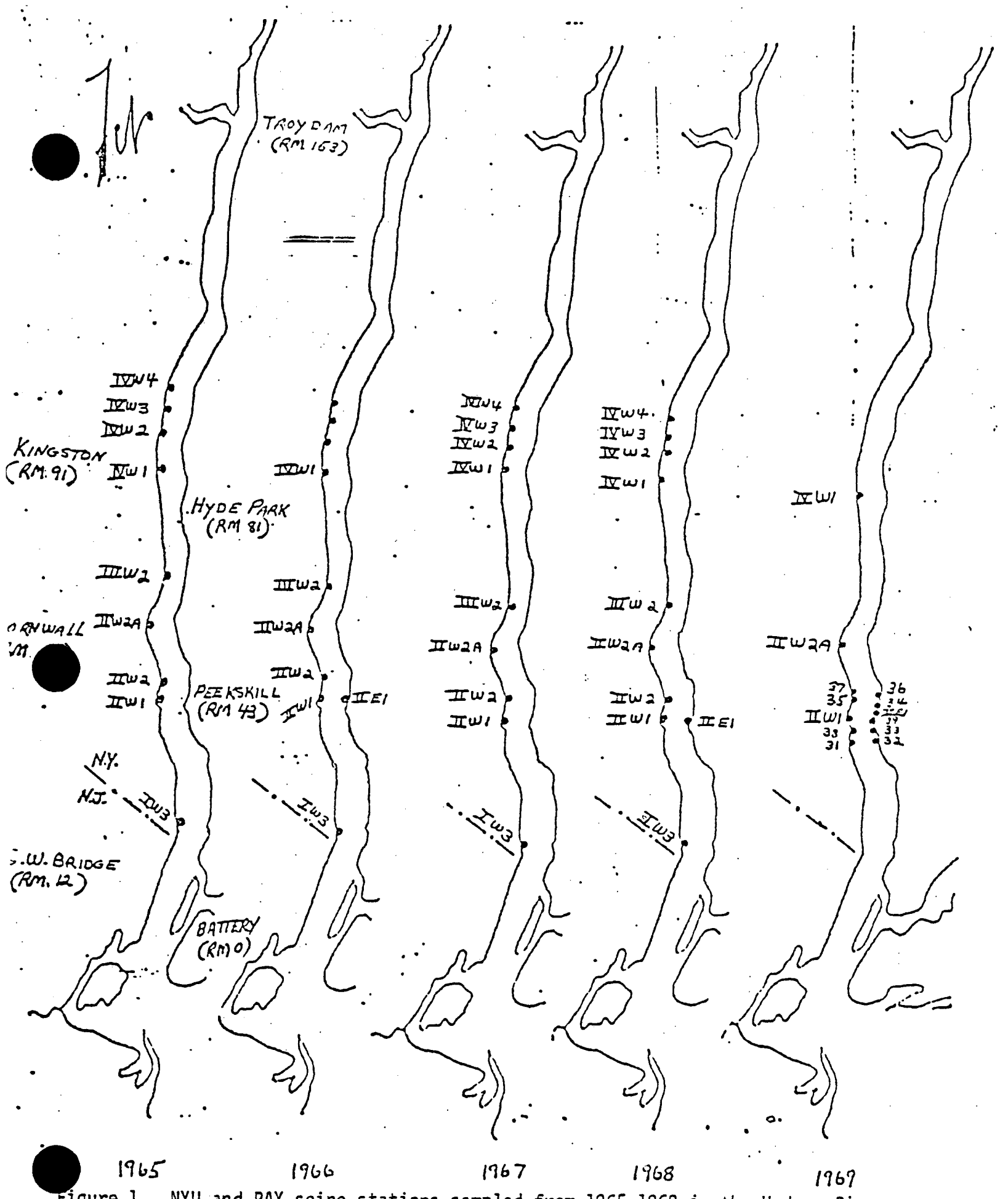


Figure 1. NYU and RAY seine stations sampled from 1965-1969 in the Hudson River. RAY sampled during 1969 at the stations 31-39.

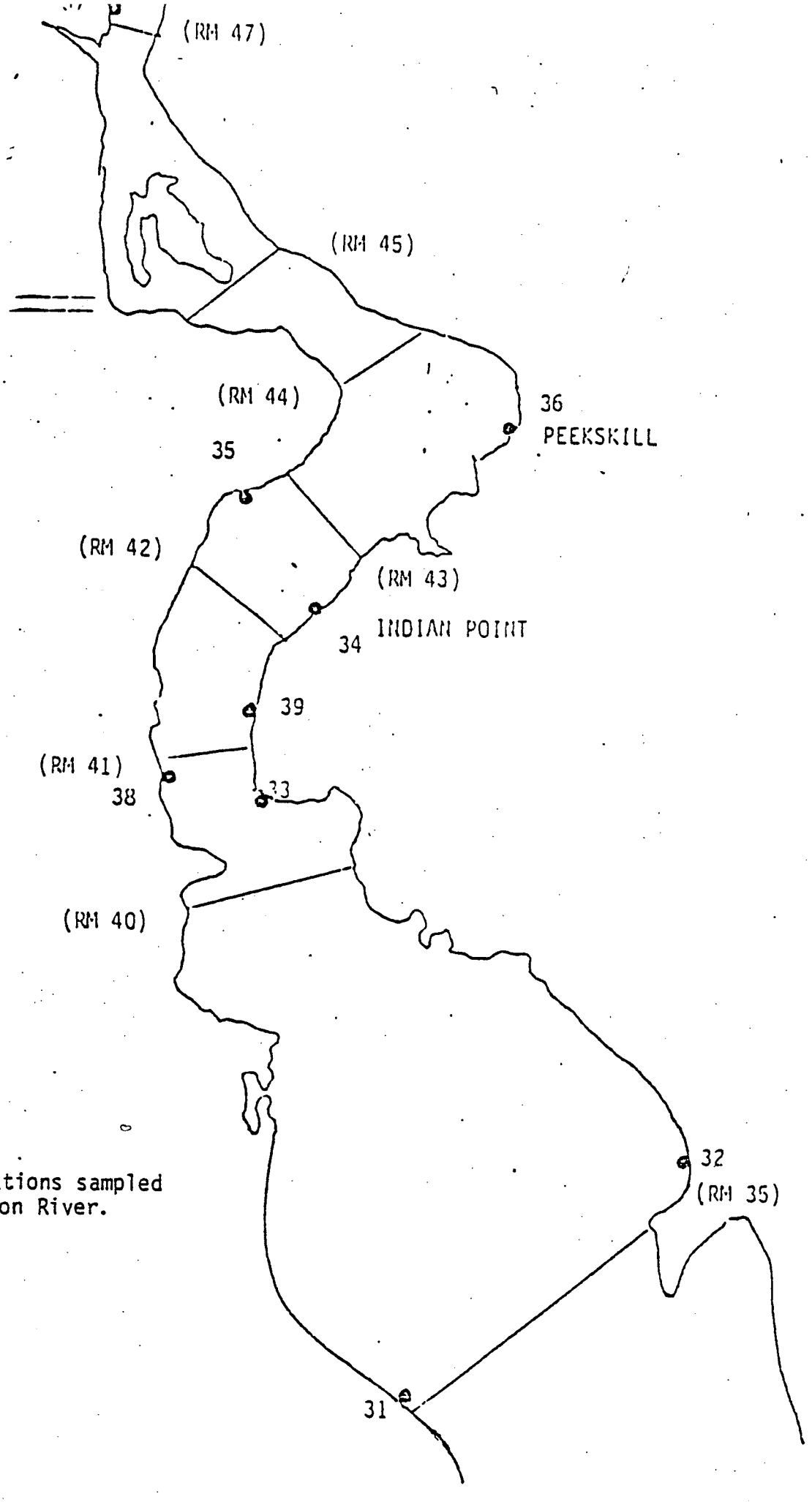


Figure 2. RAY seine stations sampled in 1970, Hudson River.

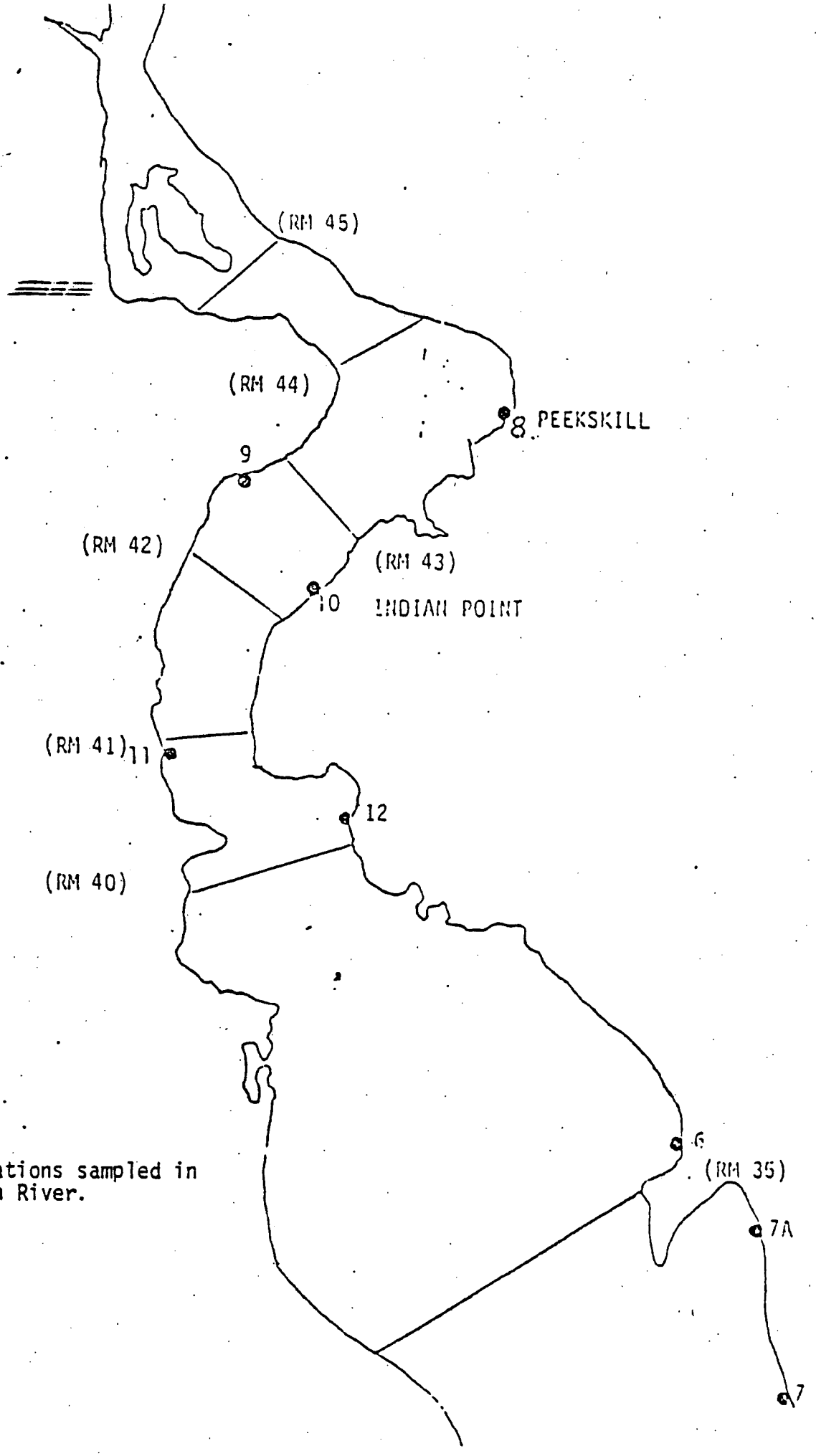


Figure 3. TI seine stations sampled in 1972, Hudson River.

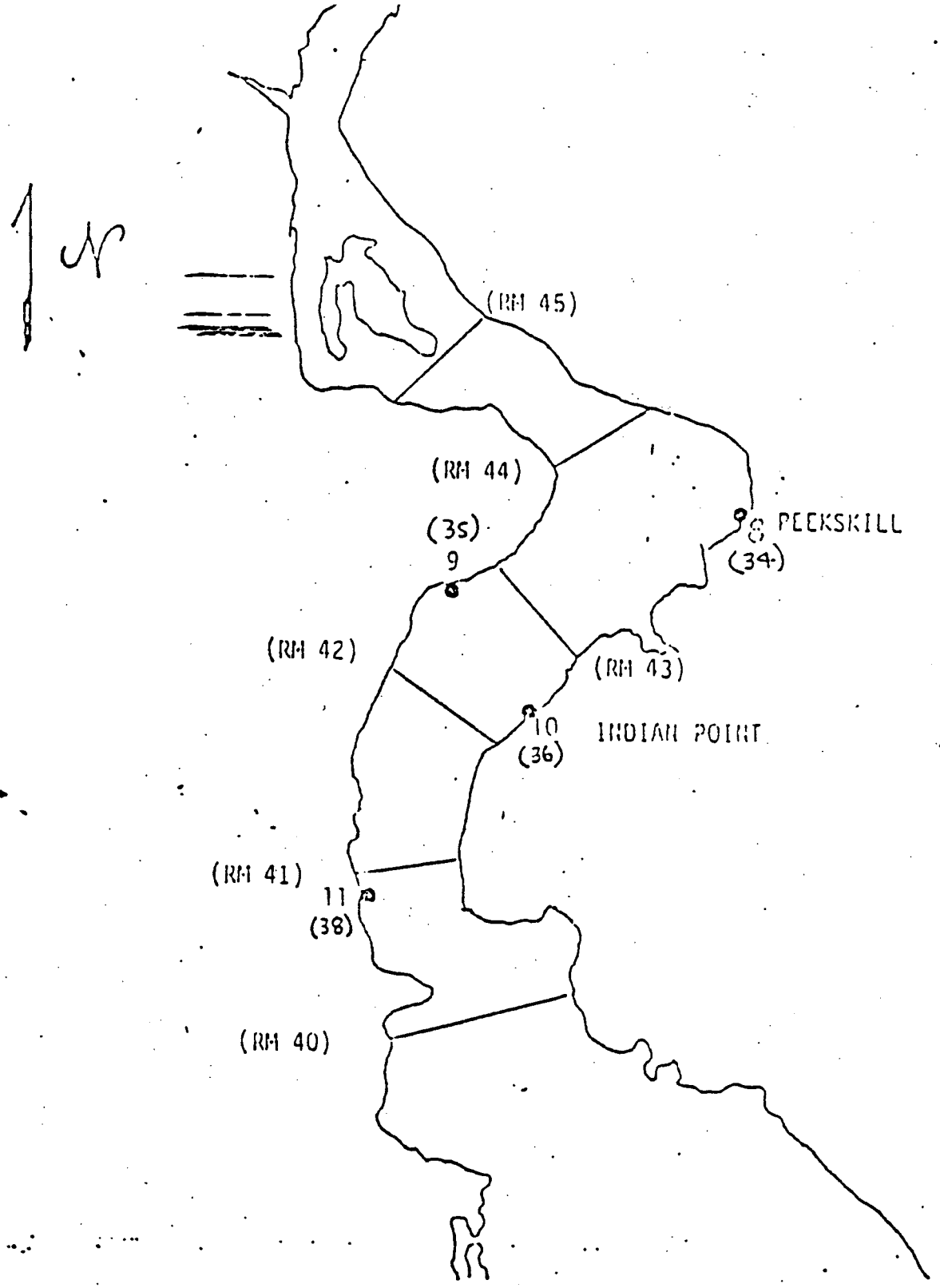


Figure 4. Indian Point area of the Hudson River showing four comparable sampling stations used to approximate riverwide densities for juvenile striped bass in 1969, 1970 and 1972.
1969-70 RAY Stations: (34), (35), (36), (38)
1972-76 TI Stations: 8, 9, 10, 11

Table 1. Time periods used to calculate annual density and growth indices for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

Year	Time Periods Used		
	Density Indices	Growth Indices	
		July	August
1965	19 July - 17 August	19-20	16-17
1966	18 July - 23 August	18-27	15-24
1967	17 July - 21 August	17-31	14-21
1968	15 July - 19 August	15-31	12-19
1969	13 July - 30 August	17	13
1970	12 July - 29 August	12 Jul-2 Aug	16-30
1971	*	*	*
1972	16 July - 2 September	16-29	20 Aug-2 Sep
1973	15 July - 8 September	15-28	12-25
1974	14 July - 7 September	14-27	11-24
1975	13 July - 6 September	13-26	10-23
1976	11 July - 4 September	11-24	8-21

*no data

Table 2. Sampling effort (area swept in ft^2) for seines used to generate annual riverwi density indices for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

Year	Investigator	Sample Dates Used	Area of River Sampled (RM)	Seine Length (ft)	Area Swept (ft^2)
1965	NYU	7/19-8/17	27-105	50	227,000
1966	NYU	7/18-8/23	27-105	50	216,750
1967	NYU	7/17-8/21	27-105	50	277,500
1968	NYU	7/15-8/19	27-105	50	389,700
1969	NYU	7/17-8/13	41- 87	50	14,000
1969	RAY	7/13-8/30	31- 39	75	46,325
1970	RAY	7/12-8/29	35- 47	100	266,420
1971	*	*	*	*	*
1972	TI	7/16-9/02	32- 43	100	208,292
1973	TI	7/15-9/08	12-152	100	2,141,048
1974	TI	7/14-9/07	12-152	100	2,853,116
1975	TI	7/13-9/06	12-152	100	3,599,092
1976	TI	7/11-9/04	12-152	100	3,322,984

*no data

RM = river mile

Table 3. Seine catch and effort data used to calculate annual riverwide density indices for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

Year	Number caught	Area Swept (ft^2)	Density Index
1965	27	227,000	1.2
1966	217	216,750	10.0
1967	116	277,500	4.2
1968	51	389,700	1.3
1969	93(NYU)	14,000	weighted average 32.1 (71.4 x 0.45*)
1969	338(RAY)	46,325	
1970	987	266,420	16.7 (37.0 x 0.45*)
1971	**	**	**
1972	447	208,292	9.7 (21.5 x 0.45*)
1973	6,127	2,141,048	28.6
1974	2,713	2,853,116	9.5
1975	6,574	3,599,092	18.3
1976	4,241	3,758,944	11.3

*adjustment factor used to yield approximate "riverwide" density as follows:

(1) Year	Riverwide Density Index	Indian Point Density Index	Ratio of Riverwide/ Indian Point
1973	28.6	103.4	0.2766
1974	9.5	23.9	0.3975
1975	18.3	22.4	0.8170

geometric mean of ratios=0.45

(2) Year	Indian Point Density Index		Adjustment Ratio	Approximate Riverwide Density
1969	71.4	x	0.45	32.1
1970	37.0	x	0.45	16.7
1972	21.5	x	0.45	9.7

** no data

Table 4. Seine catch and length data used to calculate annual growth indices for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

Year	Last Half July		Last Half August			
	Number Measured	Mean Total Length (mm)	Number Measured	Mean Total Length(mm)	Incremental Growth Index	Relativ Growth Index
1965	9	47.4	9	71.1	23.7	0.50
1966	71	53.3	72	71.6	18.3	0.34
1967	50	37.7	35	65.5	27.8	0.74
1968	21	48.9	17	67.4	18.5	0.38
NYU	55	54.0	38	56.8	weighted average 7.9	0.16
1969 RAY	182	48.7	29	58.1		
1970	604	46.8	185	62.1	15.3	0.33
1971	*	*	*	*	*	*
1972	148	46.1	66	67.3	21.2	0.46
1973	792	42.1	1769	63.9	21.8	0.52
1974	465	44.0	559	66.1	22.1	0.50
1975	1501	48.4	1189	73.6	25.2	0.52
1976	1208	33.1	1113	58.2	25.1	0.76

*no data

Table 5. Simple linear correlations between the two growth indices for juvenile striped bass and selected water temperature indices, Hudson River estuary, 1965-76 (except 1971).

	Water Temperature Index	Incremental Growth Index		Relative Growth Index	
		r	P	r	P
Mean daily Temperature (°C) for Time Period	16-31 May	-0.38	0.244	-0.59	0.057
	01-15 Jun	-0.34	0.302	-0.59	0.057
	16-30 Jun	-0.15	0.656	+0.04	0.905
	01-30 Jun	-0.45	0.168	-0.55	0.082
	16 May-30 Jun	-0.41	0.209	-0.58	0.064
	01-15 Jul	-0.07	0.845	+0.09	0.790
	16-31 Jul	-0.13	0.707	-0.03	0.940
	01-31 Jul	+0.07	0.836	+0.08	0.810
	16 May-31 Jul	+0.34	0.306	-0.51	0.113
	01 Jun-31 Jul	-0.25	0.466	-0.30	0.363
	01-15 Aug	-0.06	0.871	-0.29	0.393
	16-31 Aug	-0.44	0.174	-0.52	0.099
	01-31 Aug	-0.31	0.354	-0.46	0.193
	16 May-31 Aug	-0.39	0.242	-0.59	0.056
	01 Jun-31 Aug	-0.32	0.331	-0.44	0.174
	01 Jul-31 Aug	-0.14	0.687	-0.22	0.524
Degree Rise per Day, 16-20°C		+0.52	0.097	+0.52	0.098

r = simple linear correlation coefficient

P = probability value for correlation coefficient

Table 6. Results of a multiple linear regression analysis on the effects of population density and water temperature on incremental growth for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

(1) Correlation Matrix

	Y Growth	X_1 Density	X_2* Temperature
Growth	1.000		
Density	-0.537	1.000	
Temperatures	+0.525	+0.159	1.000

(2) R^2 with X_1 on Y = 0.288 (.10 >p>.05)

(3) R^2 with X_1 and X_2 on Y = 0.669 (p<.01)

(4) Standard Regression Coefficients

X_1 = -0.636

X_2 = +0.625

(5) Equation

$$Y = 16.469 - 0.345X_1 + 26.885X_2$$

(F = 8.091 for 2/8 df, p<.05)

*degree rise per day, 16-20°C

Table 7. Results of a multiple linear regression analysis on the effects of population density and water temperature on relative growth for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

(1) Correlation Matrix

	Y Growth	X_1 Density	X_2* Temperature
Growth	1.000		
Density	-0.408	1.000	
Temperature	+0.524	+0.159	1.000

(2) R^2 with X_2 on Y = 0.275 ($p>.10$)

(3) R^2 with X_1 and X_2 on Y = 0.521 ($p<.05$)

(4) Standard Regression Coefficients

X_1 = -0.503

X_2 = +0.604

(5) Equation

$$Y = 0.323 - 0.009X_1 + 0.818X_2$$

($F = 4.354$ for 2/8 df, $.10>p>.05$)

*degree rise per day, 16-20°C

Table 8. Results of a multiple linear regression analysis on the effects of population density and water temperature on relative growth for juvenile striped bass, Hudson River estuary, 1965-76 (except 1971).

(1) Correlation Matrix

	Y Growth	X_1 Density	X_{2B}* Temperature
Growth	1.000		
Density	-0.408	1.000	
Temperature	-0.590	+0.232	1.000

(2) R^2 with X_{2B} on Y = 0.348 (.10>p>.05)

(3) R^2 with X_1 and X_{2B} on Y = 0.426 (.10>p>.05)

(4) Standard Regression Coefficients

X_1 = -0.286

X_{2B} = -0.524

(5) Equation

$$Y = 4.242 - 0.005X_1 - 0.177X_{2B}$$

(F = 2.962 for 2/8 df, .20>p>.10)

*mean daily temperature, 16 May 31 August

XII.2. Provide in detail the method used to calculate CPUA and growth increment from the above data. See also Questions V.3 and V.4, which are similar to the above two questions, but are in the context of the McFadden 1977 Report.

Response: The material presented in the First Annual Report of the Multiplant Impact Study of the Hudson River Estuary (July 1975) represented an intermediate interpretation of data which was subject to modification as the studies progressed. The following represents the description of the updating of the calculation of CPUA and growth increment since the publication of the FRR.

As a method of investigating intraspecific competition in terms of growth, ten years of data on relative abundance of juvenile striped bass (catch-per-unit-area swept in beach seines during July and August) were used as an index of population density and compared to an index of growth based on changes in mean total length between the last half of July and the last half of August. All samples used in the analysis were daytime beach seine samples, i.e., collected between ½ hr after dawn and ½ hr before sunset. Since juvenile striped bass usually are not recruited to the beaches until approximately mid-July, initial time periods for the density analysis were chosen as close to the 15th of July as possible.

The procedure used to estimate striped bass density (CPUA) is as follows:

Daylight catches of juvenile (young-of-year) striped bass were used to estimate annual density indices from 1965-1975 (except 1971 when no samples were taken). Each annual abundance index was calculated by dividing the number of juvenile striped bass caught, from approximately mid-July through August, by the total number of square feet swept. Thus, each annual index of density (expressed as catch-per-unit-area, CPUA) represented the number of fish caught per 10,000 ft^2 swept by beach seines.

For 1969, when both NYU and Raytheon sampled the river, individual CPUA's were calculated then combined into a single index by weighting the CPUA's by total area swept.

The procedure used to determine the growth of striped bass from July to August is as follows:

The sum of the lengths of all juvenile striped bass caught was divided by the total number of striped bass. These mean lengths were calculated separately for the second half of July and the second half of August of each year. The difference between the July and August means is the growth index. In those cases where subsample of striped bass juveniles were measured rather than the entire catch, the average length of the measured fish was calculated and this number multiplied by the actual total catch for the sample. For the NYU length data (1965-1969), which was taken in standard as opposed to total length, the mean of individual standard lengths, for each time period considered, was converted to a mean total length using the formula:

$$\text{total length} = \text{standard length } (1.19) + 5.21$$

For 1969 when both NYU and Raytheon sampled the river, mean total lengths for NYU and Raytheon data (for July and for August) were combined by weighting on total area swept.

XIII. Questions relating to the Texas Instruments Bluefish Predation report (February 1976)

XIII (1) Provide as much data as possible from the August 1973 "preliminary" study of bluefish predation (page III-1). Particularly relevant are

a. total number of stomachs examined;

b. total number of stomachs containing food;

c. dates and places of capture of the bluefish;

d. sizes of the bluefish;

e. breakdown of the food found;

f. total number of striped bass, white perch, and *Morone* sp. found.

Raw data would be acceptable.

Response 1.a total number of stomachs examined = 59

Response 1.b total number of stomachs containing food = 33

Response 1.c dates and places of capture of bluefish - see attached Table A.

Response 1.d sizes of bluefish - see attached Table A.

Response 1.e percent frequency of occurrence and percent frequency by number of each species found in the bluefish examined and which contained food may be obtained from raw data in attached Table A.

Response 1.f total number of striped bass, white perch and *Morone* sp found:

striped bass = 7
white perch = 0
Morone sp. = 2

Table A Bluefish Predation (1973 Sample) Food Items Present

Number	RM-Site	Date	Length	Unident. Fish	Blueback herring	Striped bass	*Leptocheirus* sp.	Clupeid	Atlantic tomcod	*Morone* sp.	*Esox* sp.	Bay anchovy	*Cyathura* sp.	Plant remains	Adult Insect	Detritus
				FOOD ITEMS (Number of Items/Volume of Item in ml).												
1	42-3	8/14	121	1/0.3												
2	42-3	8/14	116		1/1.5											
3	42-3	8/14	106	1/0.2												
4	37-1	8/10	121			1/0.9										
5	30-1	8/17	139	*/0.0			1/<0.1									
6	39-3	8/10	134			1/1.5										
7	22-31	8/3	107							1/0.1†						
8	12-21	8/3	150					1/<0.1								
9	12-21	8/3	127	1/<0.1												
10	47-12	8/16	133	1/<0.1												
11	47-12	8/16	129			1/1.3‡										
12	47-12	8/16	114			1/1.4‡										
13	39-3	8/16	147			1/1.2										
14	39-3	8/16	153						1/0.5	1/0.8						
15	39-3	8/16	147								1/1.7					
16	39-3	8/16	134		1/0.4											
17	23-3	8/17	145	1/0.4												
18	23-3	8/17	136	1/0.3												
19	38-1	8/14	113									1/0.8				
20	40-3	8/10	127	1/0.2												
21	40-3	8/10	125	1/0.3									1/<0.1			
22	40-3	8/10	126	1/0.2												
23	40-3	8/10	137	1/0.4												
24	40-3	8/10	127	1/0.2												

Table A (continued)

FOOD ITEMS (Number of Items/Volume of Item in ml).

Number	RM-Site	Date	Length	Unident. Fish	Blueback herring	Striped bass	*Leptocheirus* sp.	Clupeid	Atlantic tomcod	*Morone* sp.	*Esox* sp.	Bay anchovy	*Cyathura* sp.	Plant remains	Adult Insect	Detritus
25	40-3	8/10	117		1/0.6											
26	40-3	8/10	116											*/<0.1	3/<0.1	
27	47-12	8/16	111			1/1.2										
28	39-3	8/16	153	1/0.4												
29	27-01	8/15	146	1/0.1												
30	27-01	8/15	135													*/0.1
31	32-3	8/14	110	1/0.2												
32	42-39	8/20	126			1/0.3										
33	27-6	8/17	115	2/1.3												

*Indicates presence of a food item when a number cannot be assigned

†Scales match those of striped bass

‡length is 56 mm.

‡length is 52 mm.

XIII 2. On page II-2, the formula for "percent frequency by number" appears to be in error. Is it in fact

$$\text{Percent frequency by number} = \left(100\right)\left(\frac{\text{Number of food items of species j contained in fish stomachs}}{\text{Total number of food items of all species contained in fish stomachs}}\right)$$

Response: Your interpretation of the equation is correct.

XIV. Questions for Niagara Mohawk

XIV 1. Provide monthly estimates of impingement rate (number of fish impinged per 10^6 cubic meters of water withdrawn) as follows:

a. for each of the following six species: White Perch, Striped bass, Tomcod, Blueback herring, Alewife, and Bay Anchovy;

b. for each unit at Albany;

c. for each month during 1972, 1973, 1974, 1975, and 1976 for which the necessary data are available.

In addition to each impingement rate (which is to be given to two decimal places), provide the value for the numerator (i.e., number of fish of that species actually collected during the sampling periods during the given month) and the value of the denominator (i.e., power-plant intake flow during the sampling periods during the given month).

Response: Attached are data with which monthly estimates of impingement rates for white perch, striped bass, tomcod, blueback herring and alewife may be calculated for the period April 1974 through March 1976. Bay anchovy were only occasionally collected in the samples (less than 1% of the total impingement collection) and yield essentially zero impingement rates per 10^6 cubic meters of water withdrawn. Bay anchovy data accordingly have not been tabulated and listed in the attached tables. Impingement data have not been collected prior to April 1974 nor since March 1976.
Whereas raw impingement data have been tabulated by individual screen, with one screen associated with each of the four Units at the station, the water enters a common phenum as it passes each screen and consequently may be withdrawn by any of the operating units. Accordingly an impingement rate by screen or by unit is meaningless. Rather, the impingement rate for the station (all units combined) is the proper value to evaluate.

Please note: Table 2 (attached) extracted from the Albany Steam Electric Generation Station Impingement Survey Report (April 1974-March 1975) and dated June 1975, contains monthly plant flow in million gallons per day for the period April 1974 through March 1975. Table 4 (attached) from the above-named report contains total annual impingement collection of each of the major contributing species as well as the percentage composition by month of that total contributed by each major species for the period April 1974 through March 1975, Table IV-C-16 (attached) extracted from the Albany Steam Electric Generating Station 316(a) Demonstration Submission contains monthly plant flow in million gallons per day for the period April 1975 through March 1976. Table IVC-14 of the above named report contains the number of each of the major species impinged each month for the period April 1975 through March 1976.

TABLE IVC-16

NIAGARA MOHAWK POWER CORP.
1975-1976 AQUATIC ECOLOGY STUDIES

AVERAGE NUMBER AND BIOMASS OF IMPINGED FISH BASED ON PLANT FLOW

ALBANY STEAM ELECTRIC GENERATING STATION - 1975-1976

MONTH	AVERAGE DAILY PLANT FLOW (MGD)	TOTAL IMPINGEMENT COLLECTION	
		AVERAGE NUMBER IMPINGED PER MILLION GALLONS	AVERAGE BIOMASS IMPINGED (gms) PER MILLION GALLONS
APR 1975	415.92	1.40	50.05
MAY	349.73	3.16	1882.99
JUN	416.23	1.38	88.87
JUL	333.69	2.55	73.43
AUG	417.82	1.49	15.15
SEP	432.17	12.61	76.90
OCT	385.39	1.20	34.17
NOV	369.59	0.84	21.54
DEC	406.25	0.26	6.28
JAN 1976	430.35	0.16	4.05
FEB	375.66	0.09	2.21
MAR	327.20	0.45	12.77

Source: Albany Steam Electric Generating Station 316(a) Demonstration Submission

TABLE IVC-14

NIAGARA MOHAWK POWER CORP.
1975-1976 AQUATIC ECOLOGY STUDIES

ABUNDANCE AND PERCENT COMPOSITION OF FISH IN IMPINGEMENT COLLECTIONS

ALBANY STEAM ELECTRIC GENERATING STATION - 1975-1976

SPECIES	TOTAL		APR		MAY		JUN		JUL		1975 AUG		SEP		OCT		NOV		DEC		JAN		1976 FEB		MAR	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Blueback herring	5729	42.2	30	3.4	327	25.1	314	33.5	40	3.6	43	4.7	4792	70.7	183	31.8										
White perch	2193	16.2	23	2.6	446	34.2	304	32.4	348	31.6	69	7.6	607	9.0	242	42.1	109	31.2	1	0.5					44	11.2
Spottail shiner	1796	13.2	562	64.2	196	15.0	131	14.0	89	8.1	133	14.6	269	4.0	14	2.4	112	32.1	20	10.5	16	17.0	38	67.9	216	55.1
American shad	1418	10.5							421	38.3	403	44.2	576	8.5	18	3.1										
Alewife	713	5.3	32	3.7	217	16.6	26	2.8	72	6.5	112	12.3	254	3.7												
Gizzard shad	378	2.8					1	0.1			2	0.2	13	0.2	48	8.3	87	24.9	159	33.7	66	70.2			2	0.5
Striped bass	376	2.8			10	0.8	98	10.5	79	7.2	98	10.7	79	1.2	10	1.7	2	0.6								
American eel	287	2.1	139	15.9	11	0.8	17	1.8	17	1.5	10	1.1	12	0.2	39	6.8	10	2.9	1	0.5	2	2.1	3	5.4	26	6.6
Bluegill	154	1.1					1	0.1					125	1.8	14	2.4	12	3.4					2	3.6		
Tessellated darter	102	0.8	7	0.8	32	2.5	16	1.7	2	0.2	4	0.4	5	0.1			6	1.7							30	7.7
Yellow perch	85	0.6	38	4.3	14	1.1	6	0.6	3	0.3			1	<0.1					1	0.5	1	1.1			21	5.4
White catfish	71	0.5			1	0.1	1	0.1	8	0.7	34	3.7	24	0.4	2	0.3	1	0.3								
Pumpkinseed	42	0.3	2	0.2	19	1.5	2	0.2	1	0.1	1	0.1	11	0.2	2	0.3	2	0.6							2	0.5
Rainbow smelt	37	0.3	15	1.7																					22	5.6
Golden shiner	27	0.2	9	1.0	5	0.4	1	0.1	1	0.1	1	0.1	3	<0.1			1	0.3	1	0.5			3	5.4	2	0.5
Rock bass	20	0.1			7	0.5	6	0.6	2	0.2					1	0.2					1	1.1	1	1.8	2	0.5
Brown bullhead	20	0.1	3	0.3			4	0.4	3	0.3			1	<0.1	2	0.3							2	3.6	5	1.3
Silvery minnow	16	0.1	5	0.6	8	0.6																			3	0.8
Black crappie	16	0.1			1	0.1	2	0.2					3	<0.1					2	1.1	6	6.4	2	3.6		
Goldfish	14	0.1	4	0.5	1	0.1	1	0.1			1	0.1	1	<0.1									3	5.4	3	0.8
Hogchoker	13	0.1			1	0.1	4	0.4	8	0.7																
White sucker	12	0.1	2	0.2	3	0.2											2	0.6			1	1.1			4	1.0
Atlantic tomcod	11	0.1							4	0.4							2	0.6	4	2.1	1	1.1				
Others	36	0.3	5	0.6	5	0.4	2	0.2	2	0.2	1	0.1	5	0.1			3	0.9	1	0.5			2	3.6	10	2.6
TOTAL SPECIES	37		18		22				18		14		20		12		14		9		8		10		21	
TOTAL NUMBER	13566		876		1304				1100		912		6781		575		349		190		94		56		392	

Source: Albany Steam Electric Generating Station
316(a) Demonstration Submission

TABLE 2

NIAGARA MOHAWK POWER CORPORATION
ALBANY STEAM ELECTRIC GENERATING STATION
IMPINGEMENT STUDY
ESTIMATED IMPINGEMENT BASED ON
COOLING WATER FLOW

NUMBER OF FISH

MONTH	A PLANT FLOW (MGD)					B OBSERVED IMPINGEMENT RATE (NUMBER/MG)					C ESTIMATED DAILY IMPINGEMENT RATE					D ESTIMATED MONTHLY IMPINGEMENT RATE				
	Unit 1	Unit 2	Unit 3	Unit 4	Av. Plant Total	Unit 1	Unit 2	Unit 3	Unit 4	Plant Av.	Unit 1	Unit 2	Unit 3	Unit 4	Total	Unit 1	Unit 2	Unit 3	Unit 4	Total
(1974)																				
March	126.72	109.47	88.22	126.72	388.11	0.36	0.53	0.74	0.66	0.51	46	58	65	84	198	1426	1798	2015	2604	6138
April	78.21	126.27	126.66	118.54	448.44	1.03	2.67	1.80	3.75	2.45	81	337	228	445	1099	2430	10110	6840	13350	32970
May	114.90	126.55	126.40	126.72	494.80	1.77	2.71	1.04	4.65	2.54	203	343	131	589	1257	6293	10633	4061	18259	38967
June	126.72	126.72	126.72	126.72	506.88	1.25	2.29	1.16	3.75	2.27	158	290	147	475	1151	4740	8700	4410	14250	34530
July	126.72	126.61	125.44	126.72	505.34	1.42	2.12	1.42	3.75	2.29	180	268	178	475	1157	5580	8308	5518	14752	35867
August	126.72	126.72	126.72	126.62	506.78	2.93	2.54	1.49	3.75	2.68	371	322	189	475	1358	1501	9982	5859	14725	42098
September	126.72	126.06	126.72	122.93	488.35	6.64	5.25	4.11	4.70	5.00	841	662	518	578	2442	25230	19860	15540	17340	73260
October	126.58	126.44	124.49	105.87	483.37	4.14	4.85	2.03	6.15	4.12	524	613	254	651	1991	16244	19003	7843	20181	61721
November	126.72	126.42	126.57	126.72	506.44	0.98	1.04	0.33	1.42	0.91	124	131	42	180	461	3720	3930	1260	5400	13830
December	126.26	126.52	126.72	126.72	506.23	0.22	0.30	0.09	0.29	0.23	28	38	11	37	116	868	1178	341	1147	3596
(1975)																				
January	126.72	118.68	126.43	126.72	498.55	0.11	0.12	0.14	0.18	0.13	14	14	18	23	65	434	434	558	713	2015
February	126.57	126.72	109.03	126.72	396.23	0.08	0.02	0.21	0.20	0.12	10	3	23	25	48	280	84	644	700	1344
March	125.68	113.68	126.17	124.01	364.30	0.10	0.08	0.24	0.40	0.20	13	9	30	50	73	403	279	930	1550	2263
						AVERAGE RATE				1.80	DAILY AVERAGE				878	MONTHLY AVERAGE				26815
																YFARLY ESTIMATE*				342461*

BIOMASS OF FISH

MONTH	A PLANT FLOW (MGD)					B OBSERVED IMPINGEMENT RATE (BIOMASS/MG)					C ESTIMATED DAILY IMPINGEMENT RATE					D ESTIMATED MONTHLY IMPINGEMENT RATE				
	Unit 1	Unit 2	Unit 3	Unit 4	Av. Plant Total	Unit 1	Unit 2	Unit 3	Unit 4	Plant Av.	Unit 1	Unit 2	Unit 3	Unit 4	Total	Unit 1	Unit 2	Unit 3	Unit 4	Total
March	126.72	109.47	88.22	126.72	388.11	7.11	9.17	18.43	14.26	10.90	902	1004	1626	1807	4231	27948	31125	50408	56017	131168
April	78.21	126.27	126.66	118.54	448.44	22.22	123.98	42.34	209.85	88.13	1738	15655	5363	24876	39521	52135	469649	160884	746269	1185631
May	114.90	126.55	126.40	126.72	494.80	98.30	243.59	38.06	451.90	209.47	11295	30827	4811	57265	103646	350135	955616	149134	1775208	3213018
June	126.72	126.72	126.72	126.72	506.88	34.38	81.00	43.27	151.14	84.70	4357	10264	5483	19152	42933	130699	307930	164495	574574	1287982
July	126.72	126.61	125.44	126.72	505.34	29.83	52.42	25.49	116.24	61.36	3780	6637	3197	14730	31008	117182	205744	99121	456628	961328
August	126.72	126.72	126.72	126.62	506.78	30.81	31.72	16.99	60.74	35.06	3904	4020	2153	7691	17768	121032	124606	66742	238418	550799
September	126.72	126.06	126.72	122.93	488.35	64.68	63.17	44.08	81.26	61.95	8196	7963	5586	9989	30253	245887	238896	167575	299679	907598
October	126.58	126.44	124.49	105.87	483.37	69.66	102.91	30.95	175.50	88.58	8818	13012	3853	18580	42817	273344	403370	119442	575986	1327324
November	126.72	126.42	126.57	126.72	506.44	18.99	25.30	5.51	39.06	22.57	2406	3198	697	4950	11430	72192	95953	20922	148490	342911
December	126.26	126.52	126.72	126.72	506.23	6.45	9.43	3.45	10.62	7.49	814	1193	437	1346	3792	25246	36986	13553	41719	117542
(1975)																				
January	126.72	118.68	126.43	126.72	498.55	2.07	3.59	3.73	4.95	3.59	262	426	472	627	1790	8132	13208	14619	19445	55484
February	126.57	126.72	109.03	126.72	396.23	1.64	0.42	13.38	6.24	3.68	208	53	1459	791	1458	5812	1490	40847	22141	40828
March	125.68	113.68	126.17	124.01	364.30	3.38	2.71	6.43	16.03	6.80	425	308	811	1988	2477	13169	9550	25149	61624	76794
						AVERAGE RATE				52.64	DAILY AVERAGE				25625	MONTHLY AVERAGE				784486
																YEARLY ESTIMATE*				10067149 gms
																				10067 kg

* April 1974 - March 1975

Source: Albany Steam Electric Generating Station
Impingement Survey (April 1974-March 1975)
June 1975

TABLE 4

NIAGARA MOHAWK POWER CORPORATION
ALBANY IMPINGEMENT SURVEY
MONTHLY PERCENTAGE COMPOSITION
ABUNDANCE

SPECIES (Rank order)	YEARLY SAMPLE TOTAL ABUNDANCE	%	MONTHLY PERCENTAGES 1974 - 1975 APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
lueback herring	27058	28.58	1.56	37.93	23.77	3.84	3.33	59.40	45.68	19.70	0.19	---	---	---
hite perch	18091	19.11	11.90	14.16	22.35	34.90	14.95	13.47	28.07	25.42	0.58	0.34	2.34	0.45
pottail shiner	15067	15.91	40.62	21.64	16.04	13.03	11.59	4.33	2.87	28.42	60.17	74.32	78.36	61.19
lewife	10764	11.37	2.29	8.32	1.33	7.53	41.54	11.24	8.68	0.15	---	---	---	---
merican eel	6494	6.86	19.85	5.70	6.90	5.71	3.05	1.36	9.12	9.50	3.88	1.86	2.63	2.54
triped bass	5455	5.76	0.03	1.87	22.26	14.86	9.02	3.35	1.43	1.11	0.10	---	---	---
merican shad	3651	3.87	---	0.01	12.40	12.27	4.14	0.85	0.85	0.46	---	---	---	---
essellated darter	1570	1.66	7.21	4.24	1.34	0.68	0.36	0.10	0.17	0.78	0.10	---	---	0.75
hite catfish	1021	1.10	0.06	0.07	0.34	3.30	1.05	0.40	0.29	---	---	---	1.17	0.90
ellow perch	687	0.73	3.91	1.11	0.74	0.37	0.02	0.01	0.03	0.12	0.78	0.68	0.58	1.79
umpkinseed	564	0.60	0.91	1.29	0.52	0.72	0.24	0.18	0.47	0.80	1.84	0.84	1.17	0.90
ilvery minnow	526	0.56	3.12	1.24	0.22	0.04	---	0.02	0.01	0.07	0.29	0.68	0.58	0.75
izzard shad	468	0.49	---	---	---	---	---	0.05	0.93	5.04	7.75	3.38	---	0.15
olden shiner	429	0.45	1.28	0.61	0.35	0.39	0.24	0.11	0.07	0.44	3.20	2.20	1.75	3.28
luegill sunfish	374	0.40	0.32	0.17	0.06	0.15	0.02	0.56	0.36	2.52	1.94	0.34	0.29	0.60
tlantic tomcod	369	0.39	0.01	0.02	1.66	0.87	0.13	>0.01	0.06	0.29	7.56	5.07	1.17	0.15
ainbow smelt	302	0.32	1.92	0.01	0.02	0.01	---	---	---	---	---	---	---	13.28
oldfish	291	0.30	0.61	0.13	0.12	0.03	0.02	---	0.03	1.70	5.14	2.36	3.80	5.82
rown bullhead	183	0.19	0.45	0.18	0.67	0.13	0.04	0.02	0.02	0.34	0.39	0.68	0.58	1.94
hite sucker	167	0.18	0.74	0.26	0.15	0.07	---	0.02	0.04	0.34	0.39	1.01	0.29	0.30
lack crappie	124	0.13	0.04	0.15	0.05	0.11	---	0.06	0.07	0.39	2.33	1.52	2.05	1.49
ock bass	119	0.13	0.23	0.20	0.17	0.12	0.02	0.04	0.03	0.39	0.58	0.17	---	1.04
entral mudminnow	106	0.11	0.78	0.07	0.01	---	---	---	---	0.17	0.10	---	0.58	0.30
THERS	604	0.64	1.58	0.51	0.92	0.74	0.12	0.24	0.34	1.17	2.40	3.71	2.66	2.09
D	194	0.20	0.56	0.11	---	---	<0.01	0.25	0.27	0.39	0.29	0.84	---	0.29
OTAL SPECIES			37	34	34	34	25	31	37	33	31	22	20	24

--- Species Not Collected.

Source: Albany Steam Electric Generating Station
Impingement Survey (April 1974-March 1975)
June 1975

XIV.2 Provide an estimate (and associated variance and 95% confidence interval) of impingement efficiency. Provide a thorough discussion of data used and assumptions made.

Response: There have been no impingement collection efficiency tests conducted at the Albany Steam Electric Generating Station.

XVI. Question relating to the NYU special report entitled "Mortality of striped bass eggs and larvae in nets" (July 1976)

XVI 1. Please provide, with adequate documentation, the raw data on which this report is based. Please indicate not only whether a velocity reduction cone was present or not but also the degree of taper.

Response: Attached are the raw data upon which the report entitled "Mortality of striped bass eggs and larvae in nets" (July, 1976) is based.

Date: 5/27/15 Stage: YSL-3days old Brood #: 12

Net length: 6 Fabric: Nylon Water Velocity: 0.5 V.R.C.: — Time: 15min.

1

Total No. caught: 50

	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1 Dead	45	5										
Alive	5	0										
	10%	0%										

Total No. Caught: 50

	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2 Dead	36	14										
Alive	14	0										
	28%	0										
C Dead	27	23										
Alive	23	0										
	46%	0%										

Comments: Larvae very weak to start out with

Date: 5/27/75 Stage: YSL Brood #: 12

Net length: 6 Fabric: Nylon Water Velocity: 0.5 V.R.C.: – Time: 5 min.

Total No. caught: 42 - 8 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	35	7										
	Alive	7	0										
		14%	0%										

Total No. Caught: 50 - no lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	43	0										
	Alive	7	7										
		14%	0%										

Total - 50

C	Dead	36	14
	Alive	14	0
		28%	0%

Comments: Temp. shipped - 20.0°C
Temp-flume - 21.0°C
Holding Temp - 18.0°C

larvae very bad most dead before picking, might have to scrap.

Date: 5/30/75 Stage: Eggs 8 hours old Brood #: ?

Net length: 6 Fabric: Nylon Water Velocity: 2.76 V.R.C.: – Time: 10min

Time - 0155 Total No. caught: 57 - 0 - lost

	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1 Dead	52/16 badly damaged											
Alive	0											

0%

Total No. Caught: 65 - ?

	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2 Dead	60/9 badly damaged											
Alive	0											

0%

No Control -

Meter Measurements

	A.off	MM meter
Depth 1ft 1600 RPM	2.94 (3.00)(4-26)	3.20 (3.22)(4-26)
1ft 1200 RPM	2.25	2.25
1ft. 800	1.30	1.20
1ft. 550	0.96	1.00

Date: 5/30/75
0215 hours

Stage: Egg

Brood #: ?

Net length: 6 Fabric: Nylon Water Velocity: 276 V.R.C.: – Time: 10min

Total No. caught: 47 - 3 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	49/7											
	Alive	0											
		0 %											

Total No. Caught: 50 - 0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	50/15											
	Alive	0											
		0 %											

No Control – N.B. copepods dead in significant proportion

Date: 5/30/75 0240 Stage: Egg Brood #: ?

Net length: 6 Fabric: Nylon Water Velocity: 2.76 V.R.C.: — Time: 10 min

Total no. caught: 50-0 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	50/4											
	Alive	0											

0%

Total no. Caught: 50-0 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	50/12											
	Alive	0											

0%

~~50~~ 48 - 2 lost

C	Dead	8
	Alive	40

80%

Velocity At Mouth 6', .05 meter opening

No Colored 2.83 ft/sec

Colored 2.83 "

Date: 5/30/75
0400

Stage: Egg

Brood #: ?

Net length: 6 Fabric: Nylon Water Velocity: 2.76 V.R.C.: – Time: 30 min

Total No. caught: 57 - 0 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	57/10											
	Alive	0											
		0%											

Total No. Caught: 50 - 2 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	50/29											
	Alive	0											
		0%											

C	Dead	3	
	Alive	46	
		92%	

Date: 5/30/75
0530

Stage: Egg

Brood #:

Net length: 6 Fabric: Silk Water Velocity: 2.7 V.R.C.: – Time: 10min

Total no. caught:

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead												
	Alive												

Total no. Caught: 36 · 14 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	36/9											
	Alive	0											
		0%											

C	Dead	0	
	Alive	49	
		98%	

fps determination – Silk 2.755 vs. Nylon 2.225 0.5 meter 6' net

Date: 5/30/75
0640 + 0720

Stage: Egg

Brood #: ?

Net length: 6 Fabric: Nylon Silk Water Velocity: .55 V.R.C.: – Time: 5 min

Total No. caught: 52 - 1 lost

Duplicate

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
Nylon R1	Dead	4								7			
	Alive	48								41			
		96%								82%			

Total No. Caught: 55 - 0 lost

50 - 2 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
Silk R2	Dead	13								6			
	Alive	42								42			
		~~84%~~ 76%								84%			

50 - 4 lost

C	Dead	0
	Alive	46
		92%

Date: 5/30/75 Stage: Egg Brood #: ?

0935
1010

Net length: 6 Fabric: ~~Silk~~ Nylon Water Velocity: .55 V.R.C.: — Time: 10 min

Total No. caught: 51-8lost

Nylon	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1 Dead	9								3			
Alive	34								46			
	66%								85%			

58-4lost

Total No. Caught: 54-0lost

Silk	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2 Dead	23								4			
Alive	31								41			
	57%								73%			

46-6lost

55-0lost

C		
Dead	0	
Alive	55	
	100%	

0lost

C		
Dead	1	
Alive	49	
	98%	

Date: 5/30/75 1057 1132 Stage: Egg Brood #:

Net length: 4 Fabric: Nylon Silk Water Velocity: .55 V.R.C.: - Time: 5 min

Total no. caught: 48-2lost

	Immediate observations	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
Silk R1 Dead	7								5			
Alive	41								46			
	82%								90%			

51-0lost

Total no. Caught: 50-4lost

	Immediate observations	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
Nylon R2 Dead	9								7			
Alive	37								45			
	74%								90%			

50-1extra

50-0lost

C Dead	0	
Alive	50	
	100%	

51-0lost

C Dead	0		
Alive	51		
	100%		

Date: 5/30/75 Stage: Egg Brood #:

1215
1245

Net length: 4 Fabric: Nylon Silk Water Velocity: 1.5 V.R.C.: — Time: 5 min

Total No. caught: 31-0 lost

		1 day			2 day				3 day		4 day	
Silk	Immediate Observation	1st obs.	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
R_1 Dead	12								25			
Alive	19								18			
	61%								72%			

0 lost

Total No. Caught: 32-0 lost

		1 day			2 day				3 day		4 day	
Nylon	Immediate Observation	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
R_2 Dead	3								2			
Alive	29								46			
	90%								95%			

0 lost

23-0 lost

C Dead	1 crushed by JOC	
Alive	22	
	100%	

C Dead	~~2~~		
Alive	61		
	100%		

Date: 6/3/75 Stage: YSL - 3days old Brood #: ?

Time: 0000

Net length: 4 Fabric: Nylon Water Velocity: .56 V.R.C.: — Time: 5min

Total No. caught: 37 - 14 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	23	0										
	Alive	14	0										
		27%	0%										

Total No. Caught: 35 - 15 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	30	0										
	Alive	5	0										
		10%	0%										

50

C	DEAD	1	0										
	ALIVE	49	0										
		98%	0%										

Not good Data
Poor technique

Date: 6/3/75 Stage: YSL Brood #:

Net length: 4' Fabric: Nylon Water Velocity: .56 V.R.C.: — Time: 10min

Total No. caught: 45-5/ost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	6	39										
	Alive	39	0										
		78%	0%										

Total No. Caught: 45-5/ost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	27	18										
	Alive	18	0										
		36%											

50

C	DEAD	2	48										
	ALIVE	48	0										
		96%											

Tank may be too light causing high latent mortality even in the control - ~~much better initial survival~~ ! ~~It's control - Much better initial survival!~~

Date: 6/3/75 0130 Stage: YSL Brood #:

Net length: 4 Fabric: Nylon Water Velocity: .56 V.R.C.: – Time: 5 min

Total no. caught: 49 - 3 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	29	20										
	Alive	20	0										

38%

Total no. Caught: 52 - 0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	7	45										
	Alive	45	0										

86%

50

C	Dead	1	49										
	Alive	49	0										

98%

Date: 6/3/75 0210 Stage: YSL Brood #:

Net length: 6 Fabric: Nylon Water Velocity: .56 V.R.C.: - Time: 5 min

Total no. caught: 45-5 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	27	18										
	Alive	18	0										

36%

Total no. Caught: 50-0 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	5	45										
	Alive	45	0										

90%

50

C	DEAD	3	47										
	ALIVE	47	0										

94%

Date: 6/3/75 Stage: YSL Brood #:

Net length: 6 Fabric: Nylon Water Velocity: .57 V.R.C.: — Time: 10min

Total no. caught: 52-2 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	2	50										
	Alive	50	0										
		96%											

Total no. Caught: 50-0 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	35	15										
	Alive	15	0										
		30%											

50

C	DEAD	6	44										
	Alive	44	0										
		88%											

Note - 2ND Sample picked has higher mortality

Date: 6/3/75 0356 Stage: YSL Brood #:

Net length: 6 Fabric: Nylon Water Velocity: 1.5 V.R.C.: - Time: 5 min

Total No. caught: 48-3 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	48	0										
	Alive	0	0										

0%

Total No. Caught: 39-11 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	30	9										
	Alive	9	0										

18%

50

C	DEAD	8	42										
	Alive	42	0										

84%

Tank Temp - 20.0°C
Flume " - 22.0°C

- Two Samples picked at same time Survival much better

Date: 6/3/75
0450

Stage: YSL

Brood #: ?

Net length: 6 Fabric: Nylon Water Velocity: 1.5 V.R.C.: — Time: 10

Total No. caught: 32 - 18 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	32	0										
	Alive	0	0										

0%

Total No. Caught: 39 - 11 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	39	~~39~~ 0										
	Alive	0	0										

0%

50

C	DEAD	0	50										
	Alive	50	0										

100%

Date: 6/3/75 0559

Stage: YSL

Brood #:

Net length: 6' Fabric: Nylon Water Velocity: 1.57 V.R.C.: Yes Time: 5 min

Total No. caught: 50 - 0 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	47	3										
	Alive	3	0										

6%

Total No. Caught: 42 - 9 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	33	9										
	Alive	9	0										

18%

51

C	Dead	3	48										
	Alive	48	0										

94%

Velocities

6' net with cone - 2.09 + 2.14 - meter between net + cone - 1/2 in net

~~Cohort~~

Date: 6/3/75 0635 Stage: YSL Brood #:

Net length: 6 Fabric: Nylon Water Velocity: 1.57 V.R.C.: Yes Time: 10min

Total No. caught: 41-13/ast

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	39	3										
	Alive	3	0										

6%

Total No. Caught: 52-0/ast

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	33	16										
	Alive	16	0										

31%

50

C	DEAD	2	48										
	Alive	48	0										

96%

Date: 6/3/75 0720 Stage: YSL Brood #:

Net length: 4 Fabric: Nylon Water Velocity: 1.57 V.R.C.: — Time: 5 min

Total No. caught: 29-21-last

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	27	2										
	Alive	2	0										

4%

Total No. Caught: 48-3/last

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	44	4										
	Alive	4	0										

8%

50

C	Dead	1	49										
	Alive	49	0										

98%

Date: 6/3/75 0758 Stage: YSL Brood #:

Net length: 4 Fabric: Nylon Water Velocity: 1.57 V.R.C.: — Time: 10 min

Total no. caught: 48 - 4 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	48	0										
	Alive	0	0										

0%

Total no. Caught: 48 - 2 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	46	2										
	Alive	2	0										

4%

52

C	DEAD	3	49										
	ALIVE	49	0										

94%

Date: 6/3/75 0840 Stage: YSL Brood #:

Net length: 4' Fabric: Nylon Water Velocity: 1.57 V.R.C.: Yes Time: 5 min

Total No. caught: 40-10/ost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	39	1										
	Alive	1	0										

2%

Total No. Caught: 47-5/ost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	44	3										
	Alive	3	0										

6%

50

C DEAD	1	49										
ALIVE	49	0										

98%

Date: 6/3/75 0910 Stage: YSL Brood #:

Net length: 4 Fabric: Nylon Water Velocity: 1.57 V.R.C.: Yes Time: 10min

Total no. caught: 48- 2lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	44	4										
	Alive	4	0										

8%

Total no. Caught: 53-0lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	53	0										
	Alive	0	0										

0%

54

C	DEAD	1	53									
	Alive	53	0									

98%

Hatch May 31

Date: 6/16/75 1056 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.5 V.R.C.: — Time: 5min

Total No. caught: 43 lost 7

50	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1 Dead	22	21										
Alive	21	0										
	42%											

Total No. Caught: 45-4lost

	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2 Dead	32	13										
Alive	13	0										
	26%											

	11AM	5PM		9AM	5PM		9AM	5PM	Terminate		
C DEAD	1	3	1	9	6		16	0			
ALIVE	49	46	45	34	28		12	12			
	98%	92%	90%	68%	[illegible]%		24%	24%			

Date: 6/16/75 1143 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.51 V.R.C.: — Time: 5 min

Thermal shock

Total No. caught: 47 lost 3

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	40	7										
	Alive	7	0										
		14%											

Total No. Caught: 42-8 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	30	12										
	Alive	12	0										
		24%											

22°C to 34°C in 30 sec.
control not shocked

C DEAD	3	41	41		3	2		1				
ALIVE	47	6	6		3	1		0				
	94%	12%	12%		6%	2%		0%				

Date: 6/16/75 1331 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.51 V.R.C.: — Time: 10min

Total no. caught: 48-2 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	43	5										
	Alive	5	0										
		10%											

Total no. Caught: 51-0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	40	11										
	Alive	11	0										
		22%											

C	DEAD	1	2	0		12	9		21			
	ALIVE	49	47	47		35	26		5			
		98%	94%	94%		70%	[illegible]%		10%			

Date: 6/16/75 1412 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.51 V.R.C.: — Time: 10 min

Thermal shock

Total no. caught: 47-3 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	47											
	Alive	0											
		0%											

Total no. Caught: 44-6 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	44											
	Alive	0											
		0%											

21.5°C to 37°C in 30 sec
Control also exposed

C	DEAD	15	26	2		4	3					
	ALIVE	35	9	7		3	0					
		70%	18%	14%		6%	0%					

Date: 6/16/75 1505 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 151 V.R.C.: Yes Time: 5 min

Total no. caught: 48 - 3 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	44	4										
	Alive	4	0										
		8%	0%										

Total no. Caught: 48 - 1 lost 3

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	17	23	0		3	5						
	Alive	31	8	8		5	0						
		60%	16%	16%		10%	0%						

C	DEAD	1	11	0		14	10		8			
	Alive	49	38	38		24	11		6			
		98%	76%	76%		48%	[illegible]%		12%			

Date: 6/16/75 1545 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.51 V.R.C.: Yes Time: 5 min Thermal shock

Total No. caught: 47-3 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	21	26										
	Alive	26	0										
		52%	0%										

Total No. Caught: 48-2 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	27	21										
	Alive	21	0										
		42%	0%										

Temp - 21°C to 31.5 in 30 sec
control exposed.

C DEAD	1	5	0		6	5		10			
Alive	50	45	45		39	38		24			
	98%	88%	88%		76%	76%		47%			

Date: 6/16/75 1622 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.51 V.R.C.: Yes Time: 10min

Total no. caught: 52-0/ost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	45	7										
	Alive	7	0										
		13%	0%										

Total no. Caught:

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	25	21	0		1							
	Alive	22	1	1		0							
		44%	2%	2%		0%							

C	DEAD	2	0	0		12	1		17			
	Alive	48	48	48		36	35		18			
		96%	96%	96%		72%	70%		36%			

Date: 6/16/75 1712 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.51 V.R.C.: Yes Time: 10min

Thermal shock

Total No. caught: 49-1lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	38	11										
	Alive	11	0										
		22%	0%										

Total No. Caught: 42-8lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	34	7	1									
	Alive	8	1	0									
		16%	2%	0%									

C	DEAD	4	5	0		7	0		10				
	Alive	50	45	45		38	38		28				
		93%	83%	83%		70%	70%		52%				

Temp. 22°C → 34°C

30 sec. control exposed

Date: 6/16/75 1907 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: .059 V.R.C.: Yes Time: 5 min

Total No. caught: 39-11/ost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	17	18	0		2	0		1	0			
	Alive	21	4	4		2	2		1	1			
		42%	8%	8%		4%	4%		2%	2%			

Total No. Caught: 47-3/ost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	12	10	0		5	1		6	0			
	Alive	35	25	25		20	19		13	13			
		70%	50%	50%		40%	38%		26%	26%			

C	DEAD	12	1	0		12	0		16	0			
	ALIVE	38	37	37		25	25		9	9			
		76%	74%	74%		50%	50%		18%	18%			

Saw larvae shoot out between cone & net rim!

Date: 6/16/75 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 0.59 V.R.C.: Yes Time: 10 min

Total No. caught: 49-lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	13	4	0		32	fished spilled						
	Alive	36	32	32		0							
		72%	64%	64%		0%							

Total No. Caught: 50-0lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	21	19	0		8	2						
	Alive	29	10	10		2	0						
		58%	20%	20%		10%	0%						

C	DEAD	4	27	3		7	1	5	0				
	ALIVE	48	21	18		11	10	5	5				
		98%	42%	36%		22%	20%	10%	10%				

Date: 6/16/75 2037 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 0.55 V.R.C.: — Time: 5 min

Total no. caught: 25-0 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	8	11	0		2	3		1				
	Alive	17	6	6		4	1		0				
		68%	24%	24%		16%	4%		0%				

Total no. Caught: 25-0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	4	7	0		4	0		2	0			
	Alive	21	14	14		10	10		8	8			
		84%	56%	56%		40%	40%		32%	32%			

C	DEAD	5	4	1		3	0		8	0			
	Alive	20	16	15		12	12		4	4			
		80%	64%	60%		48%	48%		16%	16%			

Running out of fish cut rep. & control to 25

Date: 6/16/75 2059

Stage: PYSL

Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 0.53 V.R.C.: — Time: 10min

Total No. caught: ~~[illegible]~~ 25

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	5	11	0		3	1						
	Alive	15	4	4		1	0						
		60%	16%	16%		4%	0%						

Total No. Caught:

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	7	7	0	-	3	1		3				
	Alive	14	7	7		4	3		0				
		56%	28%	28%		16%	12%		0%				
C	DEAD	2	1	0		3	0	-	0	0			
	Alive	23	22	22		19	19		19	19			
		92%	88%	88%		76%	76%		76%	76%			

Date: 6/16/75 Stage: PYSL Brood #: 16

2134

Net length: 6' Fabric: Nyl. Water Velocity: 0.53 V.R.C.: — Time: 5 A/10

Total no. caught: 1 lost 3% lost

5 min

	Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1 Dead	30											
Alive	0											

Total no. Caught: 30 - 1 lost - 36%

10 min

	Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2 Dead	29											
Alive	0											

DEAD Fish RUN

Date: 6/16/75 2206 Stage: PYSL Broot #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.49 V.R.C.: - Time: 5410

Total no. caught: 5-lost 17%

		1day			2day			3day			4day	
10min	Immediate observation	1st obs.	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
R1 Dead	25											
Alive	0											

Total no. Caught: 3 lost 10%

		1day			2day			3day			4day	
5min	Immediate Observation	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
R2 Dead	27											
Alive	0											

DEAD Fish RUN

Date: 6/16/75 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 3.01 V.R.C.: — Time: 5 min

Total No. caught: 0/0st

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	25											
	Alive	0											

Total No. Caught:

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	26											
	Alive	0											

Heavy debris in codend.
NO survival.

Date: 6/16/25 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 3.01 V.R.C.: Yes Time: 5min

Total no. caught: 23 · 2 lost

R1 25

	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
Dead	23											
Alive	0											

Total no. Caught: 25 = 0 lost

R2 25

	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
Dead	25											
Alive	0											

Date: 6/23/75
1235

Stage: PYSL
23 days old

Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 0.5 V.R.C.: - Time: 5min.

Total No. caught: 29. - 1 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead	16	13										
	Alive	13	0										

43%

Total No. Caught: 0 - lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead	20	10										
	Alive	10	0										

33%

C	Dead	3	27		
	Alive	27	0		

90%

After 1st day all dead

Date: 6/23/75 1308 Stage: PYSL Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 0.5 V.R.C.: — Time: 10min

Total No. caught: 0 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	15	15										
	Alive	15	0										

50%

Total No. Caught: 0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	19	18										
	Alive	18	0										

49%

C	DEAD	4	28		
	Alive	28	0		

82%

Date: 6/23/75 1402 Stage: PYSL Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 0.5 V.R.C.: Yes Time: 5min.

Total No. caught: 35 = 4 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	17	18										
	Alive	18	0										

46%

Total No. Caught: 0 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	23	8										
	Alive	8	0										

34%

C	Dead	4	26		
	Alive	26	0		

87%

Date: 6/23/75 1439 Stage: PYSL Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 0.5 V.R.C.: Yes Time: 10min

Total no. caught: 30-1 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	18-1	12										
	Alive	12	0										
		40%											

Total no. Caught: 0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	34-13	9										
	Alive	9	0										
		30%	0										

C	DEAD	0	30		
	Alive	30	0		
		100%			

Date: 6/23/25 1525 Stage: PYSL Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 1.41 V.R.C.: Yes Time: 5 min

Total No. caught: 0 lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	28-2	6										
	Alive	6	0										

19%

Total No. Caught: 0 lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	30-13	14										
	Alive	14	0										

45%

C	DEAD	15-7	17		
	Alive	17	0		

68%

Cut control to 25

Date: 6/23/75 1606 Stage: PYSL Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 1.41 V.R.C.: Yes Time: 10min

Total no. caught: 28-2lost

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	27-5	1										
	Alive	1	0										

4%

Total no. Caught: 0lost

		Immediate observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	28-3											
	Alive	0											

0%

C	DEAD	2-2	25	
	ALIVE	25	0	

100%

Cut all samples to 25

Temp. check

Date: 6/23/75 1642 Stage: PYSL Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 1.41 V.R.C.: — Time: 5min.

Total No. caught: 21ost -29

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	23-4	4										
	Alive	4	0										

16%

Total No. Caught: 0lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	15	10										
	Alive	10	0										

40%

C	DEAD	15-R	11		
	Alive	21	0		

84%

~~uneperimented fish during last~~ fast 1

Date: 6/23/75 1730

Stage: PYSL

Brood #: 16

Net length: 4' Fabric: Nyl. Water Velocity: 1.41 V.R.C.: – Time: 10 min

Total No. caught: 0 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	35-11	1										
	Alive	1	0										

4%

Total No. Caught: 0 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	31-11	6										
	Alive	6	0										

34%

C	DEAD	9-4	20	
	Alive	20	0	

80%

Date: 6/23/25 2013 Stage: PYSL Brood #: C6

Net length: 4' Fabric: Nyl Water Velocity: 3.0 V.R.C.: — Time: 5 min

Total No. caught: 0 lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	25											
	Alive	0											

0%

Total No. Caught: 0 lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	25											
	Alive	0											

0%

C	Dead	0	25		
	Alive	25	0		

100%

Tremendous amount of debris in Nets!

Date: 6/23/75 Stage: PYSL Brood #: 16

2039

Net length: 4' Fabric: Nyl. Water Velocity: 3.0 V.R.C.: Yes Time: 5 min

Total No. caught: 0/ost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	25											
	Alive	0											

0%

Total No. Caught: 0/ost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	25											
	Alive	0											

0%

C	Dead	4	21	
	Alive	21	0	

87%

Date: _____ Stage: _____ Brood #: _____

Net length: Fabric: Water Velocity: V.R.C.: Time:

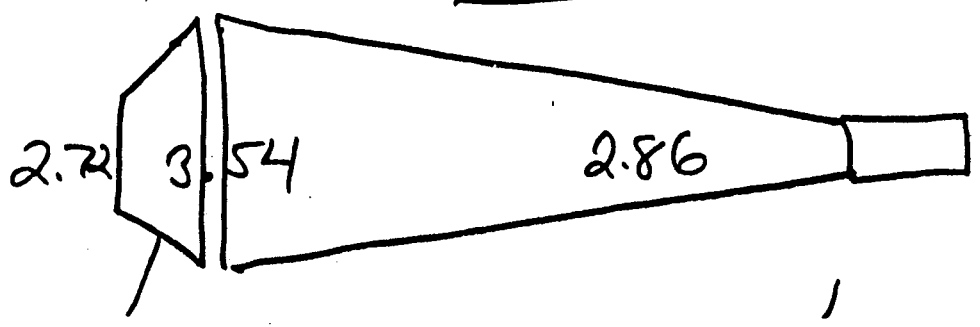
Total No. caught: _____

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead												
	Alive												

Total No. Caught: _____

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead												
	Alive												

Measurment



Date: 6/30/75
1115

Stage: PYSL
30 days old
(JGU.)

Brood #:

Net length: 6′ Fabric: Nyl. Water Velocity: 1.5 V.R.C.: — Time: 5 min

Total no. caught: 25-0lost

		Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1	Dead	0											
	Alive	25											
		100%											

Total no. Caught: 21-0lost

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2	Dead	1											
	Alive	20											
		95%											

C	DEAD	0		
	ALIVE	20		
		100%		

Date: 6/30/75 1150 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.5 V.R.C.: Yes No Time: 5 min

Total no. caught: 20 - 0 lost

NO CONE	Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1 Dead	0											
Alive	20											
	100%											

Total no. Caught: 20 - 0 lost

CONE	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2 Dead	0											
Alive	20											
	100%											

C			
DEAD	0		
Alive	20		
	100%		

Much more debris caught in net without CONE.

Date: 6/30/75 1323 Stage: PYSL Brood #: 16

Net length: 6' Fabric: Nyl. Water Velocity: 1.50 V.R.C.: Yes No Time: 10min

Total no. caught: 20 - 0 lost

NO CONE

	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1 Dead	17											
Alive	3											

15%

Total no. Caught: 20 - 0 lost

CONE

	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2 Dead	4											
Alive	16											

80%

C DEAD	0			
Alive	21			

100%

Date: 6/30/75 1400 Stage: PYSL Brood #: 10

Net length: 6' Fabric: Nyl. Water Velocity: 1.5 V.R.C.: Yes / No Time: 10min

Total no. caught: 21-0 lost

NO CONE

	Immediate Observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R1 Dead	10											
Alive	11											

52%

Total no. Caught: 18-2 lost

CONE

	Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R2 Dead	4											
Alive	14											

70%

C DEAD	0			
ALIVE	21			

100%

Repeat- because off diff. between the two net survivals.

Date 6/30/75 Stage: Brood #:

Net length: Fabric: Water Velocity: V.R.C.: Time:

Total No. caught:

		Immediate observation	1day 1st obs.	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_1	Dead												
	Alive												

Total No. Caught:

		Immediate Observation	1day 1st	1day 2nd	1day 3rd	2day 1st	2day 2nd	2day 3rd	3day 1st	3day 2nd	3day 3rd	4day 1st	4day 2nd
R_2	Dead												
	Alive												

Velocity Readings - ft./sec 6' net - Discharge Cone

In opening of net	Behind CONE	3' in net
1.37	2.20	0.59
1.90	2.73	0.61
2.94	3.41	0.90
0.94	1.50	0.29

XVII. Question related to the Texas Instruments "1974 year-class report for the multiplant impact study of the Hudson River Estuary," May 1977

XVII 1. Provide the values of the points in Table VI-1 of Volume I.

Please explain the reporting philosophy which underlies the failure to provide the actual values of these points in the original report. Explain why the 1975 data are not yet available.

Response: The values of the points in Table VI-1 of Volume 1 can be obtained from the next to last column in Table IV-2 of Volume 1. However, to aid the NRC in obtaining these values, see the modified version of Table VI-1 below.

Table VI-1, (modified)

Letter Codes for 11 New Data Points Added to Ricker Type Stock Recruitment Curve for Hudson River Striped Bass (Figure VI-2)

Data Point Letter Code	Stock Recruitment Years	Striped Bass Yield per Effort Values* Stock (Parent)		Recruits (Progeny)
A	1942-47	720	-	412
B	1947-52	412	-	725
C	1949-54	102	-	1159
D	1950-55	122	-	1864
E	1951-56	419	-	2651
F	1954-59	1159	-	2422
G	1955-60	1864	-	4665
H	1956-61	2651	-	2696
I	1959-64	4494	-	1528
J	1968-73	3663	-	4272
K	1969-74	4965	-	1429

* (From Table IV-2, p IV-14, 1974 year class report, Vol. 1)

To reiterate, the actual values for these 11 new data points were in fact provided in the original report, i.e. in Table IV-2 of Volume 1. The 1975 data were not available when the draft version of this report (1974 Year Class) was written. Since the purpose of the 1974 Year Class report was primarily to analyze and discuss the data collected through 1974 and early 1975, the commercial catch data from 1975 were not included in the final version of the 1974 Year Class report published in May 1977. The 1975 commercial fishery data for striped bass were included in the report edited by James McFadden and dated January 1977.