Food habits of Striped bass and white catfish in Clifton Court Forebay.

FOREWARD

Clifton Court Forebay (742 ha) is flooded at the discretion of State Water Project operators. To allow water exports of sufficient quality, the forebay is flooded on selected tides. Flooding the forebay entrains eggs, larvae, juvenile, sub-adult and adult fishes that are present in Old River. Because of patterns in water export, water is drafted from throughout the Sacramento River-SanJoaquin River Delta to Old River; fishes from these drainages are thus entrained into the forebay.

DRAFT

The Skinner Fish Facility is an entrained fish salvage facility located between Clifton Court Forebay and the Banks Pumping Plant. The facility is operated continuously during water exports, and many fish are diverted from the export flow (salvaged) by behavioral barriers (louvers) at the facility. Salvaged fish are trucked from Clifton Court Forebay and released at sites throughout the Delta.

Extensive work on loss to fishes entrained into Clifton Court Forebay began with a study originally intended to address aspects the proposed Peripheral Canal. Using mark-recapture methods, Schaffter (1978) estimated 97% loss to juvenile chinook salmon crossing the forebay (pre-screen loss). That level of pre-screen loss was not anticipated, and additional work was conducted to quantify pre-screen losses and mechanisms ~~of~~ for pre-screen loss. Results from early work at ~~the forebay~~ Clifton Court Forebay on estimates of pre-screen loss (Hall 1980; others summarized in Gingras 1997), fish species composition (Mecum 1980; Kano 1990), abundance (Kano 1990), and behavior (Bolster 1986; Collins *et al* 1997) indicated that predation by sub-adult and adult striped bass was a major cause of pre-screen loss to entrained fishes, and suggested mitigative measures to reduce pre-screen losses.

Large-scale predator-sized striped bass removal (predator removal) was among the mitigative measures suggested to reduce pre-screen loss at Clifton Court Forebay. In parallel with the development of a proposal to use commercial fishers in a predator removal program, the field programs reported in this publication and in Gingras and McGee (1997) were implemented to facilitate and/or assess the feasibility of predator removal. The field programs reported here were terminated in 1995, when planning for a predator removal program was suspended.

FOOD HABITS OF STRIPED BASS, WHITE, AND CHANNEL CATFISH AT CLIFTON COURT FOREBAY DURING 1983-84 AND 1993-1995.

George Edwards, Department of Fish and Game

Abstract—The objective of this study was to determine whether the food habits of predator-sized striped bass in the Clifton Court Forebay varied by season, prey availability or environmental factor (e.g., water temperature, water clarity). The stomach contents of live predatory fish captured in Clifton Court Forebay were removed by gastric lavage, preserved, sorted, identified, and measured to 0.1 mL. The diet of striped bass in Clifton Court Forebay was similar to the diet of striped bass in the Delta; juvenile striped bass fed primarily on invertebrates while sub-adult and adults fed on fish. The primary prey items of striped bass in Clifton Court Forebay were threadfin shad (*Dorosoma petenense*) and smaller striped bass. Channel catfish and white catfish were also sampled; their diet in Clifton Court Forebay was similar to the diet of channel catfish and white catfish in the Delta, primarily invertebrates and plant material.

INTRODUCTION

Food habits of predator-sized striped bass were the primary focus of this study because earlier work suggested that large numbers of these fish occurred in Clifton Court Forebay (Hall 1980, Kano 1990), and because striped bass are efficient predators in impoundments (Axon *et al* 1985). The primary objectives of this study were to determine whether the food habits of predator-sized striped bass in Clifton Court Forebay varied by season, prey availability or environmental factor (e.g., water temperature, water clarity). Previously unpublished data on the food habits of predatory fish in Clifton Court Forebay during 1983 and 1984 are incorporated in this report.

METHODS

Sampling began in 1983 and continued through 1984, began again in 1993 and continued through August 1995. Fish were captured monthly, except in 1995 when sampling was conducted quarterly. Sampling was generally independent of other IEP programs, although on occasion striped bass were randomly sampled from fish captured during mark-recapture studies. Sampling was conducted during daylight, usually from 0900 hours to 1600 hours. When possible, twenty striped bass from each of the following size classes were sampled: 180-255 mm, 255-380 mm, and > 380 mm.

Fish were captured by boat at six different areas in Clifton Court Forebay. Most sampling was conducted in the two locations where striped bass concentrate; near the radial gates and in the outlet channel. Other areas were sampled if (1) striped bass could not be captured in acceptable numbers, and/or (2) the proper size classes of striped bass could not be captured.

Fish were collected by gill net (61 m by 3.6 m with variable mesh, 6.4-10.2 cm stretched), hook and line, beach seine (305 m with 3.8 cm stretched mesh), and Kodiak trawl (183 m by 3.7 m). Gill nets were fished for 10 to 30 minutes, depending on environmental conditions and the number of fish being captured. Angling was conducted during gill net sets or when other methods of fish capture proved ineffective or too stressful on predatory fish. Beach seines were usually set 30 to 100 m from shore and pulled to shore using boats and winches. Kodiak trawls were pulled between two boats and hauled on shore by field personnel. In all cases, fish were quickly removed from the sampling gear and placed in an aerated holding tub.

The stomach contents of live predatory fish were removed by pumping water into the fish's stomach and flushing the contents into a jar (Figure 1). This method is similar to the "gastric lavage" method described by Light *et al* (1983). A waterproof label was annotated with the date, time, site number, fish species, fish length, fish number and capture gear before being placed in the jar. Samples were then preserved in 10% formalin (Bowen 1992). Samples were analyzed in the laboratory at Bay-Delta Division facility in Stockton.

Stomach contents were sorted and identified, and the volume of the contents measured to the nearest 0.1 mL. The results were recorded on a data sheet and entered into a computer database. One of every ten samples was rechecked to ensure proper identification and volumetric measurement of food items. Any discrepancies were corrected in the database.

RESULTS AND DISCUSSION

We examined the stomach contents of 1,990 striped bass (Figure 2) and found most fish in the stomachs of striped bass were too digested to identify to genus or species (using methods

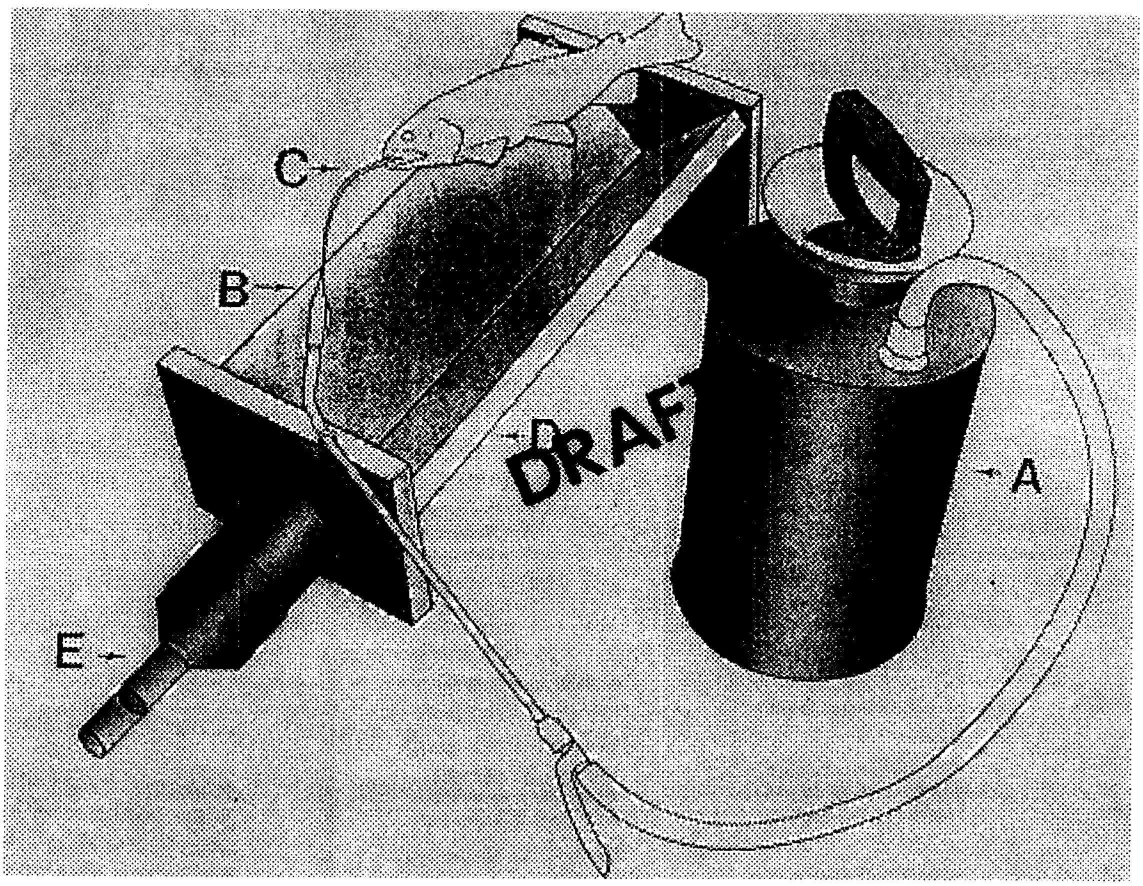

Fig 1

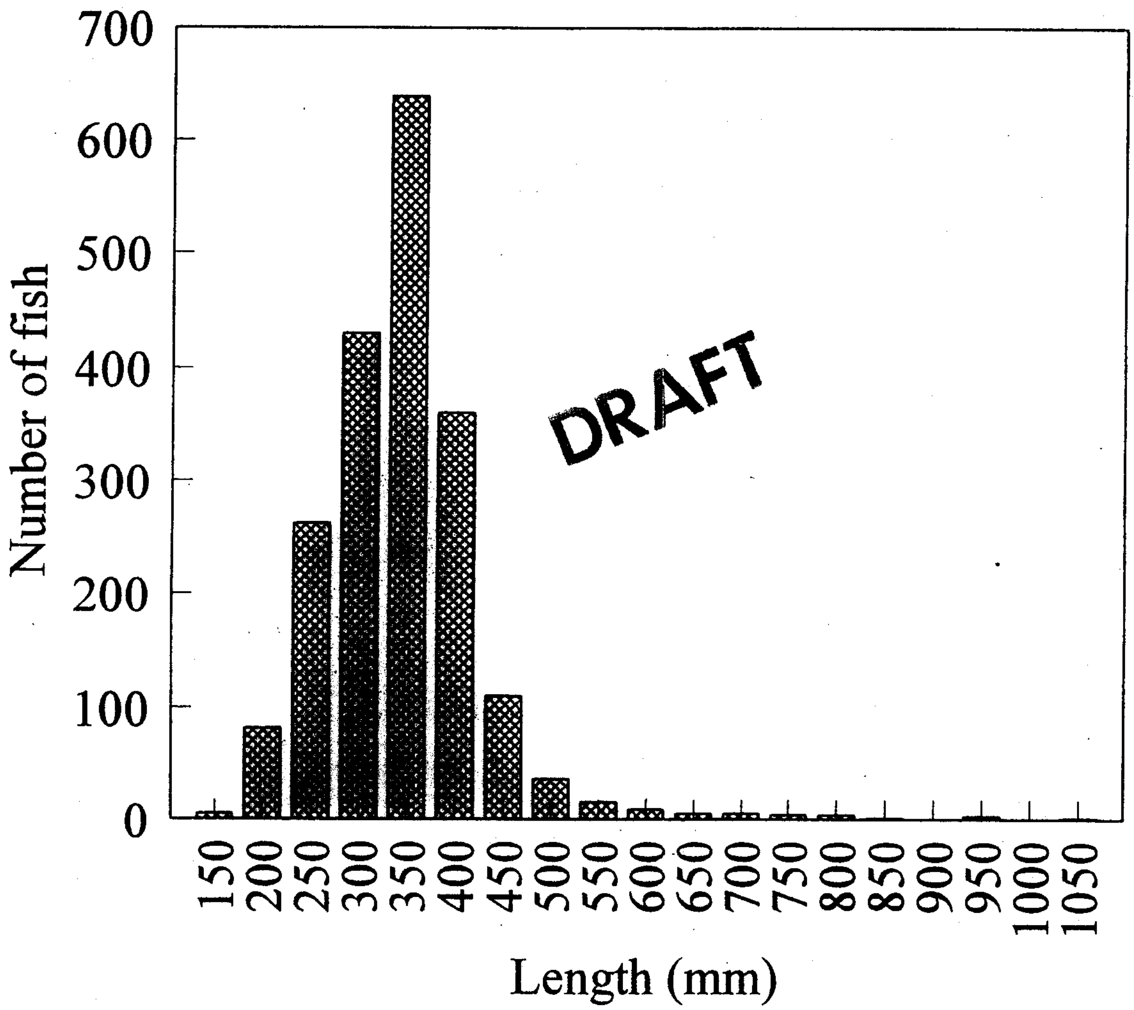
700
600
500
400
300
200
100
0
Number of fish
DRAFT
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
Length (mm)

Fig. 2

available to us), these were noted as "unidentifiable fish contents". Water temperatures were often warm enough to allow digestion of food within several hours (Hall 1977; He 1993; Buckle *et al* 1996).

The diet of striped bass in Clifton Court Forebay was similar to the diet of striped bass in the Delta (Stevens 1966; Thomas 1967); juvenile striped bass fed primarily on invertebrates while sub-adult and adults fed on fish. The primary prey items of striped bass in the forebay were threadfin shad (*Dorosoma petenense*), and smaller striped bass (Table 1). Other fishes common in the stomach contents of striped bass were yellowfin goby (*Acanthogobius flavimanus*), shimofuri goby (*Tridentiger bifasciatus*, previously identified as chameleon goby; Matern and Fleming 1995), American shad (*Alosa sapidissima*), bigscale logperch (*Percina macrolepida*), and lamprey (*Lampetra sp.*). Only two instances of predation on salmonids were observed; one chinook salmon and one steelhead trout (*Oncorhynchus mykiss*) were among in the stomach contents in of striped bass 1994.

Table 1. Total incidence and volume of food items found in the stomachs of 1,990 striped bass (1983-84 and 1993-95) sampled from Clifton Court Forebay.

Food Item	Incidence Number	Volume (mL)
Fish		
chinook salmon	1	20.0
steelhead rainbow trout	1	150.0
striped bass	60	366.8
white catfish	1	3.0

American shad	8	42.8
threadfin shad	106	1641.8
squawfish	1	1.8
Sacramento blackfish	1	195.0
bluegill	3	100.0
bigscale logperch	7	22.0
yellowfin goby	23	212.2
inland silverside	2	5.9
lampreys	8	19.7
shimofuri goby	17	34.3
unidentifiable fish	1092	2190.1
Invertebrates		
amphipods	271	95.9
neomysids	18	4.4
cladocerans	11	2.9
other crustaceans	143	52.1
odonates	25	15.1
chironomids	36	5.1
ephemeroptera	2	0.1
other insects	61	15.8
clams	35	30.8
snails	1	0.1
annelids	22	3.2
other invertebrates	40	22.0
Plant material	542	44.0
Miscellaneous	155	15.2

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*Note: An incidence means that a food item was found one or more times in the stomach contents of a fish.

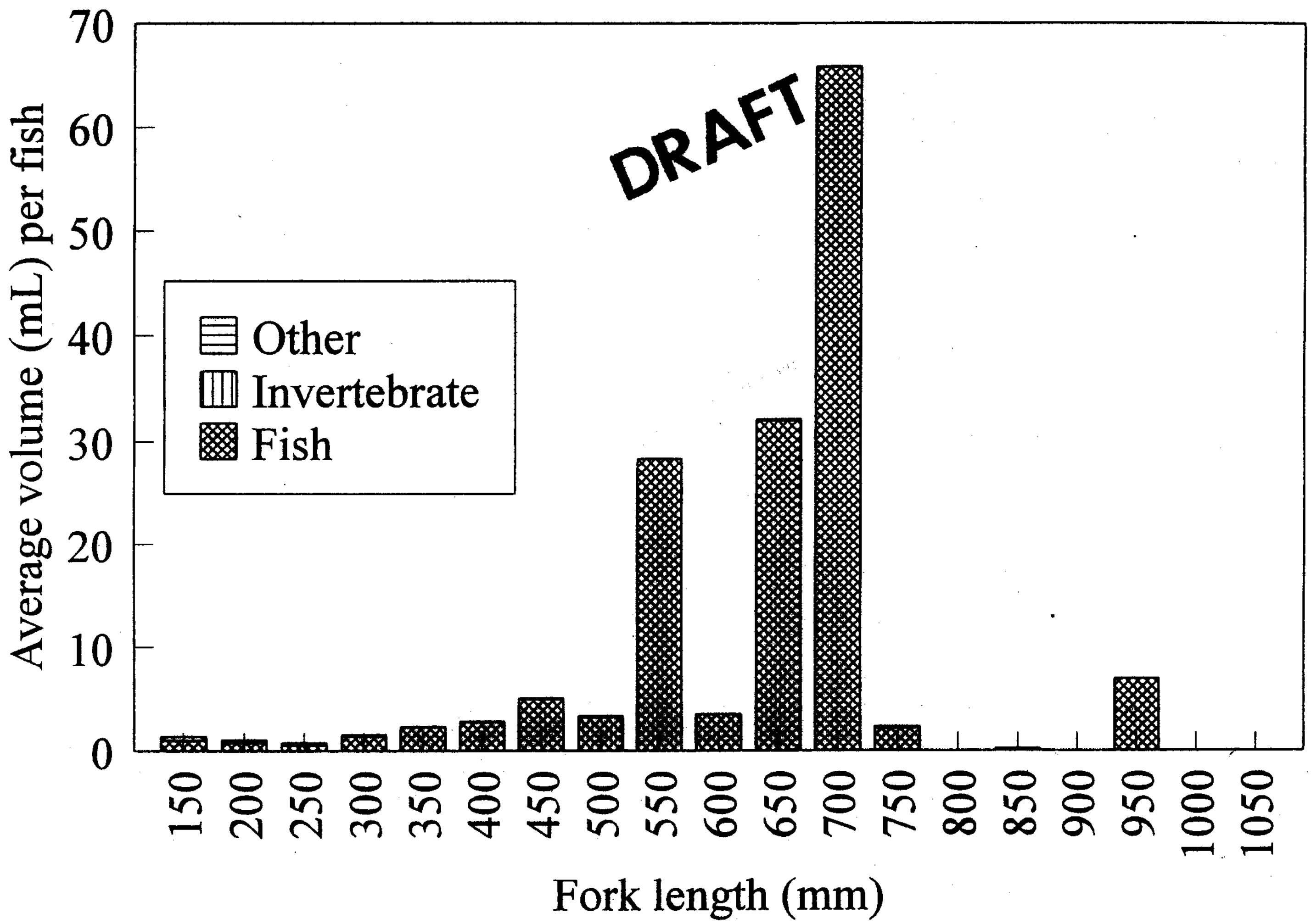
By volume, fish were 94% of the diet of striped bass in Clifton Court Forebay (Figure 3). This result is similar to the proportion of striped bass feeding on fishes elsewhere in the Delta. Among striped bass sampled near Pacific Gas and Electric Company's Pittsburg power plant, fish was 94% of the diet by volume for striped bass more than 40.6 cm and 71% of the diet by volume for striped bass 30.5-40.6 cm in length (Gritz 1971). As many as 78% of striped bass sampled at the Tracy Fish Facility had fish remains in their stomachs (Liston *et al* 1994). The similarity in piscivory of striped bass captured inside Clifton Court Forebay to striped bass captured outside Clifton Court Forebay can be explained by one or more of the following hypotheses:

* Piscivory by striped bass *is increased* due aspects of Clifton Court Forebay operation and structure, and sampling (inside or outside Clifton Court Forebay) was not of sufficient intensity to show the difference.

* Piscivory by striped bass *is not increased* due aspects of Clifton Court Forebay operation and structure.
* The forebay is an open system (Healey, this publication; Gingras, this publication), and many of the striped bass sampled may have fed outside the forebay immediately before capture.

A monthly striped bass piscivory ratio, R, was calculated using the following formula: $R = F/T$, where F is the count of striped bass with fish in their stomachs, and T is the total count of striped bass sampled. Mean piscivory ratio was significantly lower during the 1983-84 sampling period than during the 1993-95 sampling period ($P < 0.01$). This difference could be due to several factors:

* Differences in the length distribution of fish sampled between year groups (Figure 4) — a


DRAFT
Other
Invertebrate
Fish
Average volume (mL) per fish
Fork length (mm)
0
10
20
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40
50
60
70
150
200
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400
450
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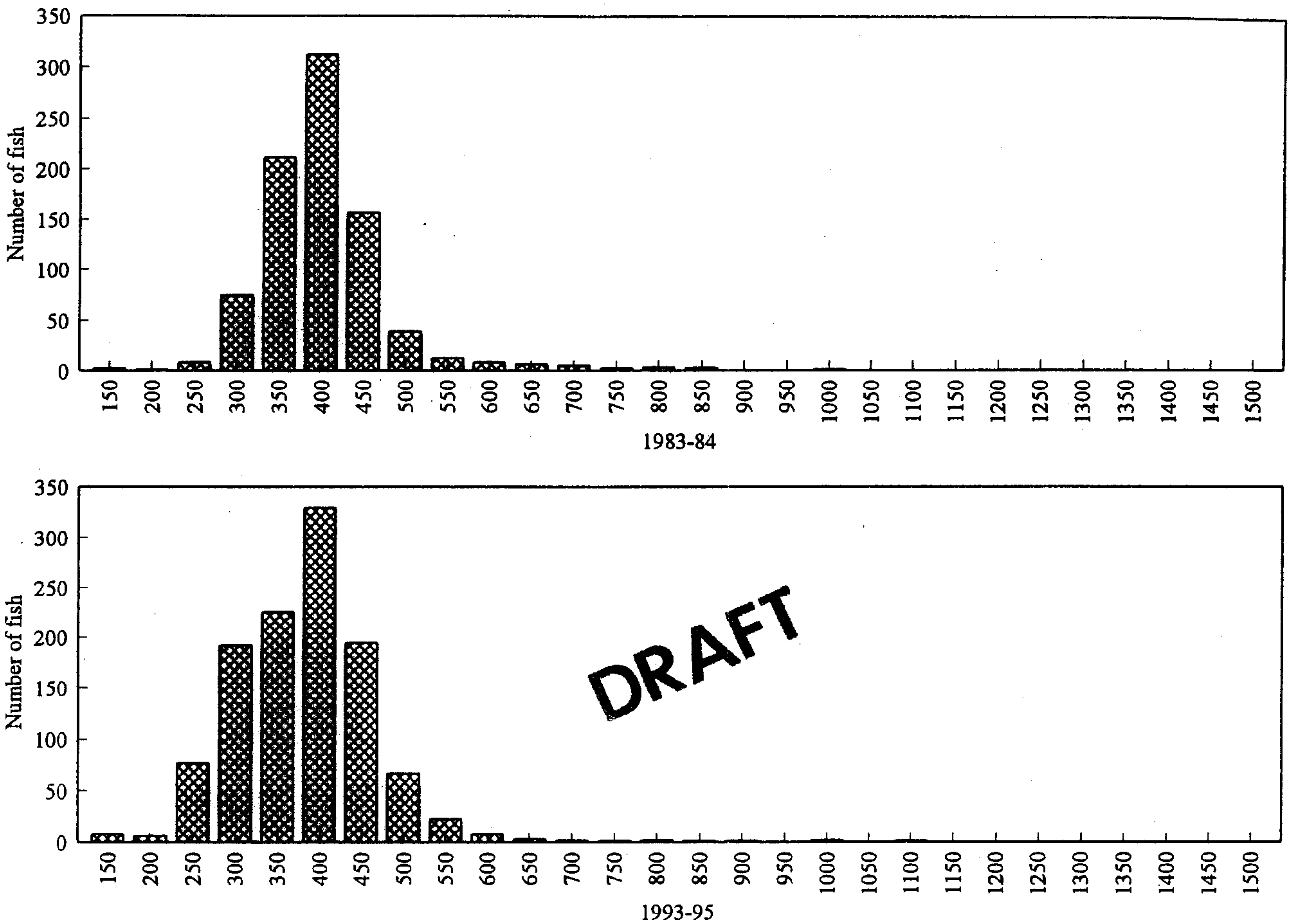
Figure 3


Number of fish
0
50
100
150
200
250
300
350
150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500
1983-84
Number of fish
0
50
100
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200
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150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500
1993-95
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Fig 4

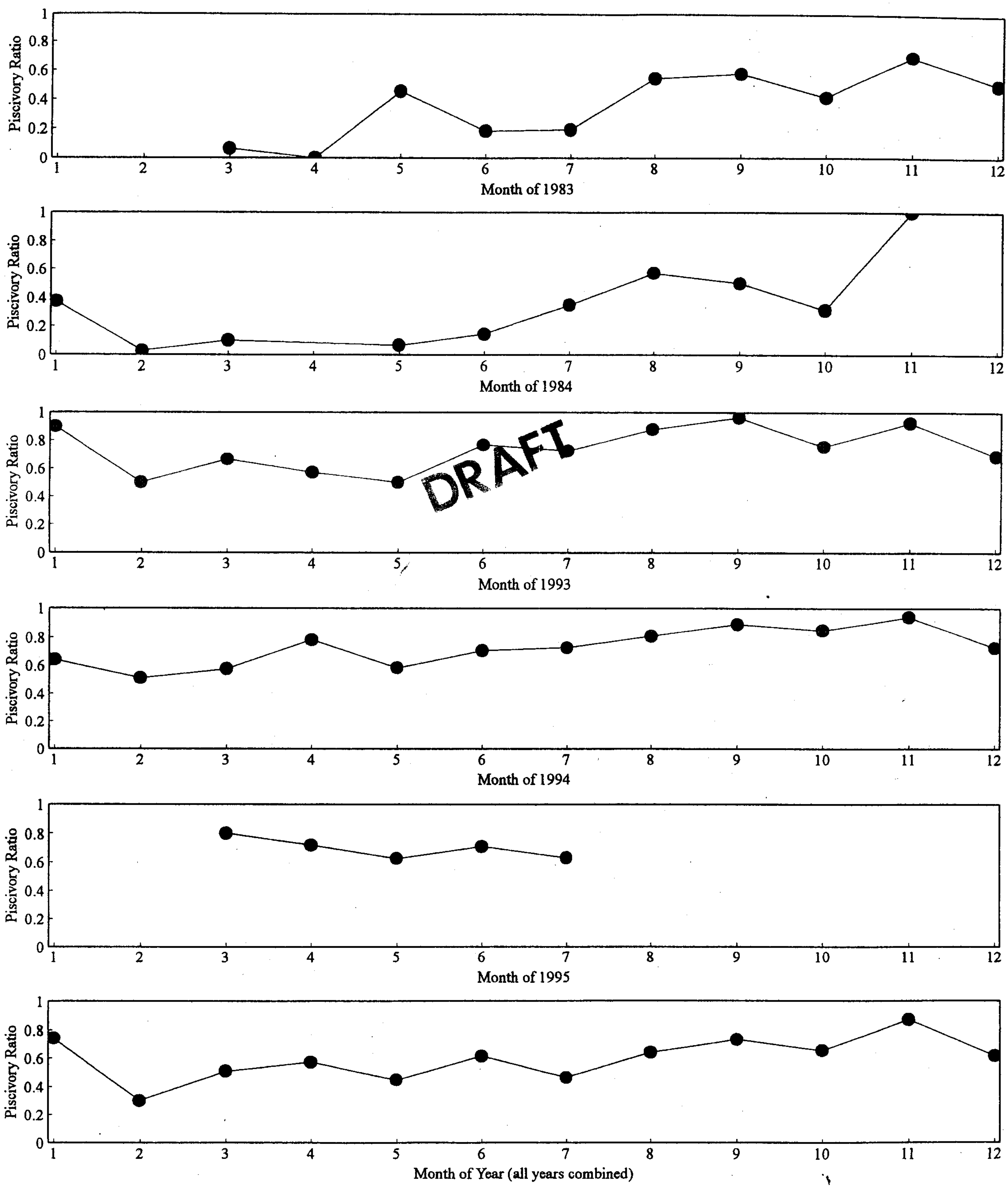
Piscivory Ratio
Month of 1983
Piscivory Ratio
Month of 1984
Piscivory Ratio
DRAFT
Month of 1993
Piscivory Ratio
Month of 1994
Piscivory Ratio
Month of 1995
Piscivory Ratio
Month of Year (all years combined)

Fig 5

two-sample *t*-test showed a significant difference ($p < 0.001$) between the mean lengths of fish sampled in 1983-84 and those sampled in 1993-95. The mean length for fish in the 1983-84 year group was 377 mm (SD = 80.5) while the mean length for the 1993-95 group was 359 mm (SD = 91.6).

* Differences in the intensity and/or uniformity of sampling between year groups — 845 striped bass were sampled in 1983-84 compared with 1,145 in 1993-95.
* Availability of preyfish — a factor influenced by water year type and State Water Project Operations.

There is a seasonal trend in fish predation by striped bass, with highest rates of predation occurring from June to November. A simple linear regression of the piscivory ratios for the 1983-84 study show an increasing trend in fish predation ($r^2 = 0.48$) from February through November (Figure 5, Table 2) with a dramatic increase occurring after May. In the 1993-95 studies, piscivory ratios appear to be fairly constant with peaks late in the year (Figure 5 and Table 3), however, the linear regression of the piscivory ratios showed only a weak relationship ($r^2 = 0.20$) by month during this period. Although the overall trend is probably due to the abundance of prey-sized striped bass, threadfin shad, American shad and other young juvenile fish from June-November, monthly piscivory ratios were not significantly correlated to monthly total Skinner Fish Facility salvage (the only long-term monitoring program that estimates the abundance and species composition of small fish moving through Clifton Court Forebay).

A simple linear regression of the monthly piscivory ratios against mean monthly temperatures and against electroconductivity measurements for 1993 and 1994 explained very little of the variance in piscivory ($R^2 < 0.50$). Water clarity was not analyzed because secchi depth and turbidity data were not collected concurrent to stomach sampling data; water clarity can vary hourly due to inflows from the radial gates, pumping regimes, and the resuspension of particles due to wave action caused by a sudden wind.

Table2. Monthly piscivory ratio for striped bass at Clifton Court Forebay, 1983-84.

Year	Month	Number of striped bass with fish in stomach	Total number of striped bass sampled	Piscivory ratio
1983	March	2	31	0.07
1983	April	0.00	15	0.00
1983	May	29	64	0.45
1983	June	7	38	0.18
1983	July	15	78	0.19
1983	August	69	127	0.54
1983	September	15	26	0.58
1983	October	22	53	0.42
1983	November	35	50	0.70
1983	December	15	30	0.50
1984	January	13	35	0.37
1984	February	1	36	0.03
1984	March	2	20	0.10
1984	May	1	15	0.07
1984	June	2	14	0.14
1984	July	42	121	0.35
1984	August	16	28	0.57
1984	September	22	44	0.50

1984	October	5	16	0.31
1984	November	3	3	1.00

Table 3. Monthly piscivory ratio for striped bass at Clifton Court Forebay, 1993-95.

Year	Month	Number of striped bass with fish in stomach	Total number of striped bass sampled	Piscivory ratio
1993	January	81	90	0.90
1993	February	1	2	0.50
1993	March	46	69	0.67
1993	April	12	21	0.57
1993	May	5	10	0.50
1993	June	70	91	0.77
1993	July	59	81	0.73
1993	August	22	25	0.88
1993	September	52	54	0.96
1993	October	44	58	0.76
1993	November	74	80	0.93
1993	December	20	29	0.69
1994	January	9	14	0.64
1994	February	23	45	0.51
1994	March	19	33	0.58
1994	April	18	23	0.78
1994	May	14	24	0.58
1994	June	41	58	0.71
1994	July	16	22	0.73
1994	August	38	47	0.81
1994	September	8	9	0.89
1994	October	50	59	0.85
1994	November	47	50	0.94

1994	December	8	11	0.73
1995	March	24	30	0.80
1995	April	18	25	0.72
1995	May	5	8	0.63
1995	June	22	31	0.71
1995	July	29	46	0.63

* No sampling was done in January or February 1995.

A total of 581 catfish were captured and their stomach contents examined. White (*Ictalurus catus*) and channel (*I. punctatus*) catfish, abundant and large enough (185-674 mm) to act as predators on small fish in Clifton Court Forebay, fed primarily on invertebrates and plant material. Channel catfish (Table 4) were more piscivorous than white catfish (Table 5). Fish were in the stomach contents of 21% of the channel catfish sampled and were 11% of the total volume. Fish were in 3% of the white catfish sampled and were 4% of the total volume. The only identifiable fish remains found in the stomach contents of catfish were striped bass, threadfin shad, and prickly and riffle sculpins (*Cottus asper* and *C. gulosus*). No salmonids were found in the stomach contents of catfish. These results are similar to the food habits of catfish in the Sacramento-San Joaquin Delta (Turner 1966) and at the Tracy Fish Facility (Liston *et al* 1994). At the Tracy Fish Facility, white catfish was the second most abundant predator captured at the facility's intakes and fish remains were found in 3% of those sampled.

Table 4. Total incidence and volume of food items found in the stomachs of 141 channel catfish (1983-84 and 1993 -95) sampled from Clifton Court Forebay.

Food Item	Incidence Number	Volume (mL)
Fish		
striped bass	2	7.5
threadfin shad	7	55.0
unidentifiable fish	23	35.0
other vertebrates	6	135.0
Invertebrates		
crustaceans	17	21.7
odonates	9	24.6
chironomids	4	0.1
other insects	12	26.9
clams	2	0.1
snails	1	0.1
other invertebrates	2	1.6
Plant material	44	318.1
Miscellaneous	41	284.4

*Note. An incidence means that a food item was found one or more times in the stomach contents of a fish.

Table 5. Total incidence and volume of food items found in the stomachs of 440 white catfish (1983-84 and 1993 -95) sampled from Clifton Court Forebay.

Food Item	Incidence Number	Volume (mL)
Fish		
prickly sculpin	2	2.0
riffle sculpin	1	3.0
unidentifiable fish	11	28.0
Invertebrates		
crustaceans	14	24.5

odonates	1	0.5
other insects	19	8.5
clams	2	0.3
annelids	3	3.8
other invertebrates	10	5.3
Plant material	134	681.0
Miscellaneous	68	86.1

Although few salmonids and no Delta smelt were detected in the stomach contents of the striped bass and catfish we sampled, these results do not indicate a lack of meaningful predation on these fishes. Rather, sampling and analytical constraints, in concert with the relative scarcity of these fishes, limited the interpretation of the results to description of the most common prey species. To accurately describe the importance of relatively scarce prey species (e.g., salmon and Delta smelt) in the diet of predatory fish in Clifton Court Forebay, much more intensive sampling would be required. Temporally intensive sampling of both prey and predator fish should be conducted during the spring, summer and fall when these prey species are more frequently present in Clifton Court Forebay. Fish capture should be timed to coincide with entrainment opportunity (i.e., when water is drafted into Clifton Court Forebay). Finally, much of what has been hypothesized about predation on entrained fishes within Clifton Court Forebay comes from the interpretation of pre-screen loss studies to juvenile fishes, yet potential predators were never sampled concurrent to the release of large numbers of experimental fish. Any additional pre-screen loss study (or similar study) should include intensive sampling of adult and sub-adult striped bass for stomach content before, during and after releases .. Such sampling would be relatively inexpensive, yet will directly address many outstanding questions about striped bass predation in Clifton Court Forebay.

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Figure 1. Stomach pump apparatus. A — Compression sprayer tank; B — Polyethylene tubing; D — Bucket or trough; E — Sample jar.

Figure 2. Length distribution of all striped bass sampled for food habits at Clifton Court Forebay, 1983-84 and 1993-95.

Figure 3. Average volume (mL) of invertebrates, fish and other prey items consumed by different size classes (mm) of striped bass at Clifton Court Forebay, 1983-84 & 1993-95.

Figure 4. Length distribution of striped bass sampled for food habits at Clifton Court Forebay, 1983-84 and 1993-95.

Figure 5. Clifton Court Forebay striped bass piscivory ratios, 1983-84 & 1993-95.

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ESTIMATES OF SUB-ADULT AND ADULT STRIPED BASS ABUNDANCE IN CLIFTON COURT FOREBAY: 1992-1994

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Abstract—To determine the seasonal abundance of sub-adult and adult striped bass, seven modified Peterson-method mark-recapture abundance estimates were made from April 1992 through May 1994. A total of 28,150 sub-adult and adult striped bass were captured during the abundance estimates. The number of fish used to make each estimate ranged from 761 to 10,596. Very few marked fish were recovered; in fall 1993, none were recovered. Abundance estimates ranged from 30,689 to 905,483. Significant differences in the mean lengths (stratified by sampling gear) of sub-adult and adult striped bass collected during several paired mark and recapture phases of the abundance estimates strongly suggests that substantial emigration and immigration occurs at relatively short time intervals, invalidating the estimates.

INTRODUCTION

To determine the seasonal abundance of sub-adult and adult striped bass seven sub-adult and adult striped bass abundance estimates were made in Clifton Court Forebay from April 1992 through May 1994. Information on seasonal striped bass abundance could be used to better understand:

* mechanisms for striped bass recruitment to Clifton Court Forebay
* any relationship between striped bass abundance and pre-screen loss

* if removal of striped bass is feasible.

METHODS

Sub-adult and adult striped bass were captured in Clifton Court forebay during seven events over three years (Table 1). A modified Peterson mark-recapture method (Ricker 1975) was used to estimate abundance in each study. Sampling gear varied by study. Angling was used during each study in some combination with:

* monofilament gill nets (3.7m x 61m; 6.4cm - 10.2cm stretched mesh)
* fyke traps (6.1m with 3.8cm mesh around 3.0m hoops)
* kodiak trawl (183m x 3.7m; 5.1cm mesh)
* 305m and 610m beach seines
* Merwin traps

Table 1. Dates of striped bass population estimate studies in Clifton Court Forebay

Season	Marking Phase	Recapture Phase
Spring 1992	April 27 - May 10	May 13 - May 20
Summer 1992	Aug 20 - Aug 28	Aug 21 - Sep. 8
Fall 1992	Nov 4 - Nov13	Nov. 16 - Nov. 24

Winter 1993	Feb 6 - Feb 25	March 1 - March 31
Spring 1993	May 17 - May 3	June7 - June 15
Fall 1993	Nov 29 - Dec 10	Dec. 13 - Dec. 16
Spring 1994	May 16 - June 3	June 6 - June 13

During each study, sub-adult and adult striped bass caught in good condition during marking phases were marked with either a fin-clip or Peterson disk-dangler tag, their forklength (mm) recorded, and released. Skinner Fish Facility staff reported any marked-fish observed, and these and other known post-release mortalities were removed from the marked-fish pool. During the recapture phases, all striped bass were examined for marks and their forklength (mm) recorded. Details of specific methods used during each study are listed below:

Spring 1992—Gill nets, two fyke traps, and angling were used in Clifton Court Forebay and in the outlet channel. Fyke nets were used only in the outlet channel and were operated continuously; they were checked and cleaned every other day. All striped bass were marked with a left ventral fin-clip and released immediately. Gill nets were anchored and set for up to one hour, then reset in a different location.

Summer 1992—Methods were identical to those used in Spring 1992, although fish were marked with a right ventral fin clip or Peterson disk-dangler tag.

Fall 1992—A holding pen was assembled in the north end of the forebay, using a 610m beach seine, to isolate marked fish during the marking phase and to reduce the rate of emigration out of the forebay. Kodiak trawl and angling were used during the marking phase, and all fish were marked with a left ventral fin-clip and released into the pen. Gill nets, angling and Kodiak trawl were used during recapture efforts, beginning two days after releasing the pen-held fish into the forebay.

Winter 1993—Kodiak trawl, angling and gill nets were used to collect fish for both marking and recapture. Fish were marked with a right ventral fin-clip. The 610m pen was again used to isolate marked fish. Most trawling was on the west side of the forebay, to avoid snags. When catches exceeded 100 fish, every third to tenth fish was subsampled and its length recorded.

The recapture phase began three days after the pen-held fish were released. When catches exceeded 100 fish, length measurements were recorded from every third to tenth fish. All striped bass captured during this phase were removed from the forebay (IESP 1994).

Spring 1993—Kodiak trawl and angling were used to collect fish for marking. Fish were marked with a dorsal fin-clip or Peterson disk-dangler tag. When catches exceeded 100 fish, every third to tenth fish was subsampled and its length recorded. The 610m pen was again used to isolate marked fish. Most hauls with Kodiak and seine were on the west side of the forebay, to avoid snags.

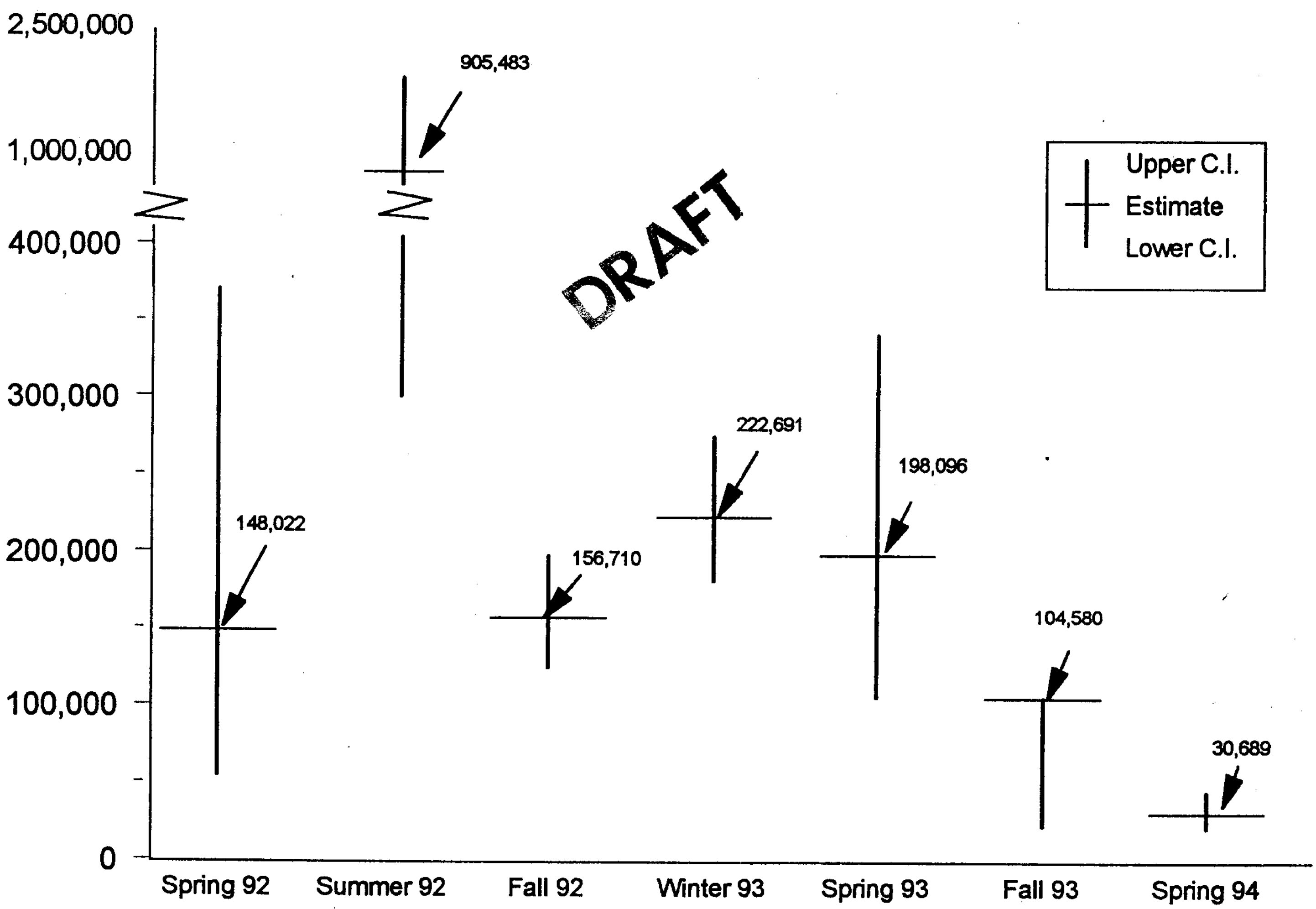
Gill nets, angling, Kodiak trawl, and both beach seines were used during recapture efforts, beginning two days after releasing the pen-held fish into the forebay. When catches exceeded 100 fish, every third to tenth fish was subsampled and its length recorded.

Fall 1993—Kodiak trawl, angling, and 305m seine were used to collect fish for marking. Fish were marked with a right ventral fin-clip or Peterson disk-dangler tag. The recapture phase began two days after the end of the marking phase and gill nets and hook and line were used.

Spring 1994—Kodiak trawl, angling, Merwin traps, gill nets, and 305m seine were used to collect fish for marking. Gill nets were used sparingly to minimize stress to the marked-fish group. Fish were marked with a left ventral fin-clip or Peterson disk-dangler tag. Most seine hauls were on the southwest side of the forebay, to avoid snags and because of higher catch-per-unit-effort there. Hook and line, kodiak trawl and merwin traps were used during the recapture phase which began two days after the end of the marking phase.

RESULTS

A total of 28,150 sub-adult and adult striped bass were captured during the abundance estimates (Table 2). The number of fish used to make each estimate ranged from 761 to 10,596. Very few marked fish were recovered; in fall 1993, none were recovered. Relatively few mortalities were observed among marked fish. Abundance estimates ranged from 30,689 to 905,483 (Table 3; Figure 1).



2,500,000
1,000,000
400,000
300,000
200,000
100,000
0
905,483
148,022
156,710
222,691
198,096
104,580
30,689
DRAFT
Upper C.I.
Estimate
Lower C.I.
Spring 92
Summer 92
Fall 92
Winter 93
Spring 93
Fall 93
Spring 94

1a

Table 2. Number of striped bass collected by each gear type during abundance studies from 1992-1994

Gear Type	Number Caught
Gill Net	1645
Hook & Line	4629
Kodiak Trawl	18544
1,000 ft Seine	2706
2,000 ft Seine	386
Merwin Trap	137
Fyke Net	103
Total	28150

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Table 3. Estimated striped bass abundance in Clifton Court Forebay (with confidence limits) from 1992 to 1994.

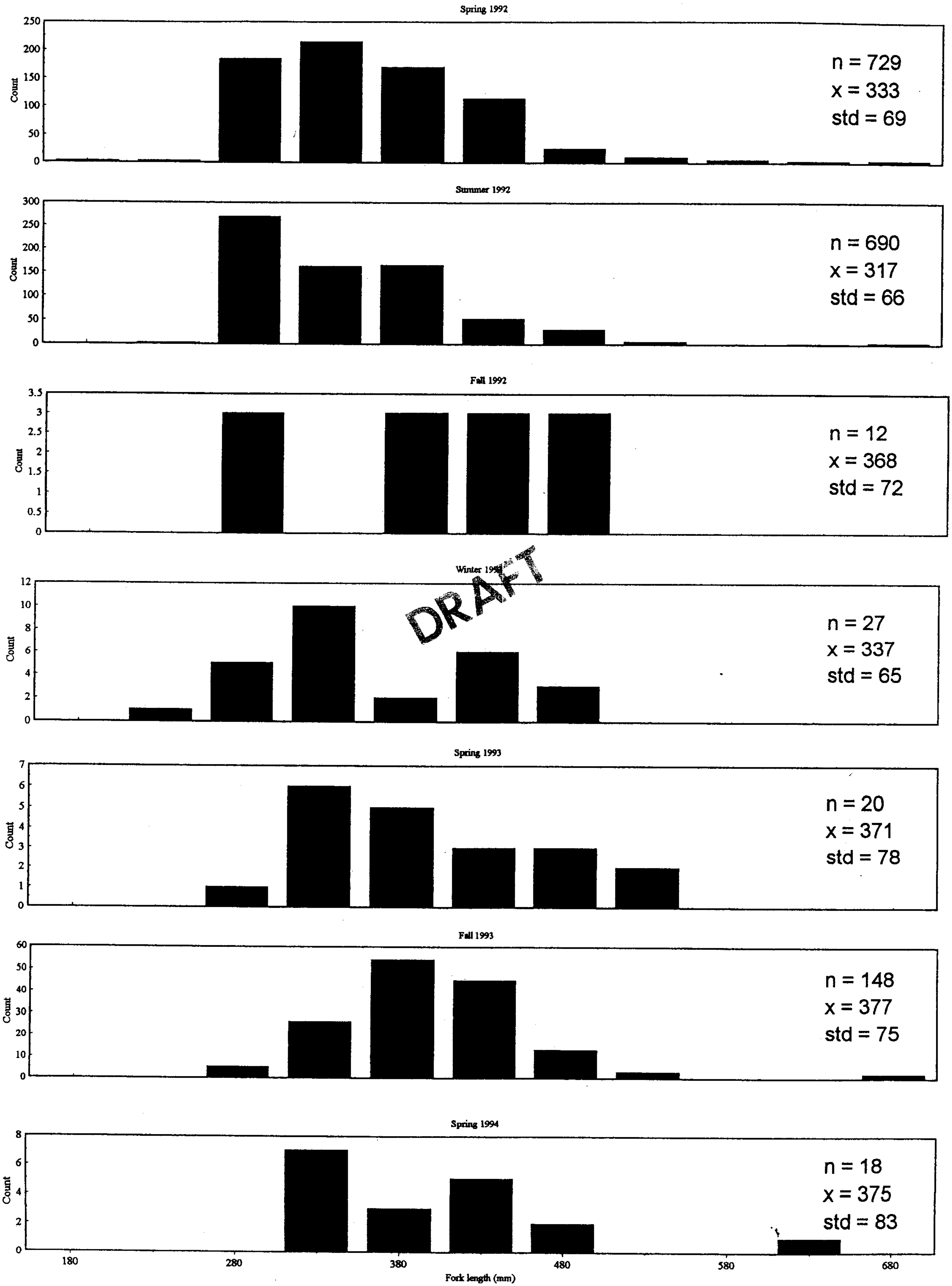
Year/Month	Number of Marked Fish	Number of Marked Fish Recaptured	Estimated Striped Bass Abundance	95% Confidence Intervals (Upper-Lower)	
1992/Apr	653	2	142,022	370,055	54,154
1992/Aug	2,143	2	905,483	2,263,707	331,274
1992/Dec	3,044	70	156,710	197,261	124,408

1993/Feb	2,424	88	222,691	273,639	181,148
1993/May	1,971	10	198,096	340,478	105,269
1993/Nov	580	0	104,580	104,580	22,251
1994/May	1,496	27	30,689	43,956	21,327

Length frequencies varied seasonally and showed that several age classes used Clifton Court Forebay (Figures 2-4). ANOVA was used to test the mean lengths from striped bass captured by kodiak trawl and angling; the means were significantly larger ($P < 0.001$ and $P < 0.001$, respectively) in fall and winter than in spring and summer. Data from other sampling gears could not analyzed statistically because the number of striped bass collected was too small.

Comparison of frequency distributions between pairs of mark and recapture phases for each gear type were determined using the "Welch's approximate t" test (Zar ????):

* Gill net catches were significantly different during Spring 1992 ($P < 0.001$) and Fall 1993 ($P < 0.001$). During Fall 1992 and Winter 1993, gill nets were only used during one phase of the abundance study and could not be tested statistically.
* Angling catches showed significant differences between mark and recapture phases during Fall 1992 ($P < 0.001$), Winter 1993 ($P < 0.01$), and Fall 1993 ($P < 0.02$). During Spring 1993, fish were collected by angling only during the recapture phase, and could not be tested statistically.
* Kodiak trawls catches were significantly different in Spring 1993 ($P < 0.001$). During Fall 1993, fish were collected with kodiak trawl only during one phase, and could not be tested


Spring 1992
n = 729
x = 333
std = 69
Summer 1992
n = 690
x = 317
std = 66
Fall 1992
n = 12
x = 368
std = 72
Winter 1993
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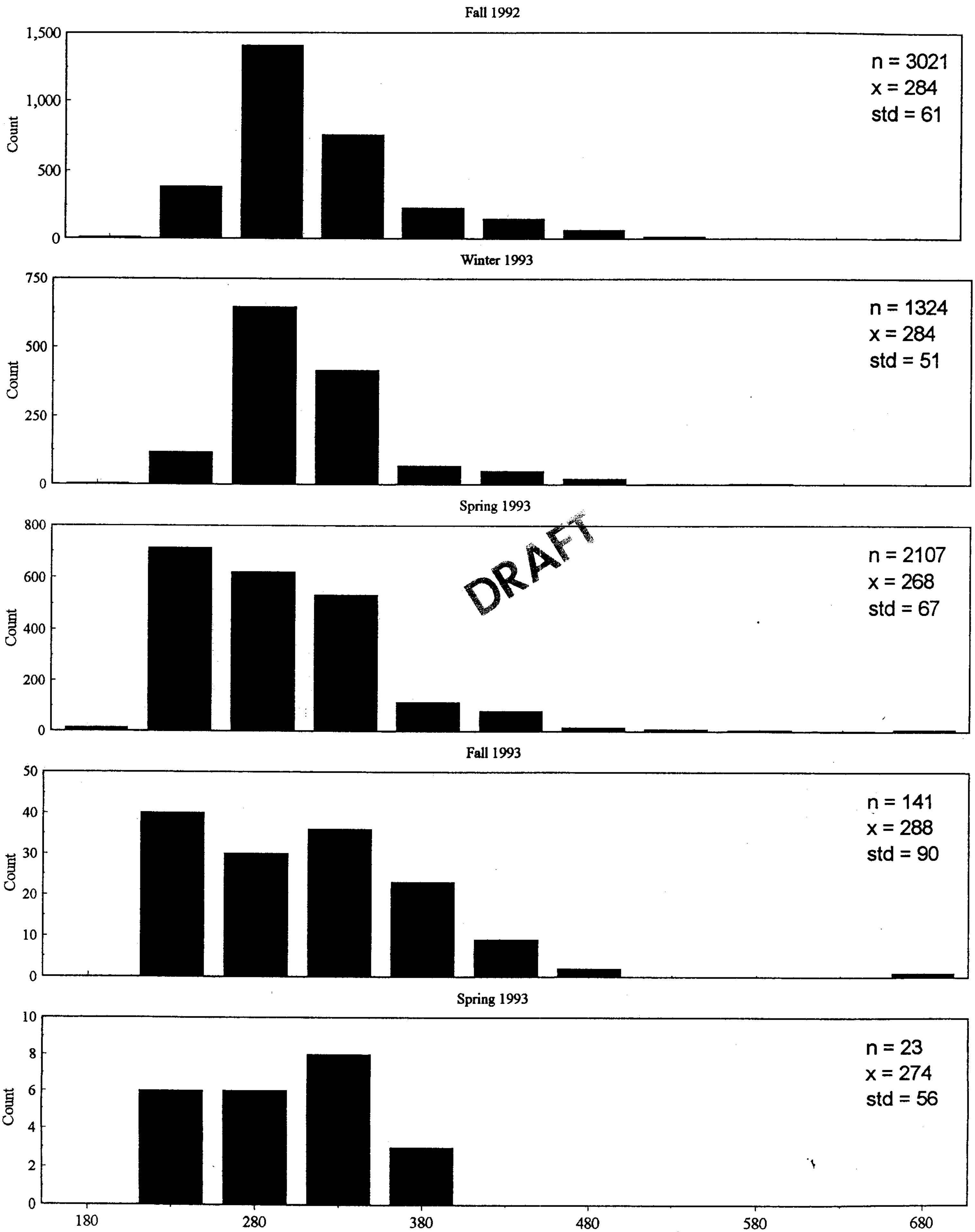
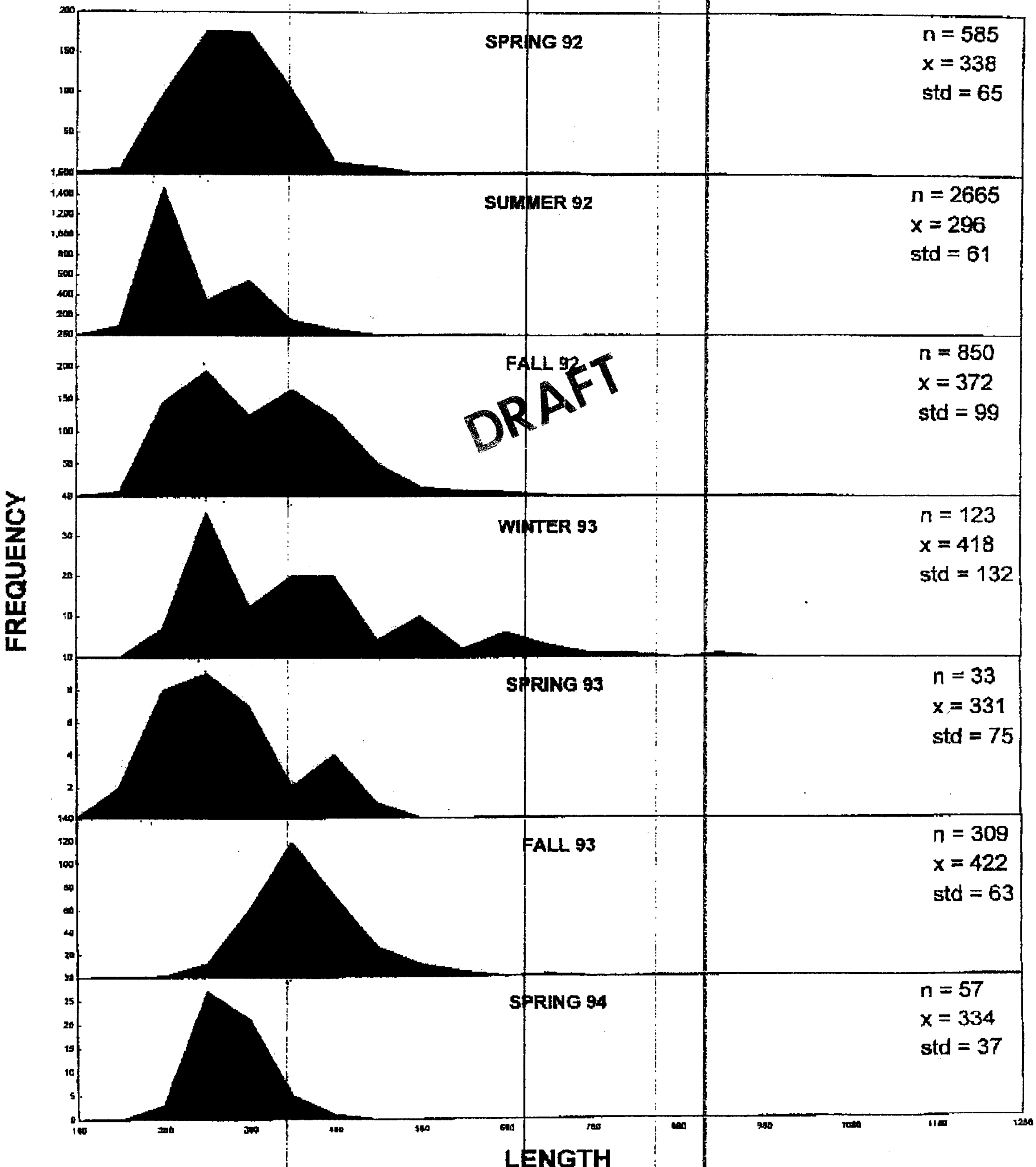
n = 27
x = 337
std = 65
Spring 1993
n = 20
x = 371
std = 78
Fall 1993
n = 148
x = 377
std = 75
Spring 1994
n = 18
x = 375
std = 83
Count
180
280
380
480
580
680
Fork length (mm)


Fall 1992
Count
1,500
1,000
500
0
n = 3021
x = 284
std = 61
Winter 1993
Count
750
500
250
0
n = 1324
x = 284
std = 51
Spring 1993
Count
800
600
400
200
0
DRAFT
n = 2107
x = 268
std = 67
Fall 1993
Count
50
40
30
20
10
0
n = 141
x = 288
std = 90
Spring 1993
Count
10
8
6
4
2
0
n = 23
x = 274
std = 56
180
280
380
480
580
680

7a

Figure 4 Length frequencies of striped bass caught by hook and line from 1992 to 1994.



statistically.

* There were no significant differences between paired mark and recapture phases for striped bass caught in merwin traps.
* There were no significant differences between paired mark and recapture phases for striped bass caught fyke traps
* Fish were collected with seines only during during one phase of the abundance study, and could not be tested statistically.

DISCUSSION

Abundance estimates from this series of studies *suggest* that a substantial proportion of the entire estimated population of striped bass in the Delta inhabit Clifton Court Forebay, and that the absolute number of striped bass in the forebay fluctuates substantially over the course of several months. The two results can only be reconciled by concluding that mark-recapture methods are not accurate when applied to sub-adult and adult striped bass in the forebay. A number of other observations strongly indicate that the method is not accurate:

* Relatively few sub-adult and adult striped bass were captured during these abundance estimates. Given that the average abundance estimate was approximately 252,000 fish and seasonal habitat restrictions within Clifton Court Forebay make fish capture relatively easy (as does striped bass schooling behavior), more fish should have been captured with the very high and directed sampling effort used.

* Very few marked fish were recaptured or were observed dead. Although consistent with having tagged relatively few fish from a large population, alternative explanations are emigration of tagged fish from the forebay and immigration of untagged fish to the forebay.

* Significant differences in the mean lengths (stratified by sampling gear) of sub-adult and adult striped bass collected during paired mark and recapture phases of several abundance estimates from 1992-1994 strongly suggests that substantial emigration and immigration occurs at relatively short time intervals.

* Sub-adult and adult striped bass catch-per-unit-effort-data suggest substantial and rapid emigration and immigration (Gingras, this publication), using much the same sampling gear and techniques as used in these abundance estimates.

* The results of a intensive tagging program (Kano 1990) and from telemetry work (Gingras and McGee 1997), showed substantial and rapid emigration and immigration. The latter study showed that emigration of telemetry-tagged striped bass occurred an average of 29 days after tagging. Tagged fish, however, may take longer to emigrate than untagged fish due to tagging stress. (Gingras, DFG, personal communication).

From the preponderance of evidence, it is clear that abundance estimates of sub-adult and adult striped bass in Clifton Court Forebay using mark-recapture methods are not accurate. Any reduction in the abundance of striped bass realized by predator removal would be impossible to accurately measure, thus any reduction in pre-screen loss attributable to predator removal would be impossible to quantify.

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Table 3. Estimated Striped bass Abundance in Clifton Court Forebay (with Confidence Limits) from 1992 to 1994.

Year/Month	Number of Marked Fish	Number of Marked Fish Recaptured	Estimated Striped Bass Abundance	95% Confidence Intervals	
				Upper Limit	Lower Limit
1992/Apr	653	2	142,022	370,055	54,154
1992/Aug	2,143	2	905,483	2,263,707	331,274
1992/Dec	3,044	70	156,710	197,261	124,408
1993/Feb	2,424	88	222,691	273,639	181,148
1993/May	1,971	10	198,096	340,478	105,269
1993/Nov	580	0	104,580	104,580	22,251
1994/May	1,496	27	30,689	43,956	21,327

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STRIPED BASS CATCH-PER-UNIT-EFFORT SAMPLING AT CLIFTON COURT FOREBAY: 1991-1995

ABSTRACT

Catch-per-unit-effort sampling was conducted in Clifton Court Forebay from 1991 through 1995 to generate relative abundance indices and absolute abundance estimates for sub-adult and adult striped bass. This information could be used to assess the effectiveness of proposed removals of predator-sized striped bass. Gill net and angling were the most common capture methods. Sampling was conducted weekly or bi-weekly at each of six areas in Clifton Court Forebay. Striped bass catch-per-unit-effort may be an acceptable measure of relative abundance, but was not well correlated with the results of five mark-recapture estimates of striped bass abundance generated concurrent to catch-per-unit-effort sampling.

INTRODUCTION

To evaluate the effectiveness of proposed striped bass removal efforts at Clifton Court Forebay, and the effect striped bass removal has on pre-screen loss, managers must have accurate estimates of striped bass abundance. These data would be related to measured changes in pre-screen loss, and entrained-fish take calculations at the Skinner Fish Facility would be adjusted for increased survival across Clifton Court Forebay. Mark-recapture studies of sub-adult and adult striped bass abundance in Clifton Court Forebay (Healey, this publication) are relatively costly. Because catch-per-unit-effort sampling appeared less costly, catch-per-unit-effort sampling was proposed as another method to estimate the absolute abundance of sub-adult and adult striped bass. Program objectives were to collect a time series of striped bass catch-per-unit-effort, and to collect a sufficient number of mark-recapture estimates concurrent to catch-per-unit-effort monitoring to allow a rigorous regression of one against the other. The regression could permit the relative abundance measure to predict absolute abundance.

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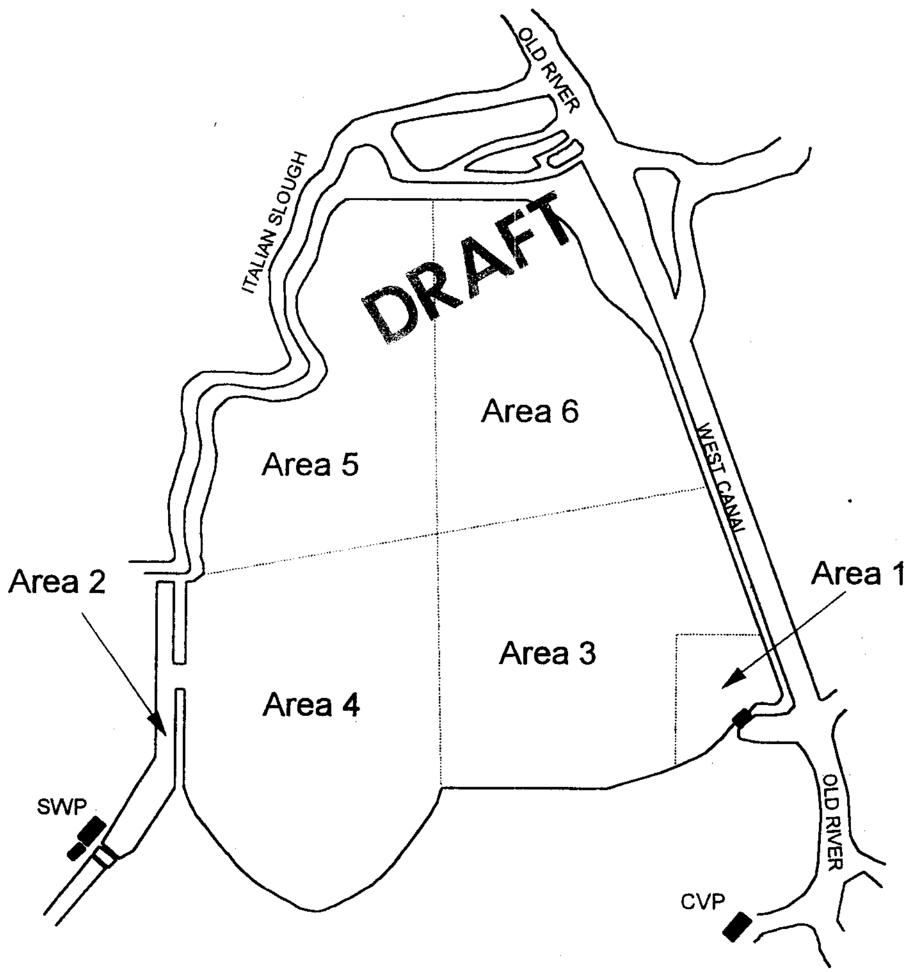
METHODS

Striped bass catch-per-unit-effort sampling began in March 1991 and continued through 1995. Sampling was conducted weekly through September 1992; between September 1992 and December 1994 sampling was biweekly; after that, sampling was conducted weekly during daylight hours and biweekly after dark. Sampling was conducted by boat, in each of six areas in Clifton Court Forebay (Figure 1). Each field day, areas were sampled in a random sequence determined with the aid of a random numbers table. Sampling protocol and techniques followed those outlined by Kano (1990). Sampling gear were selected for their efficiency in capturing sub-adult and adult striped bass, and were among the gear types used during mark-recapture studies to estimate the abundance of sub-adult and adult striped bass in Clifton Court Forebay (Healey, this publication). Gill nets were 61m by 3.7m with variable mesh (6.4 cm - 10.2 cm stretched). Nets were anchored and (typically) fished for less than 45 min, as dictated by environmental


OLD RIVER
ITALIAN SLOUGH
DRAFT
Area 6
Area 5
WEST CANAL
Area 2
Area 1
Area 3
Area 4
SWP
OLD RIVER
CVP

conditions and the condition of fish following capture. Angling was conducted using a standard artificial lure (scrounger-type), during gill net sets or when gill net fishing was not practical.

All captured fish were processed by the field crew. Species, length (mm), effort (min), capture gear, and capture area were recorded on waterproof data sheets, as were surface water temperature and secchi depth. Fork length was recorded for striped bass and other species with forked caudal fins. Total length was recorded for other species. Fish were released after processing. A water sample was taken and electrical conductivity was measured in a laboratory at Bay-Delta Division in Stockton; this value was later appended to the field data sheet.

Fish capture, effort and environmental data were entered into an electronic database. Catch-per-unit-effort (fish/min) was calculated and summarized for each date/area/gear/sample number/species combination. These data are available on the IEP Internet server at "http://wwwiep.water.ca.gov". In this report, mean catch-per-unit-effort is a "mean of ratios estimator" (Malvestuto 1992).

RESULTS

Striped bass were the most abundant fish sampled and made up 70% of the total number of fish caught. A number of species were caught coincidental to sampling for striped bass (Table 1), among these were piscivorous fishes including white catfish (*Ictalurus catus*), channel catfish (*I.*

Punctatus) and largemouth bass (*Micropterus salmoides*). Because striped bass were the most abundant and piscivorous fish sampled (Edwards, this publication), the remainder of this report will discuss only striped bass catch-per-unit-effort.

Table 1. Catch from catch-per-unit-effort monitoring of sub-adult and adult striped bass in Clifton Court Forebay, 1991-1995.

striped bass	6874
white catfish	1531
splittail	491
channel catfish	350
American shad	270
carp	124
largemouth bass	55
red ear sunfish	29
bluegill	20
steelhead trout	18
tule perch	15
black crappie	13
white sturgeon	11
Sacramento squawfish	9
Sacramento sucker	8

golden shiner	7
brown bullhead	7
green sturgeon	6
hitch	4
chinook salmon	4
goldfish	1
smallmouth bass	1
chameleon goby	1

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A posteriori evidence that mark-recapture methods to estimate the abundance of sub-adult and adult striped bass in Clifton Court Forebay are not accurate (Healey, this publication) clearly indicates that predicted absolute abundance from a regression of catch-per-unit-effort against abundance estimates would not be accurate. With that fact in mind, and in the interest of brevity, only summary statistics are presented for all area and gear combinations of catch-per-unit-effort (Table 2).

Table 2. Summary statistics from catch-per-unit-effort monitoring of sub-adult and adult striped bass in Clifton Court Forebay, 1991-1995.

Area	Gear	N	Min	Max	Mean	Var	SD
1	gill net	206	0.00	1.85	0.181	0.079	0.281
1	angler	195	0.00	0.19	0.024	0.001	0.034

2	gill net	178	0.00	0.60	0.071	0.012	0.110
2	angler	175	0.00	0.16	0.024	0.001	0.036
3	gill net	233	0.00	1.30	0.068	0.017	0.131
3	angler	184	0.00	0.13	0.010	0.000	0.021
4	gill net	250	0.00	1.45	0.076	0.023	0.153
4	angler	212	0.00	0.43	0.015	0.001	0.037
5	gill net	204	0.00	1.25	0.067	0.021	0.146
5	angler	160	0.00	0.23	0.014	0.001	0.028
6	gill net	196	0.00	0.75	0.049	0.008	0.090
6	angler	152	0.00	0.25	0.017	0.001	0.034

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Mean catch-per-unit-effort from gill net sampling and from angling among the six sampling areas was significantly different (ANOVA's; $P < 0.05$); gill net sampling near the radial gates produced the highest mean and maximum (area 1; $\bar{x}$ = 0.~~0~~181, maximum = 1.85). Low mean and minimum catch-per-unit-effort for several area/gear combinations clearly show that catchability and/or habitat limit the capture of striped bass. In that only the outlet channel (area = 2) and the area near the radial gates had essentially homogeneous habitat which was also suitable for sub-adult and adult striped bass capture across all seasons, data from these areas are best suited for use as abundance indices. Of the two areas most suitable for the capture of striped bass, the area near the radial gates has been the focus of more discussion and research related to predation. The remainder of this report will discuss only catch-per-unit-effort near the radial gates.

In a number of important respects, gill nets provided better catch-per-unit-effort data than angling.

* Gill nets were more efficient for capturing striped bass than angling gear. More striped bass were captured in gill nets than by angling, and catch-per-unit-effort was greater for gill net sampling than for angling (paired samples *t*-test; N = 135, $P < 0.01$).
* Gill net sampling was less biased than angling. Catch and effort were more strongly correlated for gill net samples than angling samples (although the correlation was weak for gill net samples; N = 206, $R^2 = 0.199$, $P = 0.001$), and gill net catch-per-unit-effort was only weakly correlated to angling catch-per-unit-effort (N = 137, $R^2 = 0.021$, $P = 0.087$; Figure 2). These are indications that factors other than fish abundance influenced angling catch-per-unit-effort more than gill netting catch-per-unit-effort.

* Gill net catch-per-unit-effort was not significantly different at night than during the day (paired samples *t*-test; N = 14, $P = 0.981$) and secchi depth was not significantly correlated with catch-per-unit-effort (Figure 3); these are indications that gill net sampling conducted almost exclusively during daylight hours was not generally influenced by net avoidance due to changes in water clarity.

Because gill net sampling was more efficient and less biased than angling, the remainder of this report will discuss only catch-per-unit-effort from gill nets.

Seasonality was evident from the time series of catch-per-unit-effort (Figure 4), with peaks in spring and late summer. Catch-per-unit-effort sometimes changed an order of magnitude in two

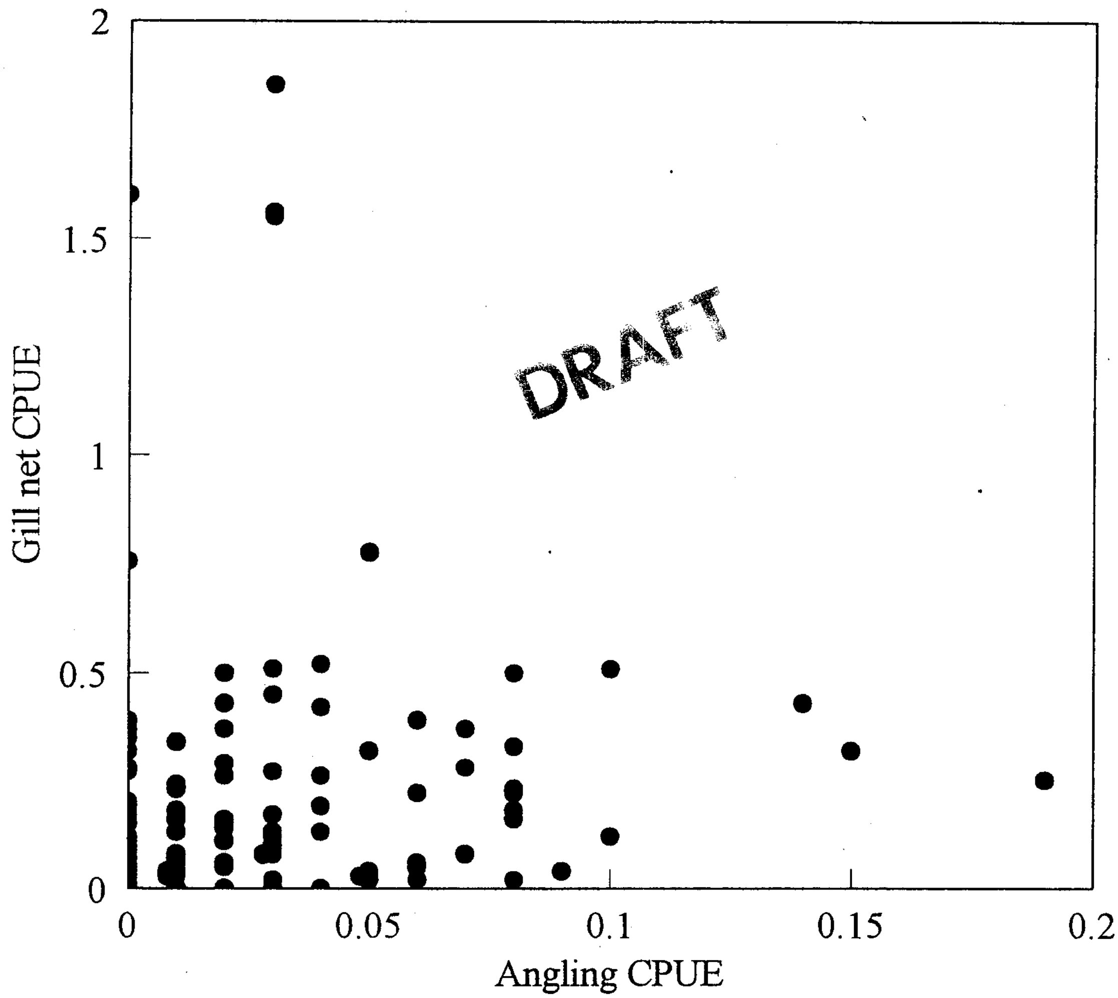
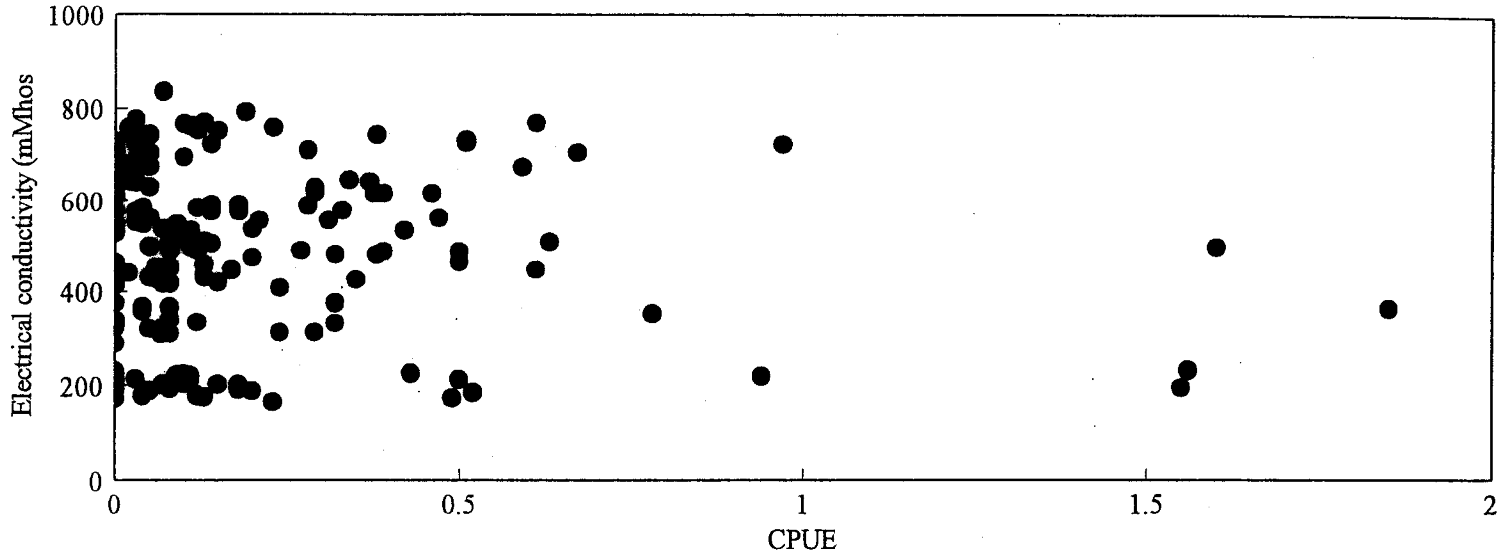
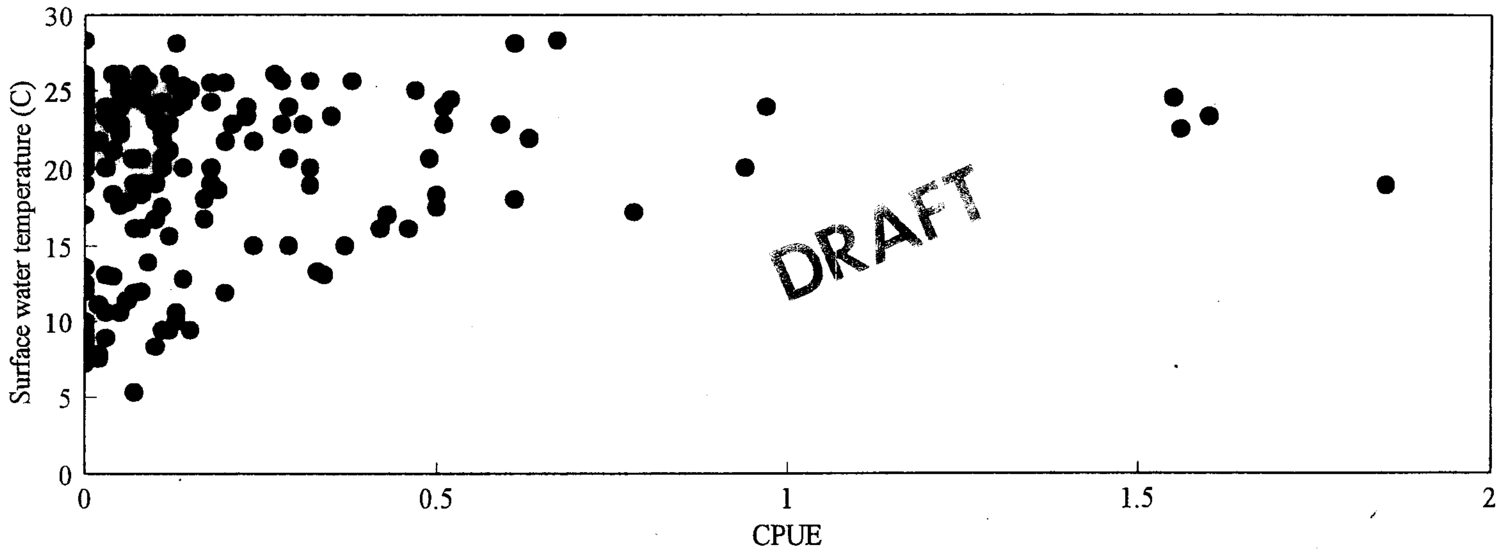


Figure 2



Electrical conductivity (mMhos)
1000
800
600
400
200
0
0
0.5
1
1.5
2
CPUE



Surface water temperature (C)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
CPUE
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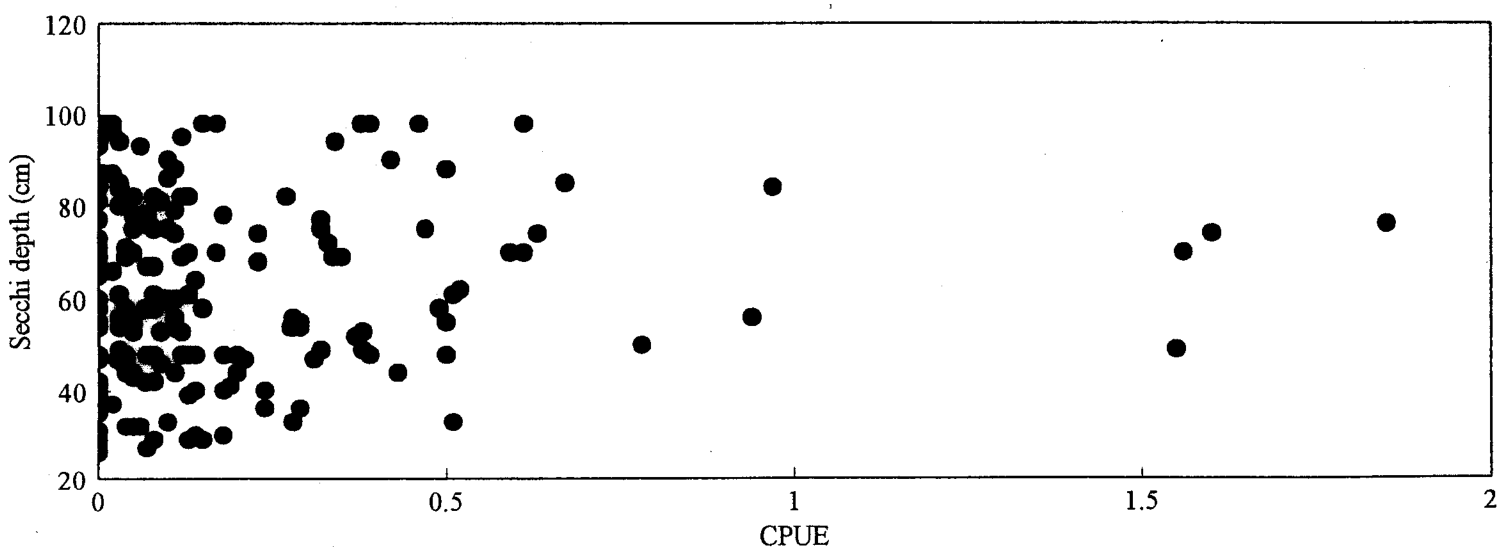
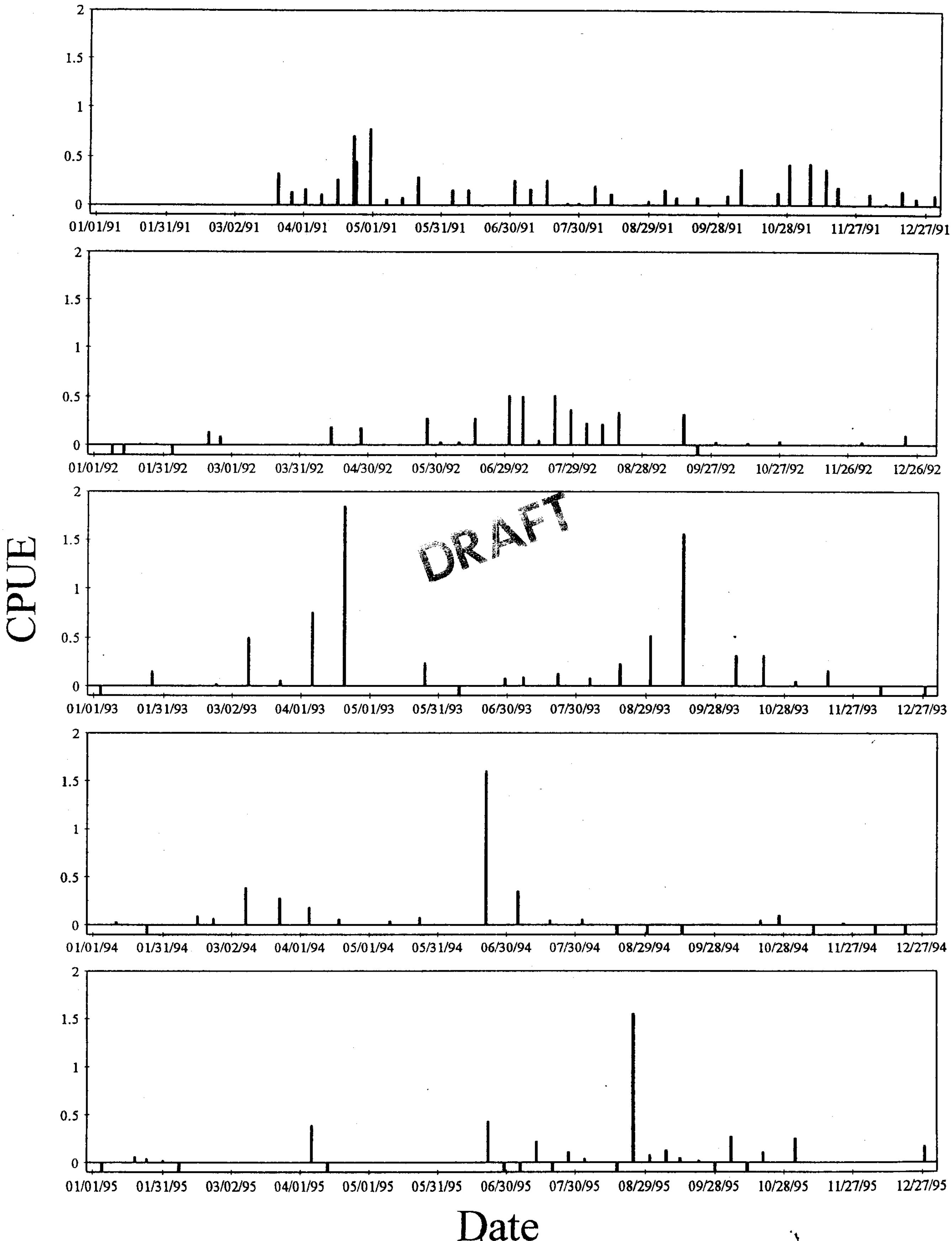


Secchi depth (cm)
120
100
80
60
40
20
0
0.5
1
1.5
2
CPUE



CPUE
DRAFT
2
1.5
1
0.5
0
01/01/91 01/31/91 03/02/91 04/01/91 05/01/91 05/31/91 06/30/91 07/30/91 08/29/91 09/28/91 10/28/91 11/27/91 12/27/91
01/01/92 01/31/92 03/01/92 03/31/92 04/30/92 05/30/92 06/29/92 07/29/92 08/28/92 09/27/92 10/27/92 11/26/92 12/26/92
01/01/93 01/31/93 03/02/93 04/01/93 05/01/93 05/31/93 06/30/93 07/30/93 08/29/93 09/28/93 10/28/93 11/27/93 12/27/93
01/01/94 01/31/94 03/02/94 04/01/94 05/01/94 05/31/94 06/30/94 07/30/94 08/29/94 09/28/94 10/28/94 11/27/94 12/27/94
01/01/95 01/31/95 03/02/95 04/01/95 05/01/95 05/31/95 06/30/95 07/30/95 08/29/95 09/28/95 10/28/95 11/27/95 12/27/95
Date

weeks or increased from zero to the highest levels observed in just one week. Although water temperature also exhibits seasonality, it was weakly correlated with catch-per-unit-effort (N = 206, R^2 = 0.023, P = 0.029; Figure 3). Electrical conductivity was not significantly correlated to catch-per-unit-effort.

Five mark-recapture estimates of striped bass abundance were successfully conducted concurrent (or nearly so) to catch-per-unit-effort monitoring (Healey, this publication). As expected, linear regression of mean catch-per-unit-effort during each abundance estimate against the abundance estimates explained very little of the variance in catch-per-unit-effort (R^2 = 0.112, P = 0.582).

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DISCUSSION

Catch-per-unit-effort data may serve either as an index of relative abundance or as a method to directly estimate abundance (Ney 1993). When catch-per-unit-effort is used as a measure of relative abundance (Low *et al* 1985), catchability must be held constant (Ney 1993). When catchability is not constant, but other factors influencing catchability are strongly correlated to catch-per-unit-effort, relative abundance measures using catch-per-unit-effort can be adjusted for increased accuracy. Catchability at Clifton Court Forebay (as elsewhere) probably varies with water clarity (secchi depth) and water temperature. In this study, these factors were not strongly correlated to catch-per-unit-effort. Changes in catch-per-unit-effort probably reflect rapid changes in the abundance of striped bass using Clifton Court Forebay, as they move in and out of

Clifton Court Forebay through the radial gates (Kano 1990; Gingras and McGee 1997).

To use catch-per-unit-effort as an estimate of absolute abundance, the literature suggests regression of a rigorous catch-per-unit-effort index against an accurate and independent abundance estimator (Hall 1986; Coble 1992). When the independent abundance estimator is generated from mark-recapture methods, closure of the population is necessary for accurate estimates. It follows that estimates of abundance from a relative measure such as catch-per-unit-effort are accurate only when closure of the population is assured. At Clifton Court Forebay, under normal operating procedures, closure cannot be assured (Kano 1990; Gingras and McGee 1997; Healey, this publication). Absolute abundance estimates generated using catch-per-unit-effort data at Clifton Court Forebay would not be accurate. Using the methods that have been tried to date, any reduction in the abundance of striped bass realized by predator removal would be impossible to accurately measure, thus any reduction in pre-screen loss attributable to predator removal would be impossible to quantify.

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Figure 1. Schematic of Clifton Court Forebay depicting six areas where catch-per-unit-effort sampling was conducted.

Figure 2. Scatter plot and linear regression line of paired catch-per-unit-effort (CPUE) samples from gill net and angling gear.

Figure 3. Scatter plot matrix of catch-per-unit-effort (CPUE) versus electrical conductivity, secchi depth, and water temperature.

Figure 4. Time series of mean daily catch-per-unit-effort (CPUE) samples. Bars below the x-axis indicate zero CPUE.