

MORTALITY OF YELLOW PERCH (Perca flavescens)
DUE TO CONFINEMENT AND HANDLING IN THE DROP NET FISHERY
IN SOUTHERN GREEN BAY, LAKE MICHIGAN

By

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Wisconsin Cooperative Fishery Research Unit

A Thesis

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

May 1986

ABSTRACT

Net confinement and catch sorting procedures associated with the drop net segment of the southern Green Bay commercial fishery for yellow perch resulted in substantial nonharvest mortality. Catches of yellow perch taken in 3-day sets (the maximum legal set duration) averaged 7.7% dead perch in 1982 and 6.0% in 1983. Sets extended 1 to 8 days beyond the 3-day legal limit resulted in catches averaging 69% (S.D. = 31) dead perch. Thirty-six percent of 2,592 sublegal perch handled by commercial methods died within 24 hours.

ANOCOV of standard drop net catches from 1982 and 1983 indicated that closing the commercial perch fishing season during June 1983 substantially decreased yellow perch mortality during that period.

A multiple regression equation was developed which explained 61% of the variation in perch mortality for 28 extended set experiments. The equation is $\sqrt{\%DEAD} = 8.0(HOLD) - 4.7(D.O.) + 1.9(TEMP) - 28.0$, where HOLD = time (days) that perch were held after a 3-day set; D.O. = dissolved oxygen (mg/l) at net depth; and TEMP = water temperature at net depth.

A second multiple regression equation was developed that explained 63% of the variation in sublegal perch (SLP) mortality for 48 handling experiments. The equation is $\%SLP = 2.07(E.T.) + 2.37(HAND) + 3.8(DECK) - 96.07$, where E.T. = elapsed time (hrs.) after handling; HAND = handling time (mins.); and DECK = deck temperature (°C).

Modified Ricker yield models predicted that minimum length limits (MLLs) and mesh size regulations for drop nets could be used to reduce handling and net mortality of yellow perch without reducing long-term yield to commercial fishermen. I developed five yield models, designated I-V, based on drop nets with mesh sizes of 48, 51, 54, 57, and 60 mm respectively. Each model was divided into four submodels, A-D, based on MLLs of 191, 203, 216, and 229 mm. I think the best compromise between yield and reductions in mortality of perch was predicted for Model IVA which combined a 191-mm MLL with 57-mm mesh nets. Model IVA predicted a 38% increase in yield, a 96% decrease in handling mortality, and 24% decrease in net mortality, per 1000 Kg of age 1 recruits, compared with 1982-83 conditions as simulated by Model IA (191-mm MLL and 48-mm mesh nets).

ACKNOWLEDGEMENTS

This study was supported by the University of Wisconsin Sea Grant Institute and the Wisconsin Cooperative Fishery Research Unit. Data and technical assistance were provided by Brian Belonger, fish manager for the Wisconsin Department of Natural Resources, Marinette, Wisconsin. I am indebted to Brian for his help and understanding.

I am grateful to all the commercial fishermen who helped with this project. I especially thank Bob Dickinson and family, Eugene and Everett Marks, and Don Tuttle. Their help and guidance made this project possible.

I also thank Dr. Fred Copes and Dr. Fred Hilpert for their assistance with data analysis, Jeff Andrews for his patient guidance in personal computing, and Dr. Daniel Coble for his critical review of this manuscript. Rory Brennae and Mike Parsley assisted with field work.

Most of all, I thank my wife, Anne, for her patient understanding and support through this whole crazy exercise.

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Introduction

Objectives of this study were to:

- 1) determine the proportion of legal and sublegal yellow perch (Perca flavescens) that die in commercial drop nets;
- 2) determine the effect of holding time in nets on survival of yellow perch;
- 3) estimate short-term (less than 24 hours) handling mortality of sublegal yellow perch;
- 4) use modified Ricker equilibrium yield models to predict handling deaths, net deaths, and yield under four minimum length limits and five mesh size regulations.

The study was conducted in southern Green Bay, Lake Michigan, in the summers of 1982 and 1983, in statistical grids 1001 and 901 (Fig. 1).

The yellow perch in southern Green Bay has been important as a commercial species since the 1880s (Smith and Snell 1891) and as a sport fish since at least the 1920s (Wells 1977). Southern Green Bay accounted for 72-96% of the total Wisconsin Lake Michigan commercial perch harvest from 1970-1982 (Appendix A). Between 1971 and 1983 the dockside value of southern Green Bay commercial perch harvests ranged from \$87,577 in 1971 to \$995,682 in 1979 (Appendix B).

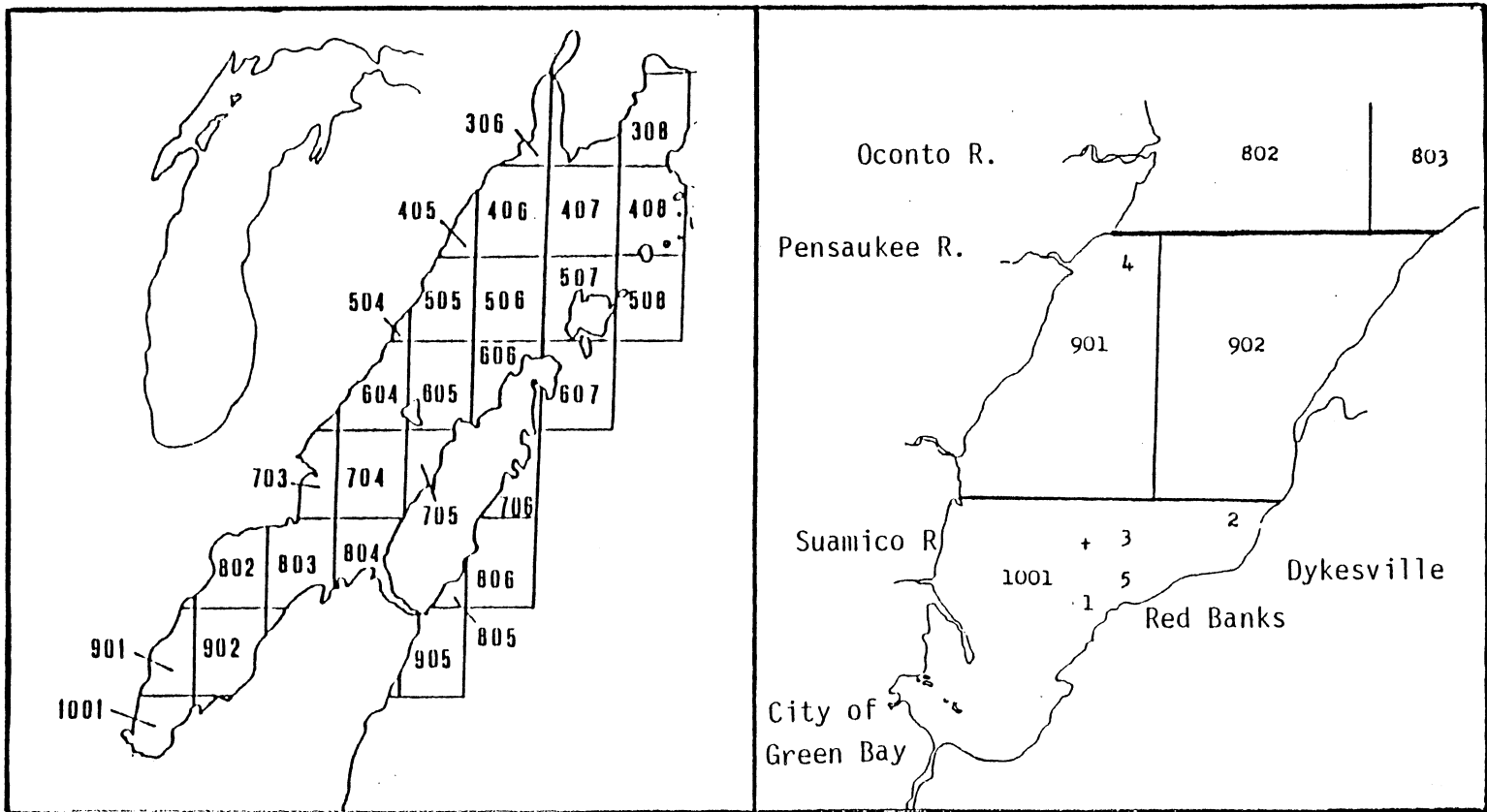


Figure 1. Left panel shows statistical grids for Green Bay and part of Lake Michigan (inset). Right panel shows the location of 1982-83 sampling sites in statistical grids 901 and 1001. Sample sites in 1982 were: Red Banks, Dykesville, Light House, and Pensaukee Bar (numbered 1-4, respectively). Point Comfort (number 5) was the 1983 sample site. The entrance light is denoted by a (+) sign.

Although an important sport fishery existed in Lake Michigan in the mid-1950s, catches declined drastically by the early 1960s (Wells and McClain 1973). By late 1973 a sizable sport fishery again developed in the Wisconsin waters of Green Bay (Wells 1977). In recent years sport fishing has accounted for 15% of the total southern Green Bay perch harvest (Wisconsin Department of Natural Resources 1980).

The commercial harvest of yellow perch in southern Green Bay has fluctuated with highs and lows at intervals of 5-15 years (Epstein et al. 1974). Since 1936, when the Wisconsin Department of Natural Resources (WDNR) began keeping separate records for southern Green Bay, yellow perch harvests have ranged from about 1,079,000 Kg in 1943 to a low of 72,000 Kg in 1966 (Fig. 2). Between 1965 and 1982 the commercial harvest averaged less than 191,000 Kg.

The erratic harvest and downward trend in yield of yellow perch since 1945 have been accompanied by increased growth rates, younger mean age and younger age at first spawning (Griffin 1979; Unpublished data, WDNR, Marinette, Wisconsin, USA). Similar trends in other percid populations have been linked to high exploitation rates (Spangler et al. 1977), indicating that southern Green Bay yellow perch are heavily exploited.

Another factor suspected to have contributed to recent trends in the yellow perch population of southern Green Bay is nonharvest mortality associated with the drop net segment of the commercial fishery (Belonger 1979). A drop net is two fyke nets one at each end of a 60 to 90-m lead (Fig. 3). About half the commercial harvest of yellow perch from Green Bay is taken with drop nets. Small-mesh gill nets (57-mm stretch mesh) account for the majority of the rest of the harvest of

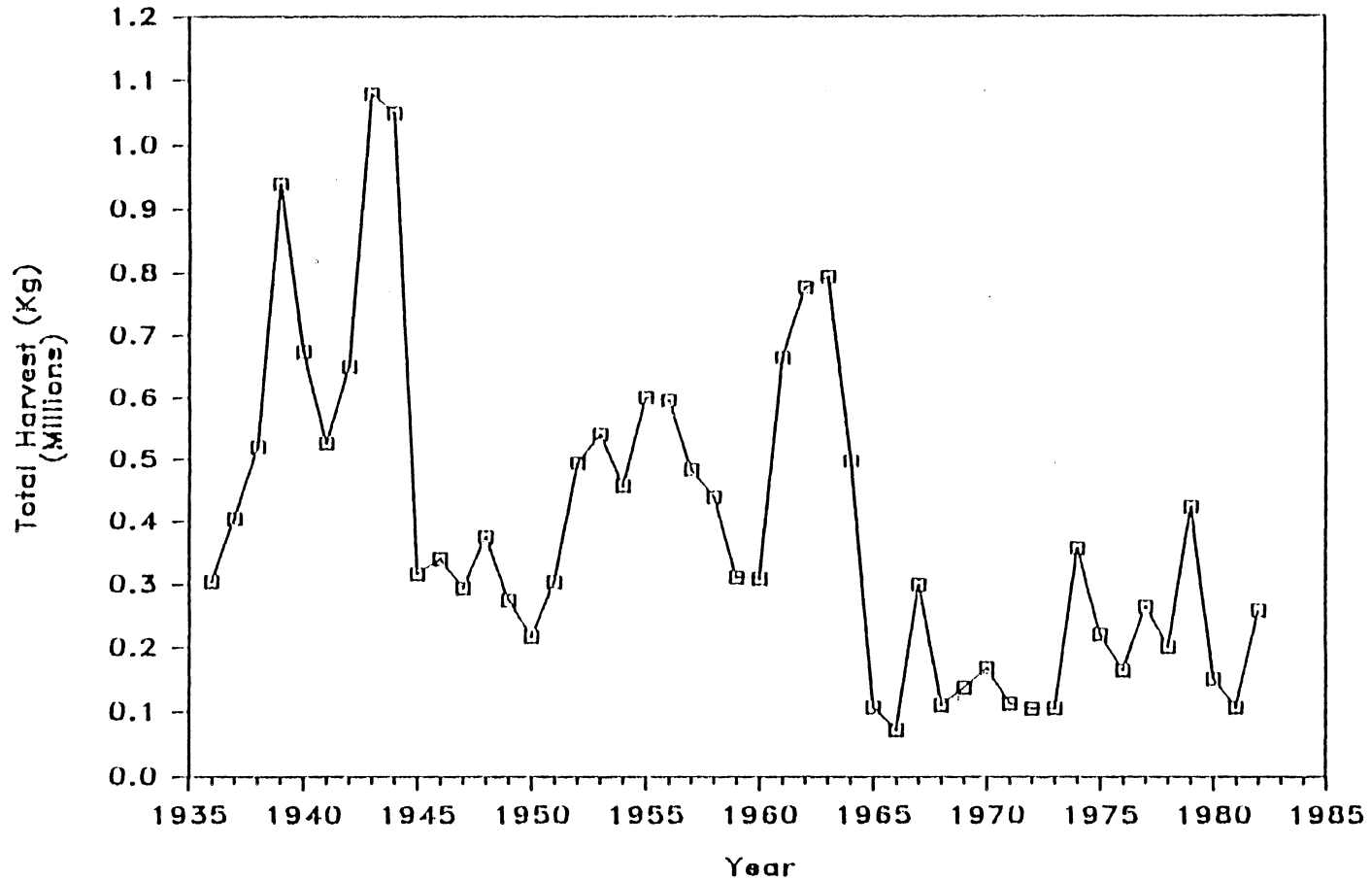


Figure 2. Southern Green Bay commercial yellow perch harvest for 1936-1982. (Unpublished data, Wisconsin Department of Natural Resources, Marinette, Wisconsin, USA).

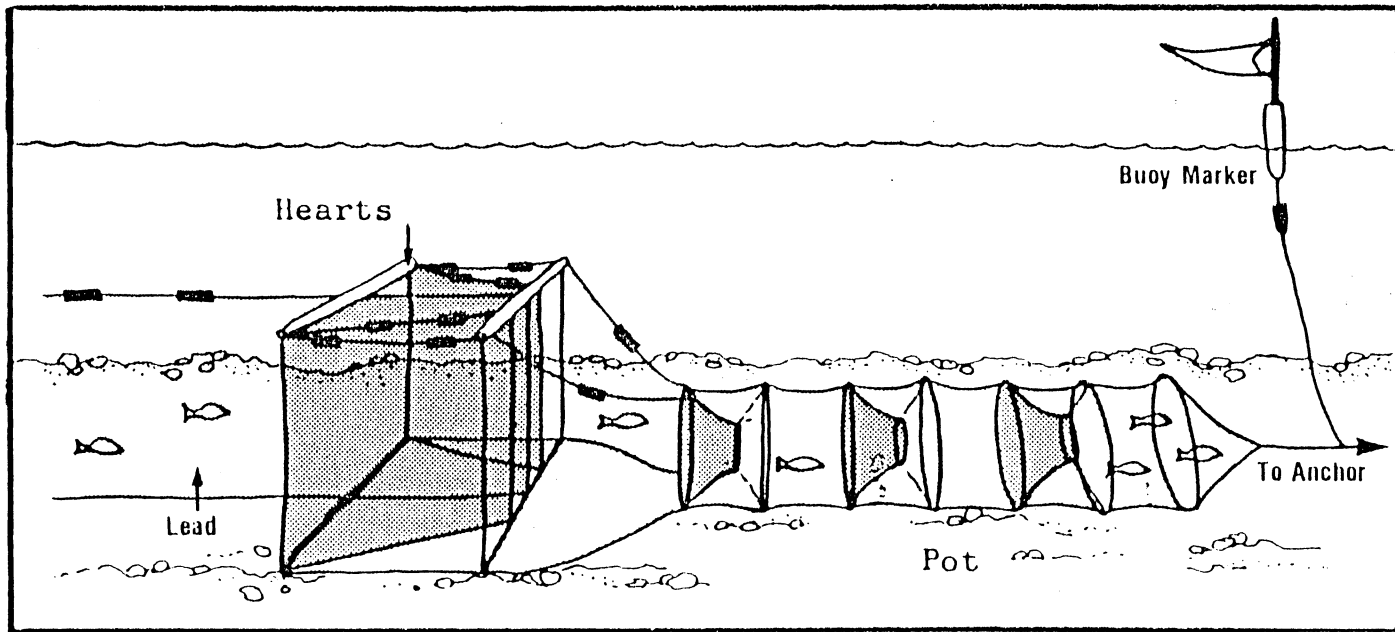


Figure 3. One end of a commercial drop net. An identical pot and hearts are attached to the other end of the lead.

perch from Green Bay. Mesh sizes currently (1982-83) fished in commercial drop nets (45 to 51-mm stretch mesh) capture many sublegal yellow perch (those fish less than 190 mm long). WDNR random samples of drop net catches averaged 66% sublegal yellow perch in 1979 and 59% in 1980 (Wisconsin Department of Natural Resources 1980). The sublegal yellow perch must be sorted from the catch and returned to the water. Repeated capture and handling of sublegal yellow perch was cited as a source of mortality (Belonger 1979). Other suspected sources of mortality were periods of low dissolved oxygen that may kill yellow perch trapped in a net and predation by gulls (Larus spp.) on released perch. This study was an effort to identify important causes of mortality and quantify losses associated with handling and entrapment.

Methods

I captured yellow perch in two 46-mm stretch mesh drop nets in the summers of 1982 and 1983. The drop nets had 70-m long leads and were 1.8 m high at the hearts (Fig. 3). The pots were constructed of 90-cm diameter steel hoops strung with number 18 nylon twine. The nets were treated with a black commercial net coating before the 1982 season.

Fishing depth was determined to the nearest 0.305 m with a Lowrance 300C depth sounder. Temperature and dissolved oxygen were measured to the nearest 0.1° C and 0.1 mg/l with a YSI model 54a oxygen/temperature meter. When the meter failed to operate, a hand thermometer and Hach kit were used.

Net Mortality

Each time a pot was lifted, captured live perch were counted and measured to the nearest millimeter. Dead perch were counted and sorted into legal and sublegal groups. An effort was made to maintain a mean lift interval of approximately three days (the legal limit). When a pot was lifted, data on four environmental variables were recorded: surface water temperature, dissolved oxygen and water temperature at the depth of the net, and the depth of the set.

I averaged the total percent dead perch in the 1982 and 1983 seasons by lift, month, and season. Commercial perch fishing was prohibited in June, 1983. I compared this period with June 1982 and

July-August 1983 when commercial fishing was concurrent with study sampling. Analysis of covariance (ANOCOV) (Nie et al. 1975) was used to adjust $\arcsin \sqrt{\text{percent}}$ dead perch for five variables (Table 1). The adjusted difference between fishing and no fishing periods was assessed for statistical significance.

Extended Set Mortality

To determine the effects of longer set intervals, perch captured during a 3-day set were transferred to a holding net and held for 1 to 8 days. The holding nets simulated the last three hoops of a drop net pot; they were 2 m long and had three 90-cm diameter hoops (Fig. 4). The hoops were strung with 46-mm stretch mesh, number 18, treated, nylon twine. All fish in a pot, regardless of species or condition, were placed in a holding net, which was set adjacent to a drop net. Dead fish were counted before and after the 1 to 8 day holding periods. After the holding period, live and dead perch were sorted, and the numbers of legal and sublegal perch were recorded.

I used stepwise multiple regression analysis (Nie et al. 1975) of $\arcsin \sqrt{\text{percent}}$ dead perch on nine variables (Table 1) to select those variables most important in determining perch mortality due to extended sets. I combined significantly contributing variables ($p < 0.05$) in a multivariate regression equation that predicted perch mortality.

Handling Mortality

I studied handling mortality of sublegal yellow perch by sorting perch caught by commercial methods and observing the sublegal fish for

Table 1. Independent variables used in closed season, extended set, and handling mortality analyses. The dependent variable in these analyses was percent dead perch.

Closed season ANOCOV	Extended Set Multiple Regression	Handling Multiple Regression
Covariates:	Depth of net	Depth of net
Depth of net	Water temperature (°C) at the the net	Water temperature (°C) at the the net
Water temperature (°C) at the the net	Dissolved oxygen at the net	Dissolved oxygen at the net
Dissolved oxygen at the net	Surface water temperature (°C)	Surface water temperature (°C)
Surface water temperature (°C)	Length of set (days)	Length of set (days)
Length of set (days)	Holding Time (days)	Handling Time (minutes)
Main Effects:	Total net time (days)	Deck temperature (°C)
Fishing/No Fishing	Number of perch caught	Elasped time after handling (hours)
	Number of dead perch after the original set	

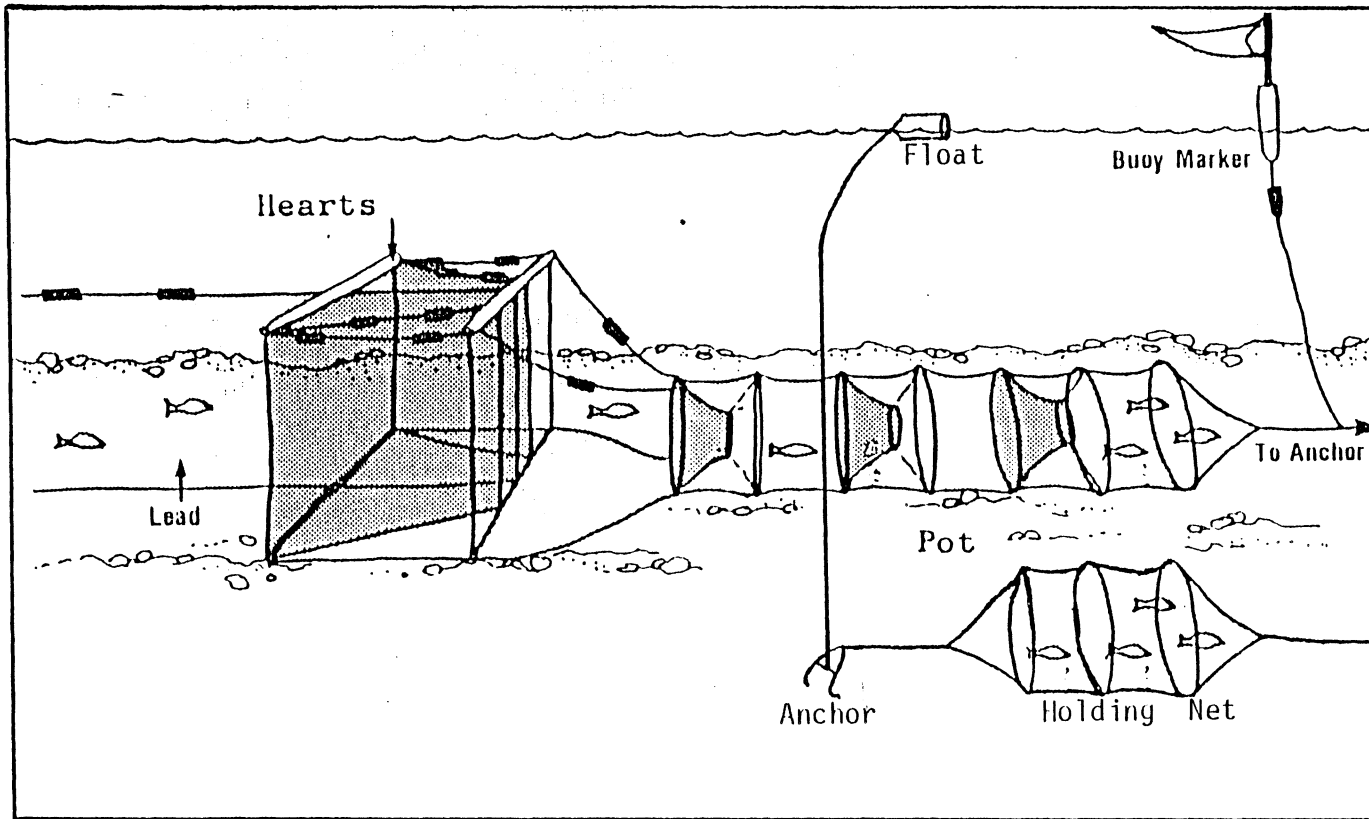


Figure 4. Position of a holding net (used in extended set experiments) in relation to a drop net pot.

the next 1 to 24 hours. Commercial handling consisted of:

- 1) unloading the catch onto the boat deck,
- 2) sorting out large fish by hand,
- 3) scooping up perch and other small fish with an aluminum shovel,
- 4) sorting out the legal size perch, and
- 5) returning sublegal perch to the water.

Handling experiments imitated commercial methods, but legal perch were released and sublegals retained in holding nets for later observation. Nets of 19-mm stretch mesh were used to hold sublegal perch. The nets were 1.5 m long and had two 90-cm diameter hoops. Holding nets containing sublegal perch were attached to a drop net buoy and suspended 2 meters below the water surface (Fig. 5). At this depth perch had sufficient oxygen and were out of view of potential vandals. The number of dead perch in the nets was recorded at intervals of 1 to 24 hours.

I expressed the number of dead sublegal perch in 48 handling experiments as a percent of sublegals held. I used stepwise multiple regression analysis (Nie et al. 1975) of percent dead sublegal perch on eight variables (Table 1) to select important handling mortality variables. Significantly contributing variables ($p < 0.05$) were combined in a regression equation that predicted perch mortality.

Modified Ricker Yield Models

I constructed Ricker equilibrium yield models (Appendix F) from data supplied by WDNR. Weights and lengths of 5,900 yellow perch from 1980-83 fall (September-October) trawl samples were used to compute mean weight (Appendix D) and length (Appendix C) at age. Mean weights and

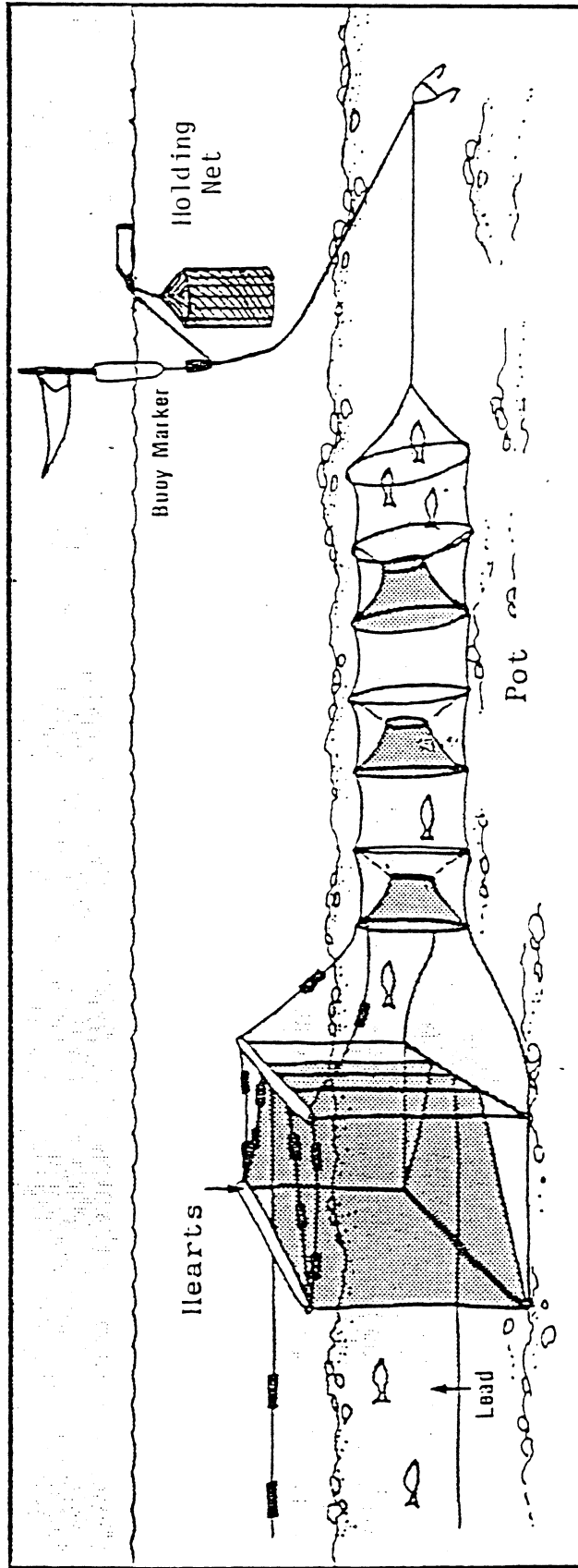


Figure 5. Relative positioning of a holding net used in perch handling experiments.

lengths for males and females were calculated separately and averaged with equal weighting.

Fall trawl samples contained too few older yellow perch to be considered representative of the perch population, as a whole. Therefore, I fitted available data to a length-weight equation by GM functional regression (Ricker 1975). I then used the predicted mean weights to calculate the instantaneous growth rate (G) between ages from the formula,

$$G = \log_e \left(\frac{\bar{W}_{t+1}}{\bar{W}_t} \right), \quad (1)$$

where W = weight at successive time intervals t and t+1.

Three separate estimates of the instantaneous rate of total mortality (Z) were computed and averaged (Appendix E). Catch curve analysis was used to compute Z values for 1979-83 WDNR fall trawl and commercial drop net harvest samples. A third Z was calculated based on 2 successive years of recaptures (R) from 1980-82 WDNR tagging, as follows:

$$Z = -(\log_e R_2 - \log_e R_1). \quad (2)$$

Because instantaneous rate of natural mortality (M) could not be estimated from available WDNR data, I set M at 0.255 based on data for other heavily exploited perch populations (0.233-0.288, Heyerdahl and Smith 1970 for Red Lakes, Minnesota; 0.255, Hartman et al. 1980 for western Lake Erie). M was considered uniform for all age groups recruited to the fishery and was divided in half (M = 0.1275) for each one half year interval in all Ricker models.

Instantaneous rate of mortality due to fishing (F) was computed by:

$$Z - M = F. \quad (3)$$

I assumed F was made up of three components:

- 1) instantaneous rate of net mortality (fish that die in nets but are not harvested) (NET),
- 2) instantaneous rate of handling mortality (H), and
- 3) instantaneous rate of fishing mortality (fish harvested) (F').

I divided F into these components based on: predicted catch composition values (Table 2), mean percent dead sublegal perch found in 1983 handling experiments, and mean percent dead perch caught in 1983 sampling.

Percent mortality due to drop net fishing (% D_T) was computed as:

$$\% D_T = \% D_L + \% D_{NET} + \% D_H, \quad (4)$$

where % D_L = legal size perch as % of catch,

% D_{NET} = % of catch dead when a pot is lifted, and

% D_H = sublegal perch killed by handling as % of catch.

F was partitioned by the equations:

$$NET = \frac{\%D_{NET}}{\%D_T} \times F, \quad (5)$$

$$H = \frac{\%D_H}{\%D_T} \times F, \quad (6)$$

$$F' = \frac{\%D_L}{\%D_T} \times F. \quad (7)$$

I combined instantaneous rates G, NET, H, F', and M in modified Ricker

Table 2. Predicted percent legal-sized perch captured in nets of five mesh sizes under four minimum length limits. Based on 1983 data (Parsley 1984).

Mesh Size (mm)	Minimum Length Limit (mm)			
	191	203	216	229
48	60	34	14	4
51	70	47	24	10
54	81	61	34	15
57	91	74	43	21
60	91	88	53	27

equilibrium yield models (Appendix F) to predict handling deaths (weight and number), net deaths (weight and number), and yield per 1000 kg of age 1 recruits. Weight of net deaths from age 1 through 7 was calculated as:

$$\text{Weight of net deaths} = \sum_{t=t_R}^{t=t} \text{NET}_t \bar{B}_t, \quad (8)$$

where t = successive time intervals; t is the first interval under consideration and t_R the last, and

$$\bar{B}_t = \frac{B_t(1+e^{G_t-Z_t})}{2}. \quad (9)$$

where B_t is the biomass at times t and $t+1$; and $Z = M + N + H + F'$.

Weight of handling deaths was given by:

$$\text{Weight of handling deaths} = \sum_{t=t_R}^{t=t} H_t \bar{B}_t. \quad (10)$$

Equilibrium yield (YE) was computed as:

$$\text{YE} = \sum_{t=t_R}^{t=t} F'_t \bar{B}_t \quad (11)$$

I developed 5 yield models (Appendix F), designated Models I, II, III, IV, and V, based on dropnets with mesh sizes of 48, 51, 54, 57 and 60 mm, respectively. Each model was divided into 4 submodels based on minimum length limits (MLLs) of 191, 203, 216, and 229 mm. The four submodels were designated A, B, C, and D. The MLL for Green Bay yellow perch in 1982-83 was 191 mm. Mesh sizes of drop nets used by Green Bay fishermen ranged from 45 to 51 mm. Model 1A, which combines a 191-mm MLL with 48-mm mesh nets, closely approximated conditions in 1982-83.

I assumed that all perch growth and 85% of fishing related mortalities occurred between May 1 and October 31, based on WDNR

estimates (Belonger, personal communication¹). Therefore, I applied growth and mortality rates to one-half year intervals. Age intervals 1.0 to 1.5, 2.0 to 2.5, etc, represented the May 1 to October 31 period. All growth and 85% of fishing related mortalities were applied to this period. Age intervals of 1.5 to 2.0, 2.5 to 3.0, etc. represented the November 1 to April 30 period, when I considered no growth and 15% of fishing related mortality occurred.

Parsley (1984) found that for a given MLL, as mesh size of drop nets was increased, the percent of legal-sized perch caught increased, and catch per unit effort (CPUE) of both legal and sublegal perch decreased. I incorporated differences in the predicted proportion of legal-sized perch caught by 48 to 60-mm nets, based on Parsley's data, in 5 Ricker models by equation 7 above. The NET, H, and F' values for each model were multiplied by the CPUE Parsley found for each mesh size (Table 3).

I used Z-score analysis (Zar 1969) to determine the proportion of perch from each age group that were longer than the minimum size caught by a given mesh size based on Parsley's data. Net mortality (NET) was applied to these fish. Then I again used Z-score analysis to calculate the percentage of the captured fish from each age group that were longer than the MLL. F' values were applied to these legal fish. H values were applied to the remainder of the captured fish.

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Table 3. Ratio of predicted catch per unit effort (CPUE) of legal size yellow perch caught with 48-mm stretch mesh nets, under a 191-mm minimum length limit (MLL), to CPUE's for four other mesh sizes and four MLL's. Values given are based on data from Parsley (1984).

Mesh Size (mm)	Minimum Length Limit (mm)			
	191	203	216	229
48	1.00	0.52	0.17	0.04
51	0.83	0.46	0.16	0.04
54	0.66	0.38	0.15	0.04
57	0.48	0.31	0.14	0.04
60	0.31	0.24	0.13	0.04

Results and Discussion

Net Mortality

Even with compliance with the 3-day set regulation, some yellow perch caught in standard drop net pots died before the pots were lifted (Table 4). In 1982, 7.7% of 14,690 yellow perch caught in four standard pots were dead after a mean set interval of 2.9 days (S.D. = 1.6). Thirty-one percent of the dead perch were legal length and 69% were sublegal. Total CPUE was 52 perch/pot-day. CPUE's for dead legal and sublegal perch were 1.3 and 2.8/pot-day, respectively.

Six percent of 15,501 yellow perch caught in 1983 were dead when the pots were lifted. The mean set interval was 3.4 days (S.D. = 1.5). Thirty-three percent of the dead yellow perch were legal length and 67% were sublegal. CPUE's for dead perch were 1.0 legal and 2.2 sublegals/pot-day. Total CPUE for 1983 was 53 perch/pot-day.

Other researchers have reported fish mortalities associated with nets similar to drop nets. Carter (1954) reported 10.8% net mortality for multi-fish species wing-net catches from Barkley Lake Kentucky. Hansen (1953) found mortalities as high as 9% for fish captured in hoop nets. WDNR personnel estimated 21.4% net mortality from a June 1979 random sample of 913 yellow perch caught in drop nets in southern Green Bay (Belonger 1979). I found that net mortality of yellow perch from the combined catches of the four standard pots I fished in 1982-83 ranged from 0-32% (Fig. 6).

Table 4. Summary of yellow perch catch for four standard (46-mm) drop net pots. The pots were fished during the summers of 1982-83.

	1982 -----	1983 -----
Number of Perch Caught	14,690	15,501
Number of Dead Perch	1,135	931
Number of Dead Legal Perch	349	303
Number of Dead Sublegal Perch	786	628
% Dead Perch	7.7	6.0
% Legal Dead Perch	2.4	2.0
% Sublegal Dead Perch	5.3	4.0
Total Effort (Pot-days)	279	292
Catch/Pot-Day	52.7	53.1
Legal Dead/Pot-Day	1.3	1.0
Sublegal Dead/Pot-Day	2.8	2.2
Mean Lift Interval (Days)	2.9	3.4

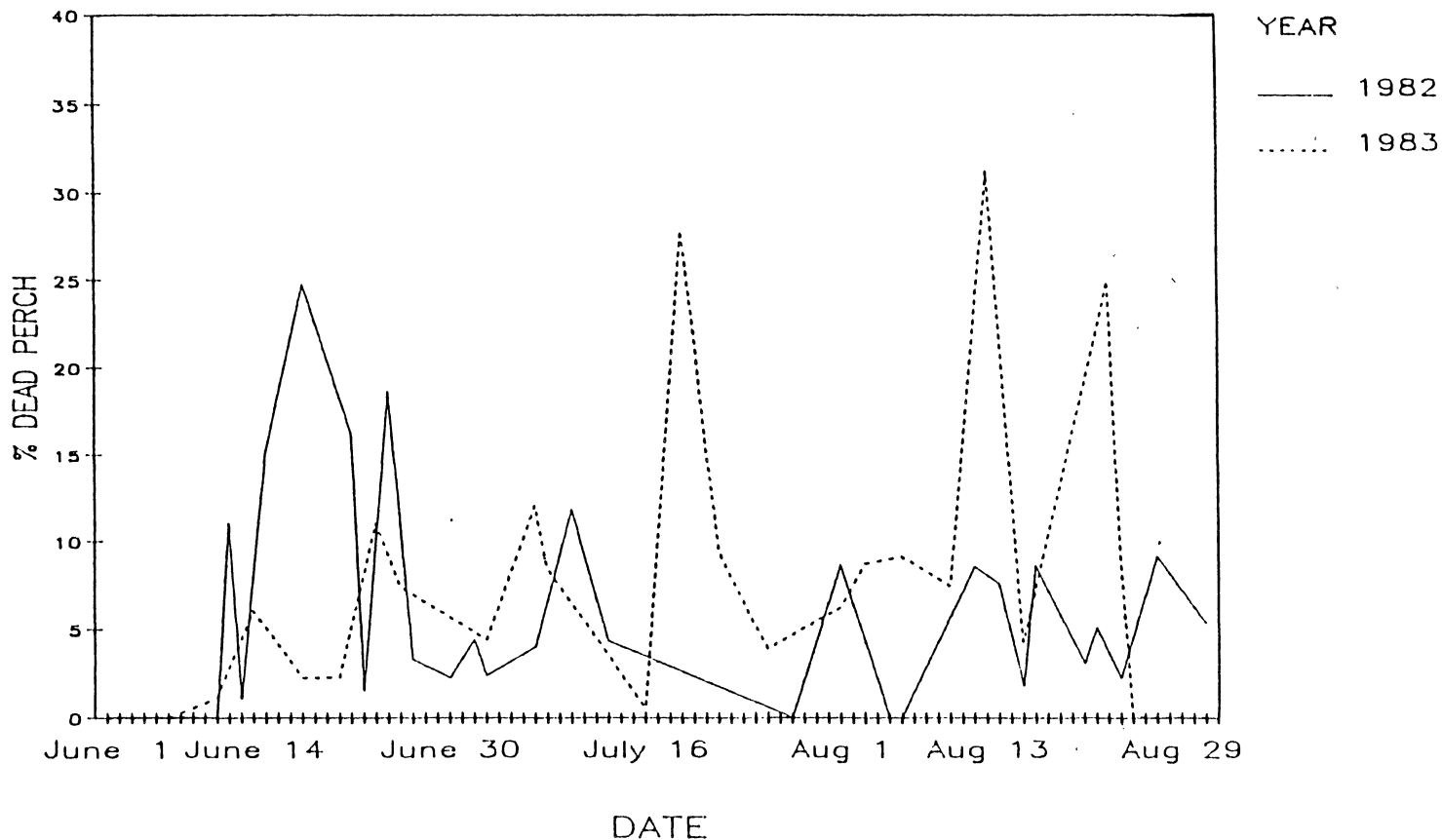


Figure 6. Mean percent dead perch per lift for four standard (46-mm stretch mesh) drop net pots. The pots were fished in the summers of 1982 and 1983 in southern Green Bay.

Repeated capture and handling of yellow perch by commercial drop net fishermen may increase mortality of perch. A change in WDNR regulations for the southern Green Bay yellow perch commercial fishery during my study enabled me to examine that possibility. Commercial perch fishing was permitted in June 1982, and July and August of both years but prohibited in June 1983. I found a greater percentage of dead yellow perch in my four standard pots during the periods when commercial fishing was occurring than when it was not. Average perch mortality for June 1982 (10%) was 3.8 times that for June 1983 and nearly twice the July- August 1982 average (Fig. 7). Average mortality for July-August 1983 (11%) was 4.2 times the June 1983 average.

After adjustment (ANOCOV (Nie et al. 1975)) for differences in five variables recorded for each lift (Table 1), a statistically significant difference existed between mean percent dead perch for June 1982 and June 1983 ($p < 0.005$). July-August 1983 mean percent dead perch was significantly greater than that for June 1983 ($p < 0.021$). July-August 1982 mean percent dead perch was significantly less than June 1982 ($p < 0.05$).

These results indicate that closing the commercial fishing season during June 1983 substantially decreased yellow perch mortality during that period. My observations during fishing support this conclusion. Study nets were set in a heavily fished area in June 1982. Many perch captured in that month had red surface abrasions that were long and thin and occurred along the sides of the fish where they would have rubbed against twine. The injured perch seemed listless and flopped and struggled less vigorously during sorting than did apparently healthy individuals. The injured perch struggled on the surface of the water

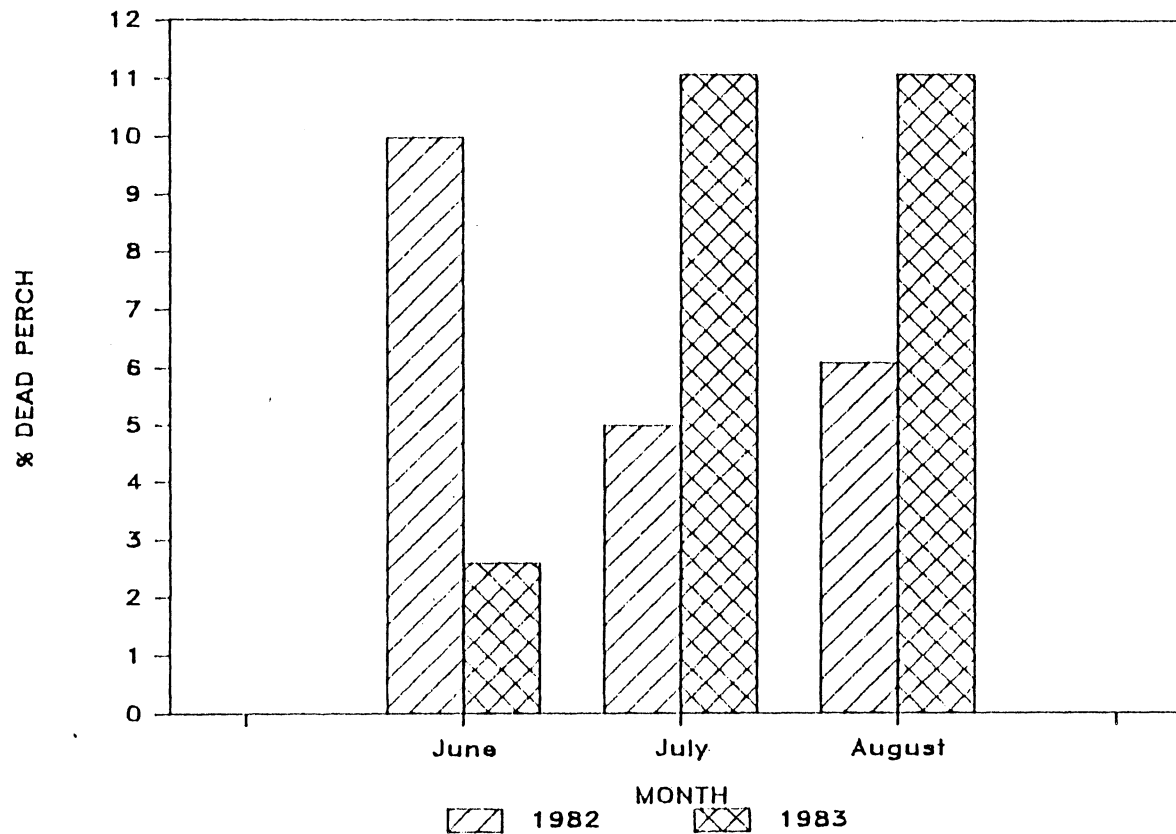


Figure 7. Monthly mean percent dead perch for four standard (46-mm stretch mesh) drop net pots. The pots were fished in southern Green Bay in the summers of 1982 and 1983.

when released rather than sounding and seemed less likely to survive.

Differences in yellow perch mortality between June 1983 and the other periods may have been due to variables not measured in this study. The ANOCOV results indicate that seasonal or time differences between the periods that I compared probably did not confound the analyses. The significant decrease in percent dead perch from June 1982 to July-August 1982 indicates that seasonal differences between periods did not account for the increase in perch mortality that I found between June 1983 and July-August 1983. However, dissolved oxygen and water temperatures were not monitored between lifts. Differences in point measurements of these variables may not have accurately reflected daily and hourly extremes. Patterson et al. (1975) found that low dissolved oxygen levels at times hindered commercial fishing operations over as much as 150 miles of lower Green Bay. Sager (1971) reported 0.2 mg/l dissolved oxygen at the entrance light (Fig. 1) on August 21, 1970. Point samples of dissolved oxygen in my study averaged less than 2.0 mg/l (\bar{x} = 1.8, S.D. = 0.2) for eight lifts from July 15-21, 1983. I may have missed other periods of low oxygen concentrations during this study.

Extended Set Mortality

Mortality of yellow perch was greater (\bar{x} = 69%; S.D. = 31) in extended set experiments than in average 3-day sets (\bar{x} = 7.7% in 1982 and 6.0% in 1983). Mortality of perch in 28 extended set experiments ranged from 2 to 100% (Table 5). Stepwise multiple regression analysis of extended set data gave the following equation:

$$\arcsin \sqrt{\%DEAD} = 8.0(\text{HOLD}) - 4.7(\text{D.O.}) + 1.9(\text{TEMP}) - 28.0 \quad (12)$$

Table 5. Percent of yellow perch held in 28 extended set experiments that were dead at the end of the holding period. Values for three variables chosen by stepwise multiple regression analysis as explaining 61% of the variation in perch mortality are included. HOLD is the time (days) that perch were held after a 3-day set. D.O. is the dissolved oxygen concentration (mg/l) at net depth. TEMP is the water temperature (C) at net depth. The data are arranged in ascending order of the most important independent variable, HOLD (R = 39%).

<u>HOLD</u>	<u>TEMP</u>	<u>D.O.</u>	<u>Number Held</u>	<u>Number Dead</u>	<u>Percent Dead</u>
1	17	9	370	8	2
2	23	7	121	101	83
2	15	3	329	271	82
2	16	10	63	23	37
2	16	10	27	10	37
2	15	3	188	123	65
3	16	7	187	19	10
3	17	7	297	269	91
3	16	7	199	33	17
3	21	8	198	66	33
3	22	5	39	34	87
3	20	7	161	97	60
3	18	11	151	50	33
3	18	11	230	104	45
3	22	7	36	28	78
3	16	2	149	149	100
3	20	8	140	31	22
4	17	7	97	96	99
4	23	7	150	132	88
5	23	5	20	20	100
5	17	7	114	97	85
5	20	8	207	195	94
6	21	8	143	142	99
6	21	8	165	165	100
7	18	7	87	74	85
7	16	10	88	87	99
7	20	7	14	14	100
8	18	7	98	87	89
			Mean		69

where HOLD = time (days) that perch were held after a 3-day set,

D.O. = dissolved oxygen (mg/l) at net depth, and

TEMP = water temperature ($^{\circ}$ C) at net depth.

The independent variables were chosen by the stepwise procedure in the order that they appear in the equation. HOLD was the most important variable, accounting for 39% of the variation in perch mortality. D.O. accounted for an additional 18%. TEMP accounted for 4% of the variation in perch mortality. The coefficient of determination, R^2 was 61% for the model as a whole ($S_{x \cdot y} = 15.9$, $n = 28$).

Percentages of dead yellow perch that I found in holding were different than those that would be seen in normal commercial operations. The holding nets were closed whereas commercial pots are open. Open pots would continue to capture perch. Immigration of live fish would tend to keep observed percentages of dead perch low.

Results of extended set experiments indicate that the 3-day set regulation for drop nets is sound. Longer sets increase the probability of death of captured perch from low dissolved oxygen or other causes.

Handling Mortality

Many sublegal yellow perch captured in drop nets died following simulated commercial sorting. An average of 36% of 2,592 sublegal perch (SLP) sorted in 48 handling experiments were dead after a mean of 9.5 hours (S.D. = 9.3) (Table 6). Perch used in the handling experiments may have been previously captured and handled by commercial fishermen. The mortality that I found may have resulted from previous holding and

Table 6. Percent of sublegal-sized yellow perch handled in 48 experiments that were dead at the end of the holding period. Values for three variables selected by stepwise multiple regression analysis as accounting for 63% of the variation in mortality of sublegal yellow perch are included. E.T. is elapsed time (hrs.) after handling. HAND is handling time (mins.). DECK is the temperature of the boat deck (C). E.T. was the most important independent variable ($R = 42\%$). The data are arranged in ascending order of E.T. values.

E.T.	HAND	DECK	Number Held	Number Dead	Percent Dead
1.0	14	20	102	1	1
1.5	28	18	146	69	47
2.0	14	20	102	2	2
2.0	20	20	103	34	33
2.0	16	20	107	23	21
2.0	16	18	157	68	43
2.0	37	18	161	93	58
2.0	19	20	107	29	27
2.0	12	20	107	24	22
2.0	18	19	109	17	16
2.5	11	20	108	22	20
2.5	14	18	115	49	43
3.0	12	26	108	24	22
3.0	19	20	107	34	32
3.0	18	19	109	90	83
3.0	8	21	17	5	29
3.0	12	20	107	27	25
3.0	19	20	100	18	18
3.0	14	20	102	3	3
3.0	18	19	109	22	20
3.0	7	22	19	3	16
3.5	9	20	118	9	8
3.5	16	20	107	26	24
4.0	9	24	78	12	15
4.0	17	22	111	49	44
4.0	13	24	108	28	26
4.0	21	14	100	22	22
4.0	7	22	109	7	6
4.0	11	19	75	8	11
4.0	12	20	107	32	30
4.0	19	20	107	37	35
5.0	14	20	102	3	3
6.0	14	19	91	10	11
19.5	12	26	108	94	87
20.5	11	19	75	36	48
21.0	7	22	109	65	60
21.0	17	22	111	100	90
21.0	14	19	91	54	59
21.5	16	15	155	26	17
21.5	15	14	103	20	19
22.5	15	15	85	14	16
23.0	9	24	78	21	27
23.5	21	14	100	55	55
24.0	16	20	107	88	82
24.0	12	20	107	103	96
24.0	13	24	108	58	54
24.0	19	20	107	106	99
24.0	14	20	102	53	52

Mean = 36%

handling or experimental handling or some combination of the three. I used handling mortality as a convenient term to describe perch deaths following handling.

Multiple regression analysis identified three variables that significantly ($p < 0.05$) affected handling losses: elapsed time (hrs.) after handling (E.T.), handling time (mins.) (HAND), and deck temperature ($^{\circ}\text{C}$) (DECK). The resulting equation was:

$$\% \text{ dead SLP} = 2.07(\text{E.T.}) + 2.37(\text{HAND}) + 3.8(\text{DECK}) - 96.07 \quad (13)$$

Approximately 63% of the variation in mortality of sublegal yellow perch that occurred during handling experiments was explained by the equation ($R^2 = 0.63$, $S_{x.y} = 16.5$).

Elapsed time was the most important variable, accounting for 42% of the variation in perch deaths. The importance of time after handling indicates that initial injuries have delayed effects. Therefore, estimates of mortality based on observations of floating fish at boatside would be underestimates.

The WDNR has also estimated substantial losses of yellow perch which are presumed to be caused by commercial holding and handling. Their estimates (Table 7) were based on counts of dead perch in mid-June 1979-82 in 25, 1/4-mile transects along the shores of southern Green Bay. The mid-June period was selected as a period of high fishing pressure when local residents reported many dead perch along beaches. The annual mean number of dead perch estimated along shorelines of southern Green Bay from 1979 to 1982 was 52,036.

Table 7. Wisconsin Department of Natural Resources (WDNR) estimates of dead perch along 130 miles of southern Green Bay shoreline in mid-June. (Unpublished data, WDNR, Marinette, Wisconsin, USA).

<u>Year</u>	<u>Number of perch Counted in 25 1/4 Mile Transects</u>	<u>Expanded Number of Perch/130 Miles Of Shore</u>
1979	3130	66,065
1980	622	12,524
1981	3028	77,518
1982	2146	64,852
1983	21	623

During the course of my study, several individuals suggested that use of a live well by commercial fishermen might reduce handling mortality. A live well large enough to accommodate commercial catches might involve costly boat alterations, and sorting fish from a live well would require more time than present methods. The extra time required would be unpopular with commercial fishermen (personal observation).

Tying off the pot and removing fish a few at a time might reduce perch mortality but would be impractical. Heavy seas and high winds would make tying off a pot difficult. The weight of the boat could break lines and pull one end of the net downwind of the original set. Scooping perch a few at a time would slow a fishing operation. Commercial fishermen are not likely to use this method.

Keeping the boat deck wet during sorting would lower deck temperature via evaporation and help prevent desiccation of gill tissues of yellow perch. Boat decks equipped with adequate drain holes could be safely kept wet with a few buckets of water while sorting is in progress. This practice was used by some fishermen that I observed.

The best solution, and the most practical to regulate, would be to fish drop nets that captured fewer sublegal perch.

Ricker Yield Modeling

Growth:

Green Bay yellow perch are heavily exploited ($F = 1.445$), and are fast growing (Table 8). The high growth rate may reflect a low stock density. Historical evidence suggests that growth of yellow perch in

Table 8. Calculated instantaneous growth rates (B) between mean weights at ages for yellow perch from various waters.

Age Interval						Water	Reference
1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7		
1.6906	0.7718	0.4162	0.3278	0.2969	0.2424	Southern Green Bay, Lake Michigan	Present study
1.7859	0.8481	0.5491	0.3091	0.1664	0.0799	Red Lakes, Minnesota	Smith (1977)
1.4955	0.3704	0.2513	0.4595	0.3094	0.2758	Southwest Lake Michigan	Schaefer (1977)
1.8632	0.7187	0.3684	0.2642	-	-	Lake Erie	Kitchell (1977)
-	-	0.4761	0.3212	0.1805	0.2065	Lake Mendota, Wisconsin	Mackenthum (1949)
1.7918	1.3049	0.6199	0.3736	0.3829	0.2240	Saginaw Bay, Lake Huron	Hile & Jobes (1941)

Green Bay is density dependent. Yellow perch abundance was probably high in 1935-45 when the average commercial harvest exceeded 680,000 Kg. (Fig. 2). Hile and Jobes (1942) reported slow growth for yellow perch in Green Bay based on data collected in the 1930's. Wells (1977) stated that growth rates of yellow perch throughout Lake Michigan began to increase between 1954 and 1963, were even greater in 1964, and greater still in 1970. He attributed increased growth rates to declining yellow perch abundance. El-Zarka (1959), Eshenroder (1977), and Henderson (1985) reported higher growth rates for yellow perch during periods of low abundance in Lake Huron. Low perch abundance and high growth rates followed periods of intense fishing pressure in Saginaw Bay, Lake Huron.

The high instantaneous growth rates for yellow perch in southern Green Bay were similar to those for other perch populations (Table 8). Mean total lengths (empirical) at age for southern Green Bay yellow perch were similar to those found for other commercially exploited populations (Table 9). Predicted mean weights fell within the range reported for yellow perch in other waters (Table 10). The length-weight equation was:

$$\log \bar{W} = 3.1668 \log \bar{L} - 5.259 \quad (14)$$

where \bar{W} = mean weight in grams, and

\bar{L} = mean length (mm) for age I to VII perch (Fig. 8).

Table 9. Mean total lengths (mm) at the end of each year of growth for yellow perch from various waters. Values for the present study were calculated from unpublished Wisconsin Department of Natural Resources data (Appendix C).

	Years of Growth Completed							Water	Reference	
	1	2	3	4	5	6	7			
85	145	185	211	234	257	279	Green Bay, Lake Michigan	Present study	a	
77	135	200	240	270	302	324	Saginaw Bay, Lake Huron	Hile & Jobes (1941)	b	
68	108	146	181	209	236	259	Saginaw Bay, Lake Huron	el-Zarka (1959)	b	
90	151	189	215	238	-	-	Saginaw Bay, Lake Huron	Eshenroder (1977)	b	
71	117	157	196	221	254	274	Green Bay, Lake Michigan	Hile & Jobes (1942)	b	
81	130	163	183	-	-	-	Green Bay, Lake Michigan	Joeris (1956)	b	
100	161	183	213	232	-	-	Green Bay, Lake Michigan	Hartman (1978)	b	
94	170	216	244	264	-	-	Lake Erie	Jobes (1952)	b	
102	157	185	206	224	244	264	Western Lake Erie	Hartman et al (1980)	b	
77	138	175	200	228	247	269	Southwest Lake Michigan	Schaefer (1977)	a	
-	177	212	243	269	286	305	Southeast Lake Michigan	Wells (1977)	b	
74	132	176	210	231	244	252	Red Lakes, Minnesota	Smith (1977)	b	
99	140	175	206	226	251	269	Lake of the Woods, Canada and Minnesota	Carlander (1949)	b	

a - Empirical lengths were used.

b - Back-calculated lengths were used.

Table 10. Mean weight (g) at the end of each year of growth for yellow perch from various waters. Values for the present study were calculated from unpublished Wisconsin Department of Natural Resources data (Appendix D).

Years of Growth Completed							Water	Reference
1	2	3	4	5	6	7		
7.1	38.5	83.3	126.3	175.3	235.9	300.6	Green Bay, Lake Michigan	Present study
5.7	34.0	79.4	137.5	187.3	221.2	239.6	Red Lakes, Minnesota	Smith (1977)
13.0	58.0	84.0	108.0	171.0	233.0	307.0	Southwest Lake Michigan	Schaefer (1977)
9.0	58.0	119.0	172.0	224.0	-	-	Lake Erie	Kitchell et al (1977)
-	-	82.0	132.0	182.0	218.0	268.0	Lake Mendota, Wisconsin	Mackenthum & Herman (1949)
4.0	24.0	88.5	164.3	239.0	350.5	438.5	Saginaw Bay, Lake Huron	Hiles & Jobes (1941)

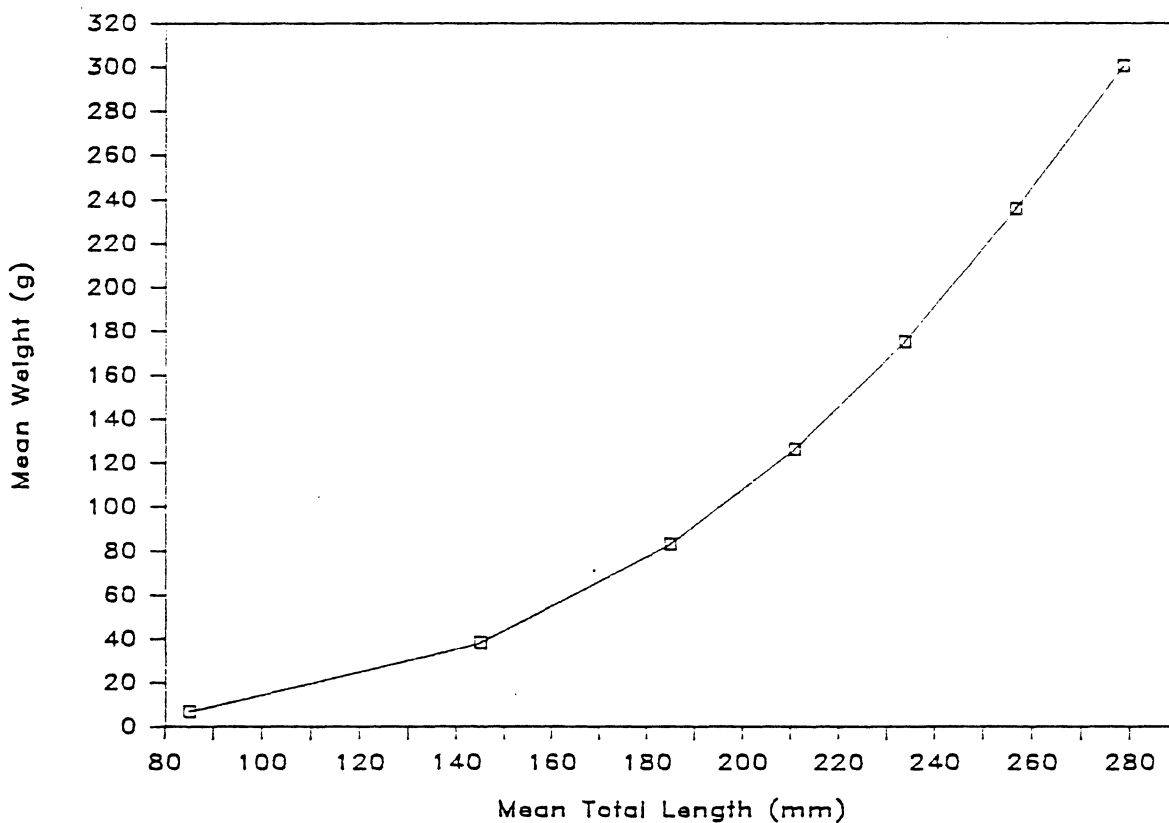
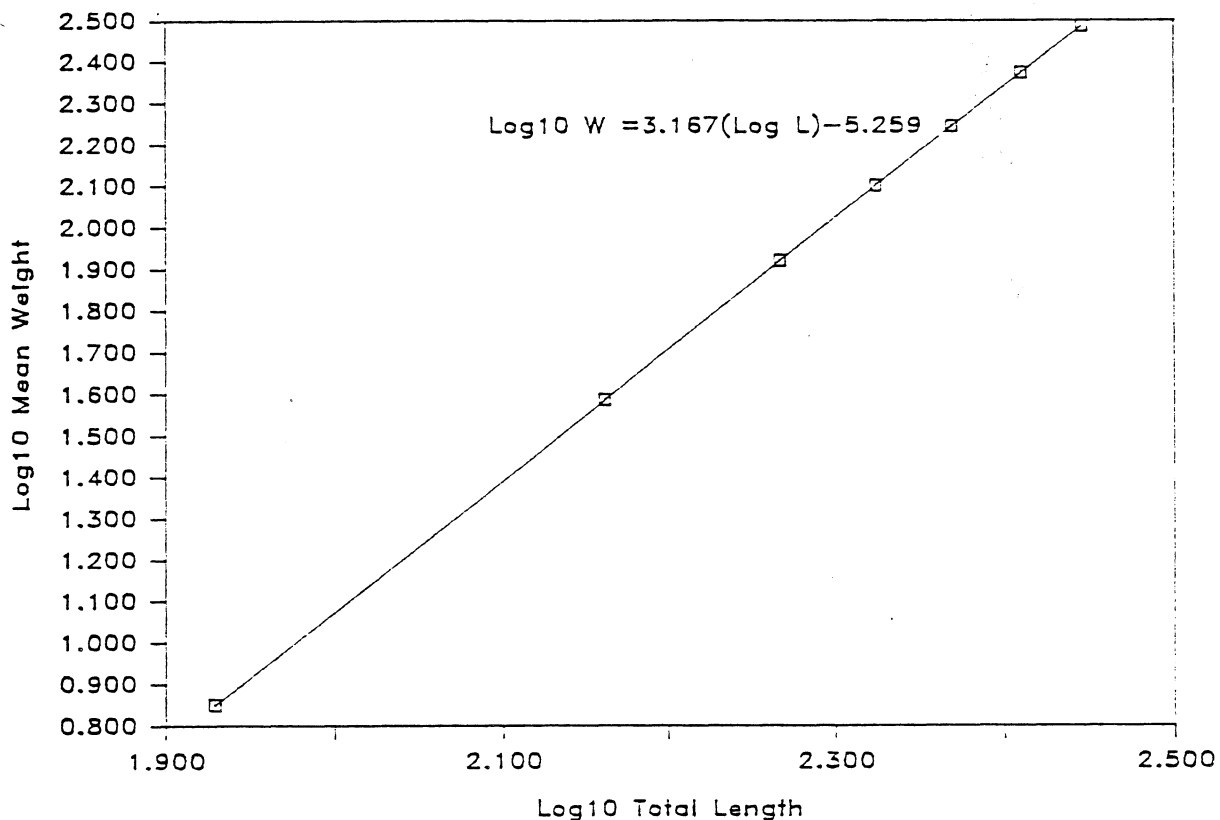


Figure B. Weight-length curves for southern Green Bay yellow perch. Curves are based on mean weights (g) and mean total lengths (mm) at age from Wisconsin Department of Natural Resources (WDNR) fall trawl assessments in 1980-83. (Unpublished data, WDNR, Marinette, Wisconsin, USA).

Instantaneous Rate of Total Mortality (Z):

Total mortality of yellow perch in Green Bay was high. I calculated a grand mean instantaneous rate of mortality (\bar{Z}_G) of 1.70 from three independent estimates of \bar{Z} (Table 11). Eight year classes were represented by the data (Appendix F). WDNR also estimated a Z of 1.70 for the 1977 year class of yellow perch in Green Bay from fall trawl relative abundance estimates ($Z = -\log_e R_2 - \log_e R_1$) (Southern Green Bay Operations Staff 1980).

The total mortality rate for yellow perch from Green Bay was higher than that reported for three other perch populations (Table 12). Substantial non-harvest mortalities associated with drop net fishing could contribute to the high total mortality.

Instantaneous Rate of Fishing Mortality (F):

The instantaneous rate of fishing mortality that I found ($F = 1.445$) was greater than that of other commercially exploited yellow perch populations (Table 13). The value of M of 0.255 (Hartman et al 1980) that I subtracted from Z to calculate F did not account for perch handling and net mortalities associated with drop nets. The adjusted F, which I designated F', is similar to F for yellow perch in western Lake Erie (Hartman 1980) (Table 13).

Yield and Number Harvested:

Yield and number of perch harvested would increase if the 191-mm MLL were retained and mesh size of drop nets increased. Predicted yield

Table 11. Percent annual mortality (A) and instantaneous rate of total mortality (Z) for yellow perch from southern Green Bay, Lake Michigan. Mean Z values were calculated by catch curve analysis from commercial catch data and fall trawl data provided by the Wisconsin Department of Natural Resources (WDNR) (Appendix E). Data from WDNR mark-recapture studies were used in a third estimate of Z ($Z = -\log_e R2 - \log_e R1$) (Appendix E). A grand mean Z was calculated by averaging the three estimates.

% Annual Mortality (A)	Instantaneous Rate of Total Mortality (Z)	Waters	References
83.5	1.80	Green Bay, Lake Michigan	Fall trawl data 1978-83
78.3	1.53	Green Bay, Lake Michigan	Commercial harvest data 1978-82
83.1	1.78	Green Bay, Lake Michigan	Mark & recapture data 1980-82
81.7	1.70	Green Bay, Lake Michigan	Grand mean

Table 12. Percent annual mortality (A) and instantaneous rate of total mortality (Z) for yellow perch from various waters.

% Annual Mortality (A)	Instantaneous Rate of Total Mortality (Z)	Waters	References
81.7	1.70	Green Bay, Lake Michigan	Grand mean, present study
54.0	0.78	Lake Oahe, South Dakota	Nelson & Walburg (1977)
57.0	0.84	Red Lakes, Minnesota	Smith (1977)
70.0	1.20	Western Lake Erie	Hartman et al. (1980)
81.8	1.70	Green Bay, Lake Michigan	Wisconsin Department of Natural Resources (1980)

Table 13. Annual fishing mortality (m) and instantaneous rate of fishing mortality (F and F') for yellow perch from various waters.

% Annual Fishing Mortality (m)	Instantaneous Rate of Fishing Mortality (F)		Water	References
76.4	1.445	-	Green Bay Lake Michigan	Present study a
64.5	-	1.037	Green Bay Lake Michigan	Present study b
61.3	0.949	-	Western Lake Erie	Hartman et al (1980)
44.7	0.592	-	Red Lakes Minnesota	Smith (1977)

a - unadjusted value (F = Z - M)

b - value adjusted for NET = .087, H = .321.

(Kg) and number of perch harvested, per 1000 Kg of age 1 recruits, were greatest with a combination of 191-mm MLL and 54-mm mesh nets (Model IIIA) (Fig. 9). Model IIIA was based on an average catch in which only 19% of the perch were less than 191 mm long (Table 2). When compared to the base model (Model IA), Model IIIA predicted a 44% increase in yield (Table 15) and a 31% increase in number of perch harvested (Table 16) per 1000 Kg of age 1 recruits. The average weight of a perch harvested in Model IIIA was 144 g, 11% greater than in Model IA (Table 14). Larger average weight explains why yield increased by a greater proportion than number harvested.

When I simulated increased MLL's, the predicted yield and number of perch harvested decreased (Fig. 9). Decreases in yield and number were most dramatic for Model I, with 48-mm mesh nets. A change in MLL from 191 mm to 203 mm within Model I resulted in a 2,906 Kg (59%) loss in yield (Table 15) and 65% loss in number of perch harvested (Table 16). However, the same change for a 60-mm mesh net (Model V) resulted in only a 5% drop in yield and 14% loss in number of perch harvested. Larger MLL's delayed yellow perch harvest, but a greater portion of the population was sublegal. Because I applied 36% handling mortality to these larger sublegal perch, few perch lived to reach the larger MLL's. Combining larger MLL's with larger mesh sizes moderated, but did not prevent, decreases in predicted perch harvests.

Handling Mortality:

If mesh size in drop nets were increased, fewer sublegal perch would be caught, and therefore, handling deaths would decrease (Fig. 10). Models

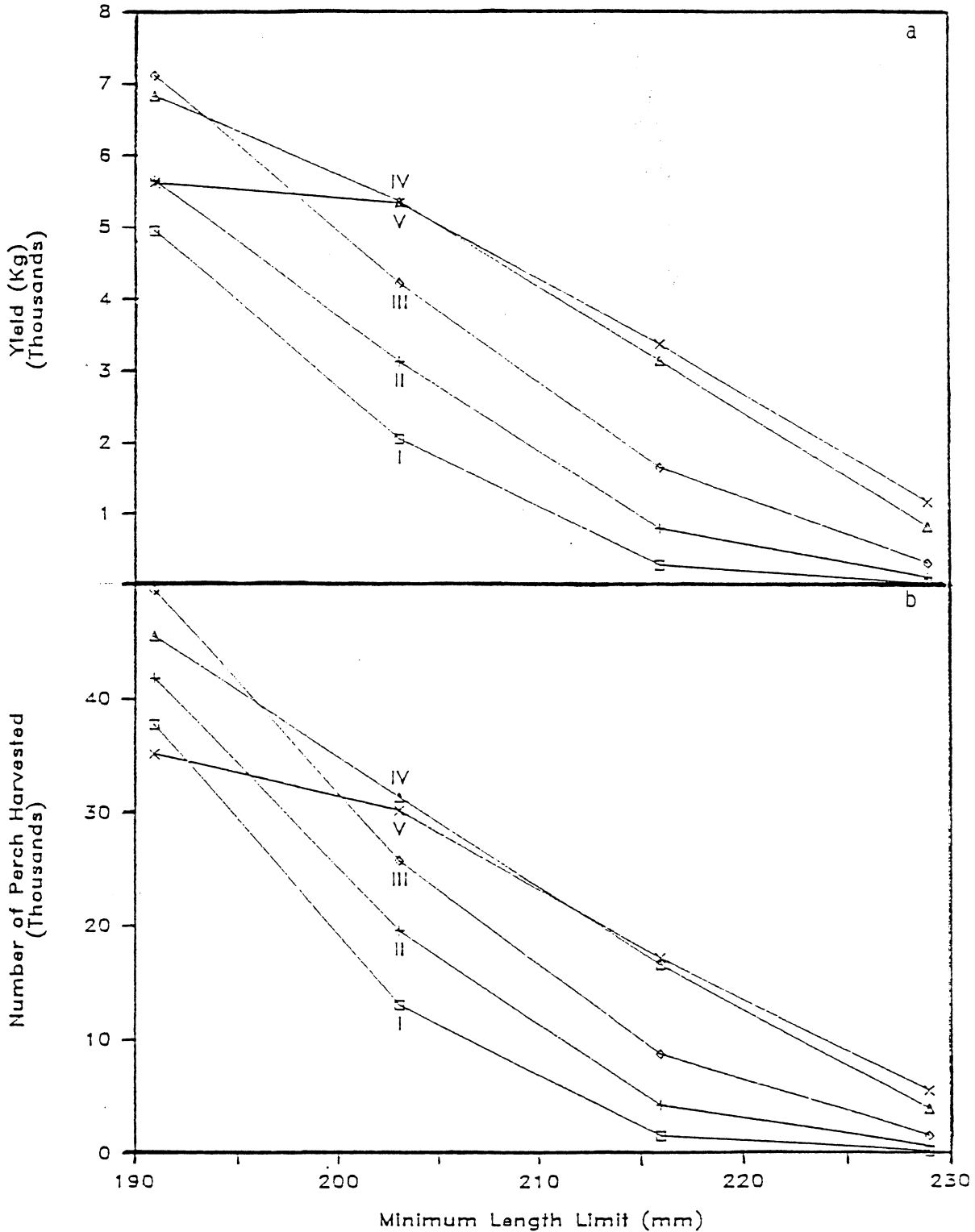


Figure 9. Total predicted yield (Kg) (upper panel) and number of perch harvested (lower panel), per 1000 Kg of age 1 recruits, based on five Ricker yield models (Appendix F), I-V, with nets of mesh sizes 48, 51, 54, 57, and 60 mm, respectively. Each model contained four submodels with minimum length limits of 191, 203, 216, and 229 mm, respectively.

Table 14. Predicted mean weight (g) of yellow perch harvested, with nets of five mesh sizes under four minimum length limits, predicted by modified Ricker yield models (Appendix F).

Mesh Size (mm)	Minimum Length Limit (mm)			
	191	203	216	229
48	130	156	188	217
51	135	160	188	217
54	144	164	188	217
57	150	171	188	217
60	160	177	196	217

Table 15. Predicted yield (Kg) of perch/1000 Kg age 1 recruits caught in nets of five mesh sizes under four minimum length limits. Numbers in brackets indicate percent change (+/-) relative to Model I. Numbers in parentheses indicate percent change (+/-) relative to Submodel A. Values were predicted by modified Ricker yield models (Appendix F).

Model	Mesh size (mm)	Minimum Length Limit (mm)			
		Submodel A 191	Submodel B 203	Submodel C 216	Submodel D 229
I	48	4952	2046 (-59)	290 (-94)	26 (-99)
II	51	5649 [14]	3128 (-45) [52]	805 (-86) [177]	117 (-98) [345]
III	54	7115 [44]	4218 (-41) [106]	1656 (-77) [470]	316 (-96) [1100]
IV	57	6829 [38]	5350 (-22) [161]	3148 (-54) [985]	825 (-88) [3038]
V	60	5621 [14]	5328 (-5) [160]	3377 (-40) [1064]	1170 (-79) [4348]

Table 16. Predicted number of perch/1000 Kg age 1 recruits harvested in nets of five mesh sizes under four minimum length limits. Numbers in brackets indicate percent change (+/-) relative to Model I. Numbers in parentheses indicate percent change (+/-) relative to Submodel A. Values were predicted by modified Ricker yield models (Appendix F).

Model	Mesh Size (mm)	Minimum Length Limit (mm)							
		Submodel A 191		Submodel B 203		Submodel C 216		Submodel D 229	
I	48	37766	13051	(-65)	1549	(-96)	122	(-99)	
II	51	41815 [11]	19578 [50]	(-53)	4289 [177]	(-90)	540 [343]	(-98)	
III	54	49532 [31]	25725 [97]	(-48)	8812 [469]	(-82)	1461 [1098]	(-97)	
IV	57	45475 [20]	31323 [140]	(-31)	16647 [975]	(-63)	3814 [3026]	(-92)	
V	60	35209 [-7]	30136 [131]	(-14)	17232 [1012]	(-51)	5416 [4339]	(-85)	

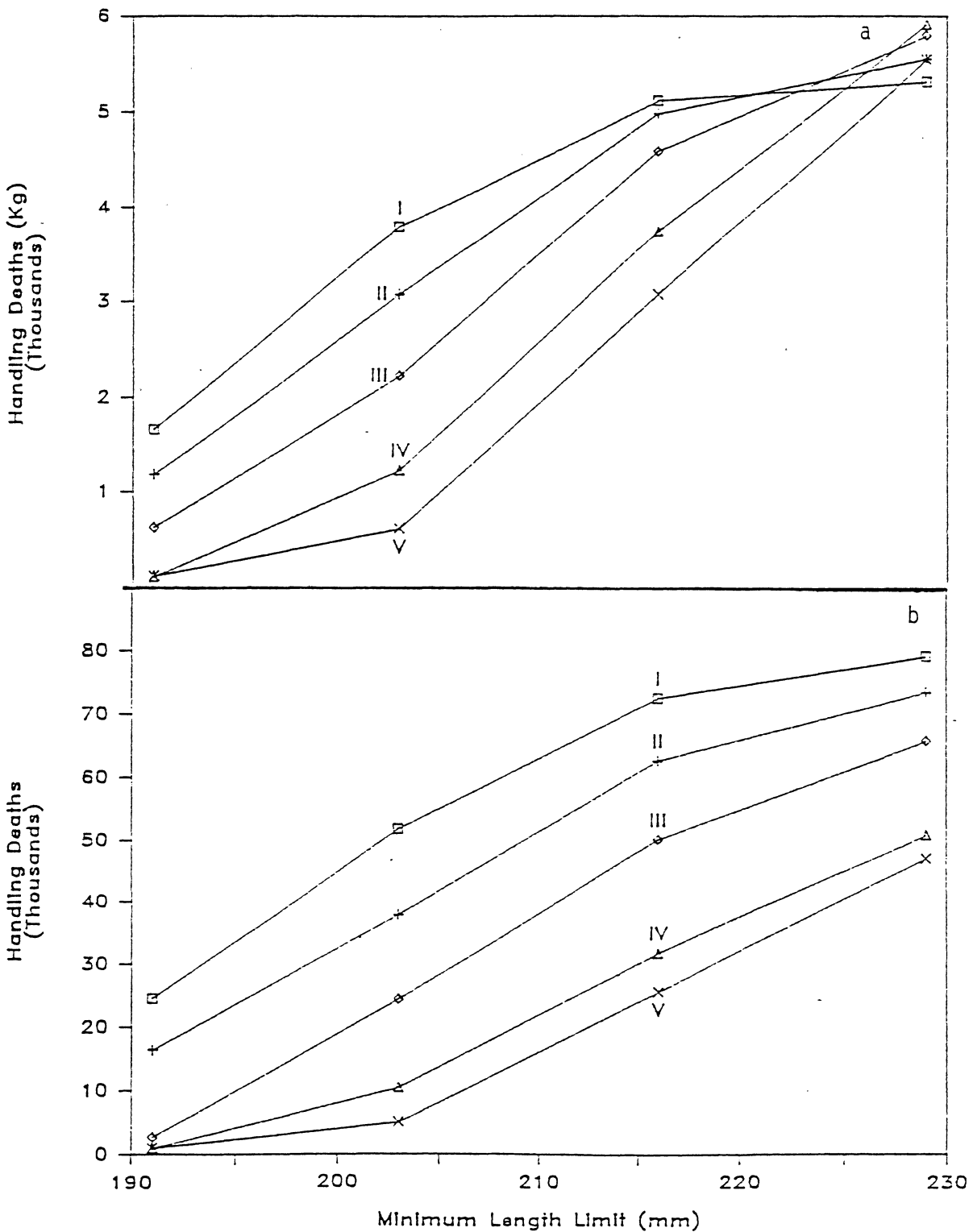


Figure 10. Total weight (Kg) (upper panel) and number (lower panel) of handling deaths, per 1000 Kg of age 1 recruits, based on five Ricker yield models (Appendix F), I-V, with nets of mesh sizes 48, 51, 54, 57, and 60 mm, respectively. Each model contained four submodels with minimum length limits of 191, 203, 216, and 229 mm, respectively.

combining a 191-mm MLL with 57 or 60-mm mesh nets (Models IVA and VA) resulted in the lowest predicted number and weight of perch lost to commercial handling. Models IVA and VA predicted 96% fewer dead sublegal perch, per 1000 Kg of age 1 recruits, than Model IA (Table 17). In terms of weight, 1,559 Kg of perch, per 1000 Kg of age 1 recruits, would be saved with Model IVA (Table 18). Models IVA and VA were based on a catch consisting of 9% sublegal perch (Table 2).

Handling deaths would increase if the MLL were increased. Predicted handling deaths of sublegal yellow perch, per 1000 Kg of recruits, increased in weight and number in all models when the MLL was increased (Fig. 10). For example, Model I predicted that 27,357 (111%) or 2,127 Kg (128%) more sublegal perch would be killed if the MLL was changed from 191 mm to 203 mm (Tables 17, 18). Increasing the MLL subjected more perch to the 36% handling mortality by defining them as sublegal.

Net Mortality:

Fewer perch would die in larger mesh nets at all the MLL's I examined because more fish would escape through the larger mesh (Fig. 11). For a MLL of 191 mm, Model VA predicted 5,542 (35%) fewer dead perch in nets (per 1000 Kg of age 1 recruits) than Model IA (Table 19).

In terms of weight, predicted deaths of yellow perch in nets were greater the larger the mesh (Fig. 11). With a MLL of 191 mm, 60-mm mesh nets (Model VA) contained 30% more (388 Kg) dead perch, per 1000 Kg of age 1 recruits, than Model IA (Table 20). Larger mesh nets contained fewer dead perch, but the average dead perch weighed more (Table 21).

Table 17. Predicted number of handling deaths/1000 Kg age 1 recruits for perch caught in nets of five mesh sizes under four minimum length limits. Numbers in brackets indicate percent change (+/-) relative to Model I. Numbers in parentheses indicate percent change (+/-) relative to Submodel A. Values were predicted by modified Ricker yield models (Appendix F).

Model	Mesh Size (mm)	Minimum Length Limit (mm)							
		Submodel A 191		Submodel B 203		Submodel C 216		Submodel D 229	
I	48	24599	51956	(111)	72655	(195)	79315	(222)	
II	51	16430 [-33]	38379 [-26]	(134)	62748 [-14]	(282)	73671 [-7]	(348)	
III	54	2754 [-89]	24709 [-52]	(797)	50230 [-31]	(1724)	66005 [-17]	(2297)	
IV	57	1011 [-96]	10860 [-79]	(974)	32162 [-56]	(3081)	51118 [-36]	(4956)	
V	60	1069 [-96]	5381 [-90]	(403)	26004 [-64]	(2332)	47354 [-40]	(4330)	

Table 18. Predicted weight of handling deaths (Kg)/1000 Kg of age 1 recruits for perch caught in nets of five mesh sizes under four minimum length limits. Numbers in brackets indicate percent change (+/-) relative to Model I. Numbers in parentheses indicate percent change (+/-) relative to Submodel A. Values were predicted by modified Ricker yield models (Appendix F).

Model	Mesh Size (mm)	Minimum Length Limit (mm)							
		Submodel A 191		Submodel B 203		Submodel C 216		Submodel D 229	
I	48	1665	3792	(128)	5122	(208)	5321	(220)	
II	51	1185 [-29]	3073 [-19]	(159)	4993 [-3]	(321)	5560 [4]	(369)	
III	54	622 [-63]	2228 [-41]	(258)	4601 [-10]	(639)	5797 [8]	(831)	
IV	57	107 [-93]	1231 [-68]	(1055)	3742 [-27]	(3410)	5911 [11]	(5445)	
V	60	114 [-93]	618 [-84]	(444)	3078 [-40]	(2610)	5548 [4]	(4783)	

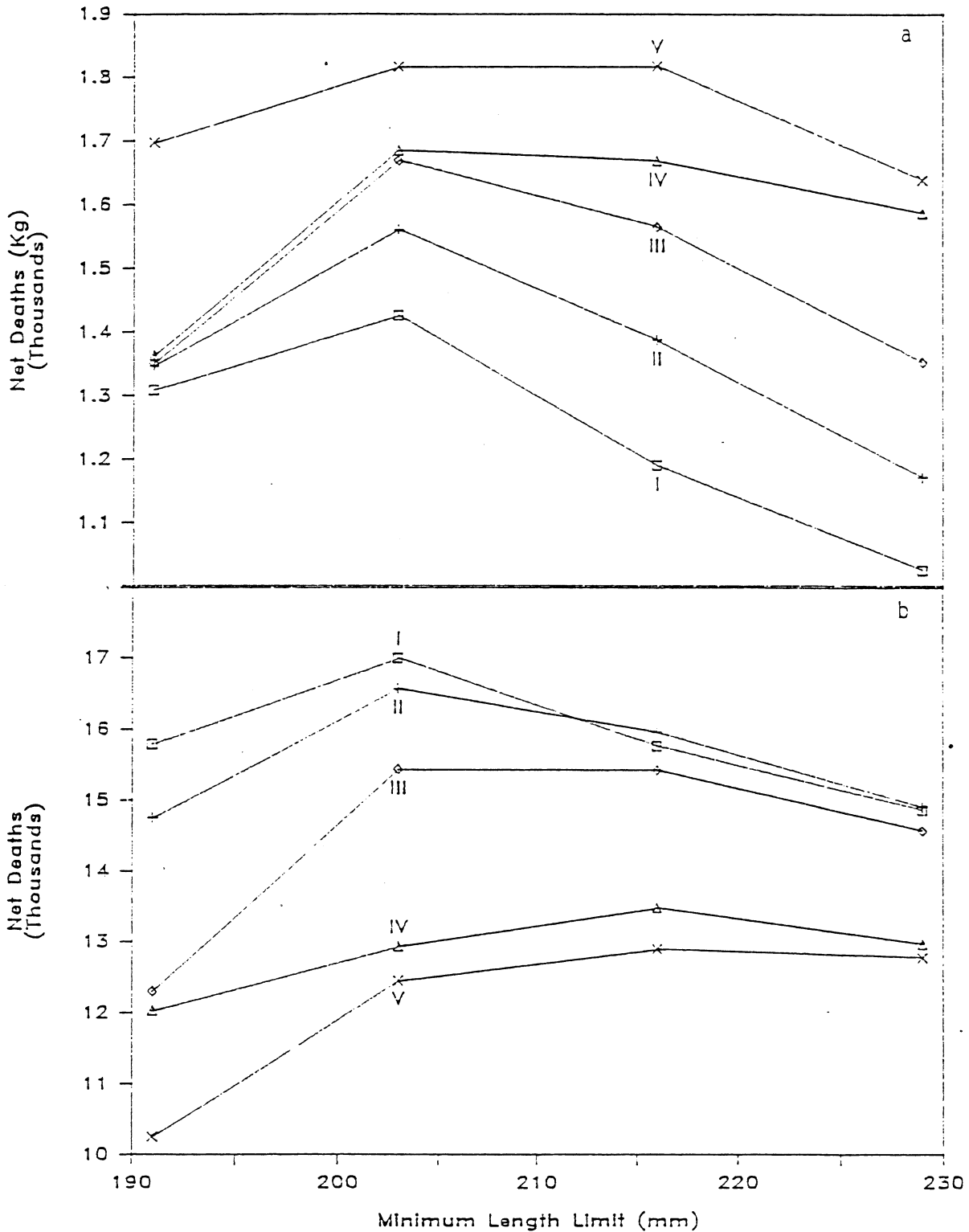


Figure 11. Total weight (Kg) (upper panel) and number (lower panel) of perch that died due to confinement in nets, per 1000 Kg of age 1 recruits, based on five Ricker yield models (Appendix F), I-V, with nets of mesh sizes 48, 51, 54, 57, and 60 mm, respectively. Each model contained four submodels with minimum length limits of 191, 203, 216, and 229 mm, respectively.

Table 19. Predicted number of perch deaths due to confinement in nets/1000 Kg of age 1 recruits for perch caught in nets of five mesh sizes under four minimum length limits. Numbers in brackets indicate percent change (+/-) relative to Model I. Numbers in parentheses indicate percent change (+/-) relative to Submodel A. Values were predicted by modified Ricker yield models (Appendix F).

Model	Mesh Size (mm)	Minimum Length Limit (mm)							
		Submodel A 191		Submodel B 203		Submodel C 216		Submodel D 229	
I	48	15794	16996	(8)	15763	(0)	14860	(-6)	
II	51	14757 [-7]	16569 [-3]	(12)	15955 [1]	(8)	14898 [0]	(1)	
III	54	12302 [-22]	15436 [-9]	(25)	15425 [2]	(25)	14567 [-2]	(18)	
IV	57	12033 [-24]	12935 [-24]	(7)	13481 [-14]	(12)	12965 [-13]	(8)	
V	60	10252 [-35]	12454 [-26]	(21)	12900 [-18]	(26)	12776 [-14]	(25)	

Table 20. Predicted weight (Kg) of perch that died due to confinement in nets/1000 Kg of age 1 recruits for perch caught in nets of five mesh sizes under four minimum length limits. Numbers in brackets indicate percent change (+/-) relative to Model I. Numbers in parentheses indicate percent change (+/-) relative to Submodel A. Values were predicted by modified Ricker yield models (Appendix F).

Model	Mesh Size (mm)	Minimum Length Limit (mm)							
		Submodel A 191		Submodel B 203		Submodel C 216		Submodel D 229	
I	48	1310	1426	(9)	1190	(-9)	1025	(-22)	
II	51	1348 [3]	1561 [9]	(16)	1387 [17]	(3)	1172 [14]	(-13)	
III	54	1351 [3]	1669 [17]	(23)	1565 [31]	(16)	1352 [32]	(0)	
IV	57	1364 [4]	1685 [18]	(24)	1668 [40]	(22)	1586 [55]	(16)	
V	60	1689 [30]	1817 [27]	(7)	1818 [53]	(7)	1638 [60]	(-4)	

Table 21. Mean weight (g) of dead yellow perch caught in nets of five mesh sizes under four minimum length limits, predicted by modified Ricker yield models (Appendix F).

Mesh Size (mm)	Minimum Length Limit (mm)			
	191	203	216	229
48	83	84	76	69
51	91	94	87	79
54	109	110	101	93
57	113	130	124	122
60	165	146	141	128

Conclusions and Management Implications

The results of this study indicate there are substantial losses of yellow perch due to handling and net mortality associated with the drop net fishery in southern Green Bay. The 3-day set duration regulation seems to be sound. My results indicate that increasing set duration past the 3-day limit would greatly increase wastage of perch. The regulation (in 1983) to delay the start of commercial drop net fishing for perch in southern Green Bay until July 1 may have substantially reduced the nonharvest mortality during June.

I think length limits and mesh size regulations can be used to reduce handling and net mortality of perch without reducing long-term yield to the commercial fishermen. I think the best compromise between yield and reductions in mortality of perch was predicted for Model IVA which combined a 191-mm MLL and 57-mm mesh nets. Model IVA predicted a 38% increase in yield (Table 15), a 96% decrease in handling mortality (Table 17), and 24% decrease in net mortality (Table 19), per 1000 Kg of age 1 recruits, compared with current conditions as simulated by Model IA.

The use of 57-mm mesh nets would lead to greater perch abundance, which is reflected in the higher predicted yield and harvest (Tables 15-16). Greater perch abundance might mean a reduction in growth rate (El-Zarka 1959; Eshenroder 1977; Wells 1977; Henderson 1985). Slower growth rates would mean that a share of the predicted yield would not be realized. Changes in growth rate, if they occur, would be apparent in routine WDNR sampling, and the yield models can be easily modified to reflect such changes.

The use of 57-mm mesh drop nets should also increase egg deposition of yellow perch in Green Bay. The numbers of older, therefore larger, perch increased with 57-mm mesh nets over the smaller mesh sizes (Table 14). Fecundity is greater for larger female yellow perch (Hartman 1980). For example, an average 196-mm female yellow perch in Green Bay deposits 17,000 eggs, whereas an average 228-mm female deposits 62,083 eggs (unpublished data, WDNR, Marinette, Wisconsin, USA).

Models should be adjusted to fit the best available biological data. Any changes in growth or mortality rates after new regulations are initiated should be incorporated in the models. Mathematical models have the advantage of showing, at a glance, the probable results from a variety of regulation combinations, but several years may be required to evaluate such changes in practice. Mathematical modelling, combined with biological data, can aid managers in predicting the outcome of their decisions.

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Appendix A. Percent of the Wisconsin Lake Michigan yellow perch harvest (lbs) from southern Green Bay. (Great Lakes Fishery Commission data 1970-82).

Year	Perch Harvest (lbs) for Wisconsin Lake Michigan	Perch Harvest (lbs) for southern Green Bay	Southern Green Bay's Perch Harvest as Percent of Total
1970	431,000	371,295	86
1971	306,000	250,221	82
1972	325,000	233,563	72
1973	308,000	234,800	76
1974	835,000	786,609	94
1975	548,000	487,643	89
1976	449,000	362,594	81
1977	622,000	584,106	94
1978	462,534	442,912	96
1979	1,001,918	930,544	93
1980	345,221	332,239	96
1981	298,438	236,470	79
1982	621,285	570,448	92

Appendix B. Dockside value of southern Green Bay yellow perch harvest as a percent of the total Wisconsin Lake Michigan commercial fish harvest. (Great Lakes Fishery Commission data 1971-82).

Year	Dockside Value of WI. Lake Michigan Commercial Harvest	Dockside Value of southern Green Bay Perch Harvest	Percent of Value from southern Green Bay
1971	\$1,416,217	\$87,577	6
1972	1,583,223	91,090	6
1973	2,004,307	105,660	5
1974	2,729,027	306,778	11
1975	2,314,007	326,721	14
1976	2,691,677	362,594	13
1977	3,010,438	414,715	14
1978	2,788,151	349,900	13
1979	3,646,008	995,682	27
1980	2,508,856	199,343	8
1981	3,342,912	290,858	9
1982	3,813,624	804,332	21
Mean	2,654,037	361,271	12

Appendix C. Mean total lengths (mm) at the end of each year for yellow perch (males and females combined with equal weighting) from southern Green Bay. (Unpublished 1980-83 fall trawl data, Wisconsin Department of Natural Resources, Marinette, Wisconsin, USA).

	AGE						
	1	2	3	4	5	6	7
Sample Size	3632	1397	658	160	34	31	7
Mean Total Length (mm)	85	145	185	211	234	257	279
Standard Deviation	18	15	14	13	22	16	20

Appendix D. Empirical and predicted mean weight (g) at the end of each year for yellow perch (males and females combined with equal weighting) from southern Green Bay. (Unpublished 1980-83 fall trawl data, Wisconsin Department of Natural Resources, Marinette, Wisconsin, USA). The length-weight equation for predicted mean weights was $\log W = 3.1668 \log L - 5.259$.

	AGE						
	1	2	3	4	5	6	7
Sample Size	3632	1397	658	160	11	4	1
Mean Weight (g)	7.1	38.7	82.1	114.8	192.5	381.6	418.0
Mean Predicted Weight (g)	7.1	38.5	83.3	126.3	175.3	235.9	300.6

Appendix E. Data used to estimate instantaneous rate of total mortality (Z) for yellow perch from southern Green Bay. Mean Z values (average of a series of annual estimates) were calculated by catch curve analysis of commercial catch data and fall trawl data. Mark-recapture data were used in a third estimate of mean Z ($Z = \log_e R2 - \log_e R1$). A grand mean Z (1.70) was calculated by averaging the three estimates. The Pearson correlation coefficient (r) is given for each equation (for ages listed below). (Unpublished Wisconsin Department of Natural Resources, Marinette, Wisconsin, USA).

Mean Z calculated from fall trawl data.

AGE	FREQUENCY					
	1978	1979	1980	1981	1982	1983
1	1,512	168	677	493	231	2,117
2	21	512	95	115	238	205
3	1	3	58	9	39	44
4	2	2	2	1	1	6
5	1	1	1	1	1	2
r	0.86	0.88	0.97	0.97	0.94	0.99
Z (G M Functional)	1.98	1.80	1.74	1.76	1.74	1.77
				Mean		1.80

Mean Z calculated from commercial catch data

AGE	FREQUENCY			
	1978	1980	1981	1982
2	660	3,970	4,580	8,540
3	930	1,910	270	240
4	30	10	150	30
5	1	20	30	20
6	1	1	1	1
7	1	10	1	1
8	1	1	1	1
r	0.89	0.87	0.96	0.94
Z (G M Functional)	1.47	1.55	1.54	1.57
			Mean	1.53

Appendix E (continued)

Mean Z calculated from mark-recapture data.

Tagging Period	Number Tagged	Returns		Z
		1st Yr	2nd Yr	
1	1,960	18	3	1.79
2	5,000	93	17	1.70
3	4,379	16	3	1.67
4	4,128	20	4	1.61
5	836	13	2	1.87
6	1,497	27	4	1.91
7	849	47	7	1.90
			Mean	1.78
Grand mean of trawl, commercial, and mark-recapture estimates.				1.70

Appendix F. Modified Ricker yield models. I developed five yield models designated I-V, based on nets with mesh sizes of 48, 51, 54, 57, and 60 mm, respectively. Each model was divided into 4 submodels based on minimum length limits (MLLs) of 191, 203, 216, and 229 mm. The four submodels were designated A, B, C, and D. The MLL for southern Green Bay yellow perch in 1982-83 was 191 mm. Mesh sizes of drop nets used by Green Bay commercial fishermen ranged from 45 to 51 mm. Model IA, which combines a 191-mm MLL with 48-mm mesh nets, closely approximated conditions in 1982-83.

RICKER EQUILIBRIUM YIELD MODEL I

Submodel A 48mm Mesh Net 191mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0142	0.1275	0.0291	0.0002	4773.4	4398.3	0.039	0.9	23	127.99	3282	62.46	1601
2.0	0.039	0.7718	0.0790	0.1275	0.1616	0.0012	4023.1	5020.0	0.057	6.0	106	811.23	14232	396.58	6958
2.5	0.083	0.0000	0.0169	0.1275	0.0220	0.0613	6016.8	5404.2	0.083	331.3	3991	118.89	1432	91.33	1100
3.0	0.083	0.4162	0.0941	0.1275	0.1227	0.3407	4791.5	4226.9	0.103	1440.1	13982	518.64	5035	397.75	3862
3.5	0.126	0.0000	0.0169	0.1275	0.0061	0.1394	3662.2	3201.4	0.126	446.3	3542	19.53	155	54.10	429
4.0	0.126	0.3278	0.0941	0.1275	0.0334	0.7752	2740.6	2049.1	0.149	1588.5	10661	68.44	459	192.82	1294
4.5	0.175	0.0000	0.0169	0.1275	0.0001	0.1682	1357.7	1175.4	0.175	197.7	1130	0.12	1	19.86	114
5.0	0.175	0.2969	0.0941	0.1275	0.0006	0.9350	993.1	706.6	0.203	660.7	3255	0.42	2	66.49	328
5.5	0.236	0.0000	0.0169	0.1275	0.0000	0.1687	420.1	363.7	0.236	61.4	260	0.00	0	6.15	26
6.0	0.236	0.2424	0.0941	0.1275	0.0000	0.9380	307.2	215.0	0.266	201.7	758	0.00	0	20.23	76
6.5	0.301	0.0000	0.0169	0.1275	0.0000	0.1687	122.8	106.3	0.301	17.9	60	0.00	0	1.80	6
7.0	0.301						89.8								
MEAN WT OF HARVEST = 0.130									TOTALS	4952.4	37766	1665.3	24599	1309.6	15794

RICKER EQUILIBRIUM YIELD MODEL I

Submodel B 48mm Mesh Net 203mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	B	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0178	0.1275	0.0625	0.0000	3877.8	4325.6	0.039	0.0	0	270.35	6932	77.00	1974	
2.5	0.083	0.7718	0.0989	0.1275	0.3477	0.0001	4724.9	4301.4	0.057	0.4	8	1495.60	26239	425.41	7463	
3.0	0.083	0.0000	0.0212	0.1275	0.0663	0.0136	3759.4	4242.2	0.083	57.7	695	281.26	3389	89.93	1084	
3.5	0.126	0.4162	0.1177	0.1275	0.3687	0.0758	2859.8	3309.6	0.103	250.9	2436	1220.25	11847	389.54	3782	
4.0	0.126	0.0000	0.0212	0.1275	0.0372	0.0624	2231.0	2545.4	0.126	158.8	1261	94.69	751	53.96	428	
4.5	0.175	0.3278	0.1177	0.1275	0.2070	0.3466	1393.1	1812.0	0.149	628.0	4215	375.08	2517	213.27	1431	
5.0	0.175	0.0000	0.0212	0.1275	0.0095	0.1088	1066.6	1229.8	0.175	133.8	765	11.68	67	26.07	149	
5.5	0.236	0.2969	0.1177	0.1275	0.0526	0.6051	581.9	824.3	0.203	498.8	2457	43.36	214	97.02	478	
6.0	0.236	0.0000	0.0212	0.1275	0.0000	0.1246	442.7	512.3	0.236	63.8	270	0.00	0	10.86	46	
6.5	0.301	0.2424	0.1177	0.1275	0.0001	0.6931	220.7	331.7	0.266	229.9	864	0.03	0	39.04	147	
7.0	0.301	0.0000	0.0212	0.1275	0.0000	0.1246	167.9	194.3	0.301	24.2	80	0.00	0	4.12	14	
MEAN OF HARVEST = 0.156										TOTALS	2046.4	13051	3792.3	51956	1426.2	16996

RICKER EQUILIBRIUM YIELD MODEL I

Submodel C 48mm Mesh Net 216mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0	
1.5	0.039	0.0000	0.0228	0.1275	0.1098	0.0000	4773.4	4226.8	0.039	0.0	0	464.10	11900	96.37	2471	
2.0	0.039	0.7718	0.1268	0.1275	0.6108	0.0000	3680.2	3516.3	0.057	0.0	0	2147.76	37680	445.87	7822	
2.5	0.083	0.0000	0.0272	0.1275	0.1285	0.0011	3352.3	2937.5	0.083	3.2	39	377.47	4548	79.90	963	
3.0	0.083	0.4162	0.1510	0.1275	0.7144	0.0060	2522.8	1965.7	0.103	11.8	115	1404.30	13634	296.82	2882	
3.5	0.126	0.0000	0.0272	0.1275	0.1080	0.0108	1408.7	1240.2	0.126	13.4	106	133.94	1063	33.73	268	
4.0	0.126	0.3278	0.1510	0.1275	0.6009	0.0602	1071.6	826.4	0.149	49.7	334	496.58	3333	124.79	837	
4.5	0.175	0.0000	0.0272	0.1275	0.0372	0.0446	581.2	520.0	0.175	23.2	133	19.34	111	14.14	61	
5.0	0.175	0.2969	0.1510	0.1275	0.2067	0.2480	458.8	377.7	0.203	93.7	461	78.07	385	57.03	281	
5.5	0.236	0.0000	0.0272	0.1275	0.0004	0.0621	296.6	267.6	0.236	16.6	70	0.11	0	7.28	31	
6.0	0.236	0.2424	0.1510	0.1275	0.0023	0.3455	238.7	200.6	0.266	69.3	261	0.46	2	30.29	114	
6.5	0.301	0.0000	0.0272	0.1275	0.0001	0.0632	162.6	146.7	0.301	9.3	31	0.01	0	3.99	13	
7.0	0.301						130.7									
MEAN OF HARVEST = 0.188										TOTALS	290.2	1549	5122.1	72655	1190.2	15763

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RICKER EQUILIBRIUM YIELD MODEL I

Submodel D 48mm Mesh Net 229mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0262	0.1275	0.1417	0.0000	3552.5	4163.0	0.039	0.0	0	589.90	15126	109.07	2797	
2.5	0.083	0.7718	0.1458	0.1275	0.7880	0.0000	2659.5	3106.0	0.057	0.0	0	2447.53	42939	452.85	7945	
3.0	0.083	0.0000	0.0312	0.1275	0.1685	0.0000	1917.4	2288.5	0.083	0.0	0	385.61	4646	71.40	860	
3.5	0.126	0.4162	0.1736	0.1275	0.9368	0.0002	842.9	1380.1	0.103	0.3	3	1292.88	12552	239.59	2326	
4.0	0.126	0.0000	0.0312	0.1275	0.1638	0.0006	610.2	726.5	0.126	0.4	3	119.00	944	22.67	180	
4.5	0.175	0.3278	0.1736	0.1275	0.9105	0.0033	251.3	430.7	0.149	1.4	10	392.15	2632	74.77	502	
5.0	0.175	0.0000	0.0312	0.1275	0.0843	0.0102	195.1	223.2	0.175	2.3	13	18.82	108	6.96	40	
5.5	0.236	0.2969	0.1736	0.1275	0.4691	0.0565	114.9	155.0	0.203	8.8	43	72.71	358	26.91	133	
6.0	0.236	0.0000	0.0312	0.1275	0.0044	0.0198	95.7	105.3	0.236	2.1	9	0.46	2	3.29	14	
6.5	0.301	0.2424	0.1736	0.1275	0.0246	0.1101	78.8	87.2	0.266	9.6	36	2.15	8	15.14	57	
7.0	0.301	0.0000	0.0312	0.1275	0.0005	0.0202	65.9	72.4	0.301	1.5	5	0.04	0	2.26	8	
MEAN OF HARVEST = 0.217										TOTALS	26.3	122	5321.2	79315	1024.9	14860

RICKER EQUILIBRIUM YIELD MODEL II

Submodel A 51mm Mesh Net 191mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIDMASS (Kg)	MEAN BIDMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0	
1.5	0.039	0.0000	0.0100	0.1275	0.0161	0.0001	4773.4	4433.4	0.039	0.4	11	71.38	1830	44.33	1137	
2.0	0.039	0.7718	0.0559	0.1275	0.0892	0.0011	4093.3	5414.6	0.057	6.0	104	482.98	8473	302.68	5310	
2.5	0.083	0.0000	0.0159	0.1275	0.0162	0.0539	6735.9	6088.4	0.083	328.2	3954	98.63	1188	96.81	1166	
3.0	0.083	0.4162	0.0887	0.1275	0.0903	0.2998	5441.0	4970.0	0.103	1490.0	14466	448.79	4357	440.84	4280	
3.5	0.126	0.0000	0.0159	0.1275	0.0044	0.1226	4499.0	3966.1	0.126	486.2	3859	17.45	138	63.06	500	
4.0	0.126	0.3278	0.0887	0.1275	0.0246	0.6821	3433.1	2663.3	0.149	1816.6	12192	65.52	440	236.23	1585	
4.5	0.175	0.0000	0.0159	0.1275	0.0000	0.1479	1893.5	1654.2	0.175	244.7	1398	0.00	0	26.30	150	
5.0	0.175	0.2969	0.0887	0.1275	0.0005	0.8227	1415.0	1044.2	0.203	859.1	4232	0.52	3	92.62	456	
5.5	0.236	0.0000	0.0159	0.1275	0.0000	0.1484	673.4	588.2	0.236	87.3	370	0.00	0	9.35	40	
6.0	0.236	0.2424	0.0887	0.1275	0.0000	0.8253	503.0	364.5	0.266	300.8	1131	0.00	0	32.33	122	
6.5	0.301	0.0000	0.0159	0.1275	0.0000	0.1484	226.1	197.5	0.301	29.3	97	0.00	0	3.14	10	
7.0	0.301						168.9									
MEAN WT. OF HARVEST = 0.135										TOTALS	5648.6	41815	1185.3	16430	1347.7	14757

RICKER EQUILIBRIUM YIELD MODEL II

Submodel B 51mm Mesh Net 203mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007						1000.0								
		1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0119	0.1275	0.0335	0.0000	4015.5	4394.5	0.039	0.0	0	147.22	3775	52.29	1341
2.0	0.039	0.7718	0.0662	0.1275	0.1864	0.0001	5940.3	4977.9	0.057	0.5	9	927.88	16279	329.54	5781
2.5	0.083	0.0000	0.0189	0.1275	0.0473	0.0138	4827.1	5383.7	0.083	74.3	895	254.65	3068	101.75	1226
3.0	0.083	0.4162	0.1051	0.1275	0.2636	0.0765	4127.9	4477.5	0.103	342.5	3326	1180.27	11459	470.59	4569
3.5	0.126	0.0000	0.0189	0.1275	0.0267	0.0630	3259.8	3693.8	0.126	232.7	1847	98.62	783	69.81	554
4.0	0.126	0.3278	0.1051	0.1275	0.1479	0.3501	2179.1	2719.4	0.149	952.1	6390	402.20	2699	285.81	1918
4.5	0.175	0.0000	0.0189	0.1275	0.0068	0.1099	1675.0	1927.0	0.175	211.8	1210	13.10	75	36.42	208
5.0	0.175	0.2969	0.1051	0.1275	0.0376	0.6112	933.6	1304.3	0.203	797.2	3927	49.04	242	137.08	675
5.5	0.236	0.0000	0.0189	0.1275	0.0000	0.1259	711.1	822.3	0.236	103.5	439	0.00	0	15.54	66
6.0	0.236	0.2424	0.1051	0.1275	0.0001	0.7001	356.5	533.8	0.266	373.7	1405	0.05	0	56.10	211
6.5	0.301	0.0000	0.0189	0.1275	0.0000	0.1259	271.5	314.0	0.301	39.5	131	0.00	0	5.93	20
7.0	0.301														
MEAN WT OF HARVEST = 0.160									TOTALS	3127.8	19578	3073.0	38379	1560.9	16569

RICKER EQUILIBRIUM YIELD MODEL II

Submodel C 51mm Mesh Net 216mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0151	0.1275	0.0639	0.0000	3882.8	4328.1	0.039	0.0	0	276.57	7091	65.35	1676	
2.5	0.083	0.7718	0.0843	0.1275	0.3556	0.0000	4763.4	4323.1	0.057	0.0	0	1537.29	26970	364.44	6394	
3.0	0.083	0.0000	0.0240	0.1275	0.0997	0.0016	3699.3	4231.3	0.083	6.8	82	421.86	5083	101.55	1224	
3.5	0.126	0.4162	0.1338	0.1275	0.5546	0.0092	2457.8	3078.6	0.103	28.3	275	1707.39	16577	411.92	3999	
4.0	0.126	0.0000	0.0240	0.1275	0.0839	0.0165	1910.5	2184.1	0.126	36.0	286	183.25	1454	52.42	416	
4.5	0.175	0.3278	0.1338	0.1275	0.4664	0.0914	1168.9	1539.7	0.149	140.7	944	718.12	4820	206.01	1383	
5.0	0.175	0.0000	0.0240	0.1275	0.0288	0.0677	912.2	1040.6	0.175	70.4	403	29.97	171	24.97	143	
5.5	0.236	0.2969	0.1338	0.1275	0.1605	0.3770	552.2	732.2	0.203	276.0	1360	117.52	579	97.97	463	
6.0	0.236	0.0000	0.0240	0.1275	0.0004	0.0944	431.7	492.0	0.236	46.4	197	0.20	1	11.81	50	
6.5	0.301	0.2424	0.1338	0.1275	0.0017	0.5251	250.1	340.9	0.266	179.0	673	0.58	2	45.61	171	
7.0	0.301	0.0000	0.0240	0.1275	0.0000	0.0947	195.5	222.8	0.301	21.1	70	0.00	0	5.35	18	
MEAN WT OF HARVEST = 0.188										TOTALS	804.9	4289	4992.7	62748	1387.4	15955

RICKER EQUILIBRIUM YIELD MODEL II

Submodel D 51mm Mesh Net 229mm Minimum Length Limit
 M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
		1.6906	0.0000	0.1275	0.0000	0.0000	2886.7	0.017	0.0	0	0.00	0	0.00	0		
1.5	0.039						4773.4									
		0.0000	0.0181	0.1275	0.0915	0.0000	4269.6	0.039	0.0	0	390.67	10017	77.28	1982		
2.0	0.039						3765.8									
		0.7718	0.1006	0.1275	0.5090	0.0000	3832.3	0.057	0.0	0	1950.64	34222	385.53	6764		
2.5	0.083						3898.7									
		0.0000	0.0287	0.1275	0.1451	0.0000	3391.6	0.083	0.0	0	492.12	5929	97.34	1173		
3.0	0.083						2884.5									
		0.4162	0.1597	0.1275	0.8069	0.0004	2174.2	0.103	0.9	8	1754.36	17033	347.22	3371		
3.5	0.126						1463.8									
		0.0000	0.0287	0.1275	0.1410	0.0013	1275.0	0.126	1.7	13	179.78	1427	36.59	290		
4.0	0.126						1086.1									
		0.3278	0.1597	0.1275	0.7843	0.0076	799.2	0.149	6.1	41	626.81	4207	127.63	857		
4.5	0.175						512.4									
		0.0000	0.0287	0.1275	0.0727	0.0232	455.3	0.175	10.6	60	33.10	189	13.07	75		
5.0	0.175						398.2									
		0.2969	0.1597	0.1275	0.4040	0.1285	317.1	0.203	40.7	201	128.11	631	50.64	249		
5.5	0.236						236.1									
		0.0000	0.0287	0.1275	0.0038	0.0451	214.2	0.236	9.7	41	0.91	3	6.15	26		
6.0	0.236						192.3									
		0.2424	0.1597	0.1275	0.0212	0.2503	166.2	0.266	41.6	156	3.52	13	26.54	100		
6.5	0.301						140.2									
		0.0000	0.0287	0.1275	0.0004	0.0461	127.3	0.301	5.9	19	0.05	0	3.65	12		
7.0	0.301						114.4									
MEAN WT OF HARVEST = 0.217										TOTALS	117.0	540	5560.0	73671	1171.6	14698

RICKER EQUILIBRIUM YIELD MODEL II

Submodel A 51mm Mesh Net 191mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007						1000.0								
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0
2.0	0.039	0.0000	0.0100	0.1275	0.0161	0.0001	4093.3	4433.4	0.039	0.4	11	71.38	1830	44.33	1137
2.5	0.083	0.7718	0.0559	0.1275	0.0892	0.0011	6735.9	5414.6	0.057	6.0	104	482.98	8473	302.68	5310
3.0	0.083	0.0000	0.0159	0.1275	0.0162	0.0539	5441.0	6088.4	0.083	328.2	3954	98.63	1188	96.81	1166
3.5	0.126	0.4162	0.0887	0.1275	0.0903	0.2998	4499.0	4970.0	0.103	1490.0	14466	448.79	4357	440.84	4280
4.0	0.126	0.0000	0.0159	0.1275	0.0044	0.1226	3433.1	3966.1	0.126	486.2	3859	17.45	138	63.06	500
4.5	0.175	0.3278	0.0887	0.1275	0.0246	0.6821	1893.5	2663.3	0.149	1816.6	12192	65.52	440	236.23	1585
5.0	0.175	0.0000	0.0159	0.1275	0.0000	0.1479	1415.0	1654.2	0.175	244.7	1398	0.00	0	26.30	150
5.5	0.236	0.2969	0.0887	0.1275	0.0005	0.8227	673.4	1044.2	0.203	859.1	4232	0.52	3	92.62	456
6.0	0.236	0.0000	0.0159	0.1275	0.0000	0.1484	503.0	588.2	0.236	87.3	370	0.00	0	9.35	40
6.5	0.301	0.2424	0.0887	0.1275	0.0000	0.8253	226.1	364.5	0.266	300.8	1131	0.00	0	32.33	122
7.0	0.301	0.0000	0.0159	0.1275	0.0000	0.1484	168.9	197.5	0.301	29.3	97	0.00	0	3.14	10
MEAN WT. OF HARVEST = 0.135							TOTALS			5648.6	41815	1185.3	16430	1347.7	14757

RICKER EQUILIBRIUM YIELD MODEL II

Submodel B 51mm Mesh Net 203mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0119	0.1275	0.0335	0.0000	4773.4	4394.5	0.039	0.0	0	147.22	3775	52.29	1341
2.0	0.039	0.7718	0.0662	0.1275	0.1864	0.0001	4015.5	4977.9	0.057	0.5	9	927.88	16279	329.54	5781
2.5	0.083	0.0000	0.0189	0.1275	0.0473	0.0138	5940.3	5383.7	0.083	74.3	895	254.65	3068	101.75	1226
3.0	0.083	0.4162	0.1051	0.1275	0.2636	0.0765	4827.1	4477.5	0.103	342.5	3326	1180.27	11459	470.59	4569
3.5	0.126	0.0000	0.0189	0.1275	0.0267	0.0630	4127.9	3693.8	0.126	232.7	1847	98.62	783	69.81	554
4.0	0.126	0.3278	0.1051	0.1275	0.1479	0.3501	3259.8	2719.4	0.149	952.1	6390	402.20	2699	285.81	1918
4.5	0.175	0.0000	0.0189	0.1275	0.0068	0.1099	2179.1	1927.0	0.175	211.8	1210	13.10	75	36.42	208
5.0	0.175	0.2969	0.1051	0.1275	0.0376	0.6112	1675.0	1304.3	0.203	797.2	3927	49.04	242	137.08	675
5.5	0.236	0.0000	0.0189	0.1275	0.0000	0.1259	933.6	822.3	0.236	103.5	439	0.00	0	15.54	66
6.0	0.236	0.2424	0.1051	0.1275	0.0001	0.7001	711.1	533.8	0.266	373.7	1405	0.05	0	56.10	211
6.5	0.301	0.0000	0.0189	0.1275	0.0000	0.1259	356.5	314.0	0.301	39.5	131	0.00	0	5.93	20
7.0	0.301						271.5								
MEAN WT OF HARVEST = 0.160									TOTALS	3127.8	19578	3073.0	38379	1560.9	16569

RICKER EQUILIBRIUM YIELD MODEL II

Submodel C 51mm Mesh Net 216mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0151	0.1275	0.0639	0.0000	4773.4	4328.1	0.039	0.0	0	276.57	7091	65.35	1676
2.0	0.039	0.7718	0.0843	0.1275	0.3556	0.0000	3882.8	4323.1	0.057	0.0	0	1537.29	26970	364.44	6394
2.5	0.083	0.0000	0.0240	0.1275	0.0997	0.0016	4763.4	4231.3	0.083	6.8	82	421.86	5083	101.55	1224
3.0	0.083	0.4162	0.1338	0.1275	0.5546	0.0092	3699.3	3078.6	0.103	28.3	275	1707.39	16577	411.92	3999
3.5	0.126	0.0000	0.0240	0.1275	0.0839	0.0165	2457.8	2184.1	0.126	36.0	286	183.25	1454	52.42	416
4.0	0.126	0.3278	0.1338	0.1275	0.4664	0.0914	1910.5	1539.7	0.149	140.7	944	718.12	4820	206.01	1383
4.5	0.175	0.0000	0.0240	0.1275	0.0288	0.0677	1168.9	1040.6	0.175	70.4	403	29.97	171	24.97	143
5.0	0.175	0.2969	0.1338	0.1275	0.1605	0.3770	912.2	732.2	0.203	276.0	1360	117.52	579	97.97	463
5.5	0.236	0.0000	0.0240	0.1275	0.0004	0.0944	552.2	492.0	0.236	46.4	197	0.20	1	11.81	50
6.0	0.236	0.2424	0.1338	0.1275	0.0017	0.5251	431.7	340.9	0.266	179.0	673	0.58	2	45.61	171
6.5	0.301	0.0000	0.0240	0.1275	0.0000	0.0947	250.1	222.8	0.301	21.1	70	0.00	0	5.35	18
7.0	0.301						195.5								
MEAN WT OF HARVEST = 0.188									TOTALS	804.9	4289	4992.7	62748	1387.4	15955

RICKER EQUILIBRIUM YIELD MODEL II

Submodel D 5mm Mesh Net 229mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007						1000.0								
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0
2.0	0.039	0.0000	0.0181	0.1275	0.0915	0.0000	3765.8	4269.6	0.039	0.0	0	390.67	10017	77.28	1982
2.5	0.083	0.7718	0.1006	0.1275	0.5090	0.0000	3898.7	3832.3	0.057	0.0	0	1950.64	34222	385.53	6764
3.0	0.083	0.0000	0.0287	0.1275	0.1451	0.0000	2884.5	3391.6	0.083	0.0	0	492.12	5929	97.34	1173
3.5	0.126	0.4162	0.1597	0.1275	0.8069	0.0004	1463.8	2174.2	0.103	0.9	8	1754.36	17033	347.22	3371
4.0	0.126	0.0000	0.0287	0.1275	0.1410	0.0013	1086.1	1275.0	0.126	1.7	13	179.78	1427	36.59	290
4.5	0.175	0.3278	0.1597	0.1275	0.7843	0.0076	512.4	799.2	0.149	6.1	41	626.81	4207	127.63	857
5.0	0.175	0.0000	0.0287	0.1275	0.0727	0.0232	398.2	455.3	0.175	10.6	60	33.10	189	13.07	75
5.5	0.236	0.2969	0.1597	0.1275	0.4040	0.1285	236.1	317.1	0.203	40.7	201	128.11	631	50.64	249
6.0	0.236	0.0000	0.0287	0.1275	0.0038	0.0451	192.3	214.2	0.236	9.7	41	0.81	3	6.15	26
6.5	0.301	0.2424	0.1597	0.1275	0.0212	0.2503	140.2	166.2	0.266	41.6	156	3.52	13	26.54	100
7.0	0.301	0.0000	0.0287	0.1275	0.0004	0.0461	114.4	127.3	0.301	5.9	19	0.05	0	3.65	12
MEAN WT OF HARVEST = 0.217									TOTALS	117.0	540	5560.0	73671	1171.6	14898

RICKER EQUILIBRIUM YIELD MODEL III

Submodel A 54mm Mesh Net 191mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIDMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0	
1.5	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4773.4	4487.1	0.039	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.7718	0.0000	0.1275	0.0000	0.0000	4202.0	6102.7	0.057	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.0000	0.0122	0.1275	0.0054	0.0393	8003.3	7329.4	0.083	288.0	3470	39.58	477	89.42	1077	
3.0	0.083	0.4162	0.0676	0.1275	0.0303	0.2186	6655.6	6564.4	0.103	1435.0	13932	198.90	1931	443.75	4308	
3.5	0.126	0.0000	0.0143	0.1275	0.0017	0.1052	6473.2	5760.5	0.126	606.0	4810	9.79	78	82.38	654	
4.0	0.126	0.3278	0.0795	0.1275	0.0097	0.5851	5047.9	4095.2	0.149	2396.1	16081	39.72	267	325.57	2185	
4.5	0.175	0.0000	0.0143	0.1275	0.0000	0.1269	3142.5	2772.2	0.175	351.8	2010	0.00	0	39.64	227	
5.0	0.175	0.2969	0.0795	0.1275	0.0002	0.7057	2402.0	1849.7	0.203	1305.3	6430	0.37	2	147.05	724	
5.5	0.236	0.0000	0.0143	0.1275	0.0000	0.1273	1297.3	1144.3	0.236	145.7	617	0.00	0	16.36	69	
6.0	0.236	0.2424	0.0795	0.1275	0.0000	0.7080	991.3	748.6	0.266	530.0	1993	0.00	0	59.51	224	
6.5	0.301	0.0000	0.0143	0.1275	0.0000	0.1273	505.9	446.2	0.301	56.8	189	0.00	0	6.38	21	
7.0	0.301						386.5									
MEAN WT OF HARVEST = 0.144										TOTALS	7114.7	49532	622.4	2754	1351.2	12302

RICKER EQUILIBRIUM YIELD MODEL III

Submodel B 54mm Mesh Net 203mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0063	0.1275	0.0134	0.0000	4120.0	4446.7	0.039	0.0	0	59.59	1528	28.01	718	
2.5	0.083	0.7718	0.0351	0.1275	0.0743	0.0000	7034.0	5577.0	0.057	0.0	0	414.37	7270	195.75	3434	
3.0	0.083	0.0000	0.0171	0.1275	0.0321	0.0127	5820.3	6427.1	0.083	81.6	983	206.31	2486	109.90	1324	
3.5	0.126	0.4162	0.0949	0.1275	0.1788	0.0711	5502.8	5661.6	0.103	402.5	3908	1012.29	9828	537.29	5216	
4.0	0.126	0.0000	0.0171	0.1275	0.0180	0.0585	4411.3	4957.1	0.126	290.0	2302	89.23	708	84.77	673	
4.5	0.175	0.3278	0.0949	0.1275	0.1004	0.3253	3202.4	3806.8	0.149	1238.4	8311	382.20	2565	361.27	2425	
5.0	0.175	0.0000	0.0171	0.1275	0.0046	0.1021	2490.8	2846.6	0.175	290.6	1661	13.09	75	48.68	278	
5.5	0.236	0.2969	0.0949	0.1275	0.0255	0.5678	1482.6	1986.7	0.203	1128.0	5557	50.66	250	188.54	929	
6.0	0.236	0.0000	0.0171	0.1275	0.0000	0.1170	1143.6	1313.1	0.236	153.6	651	0.00	0	22.45	95	
6.5	0.301	0.2424	0.0949	0.1275	0.0000	0.6503	608.9	876.3	0.266	569.9	2142	0.00	0	83.16	313	
7.0	0.301	0.0000	0.0171	0.1275	0.0000	0.1170	468.7	538.8	0.301	63.0	209	0.00	0	9.21	31	
MEAN WT OF HARVEST = 0.164										TOTALS	4217.7	25725	2227.7	24709	1669.0	15436

RICKER EQUILIBRIUM YIELD MODEL III

Submodel C 54mm Mesh Net 216mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0080	0.1275	0.0290	0.0000	4773.4	4411.4	0.039	0.0	0	127.93	3280	35.29	905
2.0	0.039	0.7718	0.0444	0.1275	0.1610	0.0000	4049.4	5165.0	0.057	0.0	0	831.57	14589	229.33	4023
2.5	0.083	0.0000	0.0216	0.1275	0.0769	0.0020	6280.5	5640.3	0.083	11.3	136	433.74	5226	121.83	1468
3.0	0.083	0.4162	0.1199	0.1275	0.4277	0.0117	5000.1	4407.4	0.103	51.6	501	1885.04	18301	528.45	5131
3.5	0.126	0.0000	0.0216	0.1275	0.0647	0.0209	3814.7	3415.7	0.126	71.4	567	221.00	1754	73.78	586
4.0	0.126	0.3278	0.1199	0.1275	0.3597	0.1162	2031.4	2524.0	0.149	293.3	1968	907.88	6093	302.63	2031
4.5	0.175	0.0000	0.0216	0.1275	0.0223	0.0862	1570.0	1800.7	0.175	155.2	887	40.16	229	38.90	222
5.0	0.175	0.2969	0.1199	0.1275	0.1237	0.4792	902.8	1236.4	0.203	592.5	2919	152.94	753	148.24	730
5.5	0.236	0.0000	0.0216	0.1275	0.0003	0.1201	689.5	796.1	0.236	95.6	405	0.24	1	17.20	73
6.0	0.236	0.2424	0.1199	0.1275	0.0013	0.6675	351.5	520.5	0.266	347.4	1306	0.58	3	62.41	235
6.5	0.301	0.0000	0.0216	0.1275	0.0001	0.1204	268.4	309.9	0.301	37.3	124	0.00	0	6.69	22
7.0	0.301														
MEAN WT OF HARVEST = 0.188									TOTALS	1655.6	8812	4601.2	50230	1564.7	15425

RICKER EQUILIBRIUM YIELD MODEL III

Submodel D 54mm Mesh Net 229mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0098	0.1275	0.0463	0.0000	4773.4	4373.1	0.039	0.0	0	202.47	5192	42.86	1099
2.0	0.039	0.7718	0.0547	0.1275	0.2579	0.0000	3972.8	4754.1	0.057	0.0	0	1226.08	21510	260.05	4562
2.5	0.083	0.0000	0.0266	0.1275	0.1251	0.0001	5535.3	4860.9	0.083	0.5	6	608.10	7326	129.30	1558
3.0	0.083	0.4162	0.1478	0.1275	0.6960	0.0005	4186.5	3294.2	0.103	1.6	16	2292.76	22260	486.88	4727
3.5	0.126	0.0000	0.0266	0.1275	0.1216	0.0020	2401.9	2110.7	0.126	4.2	34	256.66	2037	56.14	446
4.0	0.126	0.3278	0.1478	0.1275	0.6765	0.0112	1819.5	1391.8	0.149	15.6	105	941.55	6319	205.71	1381
4.5	0.175	0.0000	0.0266	0.1275	0.0627	0.0342	964.1	857.1	0.175	29.3	168	53.74	307	22.80	130
5.0	0.175	0.2969	0.1478	0.1275	0.3485	0.1899	750.1	598.7	0.203	113.7	560	208.65	1028	88.49	436
5.5	0.236	0.0000	0.0266	0.1275	0.0033	0.0666	447.4	402.5	0.236	26.8	114	1.33	6	10.71	45
6.0	0.236	0.2424	0.1478	0.1275	0.0182	0.3699	357.6	296.1	0.266	109.5	412	5.39	20	43.76	165
6.5	0.301	0.0000	0.0266	0.1275	0.0003	0.0681	234.7	211.3	0.301	14.4	48	0.06	0	5.62	19
7.0	0.301						187.9								
MEAN WT OF HARVEST = 0.217									TOTALS	315.7	1461	5796.8	66005	1352.3	14567

RICKER EQUILIBRIUM YIELD MODEL IV

Submodel A 57mm Mesh Net 191mm Minimum Length Limit
M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4202.0	4487.3	0.039	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.7718	0.0000	0.1275	0.0000	0.0000	8003.3	6102.7	0.057	0.0	0	0.00	0	0.00	0	
3.0	0.083	0.0000	0.0116	0.1275	0.0019	0.0301	6744.7	7374.0	0.083	222.0	2674	14.01	169	85.54	1031	
3.5	0.126	0.4162	0.0643	0.1275	0.0105	0.1674	7065.8	6905.2	0.103	1155.9	11223	72.50	704	444.00	4311	
4.0	0.126	0.0000	0.0136	0.1275	0.0006	0.0864	5624.7	6345.2	0.126	548.2	4351	3.81	30	86.29	685	
4.5	0.175	0.3278	0.0756	0.1275	0.0033	0.4482	4056.8	4840.8	0.149	2169.6	14561	15.97	107	365.96	2456	
5.0	0.175	0.0000	0.0136	0.1275	0.0000	0.0972	3196.7	3626.7	0.175	352.5	2014	0.00	0	49.32	282	
5.5	0.236	0.2969	0.0756	0.1275	0.0001	0.5407	2044.4	2620.5	0.203	1416.9	6980	0.26	1	198.11	976	
6.0	0.236	0.0000	0.0136	0.1275	0.0000	0.0975	1610.4	1827.4	0.236	178.2	755	0.00	0	24.85	105	
6.5	0.301	0.2424	0.0756	0.1275	0.0000	0.5424	973.7	1292.1	0.266	700.8	2635	0.00	0	97.68	367	
7.0	0.301	0.0000	0.0136	0.1275	0.0000	0.0975	767.0	870.4	0.301	84.9	282	0.00	0	11.84	39	
MEAN WT OF HARVEST = 0.150										TOTALS	6829.0	45475	106.6	1011	1363.6	12033

RICKER EQUILIBRIUM YIELD MODEL IV

Submodel B 57mm Mesh Net 203mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4202.0	4487.7	0.039	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.7718	0.0000	0.1275	0.0000	0.0000	8003.3	6102.3	0.057	0.0	0	0.00	0	0.00	0	
3.0	0.083	0.0000	0.0133	0.1275	0.0167	0.0095	6773.1	7388.2	0.083	70.2	846	123.38	1487	98.26	1184	
3.5	0.126	0.4162	0.0736	0.1275	0.0927	0.0528	7261.3	7017.2	0.103	370.5	3597	650.49	6315	516.47	5014	
4.0	0.126	0.0000	0.0156	0.1275	0.0110	0.0511	5914.3	6587.8	0.126	336.6	2672	72.47	575	102.77	816	
4.5	0.175	0.3278	0.0866	0.1275	0.0612	0.2845	4689.9	5302.1	0.149	1508.4	10124	324.49	2178	459.16	3082	
5.0	0.175	0.0000	0.0156	0.1275	0.0028	0.0892	3703.3	4198.6	0.175	374.5	2140	11.76	67	65.50	374	
5.5	0.236	0.2969	0.0866	0.1275	0.0156	0.4966	2413.1	3060.2	0.203	1519.7	7486	47.74	235	265.01	1305	
6.0	0.236	0.0000	0.0156	0.1275	0.0003	0.1023	1887.4	2150.3	0.236	220.0	932	0.65	3	33.54	142	
6.5	0.301	0.2424	0.0866	0.1275	0.0000	0.5688	1099.3	1493.4	0.266	849.4	3193	0.00	0	129.33	486	
7.0	0.301	0.0000	0.0156	0.1275	0.0000	0.1023	860.1	979.7	0.301	100.2	333	0.00	0	15.28	51	
MEAN WT OF HARVEST = 0.171										TOTALS	5349.6	31323	1231.0	10860	1685.3	12935

RICKER EQUILIBRIUM YIELD MODEL IV

Submodel C 57mm Mesh Net 216mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIDMASS (Kg)	MEAN BIDMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0	
1.5	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4773.4	4487.7	0.039	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.7718	0.0000	0.1275	0.0000	0.0000	4202.0	6102.7	0.057	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.0000	0.0167	0.1275	0.0496	0.0020	8003.3	7290.4	0.083	14.6	176	361.60	4357	121.75	1467	
3.0	0.083	0.4162	0.0924	0.1275	0.2759	0.0116	6577.5	6284.6	0.103	72.9	708	1733.92	16834	580.70	5638	
3.5	0.126	0.0000	0.0196	0.1275	0.0490	0.0245	5991.6	5398.6	0.126	132.3	1050	264.53	2099	105.81	840	
4.0	0.126	0.3278	0.1087	0.1275	0.2730	0.1364	4805.5	4151.4	0.149	566.3	3800	1133.33	7606	451.26	3029	
4.5	0.175	0.0000	0.0196	0.1275	0.0169	0.1011	3497.3	3090.1	0.175	312.4	1785	52.22	298	60.57	346	
5.0	0.175	0.2969	0.1087	0.1275	0.0939	0.5624	2682.9	2080.9	0.203	1170.3	5765	195.40	963	226.19	1114	
5.5	0.236	0.0000	0.0196	0.1275	0.0002	0.1408	1478.9	1293.8	0.236	182.2	772	0.26	1	25.36	107	
6.0	0.236	0.2424	0.1087	0.1275	0.0010	0.7834	1108.7	808.9	0.266	633.7	2382	0.81	3	87.93	331	
6.5	0.301	0.0000	0.0196	0.1275	0.0000	0.1412	509.1	445.4	0.301	62.9	209	0.00	0	8.73	29	
7.0	0.301						381.6									
MEAN WT OF HARVEST = 0.188										TOTALS	3147.5	16647	3742.1	32162	1668.3	13481

RICKER EQUILIBRIUM YIELD MODEL IV

Submodel D 57mm Mesh Net 229mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4202.0	4487.7	0.039	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.7718	0.0000	0.1275	0.0000	0.0000	8003.3	6102.7	0.057	0.0	0	0.00	0	0.00	0	
3.0	0.083	0.0000	0.0210	0.1275	0.0918	0.0001	6293.1	7148.2	0.083	0.7	9	656.20	7906	150.11	1809	
3.5	0.126	0.4162	0.1170	0.1275	0.5105	0.0006	4481.5	5387.3	0.103	3.2	31	2750.22	26701	630.31	6120	
4.0	0.126	0.0000	0.0247	0.1275	0.1049	0.0025	3456.9	3969.2	0.126	9.9	79	416.37	3305	98.04	778	
4.5	0.175	0.3278	0.1377	0.1275	0.5838	0.0143	2023.7	2740.3	0.149	39.2	263	1599.79	10737	377.34	2532	
5.0	0.175	0.0000	0.0247	0.1275	0.0541	0.0437	1576.0	1799.8	0.175	78.7	449	97.37	556	44.46	254	
5.5	0.236	0.2969	0.1377	0.1275	0.3007	0.2428	944.7	1260.4	0.203	306.0	1508	379.00	1867	173.56	855	
6.0	0.236	0.0000	0.0247	0.1275	0.0028	0.0850	743.1	843.9	0.236	71.7	304	2.36	10	20.84	88	
6.5	0.301	0.2424	0.1377	0.1275	0.0158	0.4729	445.6	594.3	0.266	281.0	1057	9.39	35	81.84	308	
7.0	0.301	0.0000	0.0247	0.1275	0.0003	0.0871	350.6	398.1	0.301	34.7	115	0.12	0	9.83	33	
MEAN WT OF HARVEST = 0.217										TOTALS	825.2	3814	5910.8	51118	1586.3	12965

RICKER EQUILIBRIUM YIELD MODEL V

Submodel A 60mm Mesh Net 191mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007						1000.0									
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4202.0	4487.3	0.039	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.7718	0.0000	0.1275	0.0000	0.0000	8003.3	6102.7	0.057	0.0	0	0.00	0	0.00	0	
3.0	0.083	0.0000	0.0116	0.1275	0.0019	0.0188	6821.3	7412.3	0.083	139.4	1679	14.08	170	85.98	1036	
3.5	0.126	0.4162	0.0643	0.1275	0.0105	0.1046	7609.3	7215.3	0.103	754.7	7327	75.76	736	463.94	4504	
4.0	0.126	0.0000	0.0136	0.1275	0.0006	0.0504	6279.3	6944.3	0.126	350.0	2778	4.17	33	94.44	750	
4.5	0.175	0.3278	0.0756	0.1275	0.0033	0.2801	5358.1	5818.7	0.149	1629.8	10938	19.20	129	439.89	2952	
5.0	0.175	0.0000	0.0136	0.1275	0.0000	0.0608	4378.5	4868.3	0.175	296.0	1691	0.00	0	66.21	378	
5.5	0.236	0.2969	0.0756	0.1275	0.0001	0.3379	3429.8	3904.2	0.203	1319.2	6499	0.39	2	295.16	1454	
6.0	0.236	0.0000	0.0136	0.1275	0.0000	0.0610	2802.2	3116.0	0.236	190.1	805	0.00	0	42.38	180	
6.5	0.301	0.2424	0.0756	0.1275	0.0000	0.3390	2076.5	2439.4	0.266	827.0	3109	0.00	0	184.42	693	
7.0	0.301	0.0000	0.0136	0.1275	0.0000	0.0610	1696.5	1886.5	0.301	115.1	382	0.00	0	25.66	85	
MEAN WT OF HARVEST = 0.160										TOTALS	5621.2	35209	113.6	1069	1698.1	10252

RICKER EQUILIBRIUM YIELD MODEL V

Submodel B 60mm Mesh Net 203mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)	
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0	
1.5	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4773.4	4487.7	0.039	0.0	0	0.00	0	0.00	0	
2.0	0.039	0.7718	0.0000	0.1275	0.0000	0.0000	4202.0	6102.3	0.057	0.0	0	0.00	0	0.00	0	
2.5	0.083	0.0000	0.0122	0.1275	0.0077	0.0075	8003.3	7429.1	0.083	55.7	671	57.20	689	90.64	1092	
3.0	0.083	0.4162	0.0676	0.1275	0.0428	0.0415	6854.8	7357.3	0.103	305.3	2964	314.89	3057	497.35	4829	
3.5	0.126	0.0000	0.0143	0.1275	0.0051	0.0401	7859.8	7189.6	0.126	288.3	2288	36.67	291	102.81	816	
4.0	0.126	0.3278	0.0795	0.1275	0.0283	0.2232	6519.3	6120.0	0.149	1366.0	9168	173.20	1162	486.54	3265	
4.5	0.175	0.0000	0.0143	0.1275	0.0013	0.0700	5720.8	5171.8	0.175	362.0	2069	6.72	38	73.96	423	
5.0	0.175	0.2969	0.0795	0.1275	0.0072	0.3897	4622.8	4011.8	0.203	1563.4	7701	28.88	142	318.94	1571	
5.5	0.236	0.0000	0.0143	0.1275	0.0000	0.0802	3400.8	3062.3	0.236	245.6	1041	0.00	0	43.79	186	
6.0	0.236	0.2424	0.0795	0.1275	0.0000	0.4463	2723.8	2264.9	0.266	1010.8	3800	0.00	0	180.06	677	
6.5	0.301	0.0000	0.0143	0.1275	0.0000	0.0803	1805.9	1626.1	0.301	130.6	434	0.00	0	23.25	77	
7.0	0.301						1446.3									
MEAN WT OF HARVEST = 0.177										TOTALS	5327.8	30136	617.6	5381	1817.3	12454

RICKER EQUILIBRIUM YIELD MODEL V

Submodel C 60mm Mesh Net 216mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007						1000.0								
1.5	0.039	1.6906	0.0000	0.1275	0.0000	0.0000	4773.4	2886.7	0.017	0.0	0	0.00	0	0.00	0
2.0	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4202.0	4487.7	0.039	0.0	0	0.00	0	0.00	0
2.5	0.083	0.7718	0.0000	0.1275	0.0000	0.0000	8003.3	6102.7	0.057	0.0	0	0.00	0	0.00	0
3.0	0.083	0.0000	0.0152	0.1275	0.0366	0.0016	6678.9	7341.1	0.083	11.7	142	268.68	3237	111.58	1344
3.5	0.126	0.4162	0.0845	0.1275	0.2032	0.0088	6627.1	6653.0	0.103	58.5	568	1351.89	13125	562.18	5458
4.0	0.126	0.0000	0.0179	0.1275	0.0362	0.0188	5423.6	6025.4	0.126	113.3	899	218.12	1731	107.85	856
4.5	0.175	0.3278	0.0994	0.1275	0.2010	0.1041	4422.1	4922.8	0.149	512.5	3439	989.48	6641	489.33	3284
5.0	0.175	0.0000	0.0179	0.1275	0.0124	0.0772	3495.9	3959.0	0.175	305.6	1746	49.09	281	70.87	405
5.5	0.236	0.2969	0.0994	0.1275	0.0692	0.4293	2277.6	2886.8	0.203	1239.3	6105	199.77	984	286.95	1414
6.0	0.236	0.0000	0.0179	0.1275	0.0001	0.1075	1768.5	2023.0	0.236	217.5	921	0.20	1	36.21	153
6.6	0.301	0.2424	0.0994	0.1275	0.0008	0.5980	986.9	1377.7	0.266	823.9	3097	1.10	4	136.94	515
7.0	0.301	0.0000	0.0179	0.1275	0.0000	0.1078	766.1	876.5	0.301	94.5	314	0.00	0	15.69	52
MEAN WT OF HARVEST = 0.196									TOTALS	3376.8	17232	3078.3	26004	1817.6	12900

RICKER EQUILIBRIUM YIELD MODEL V

Submodel D 60mm Mesh Net 229mm Minimum Length Limit

M = .1275 N and H were varied for each mean length at age.

AGE	MEAN WEIGHT (Kg)	G	N	M	H	F	BIOMASS (Kg)	MEAN BIOMASS (Kg)	MEAN WT. INDIVIDUAL MIDPOINT (Kg)	YIELD (Kg)	HARVEST (No.)	HANDLING DEATHS (Kg)	HANDLING DEATHS (No.)	NET DEATHS (Kg)	NET DEATHS (No.)
1.0	0.007	1.6906	0.0000	0.1275	0.0000	0.0000	1000.0	2886.7	0.017	0.0	0	0.00	0	0.00	0
1.5	0.039	0.0000	0.0000	0.1275	0.0000	0.0000	4773.4	4487.7	0.039	0.0	0	0.00	0	0.00	0
2.0	0.039	0.7718	0.0000	0.1275	0.0000	0.0000	4202.0	6102.7	0.057	0.0	0	0.00	0	0.00	0
2.5	0.083	0.0000	0.0196	0.1275	0.0791	0.0002	8003.3	7192.6	0.083	1.4	17	568.93	6855	140.97	1698
3.0	0.083	0.4162	0.1095	0.1275	0.4399	0.0007	6381.8	5647.6	0.103	4.0	38	2484.38	24120	618.41	6004
3.5	0.126	0.0000	0.0231	0.1275	0.0904	0.0030	4913.4	4381.5	0.126	13.1	104	396.09	3144	101.21	803
4.0	0.126	0.3278	0.1288	0.1275	0.5030	0.0170	3849.6	3154.0	0.149	53.6	360	1586.46	10647	406.24	2726
4.5	0.175	0.0000	0.0231	0.1275	0.0466	0.0520	2458.4	2187.3	0.175	113.7	650	101.93	582	50.53	289
5.0	0.175	0.2969	0.1288	0.1275	0.2591	0.2889	1916.1	1534.9	0.203	443.4	2184	397.69	1959	197.70	974
5.5	0.236	0.0000	0.0231	0.1275	0.0024	0.1011	1153.6	1024.2	0.236	103.5	439	2.46	10	23.66	100
6.0	0.236	0.2424	0.1288	0.1275	0.0136	0.5628	894.8	695.3	0.266	391.3	1471	9.46	36	89.55	337
6.5	0.301	0.0000	0.0231	0.1275	0.0003	0.1037	495.8	440.1	0.301	45.6	152	0.13	0	10.17	34
7.0	0.301						384.4								
MEAN WT OF HARVEST = 0.217									TOTALS	1169.8	5416	5547.5	47354	1638.4	12776