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**YIELD CHARTS FOR NORTH COAST B.C. SALMON POPULATIONS  
BASED ON FRESHWATER AND OCEAN SURVIVAL INDICES**

**by**

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ABSTRACT

Wickett, W. Percy, and A. Ballantyne. 1980. Yield charts for north coast B.C. salmon populations based on freshwater and ocean survival indices. Can. Tech. Rep. Fish. Aquat. Sci. 978: 83 p.

Sets of yield charts have been calculated for odd and even year Skeena pink salmon, odd and even year Central area pink salmon, Skeena sockeye and Rivers Inlet sockeye salmon stocks. The charts demonstrate the effects of interactions between escapement or smolt output and two or more environmental indices of changing survival. Predictions of future yield can be made graphically by management with the proviso that much more field work and years of observations are needed for precision. Escapement levels that gave maximum yields in the past can be estimated.

Key words: Salmon stocks, predictions, management, climate.

RÉSUMÉ

Wickett, W. Percy, and A. Ballantyne. 1980. Yield charts for north coast B.C. salmon populations based on freshwater and ocean survival indices. Can. Tech. Rep. Fish. Aquat. Sci. 978: 83 p.

Des tableaux de rendement ont été calculés pour le saumon rose de la rivière Skeena des années paires et impaires, le saumon rose de la région du Centre des années paires et impaires, le saumon rouge de la rivière Skeena et les stocks de saumon rouge de l'inlet Rivers. Les tableaux ont révélé les interactions entre le saumon de remonte ou la production de saumoneaux et deux indices environnementaux ou plus de changement du taux de survie. Les prédictions du rendement futur pourraient être faites géographiquement par la direction, à condition qu'on fasse davantage de travaux sur le terrain et d'observations pour obtenir des données plus précises. On peut évaluer les niveaux du saumon de remonte qui ont donné le plus haut rendement par le passé.

Mots clés: Stocks de saumon, prédictions, gestion, climat.



## INTRODUCTION

Yield charts in the form of contour diagrams of total populations of pink and sockeye salmon are presented in this report. The yield (escapement plus catch) contours are calculated from response functions in which the input variables are spawning escapement or smolt output and two or more environmental indices of changing survival. The technique is one used by industry to examine the combined results of the interactions of several variables on factory output (Davies, ed. 1978), and in our case it is: (1) an empirical test of our hypotheses concerning the survival of fish stocks, (2) an aid to prediction and (3) a concise way of presenting research results to management.

The response functions that were fitted to the data were restricted to those of the form

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{44}x_4^2 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{23}x_2x_3 + b_{24}x_2x_4 + b_{34}x_3x_4$$

Lindsey's (1971) standard normal theory multiple regression analysis program (MREGI) was calculated on a XEROX 530 computer. The regression program contains an option by which non-significant terms are eliminated sequentially beginning with the least significant. In most of the functions, some of the "b" coefficients equal zero.

The ocean environment data which we must use is not under control, and it is unusual to have an analytically desirable distribution of data over the field of study. Even many more observations, taken one year at a time, will not necessarily give the mathematical refinements that may be needed. Hence, simple response functions are all that are warranted and these yield charts, while describing past performance, must be used with caution.

A word of caution to managers is in order concerning acting on advice to "perturb" or change greatly the one factor--escapement or output of young fish--that is under their control directly. At least as much information as is given in these yield charts should be available to them. In one case--Rivers Inlet sockeye--it appears that it is only with very favourable ocean conditions that large escapements to the present freshwater environment can produce large recruitments and they might even depress recruitments in some years. In most cases it appears that the environment can be such a dominant factor that the effect of changing the number of spawners or numbers of young fish entering the sea may be masked in any one year. Several years may be needed to be sure of the success or failure of any project. The charts indicate escapement levels that have maximized yields in the past. They also point out apparent differences in response by odd and even year pink salmon that suggest both the need for the study of estimations of effective spawners and of behavior and survival in coastal seas.

We agree with Clay (1974) that "priority should be given to research and studies that would permit prediction of adult returns with greater accuracy." There is a need for specific data on the biological and oceanographic processes that affect the fish populations as they move onshore and offshore. The movement, food and predation of young fish in

Hecate Strait and Queen Charlotte Sound in summer is one such specific study. Without more information, management will have to continue to use the few available survival indices as guides to the size of the annual recruitments that will give the largest yields.

Yields as used here are the total return of various age-groups from a given brood year spawning. This method of handling the data allows indexing of the environment during freshwater and early sea life. A compromise is made for the index of survival in later stages of multi-aged sockeye so that only the impact of the ocean environment on the returning 4-yr-olds is considered. Allowable catch is found by simple subtractions of desired escapement from predicted yield in the case of pink salmon. For sockeye, yields from brood years three, four and five years before need to be considered together; sampling of the catch for age composition is needed.

Yield charts drawn for the particular brood years of immediate concern will be found useful. The contours are drawn quickly and easily if a programmable hand-held calculator is available.

#### DATA SOURCES

Reports, both internal and published, of the Pacific Region, Fisheries Management, Vancouver have supplied the data on escapement and catch.

The environmental data come from a variety of sources which may vary in the future. It may be necessary to request unpublished data from the following agencies:

(1) minimum temperature - Pacific Region, Atmospheric Environment Service.

(2) rainfall and sunlight - Monthly Record--Meteorological Observations A.E.S.

(3) transport and vertical velocities - Fishery Oceanography Program, Pacific Biological Station.

(4) sea levels - Institute of Ocean Sciences, Patricia Bay.

(5) river discharge - Water Survey of Canada, Inland Waters Directorate, Pacific and Yukon Region.

(6) mean salinity at Cape St. James - records ceased in 1971. Since then the mean is calculated from salinity data from Station "P", (I.O.S. Patricia Bay) and from discharge of the Bella Coola River as follows:

mean salinity C.S.J. July<sub>n-1</sub> to June<sub>n</sub>

= 16.41 - 0.01 (mean Bella Coola River discharge Oct<sub>n-2</sub> to Sept<sub>n-1</sub>) + 0.49 (mean surface salinity at "P" Oct<sub>n-2</sub> to Sept<sub>n-1</sub>)

The nine month delay is related to the 2 mi/day eastward flow between Station "P" and the coast.

The weather ships are expected to be removed. Reinststitution of the Cape St. James salinity records, determined more precisely than by hydrometer, is needed.

We thank the staffs of the above agencies who have been so helpful by supplying unpublished data on a continuing basis over the years.



SKEENA RIVER EVEN YEAR PINK SALMON

RECRUITMENT YEARS 1952-74



SKEENA RIVER EVEN YEAR PINK SALMON

RECRUITMENT YEARS 1952-1974 (Fig. 1-4)

Variables

Y = Area 4 even year stock in year<sub>n</sub> (catch + escapement) in 10<sup>6</sup> fish  
X<sub>1</sub> = mean July-August rain at Prince Rupert<sub>n-2</sub> in inches  
X<sub>2</sub> = mean minimum air temperature at meteorological stations in °F in  
Nass and Skeena Valleys from October<sub>n-2</sub> to March<sub>n-1</sub>  
X<sub>3</sub> = escapement in year<sub>n-2</sub> in 10<sup>6</sup> fish

Response function

$$Y = 10.8679 - 1.3519X_1 - 1.0174X_2 + 0.5489X_3 + 0.1728X_1^2 + 0.0308X_2^2$$
$$R^2 = 0.95 \quad F = 43.78 \quad F_{.01} = 8.75$$

Processes

- (1) Upstream migration and deposition of eggs; rainfall used as a measure of discharge over spawning beds, Davidson and Hutchinson (1943), Davidson et al. (1943), Pritchard (1936), Wickett (1958). Yield rises quickly with increased rainfall.
- (2) Freezing and thawing of spawning beds in a climatic area where the average temperature of the coldest month is less than 26.6°F with anchor ice being most destructive at intermediate temperatures, Davidson and Hutchinson (1943), Chapman (1952), SFI Bulletin No. 319 (1980).
- (3) Linear relation between numbers of spawners and returning stock or yield, Pritchard (1948).

Comment

In 1978, there was a large tongue of low salinity water extending some 300 km to the west of Baronof Island. Some contribution appears to be made from the south i.e. Dixon Entrance (Ingraham Jr. 1979). Wickett (unpub.) has shown that the use of the northern passageways around Vancouver Island in 1978 by 70% of the mature Fraser River sockeye is associated with conditions that lead to the formation of low salinity plumes of water west of Dixon Entrance and Queen Charlotte Sound. The large Alaska pink salmon landings in 1978 (Fisheries of the United States 1978) and the missing fish predicted for the Skeena River in that year could be related through diversion and interception of the Skeena run. On the other hand, the destructive floods in the Terrace area, October 31-November 1, 1978 may affect the 1980 return adversely.

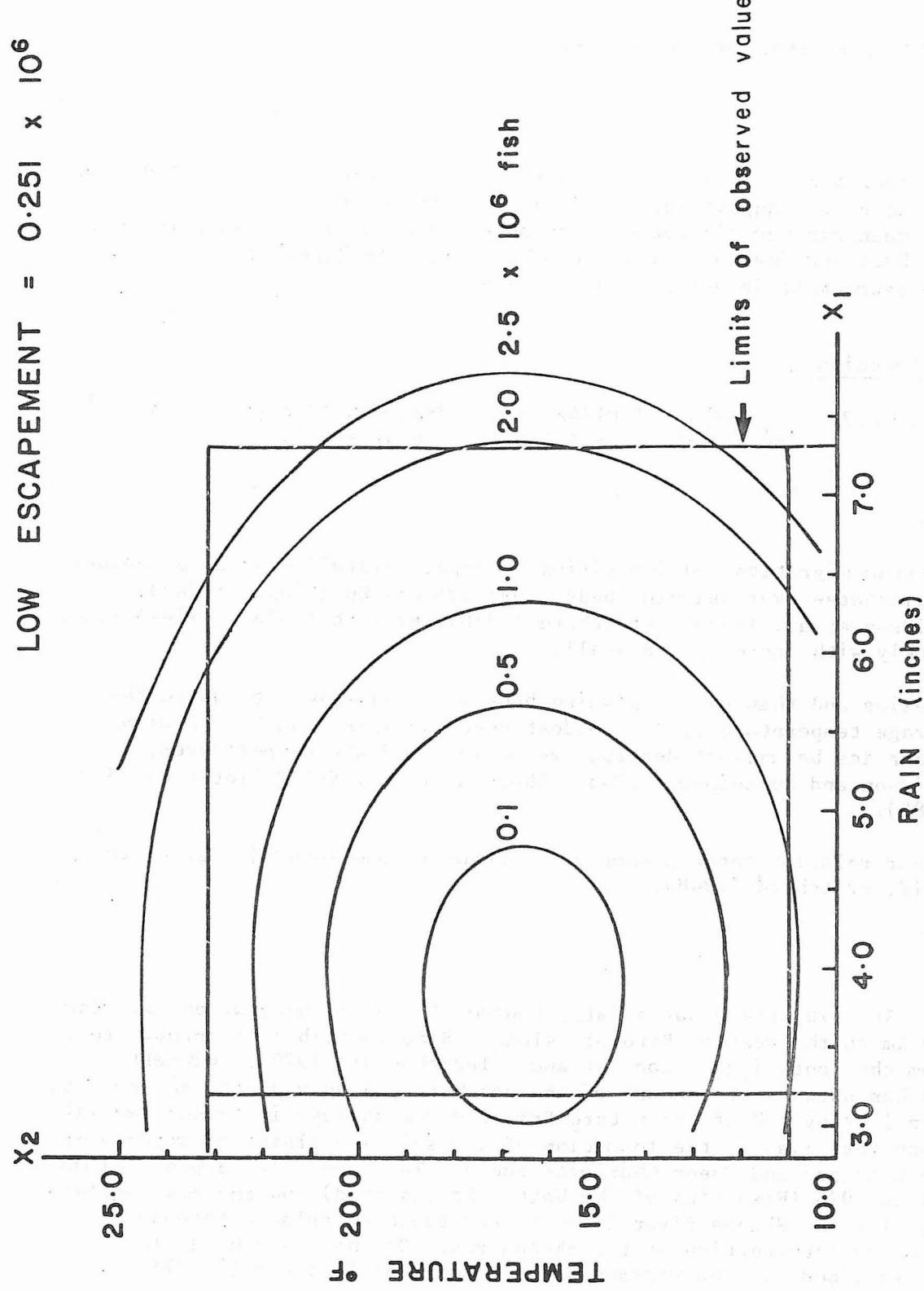


Fig. 1a. Contour diagrams of even year Skeena (Area 4) pink salmon recruitment stock in millions of fish. The variables are minimum mean air temperature during incubation and mean July-August rainfall at Prince Rupert for the low value of escapement.

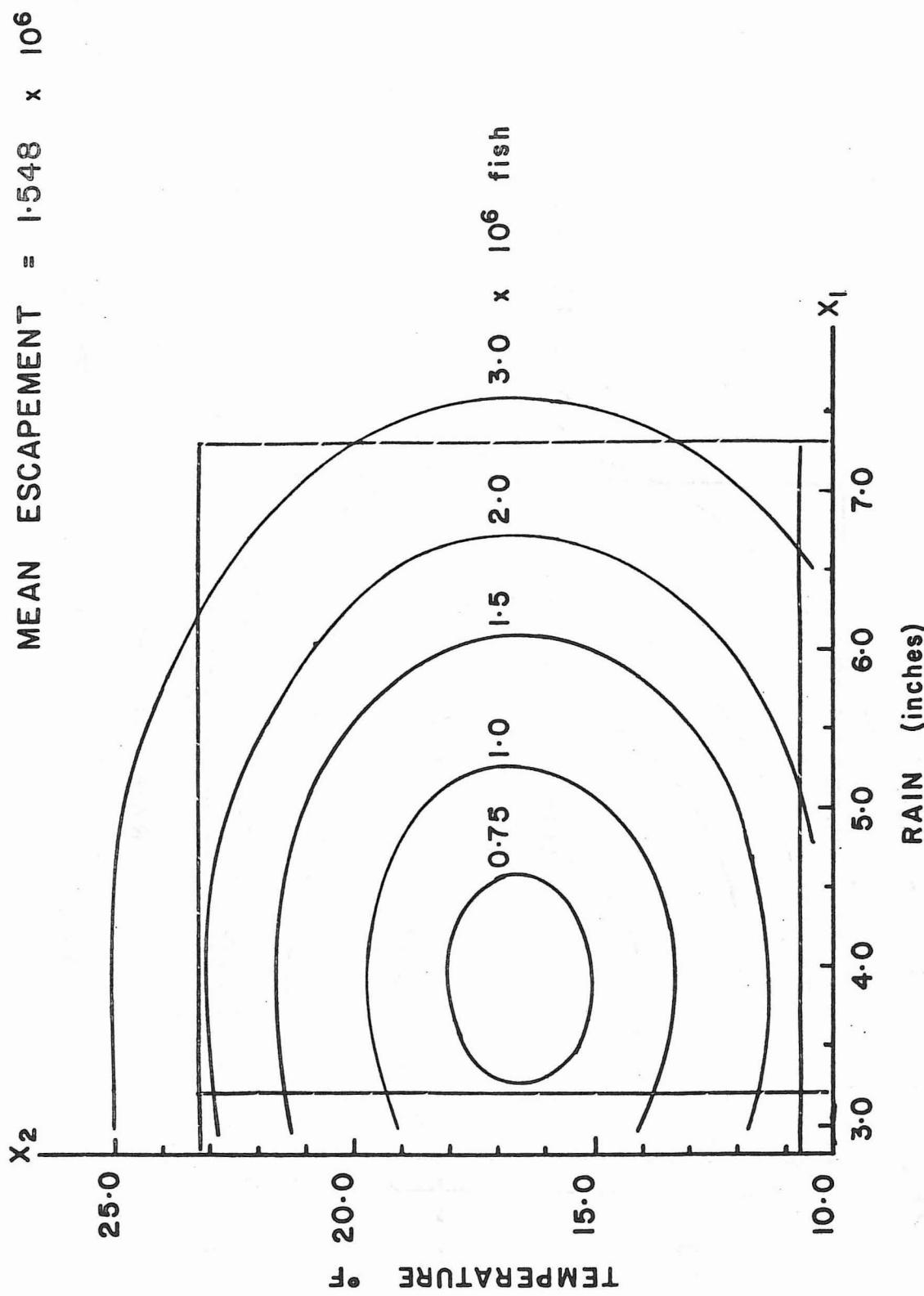


Fig. 1b. Even year Skeena pink salmon recruitment stock at mean escapement.

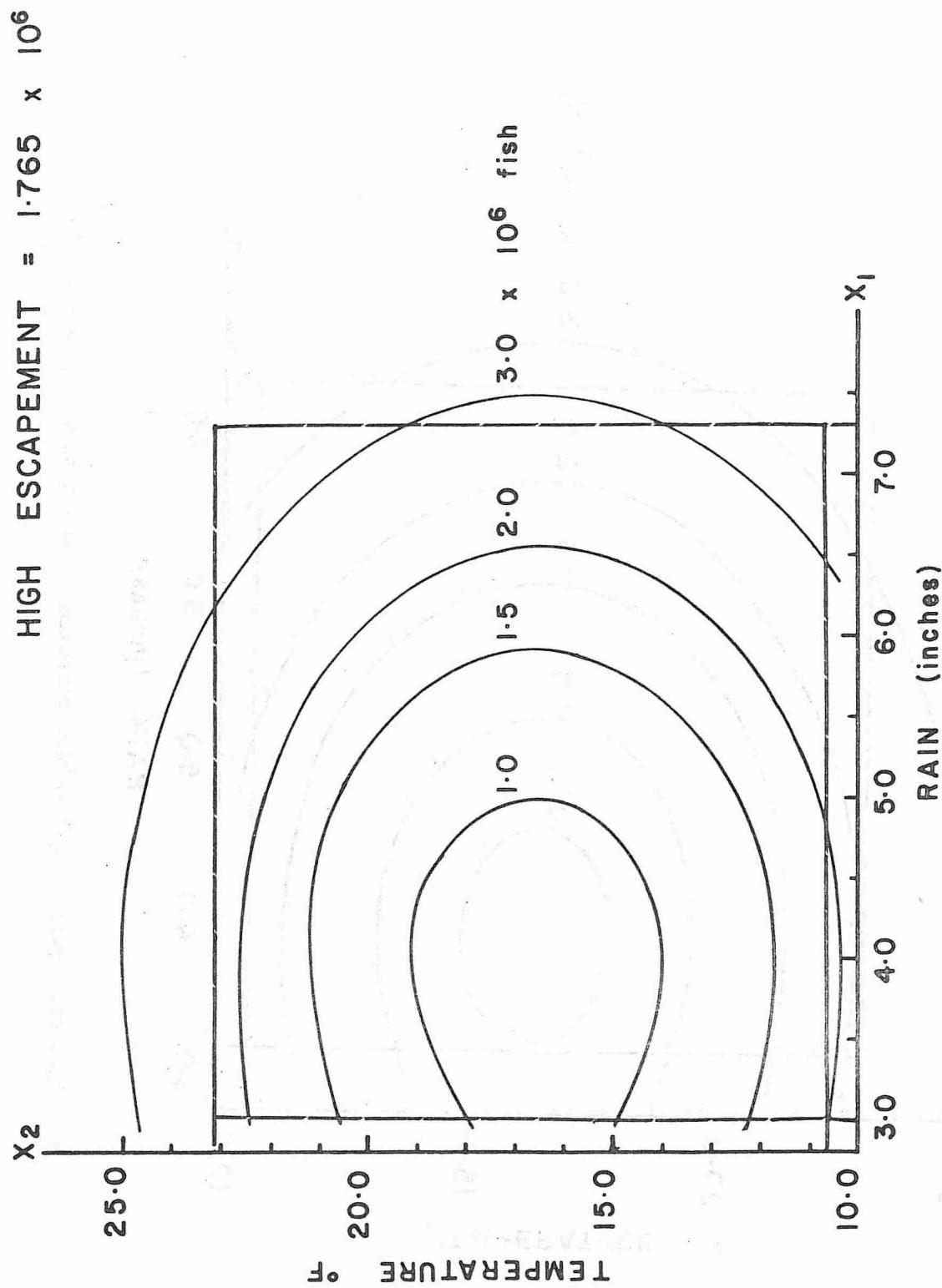


Fig. 1c. Even year Skeena pink salmon recruitment stock at high escapement.

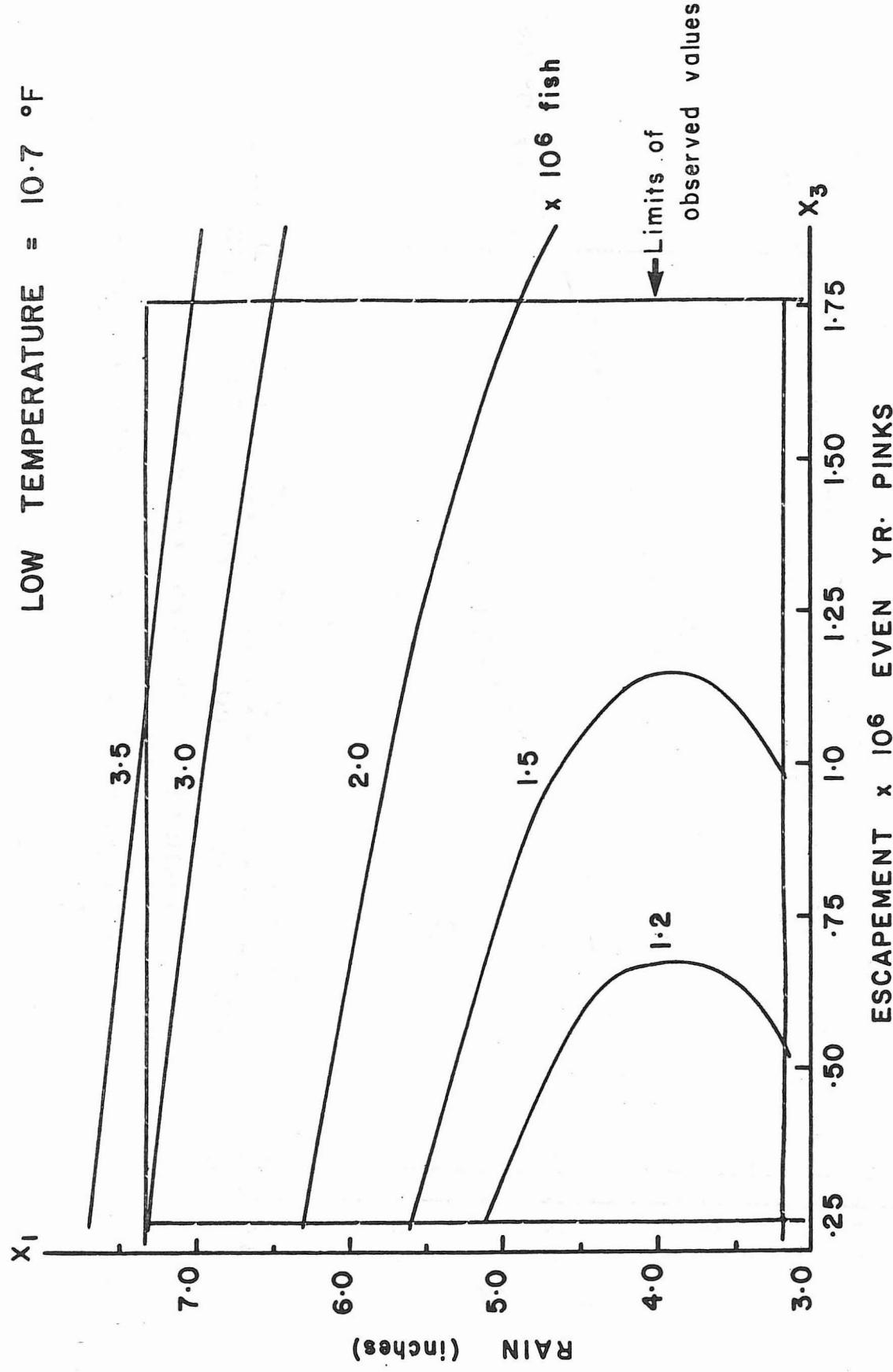


Fig. 2a. Contour diagram of even year Skeena (Area 4) pink salmon recruitment stock at low minimum air temperature.

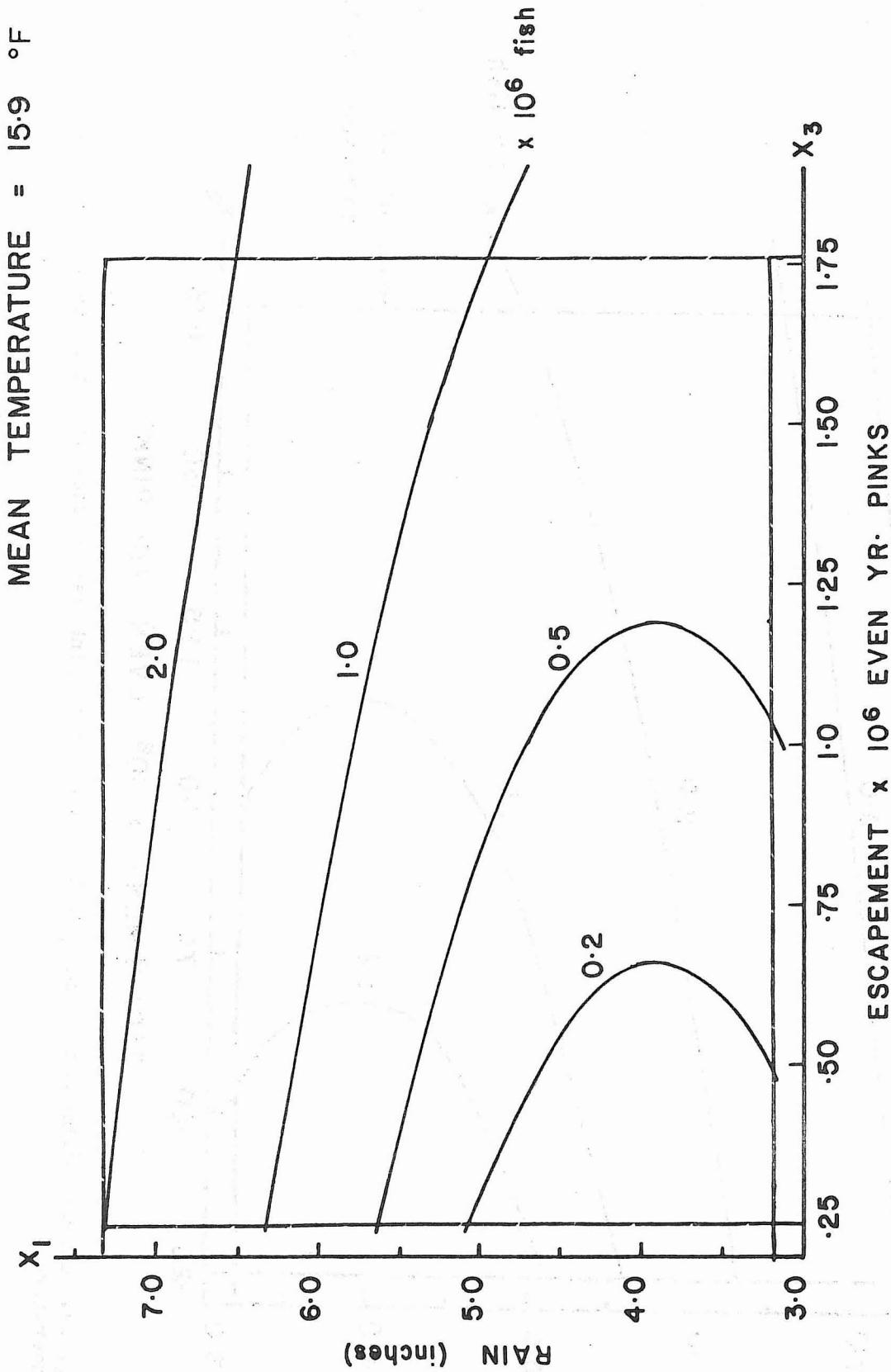


Fig. 2b. Even year Skeena pink salmon recruitment stock at mean minimum air temperature.

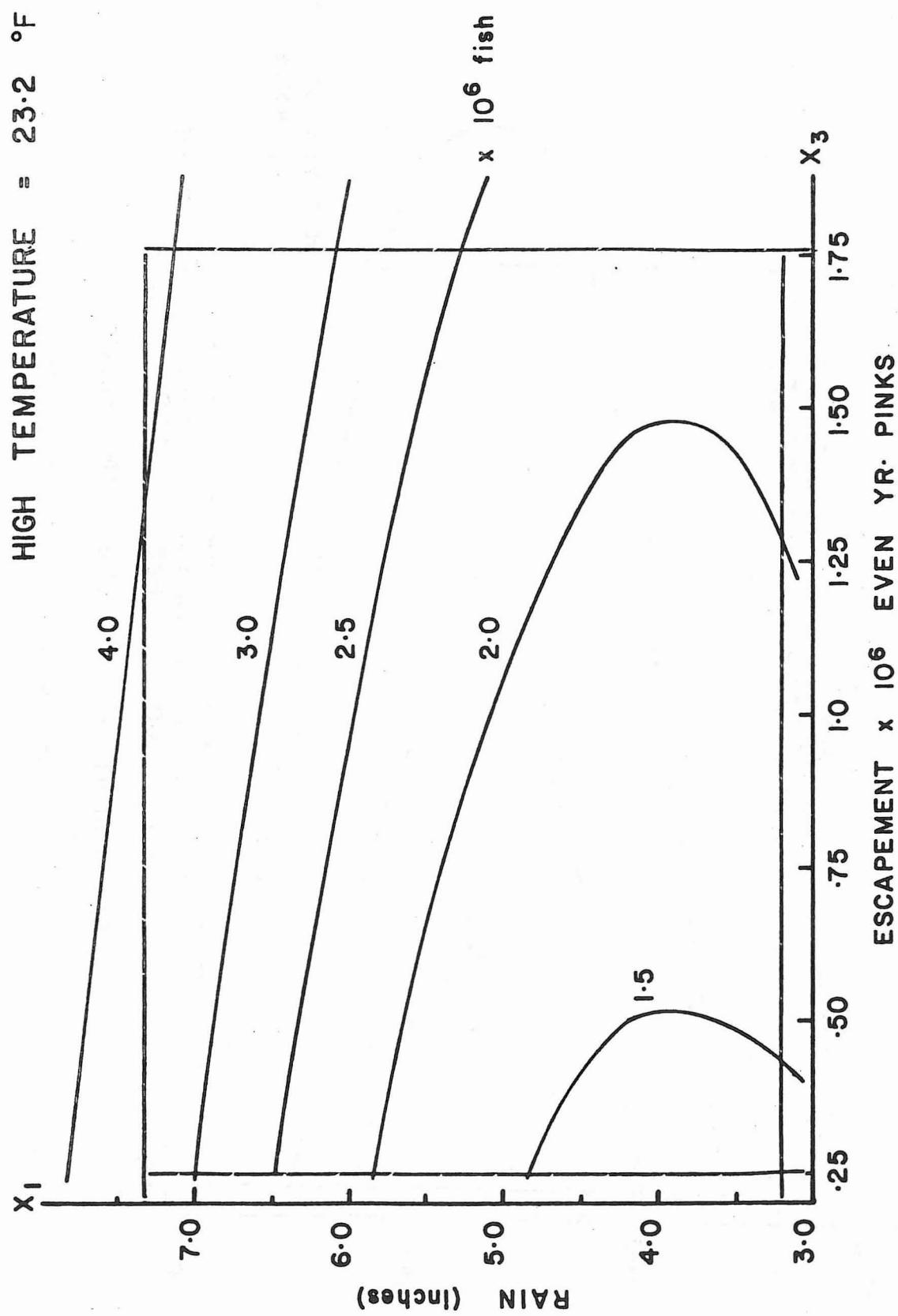


Fig. 2c. Even year Skeena pink salmon recruitment stock at high minimum air temperature.

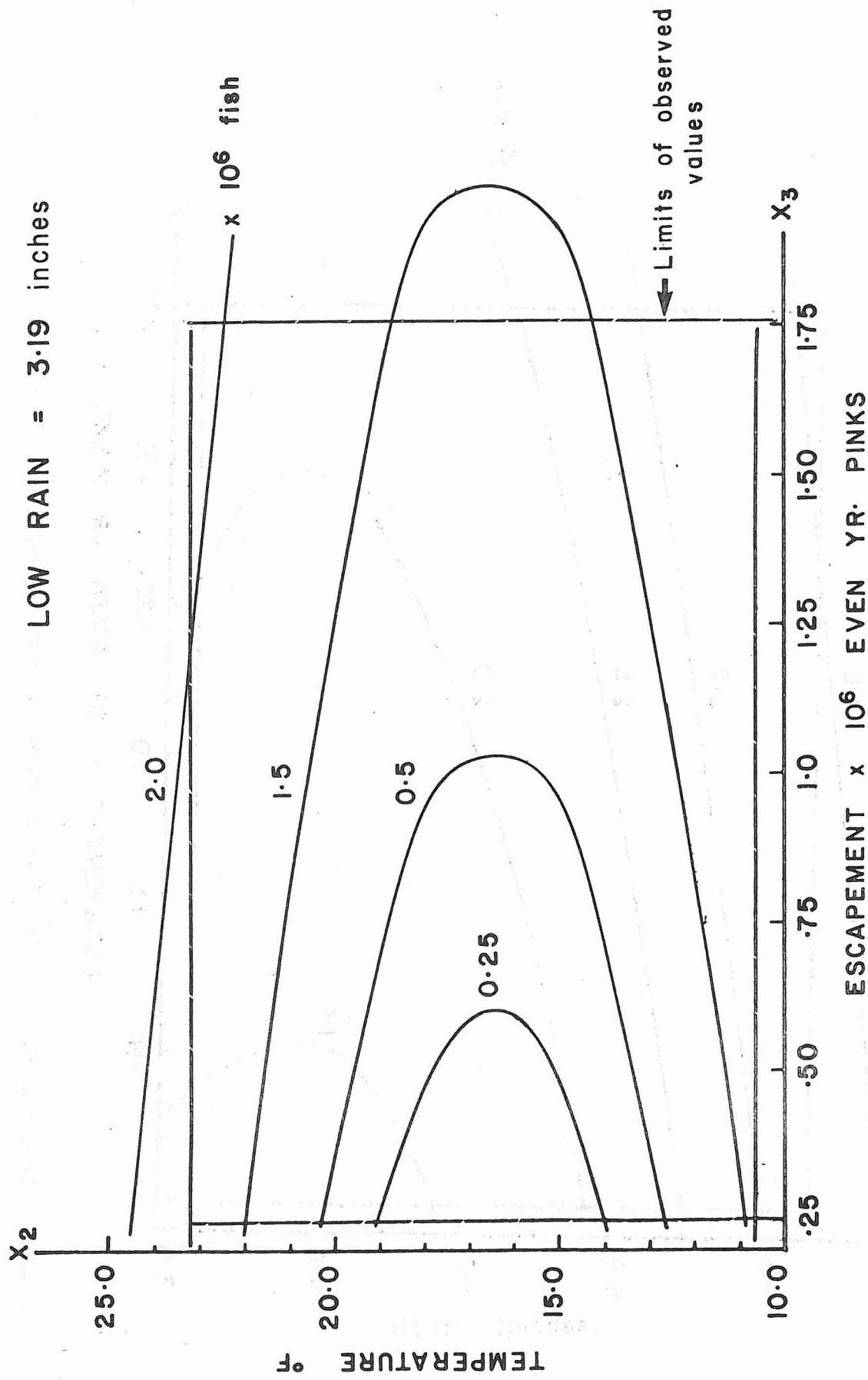


Fig. 3a. Even year Skeena (Area 4) pink salmon recruitment stock at low rainfall.

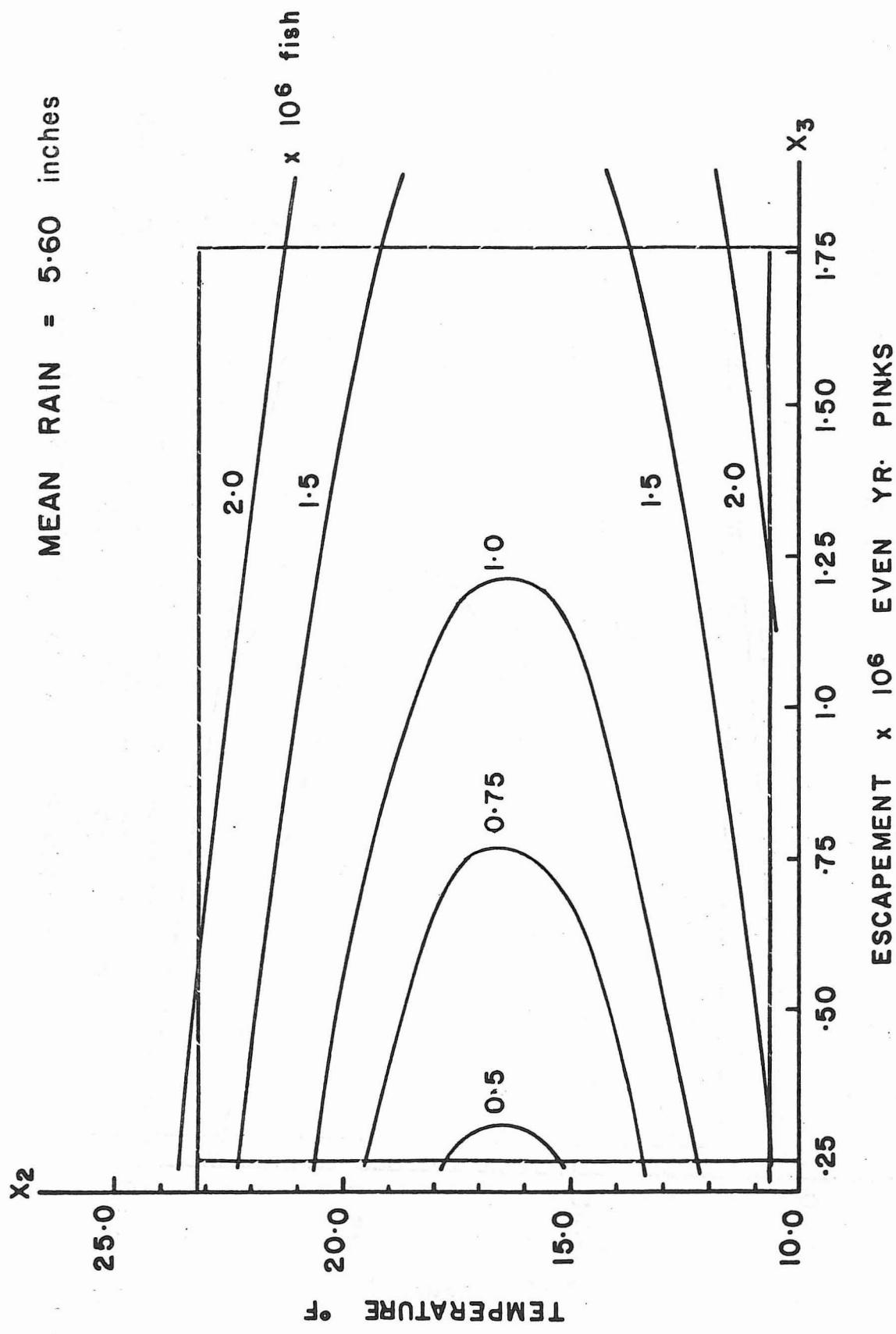


Fig. 3b. Even year Skeena pink salmon recruitment stock at mean rainfall.

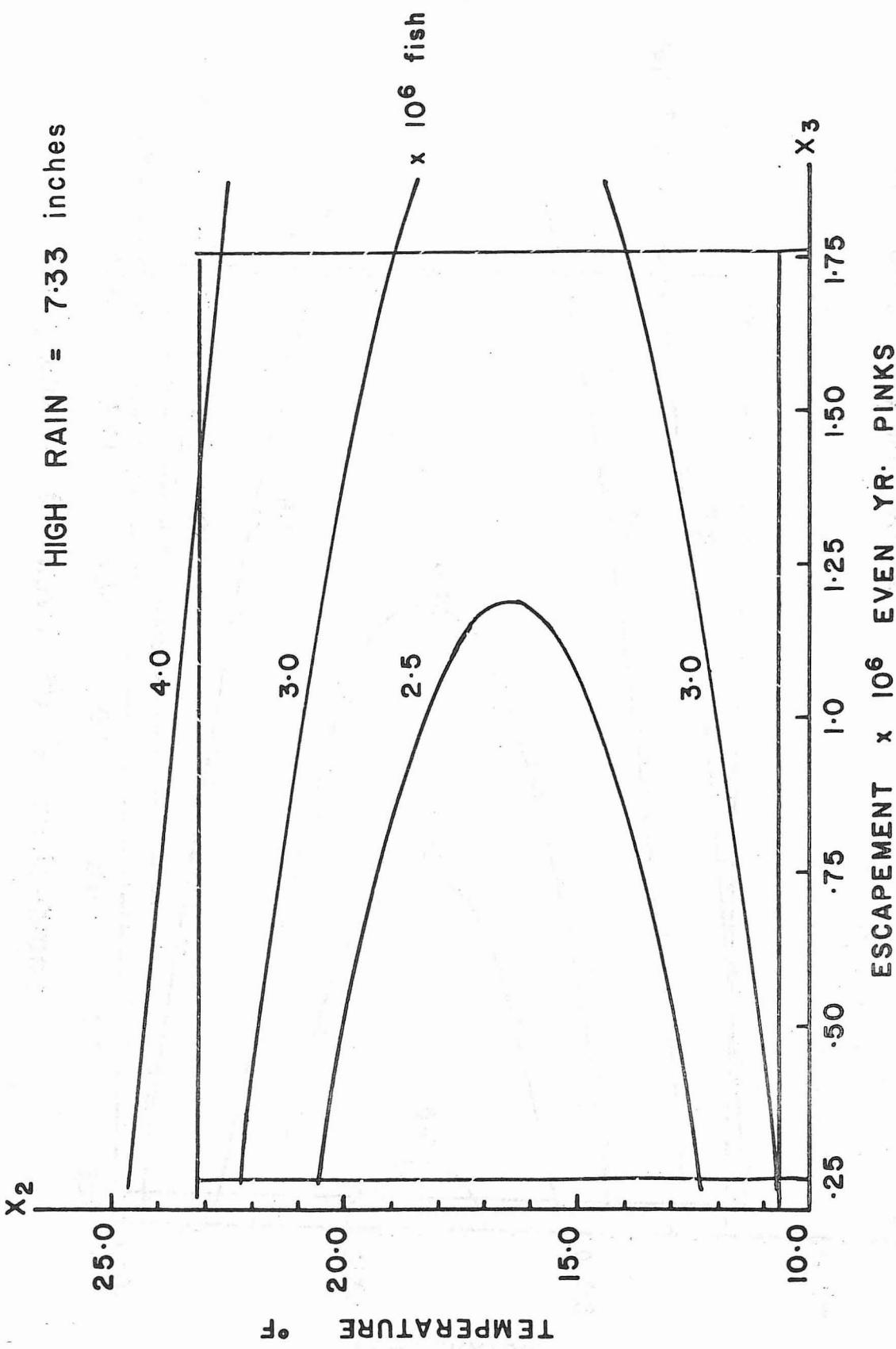


Fig. 3c. Even year Skeena pink salmon recruitment stock at high rainfall.

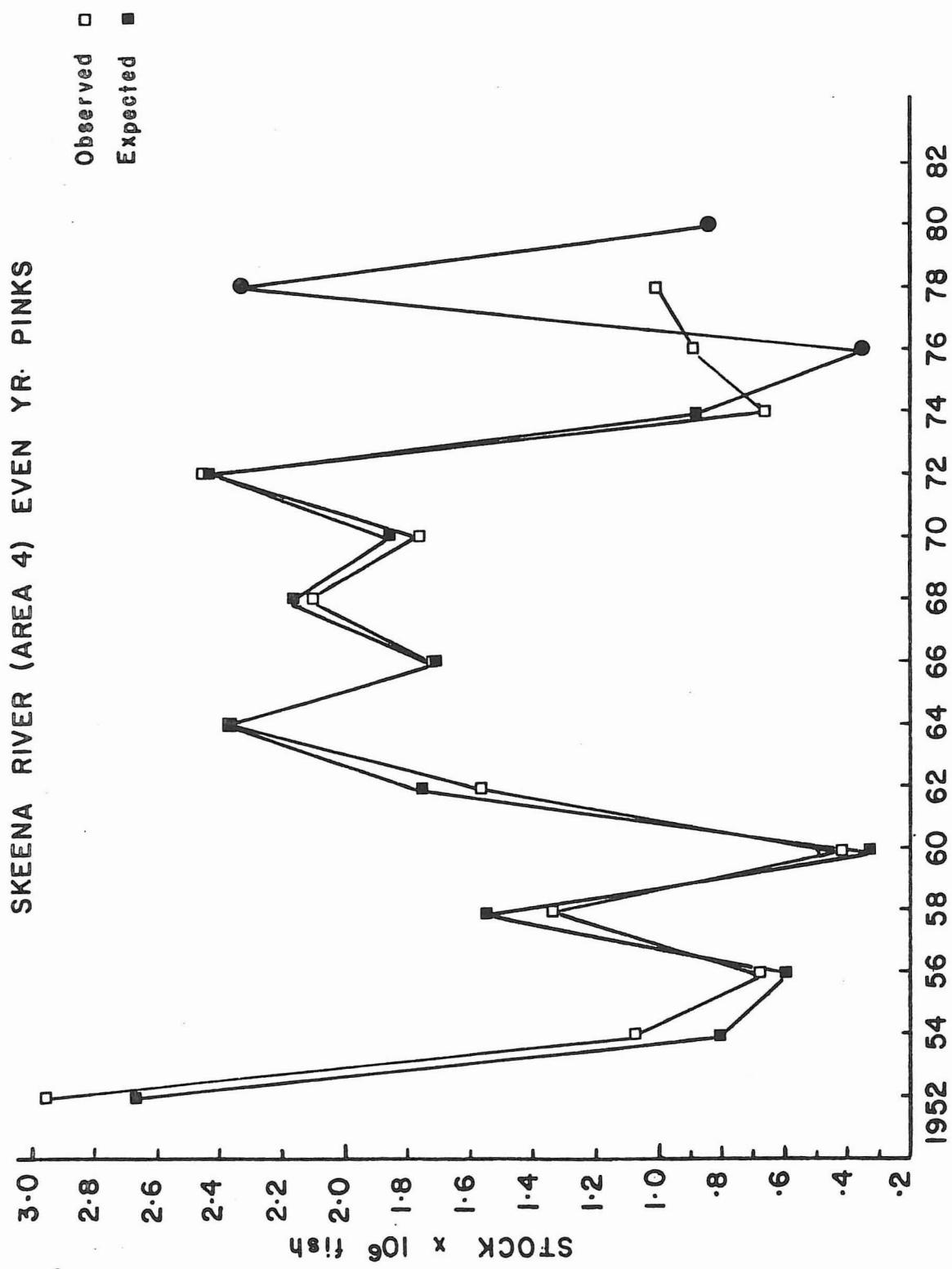


Fig. 4. Area 4 even year stocks observed and expected from equation for the years 1952 to 1974. Rainfall in July and August at Prince Rupert, the mean minimum temperature in the Skeena and Nass area October to March and the escapement are the predictive variates.



SKEENA RIVER ODD YEAR PINK SALMON

RECRUITMENT YEARS 1951-75



## SKEENA RIVER ODD YEAR PINK SALMON

RECRUITMENT YEARS 1951-1975 (Fig. 5-8)

### Variables

- $Y$  = Area 4 odd year stock in year<sub>n</sub> (catch + escapement) in  $10^6$  fish  
 $X_1$  = mean August-September rainfall at Prince Rupert, New Hazelton and Terrace in year<sub>n-2</sub> in inches  
 $X_2$  = mean minimum air temperature at meteorological stations in Nass and Skeena Valleys from October<sub>n-2</sub> to March<sub>n-1</sub> in °F.  
 $X_3$  = escapement in year<sub>n-2</sub> in  $10^6$  fish

### Response function

$$Y = 4.5314 + 1.7987X_1 - 0.7386X_2 - 4.5449X_3 - 0.1819X_1^2 + 0.0249X_2^2 + 2.7001X_3^2$$
$$R^2 = 0.90 \quad F = 9.457 \quad F_{.01} = 8.47$$

### Processes

Same as for even year pink salmon. Odd year runs to Sub-Area 4-3 are larger than in the even year hence use of additional upstream recording stations for rain. Odd year runs immediately south of the Skeena River tend to run later than even years hence a later period of rainfall is used. The drop-off in yield at higher rainfall differs from even year but is similar to that seen in Central Area populations.

### Comment

The failure of the 1977 prediction may be related to interception of Skeena fish in Southeast Alaska. The excellent run in southern Southeast Alaska, close to the Skeena River, was earlier than expected (Fisheries of the United States 1977) and is the area for which Davidson and Hutchinson (1943) discussed survival indices such as are used here.

A difference in response in even and odd years to rainfall and escapement may be an artifact of available data points.

Field observations are needed to confirm or deny differing reactions of even and odd year populations to biological and environmental factors.

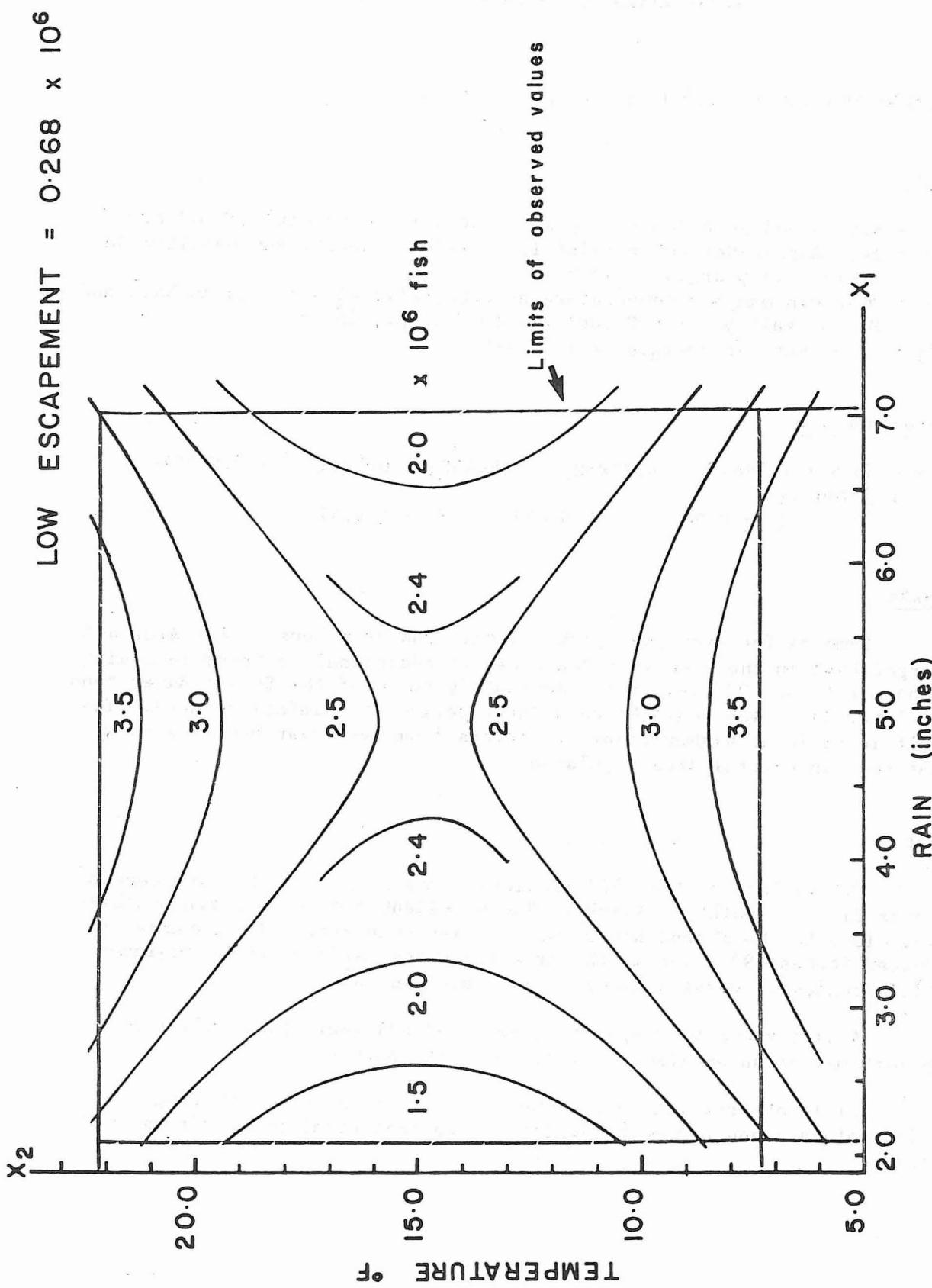


Fig. 5a. Contour diagrams of odd year Skeena (Area 4) pink salmon recruitment stock in millions of fish. The variables are minimum mean air temperature during incubation and mean August-September rainfall at Prince Rupert, Terrace and New Hazelton for the low value of escapement.

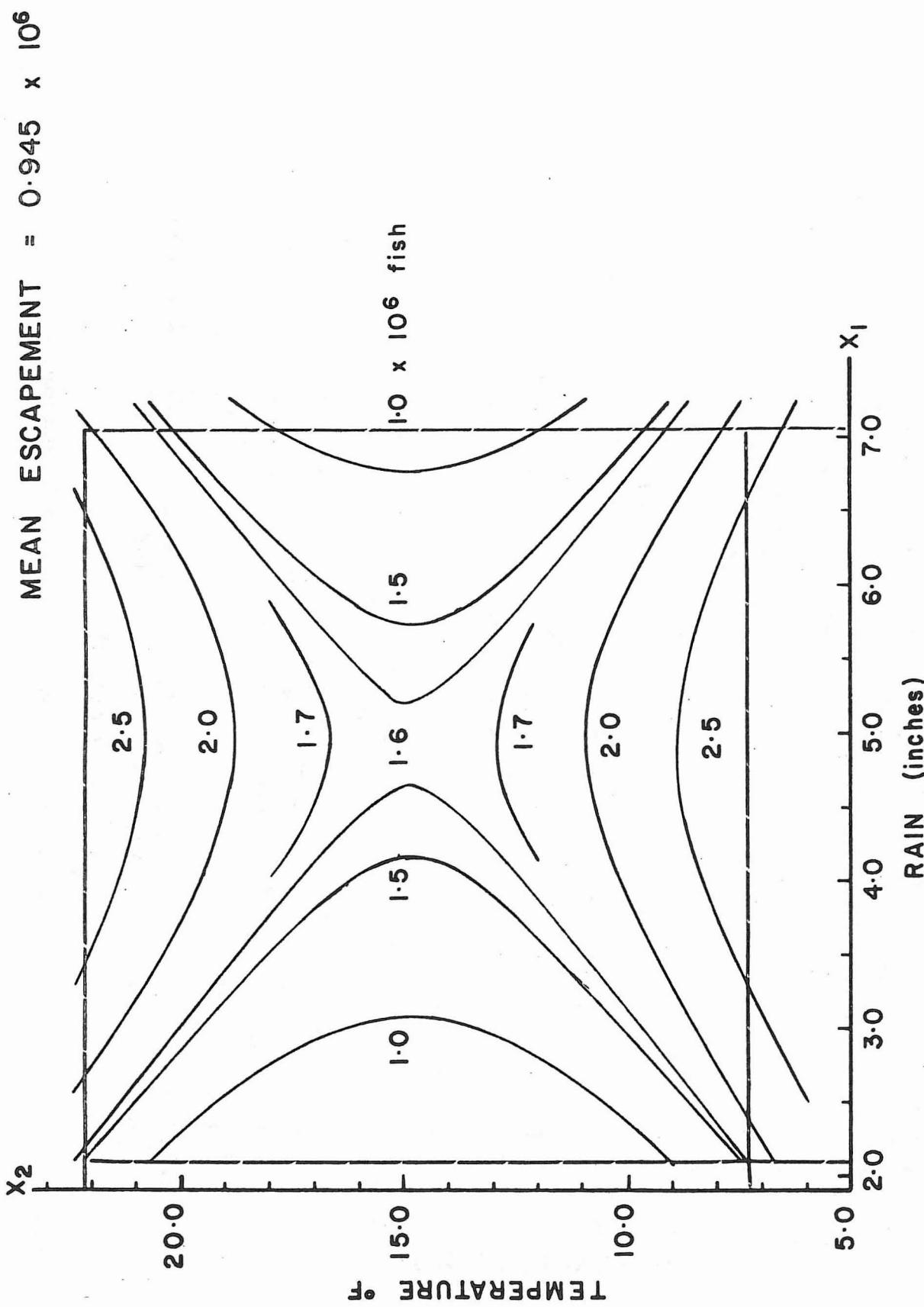


Fig. 5b. Odd year Skeena pink salmon recruitment stock at mean escapement.

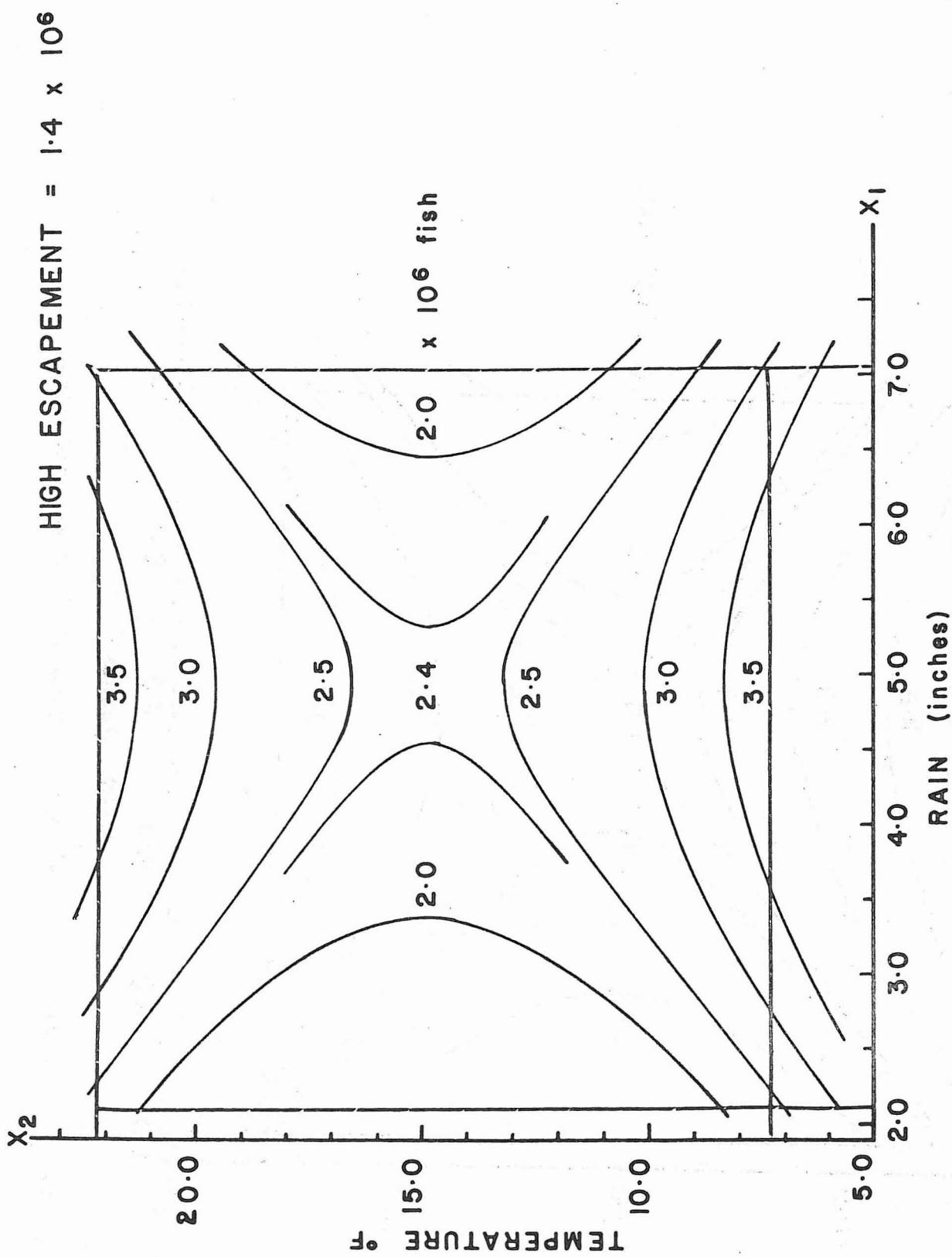


Fig. 5c. Odd year Skeena pink salmon recruitment stock at high escapement.

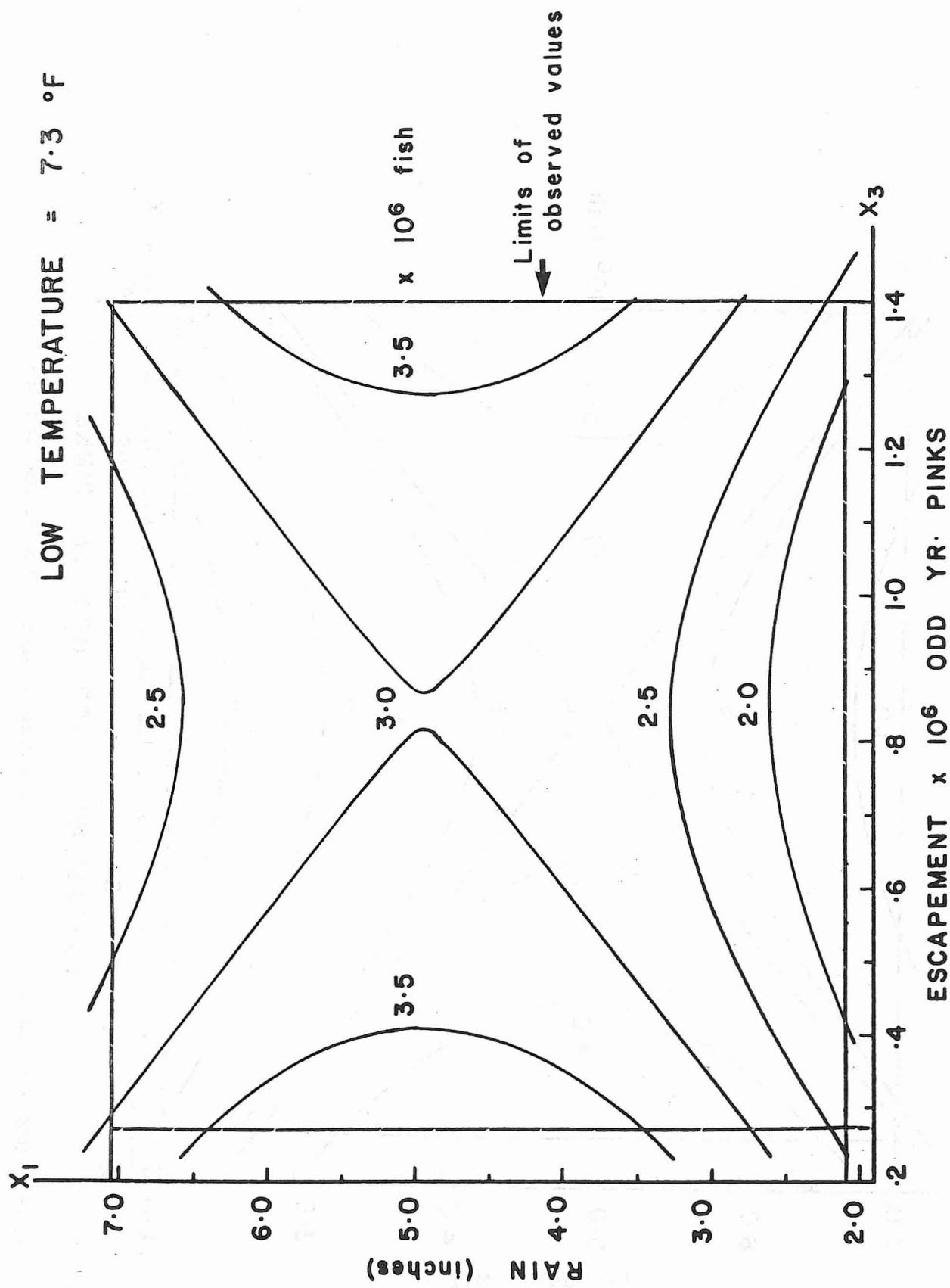


Fig. 6a. Odd year Skeena (Area 4) pink salmon recruitment stock at low temperature.

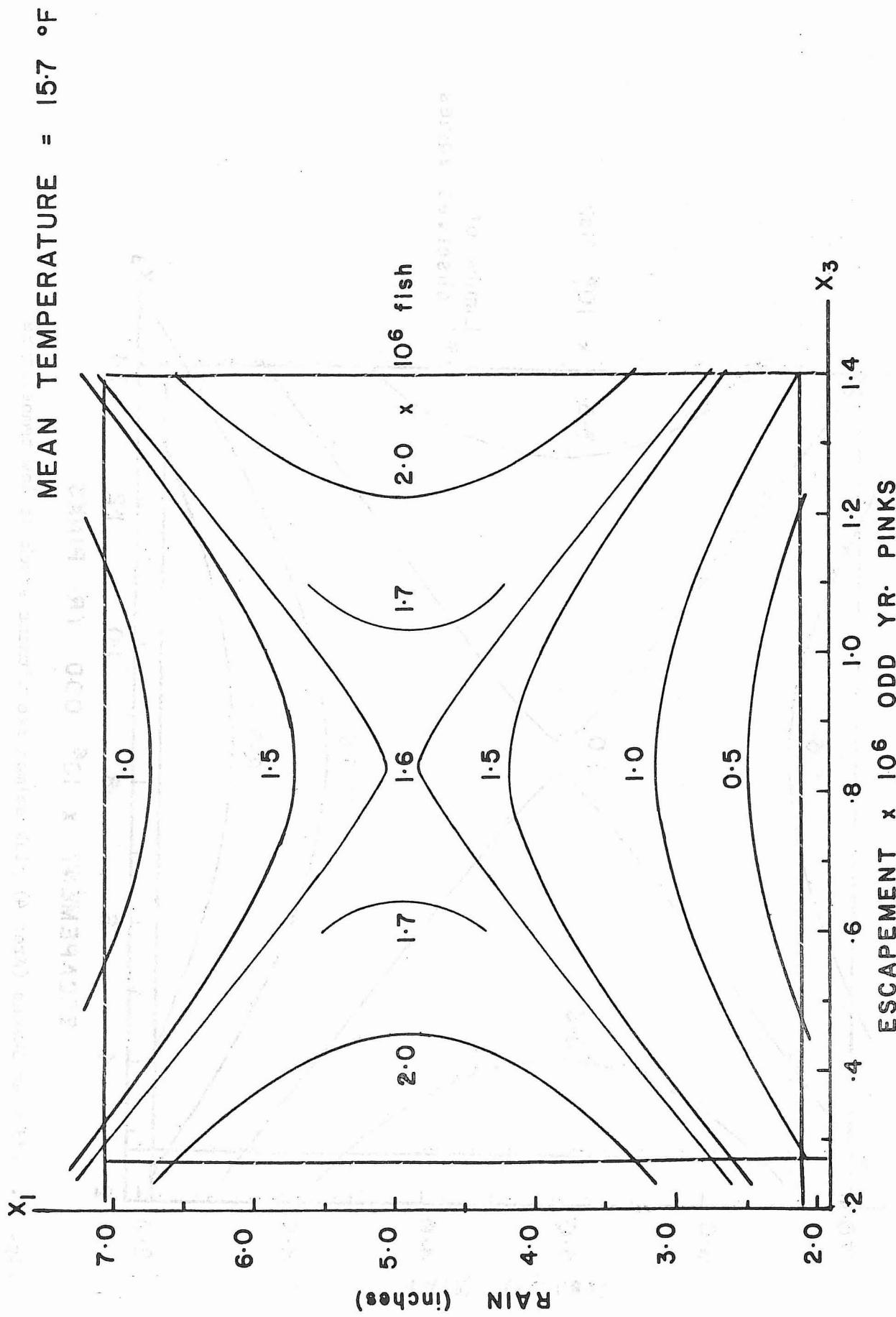


Fig. 6b. Odd year Skeena pink salmon recruitment stock at mean temperature.

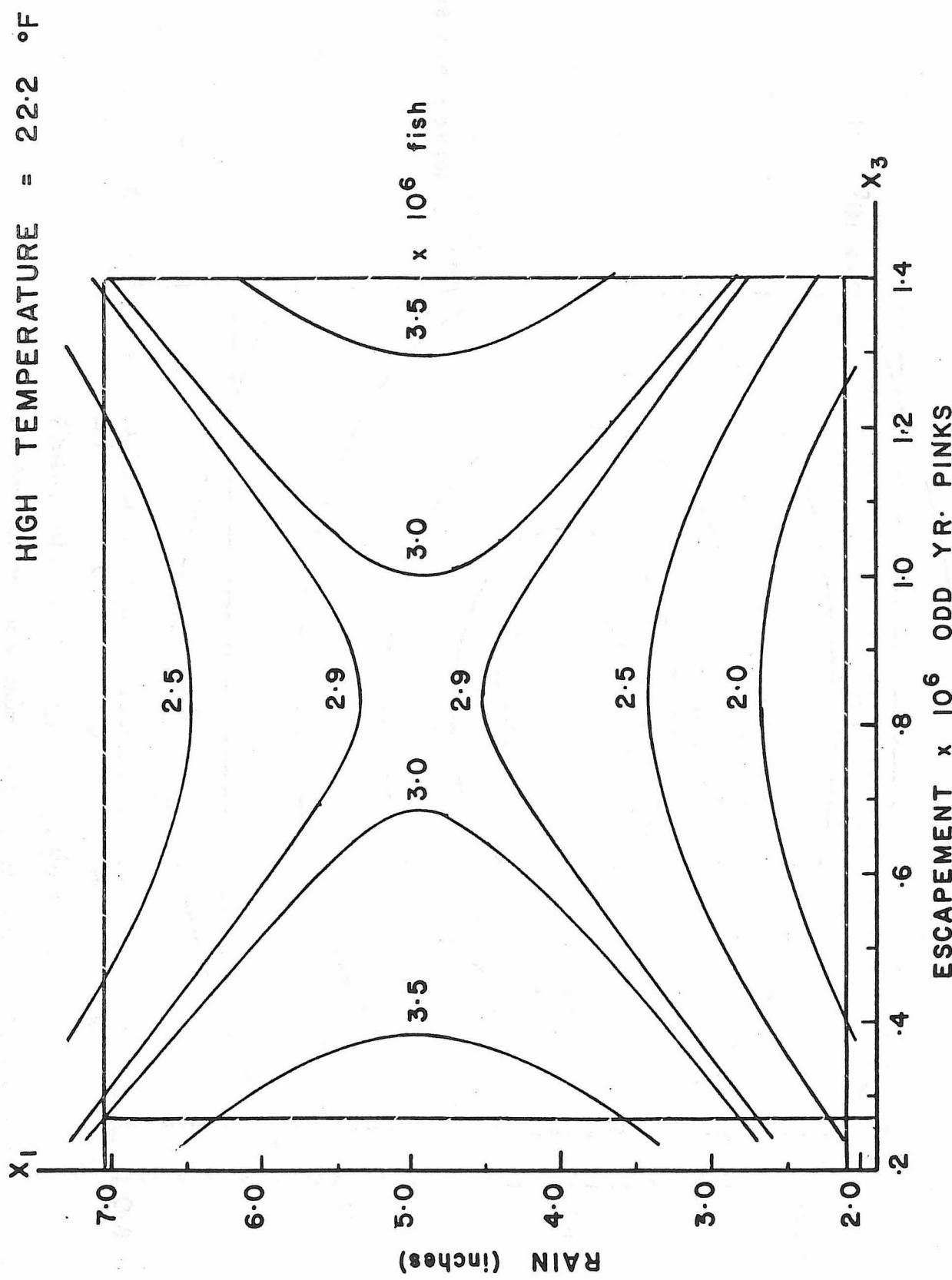


Fig. 6c. Odd year Skeena pink salmon recruitment stock at high temperature.

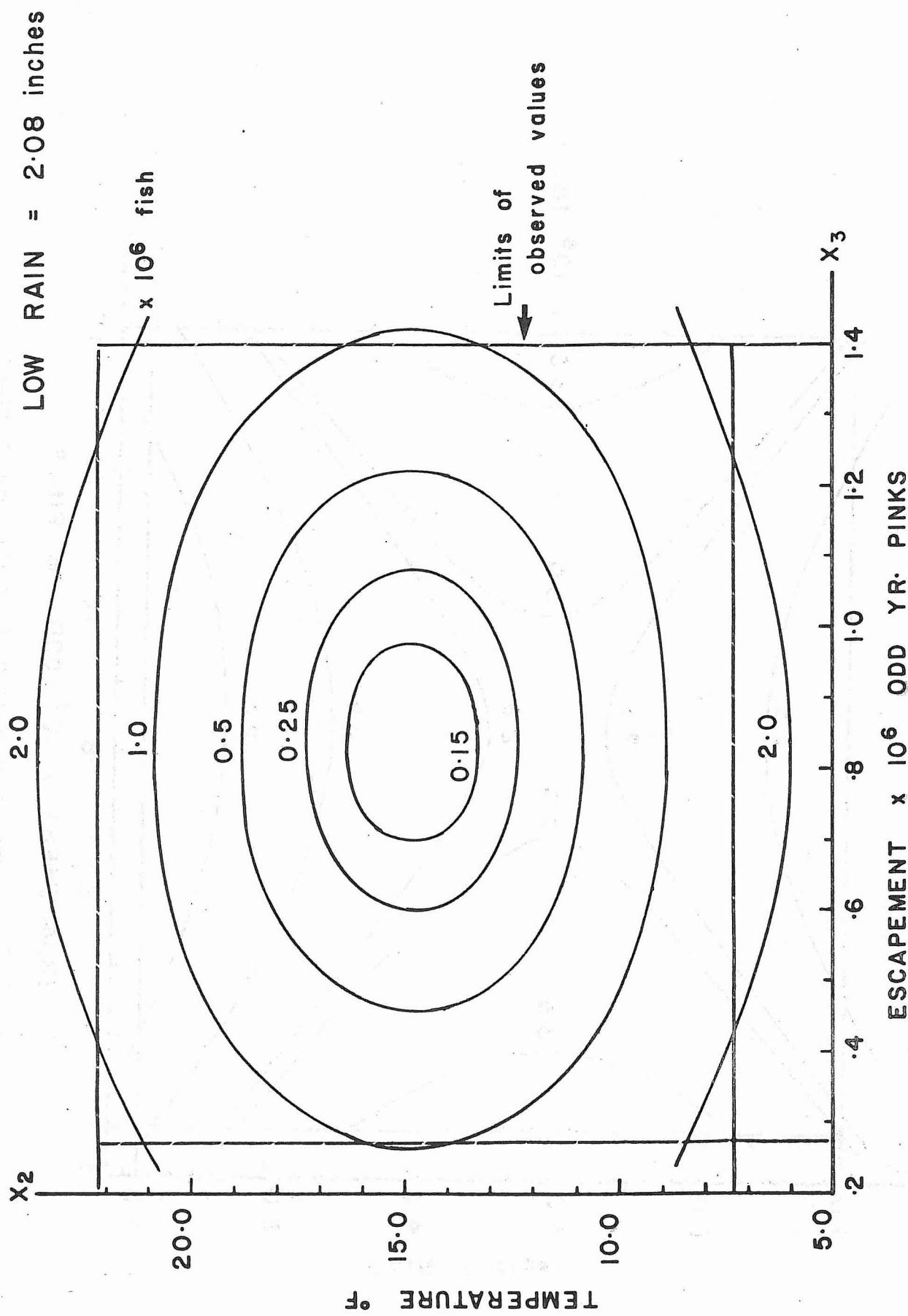


Fig. 7a. Odd year Skeena pink salmon recruitment stock at low rainfall.

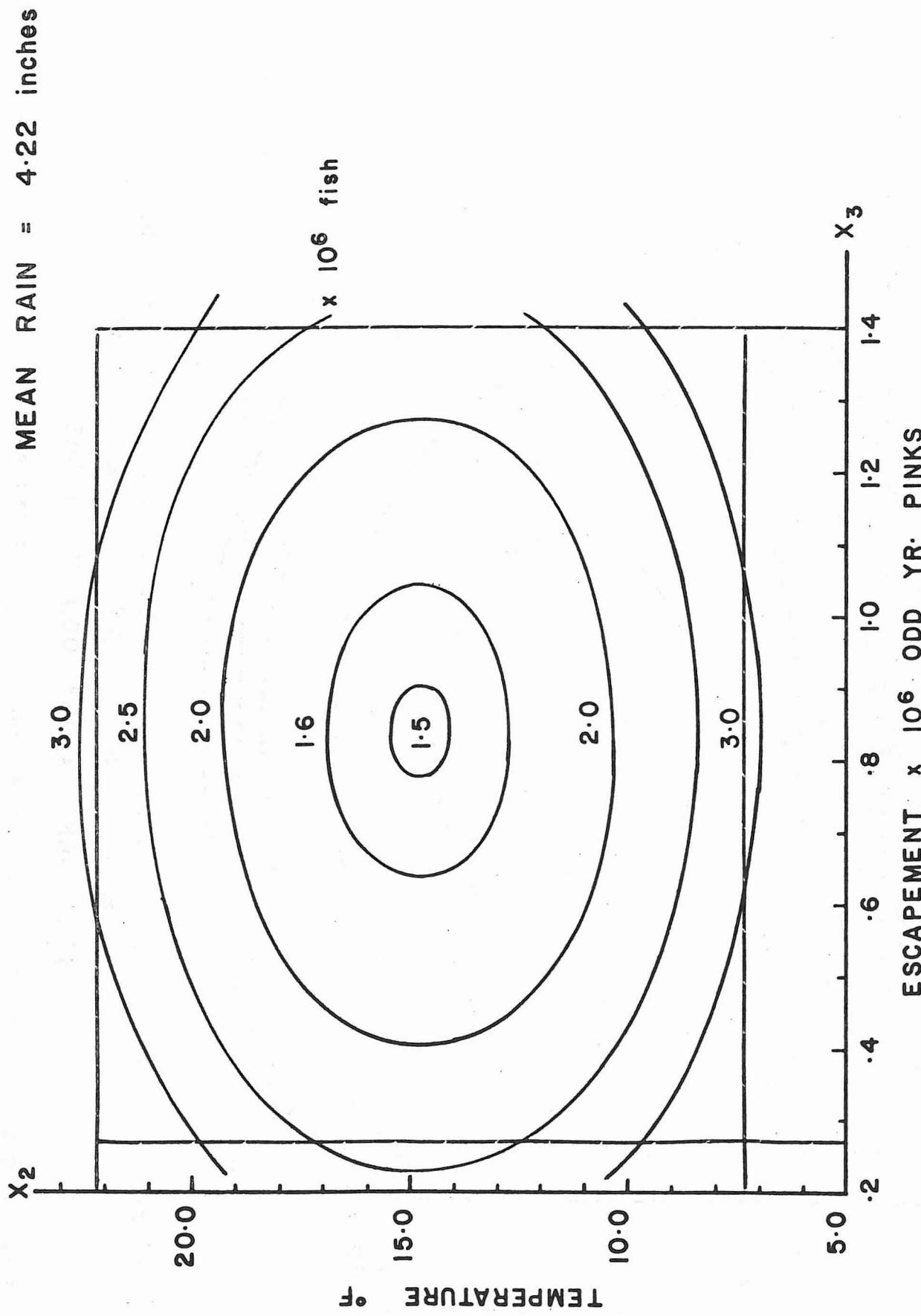


Fig. 7b. Odd year Skeena pink salmon recruitment stock at mean rainfall.

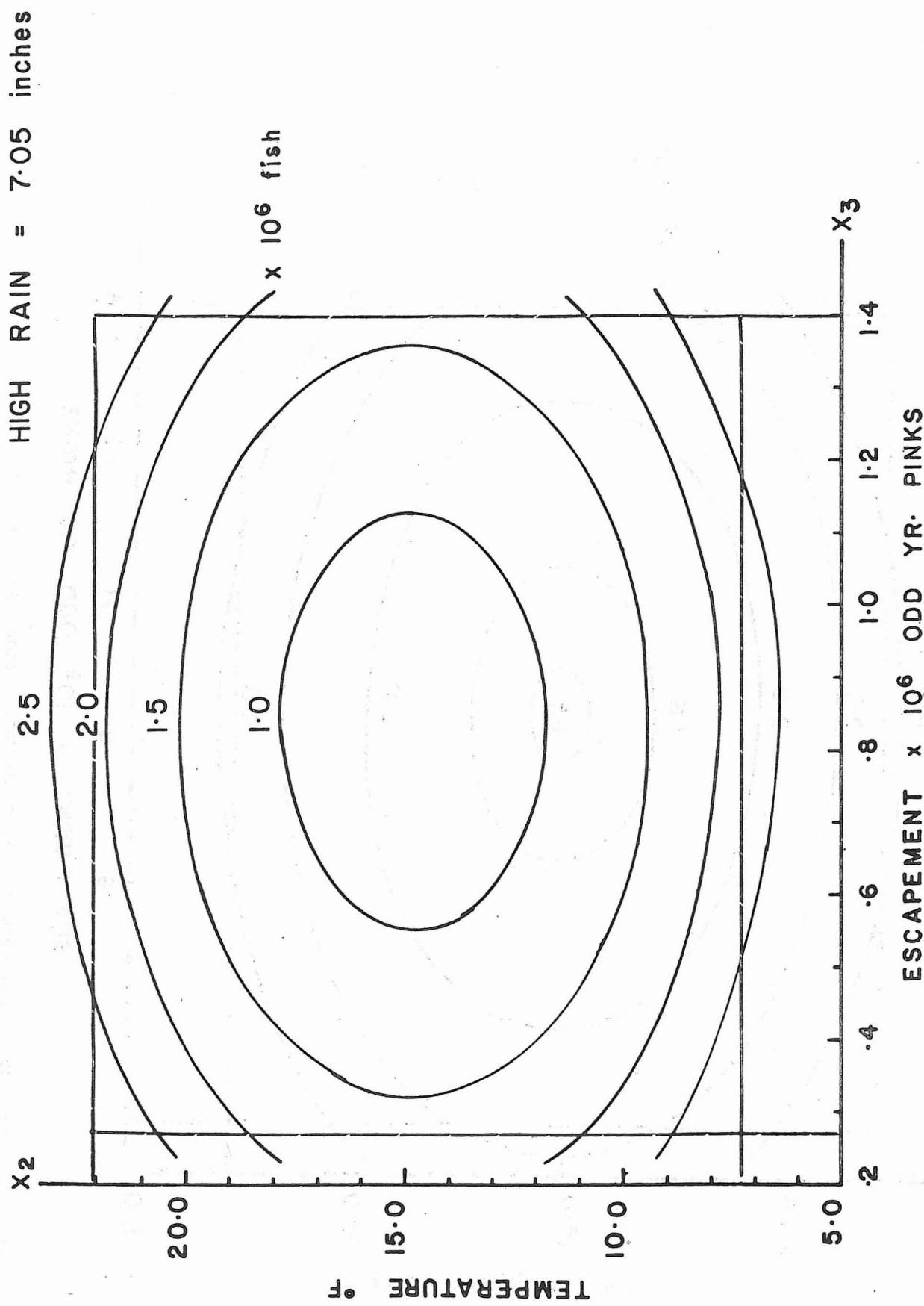


Fig. 7c. Odd year Skeena pink salmon recruitment stock at high rainfall.

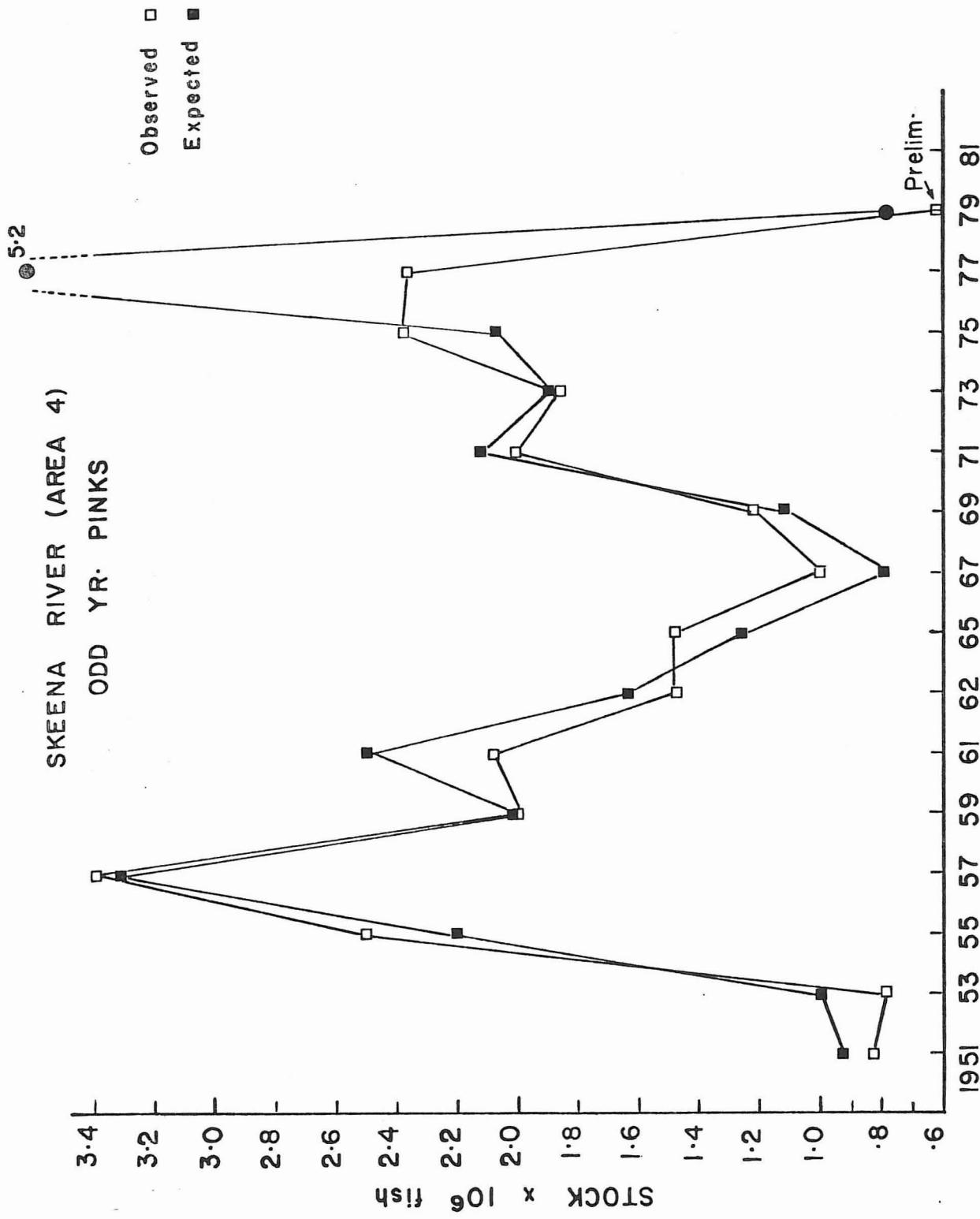


Fig. 8. Area 4 odd year stocks observed and expected from equation for the years 1951 to 1975. Rainfall in August and September at Prince Rupert, the mean minimum temperature in the Skeena and Nass area October to March and the escapement are the predictive variates. A large stock returned in 1977 to S. E. Alaska adjoining the Nass and Skeena area.



CENTRAL AREA (6, 7, 8) EVEN YEAR PINK SALMON

RECRUITMENT YEARS 1930-74



CENTRAL AREA (6,7,8) EVEN YEAR PINK SALMON

RECRUITMENT YEARS 1930-1974 (Fig. 9-12)

Variables

$Y$  = Area 6,7,8 even year stock in year<sub>n</sub> (catch + escapement) in  $10^6$  fish

$X_1$  = total July and August<sub>n-2</sub> rainfall at Ocean Falls in inches

$X_2$  = total July and August<sub>n-1</sub> hours of bright sunlight at Sandspit

$X_3$  = escapement in year<sub>n-2</sub>

Response function

$$Y = 47.3411 + 1.2235X_1 - 38.4164X_2 + 6.3265X_3 - 0.0266X_1^2 + 5.7276X_2^2 - 0.6352X_3^2$$
$$R^2 = 0.89 \quad F = 18.858 \quad F_{.01} = 4.82$$

Processes

Rainfall is a measure of discharge over the spawning grounds affecting upstream migration and spawning success. Survival increases at first and then falls off at high rainfall values (Wickett 1958). Hours of bright sunlight is related to onshore transport in the preceding winter and is used because the sunlight records can be extrapolated back in time from Prince Rupert records. Transport is shown to be related to zooplankton biomass in other parts of the Pacific Ocean (Wickett 1967). Sunlight may also have a second effect on survival of salmon by changing the clarity of the coastal waters (phytoplankton blooms) and thus the hunting success of fish-eating birds, fish and animals. A parabolic relationship approximates a Ricker stock-recruitment curve, (Wickett unpub.).

Comment

Odd and even year responses to the sunlight factor differ. This may be another expression of differences in the two lines also seen in their growth and in their time of spawning. Study of the young fish in Hecate Strait and Queen Charlotte Sound is needed. For instance, a simple genetic tendency to orient northward in one line and southward in the other line, after passing through the island chain, would lead the populations through quite different environments. The techniques for such a test are well established (Groot 1965).

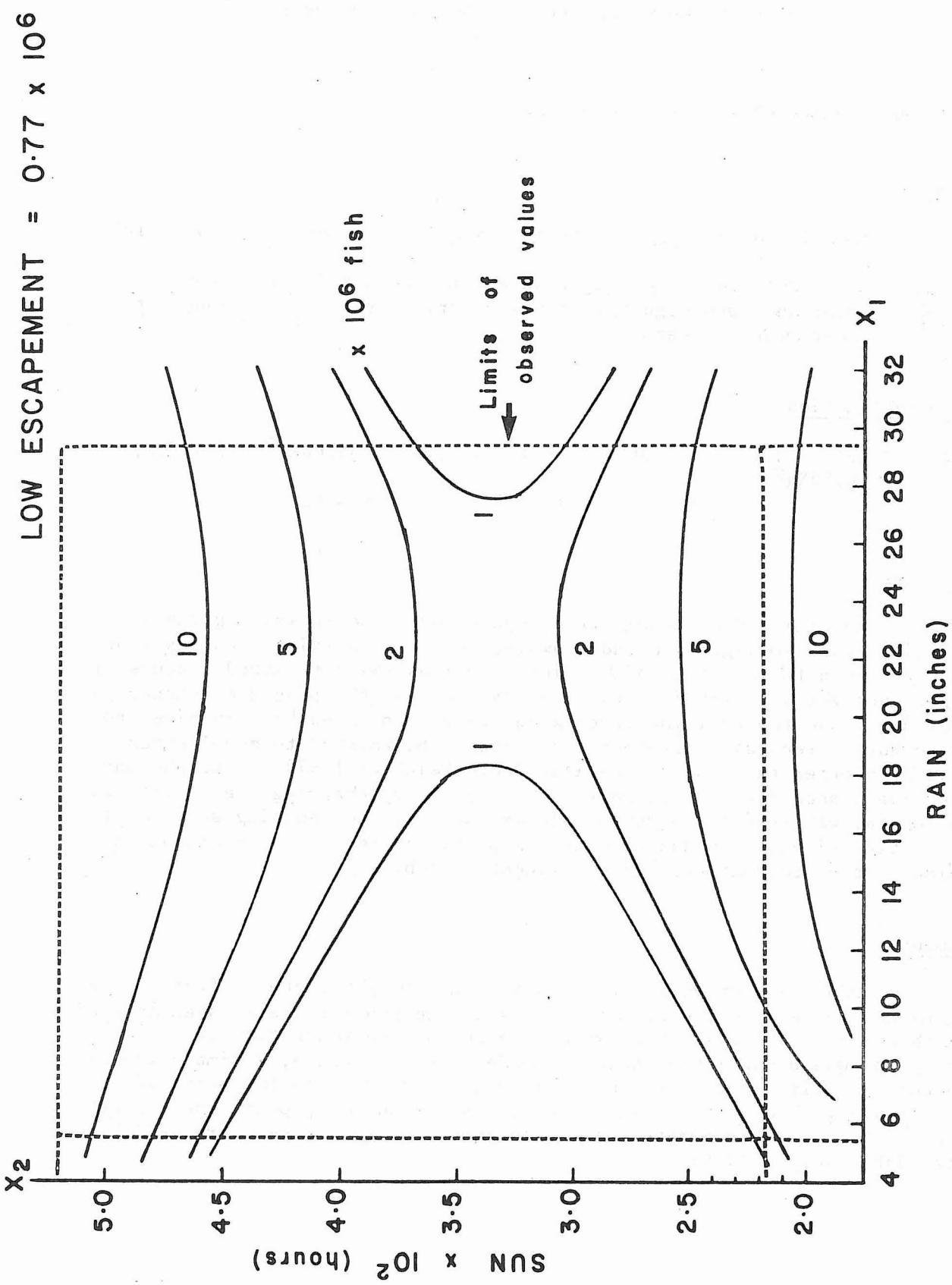


Fig. 9a. Contour diagrams of Central Area (6, 7, 8) pink salmon even year recruitment stock with hours of bright sunlight at Sandspit in July and August of the smolt year and July-August rainfall at Ocean Falls in the spawning year for low escapement.

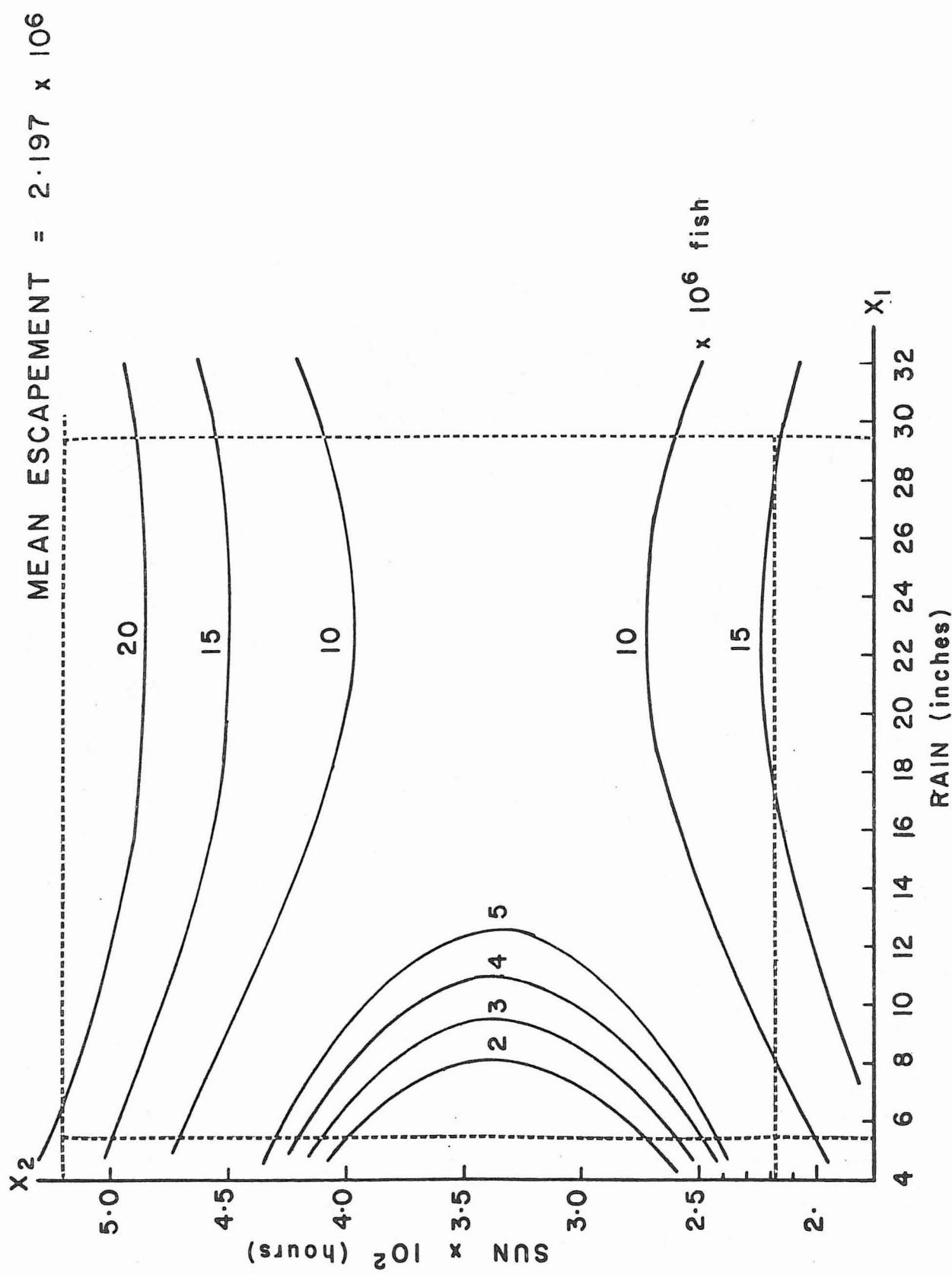


Fig. 9b. Central Area even year pink salmon recruitment stock contours for mean escapement.

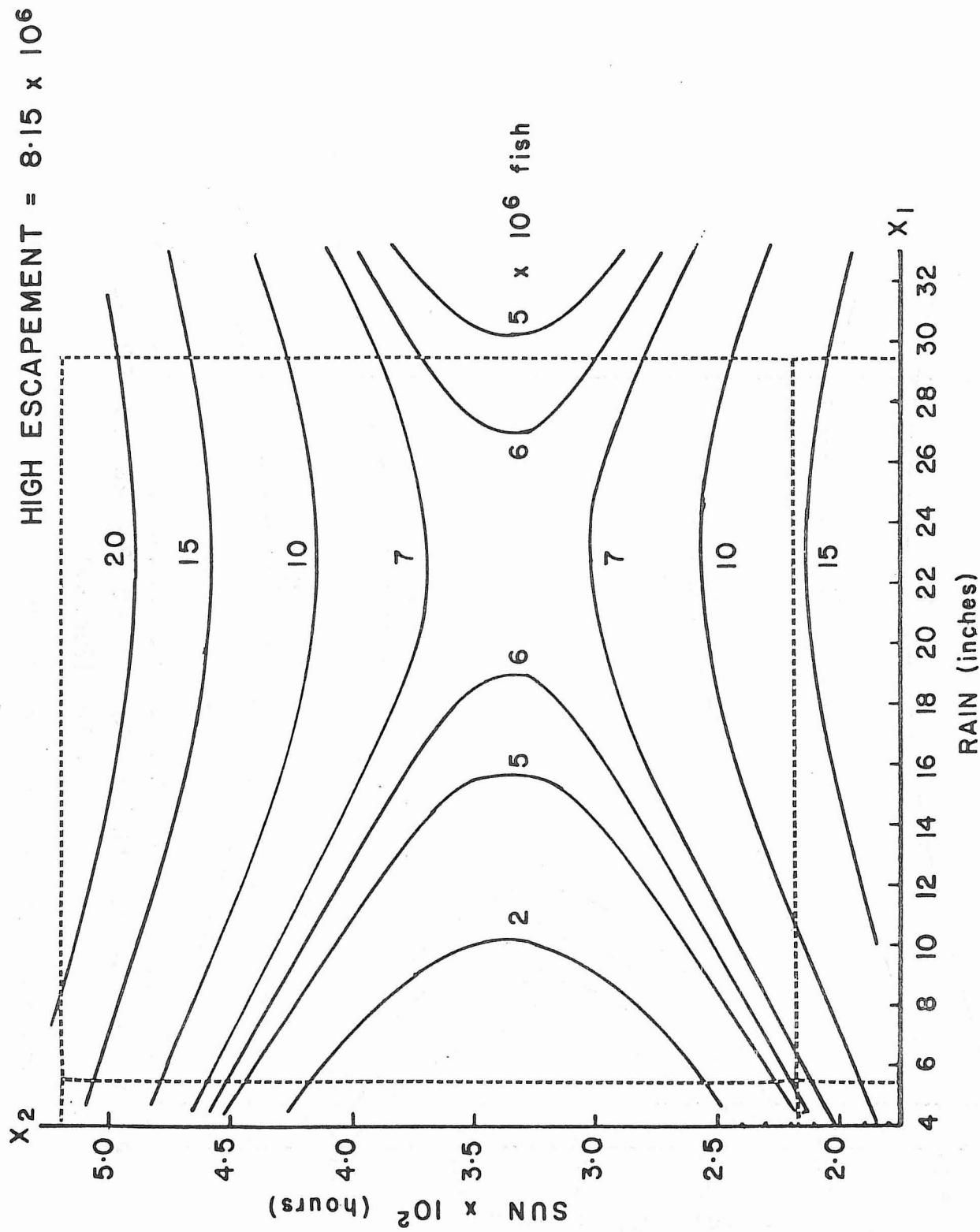


Fig. 9c. Central Area even year pink salmon recruitment stock contours for high escapement.

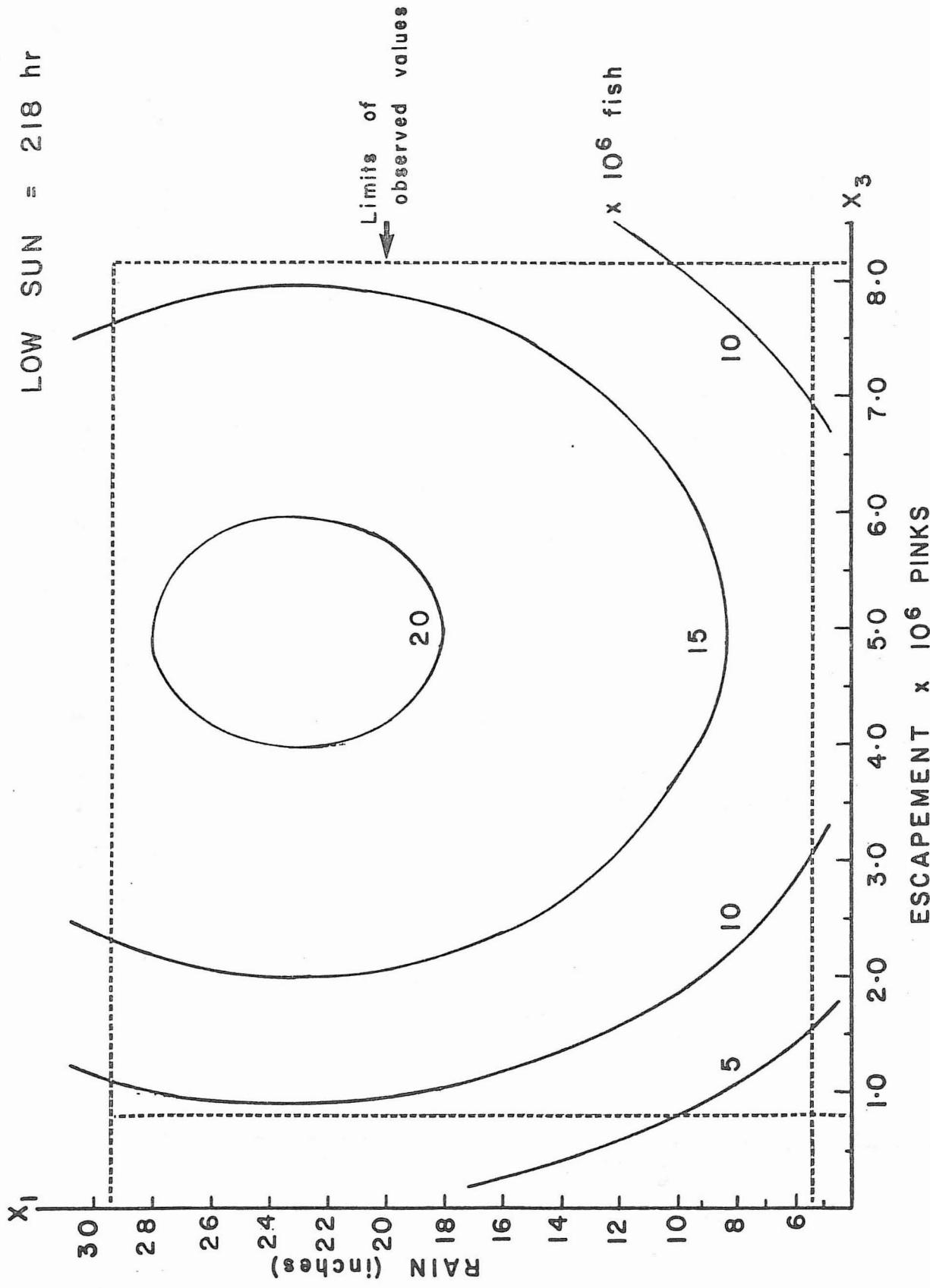


Fig. 10a. Central Area even year pink salmon recruitment stock contours for low hours of sunlight.

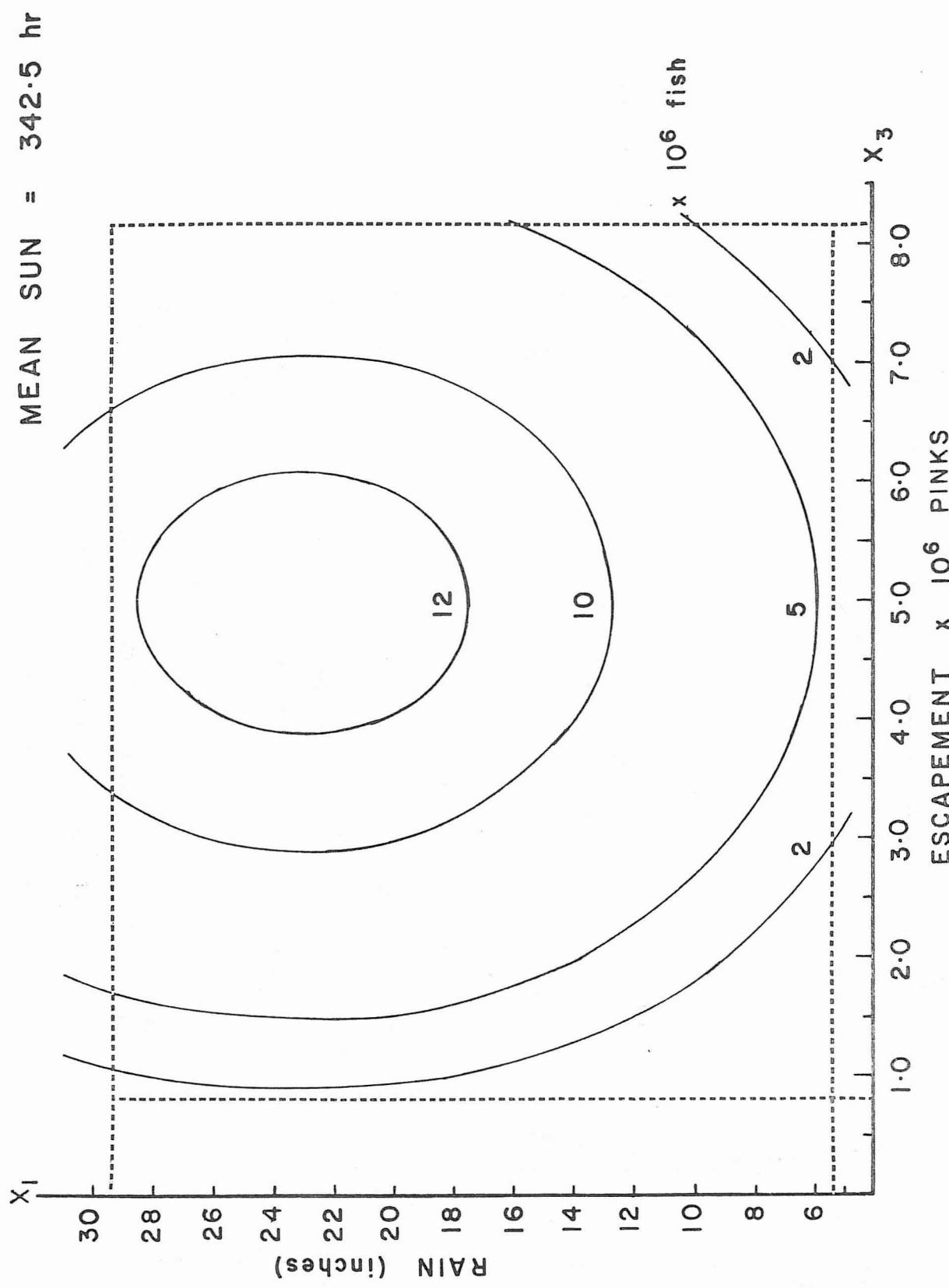


Fig. 10b. Central Area even year pink salmon recruitment stock contours for mean hours of sunlight.

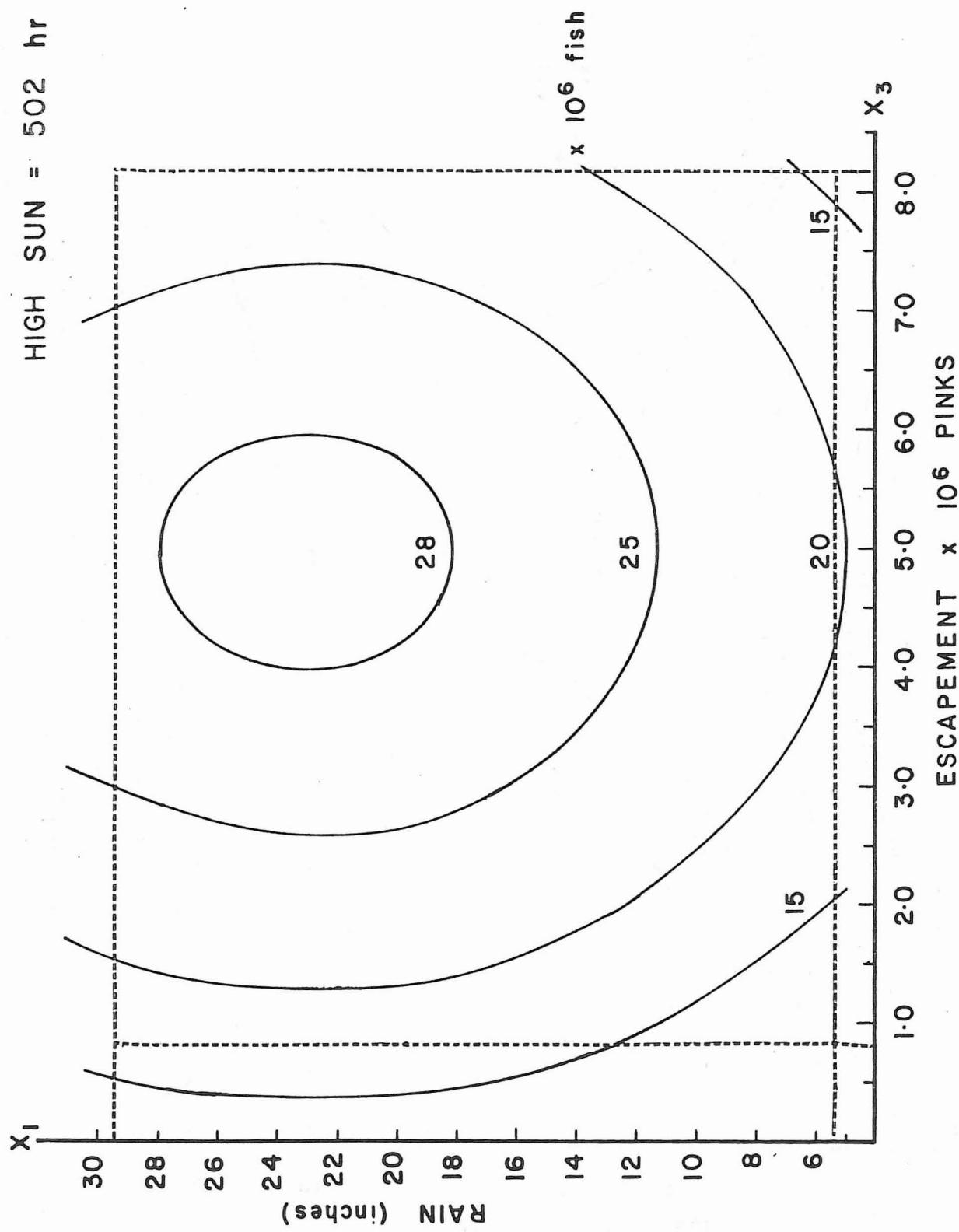


Fig. 10c. Central Area even year pink salmon recruitment stock contours for high hours of sunlight.

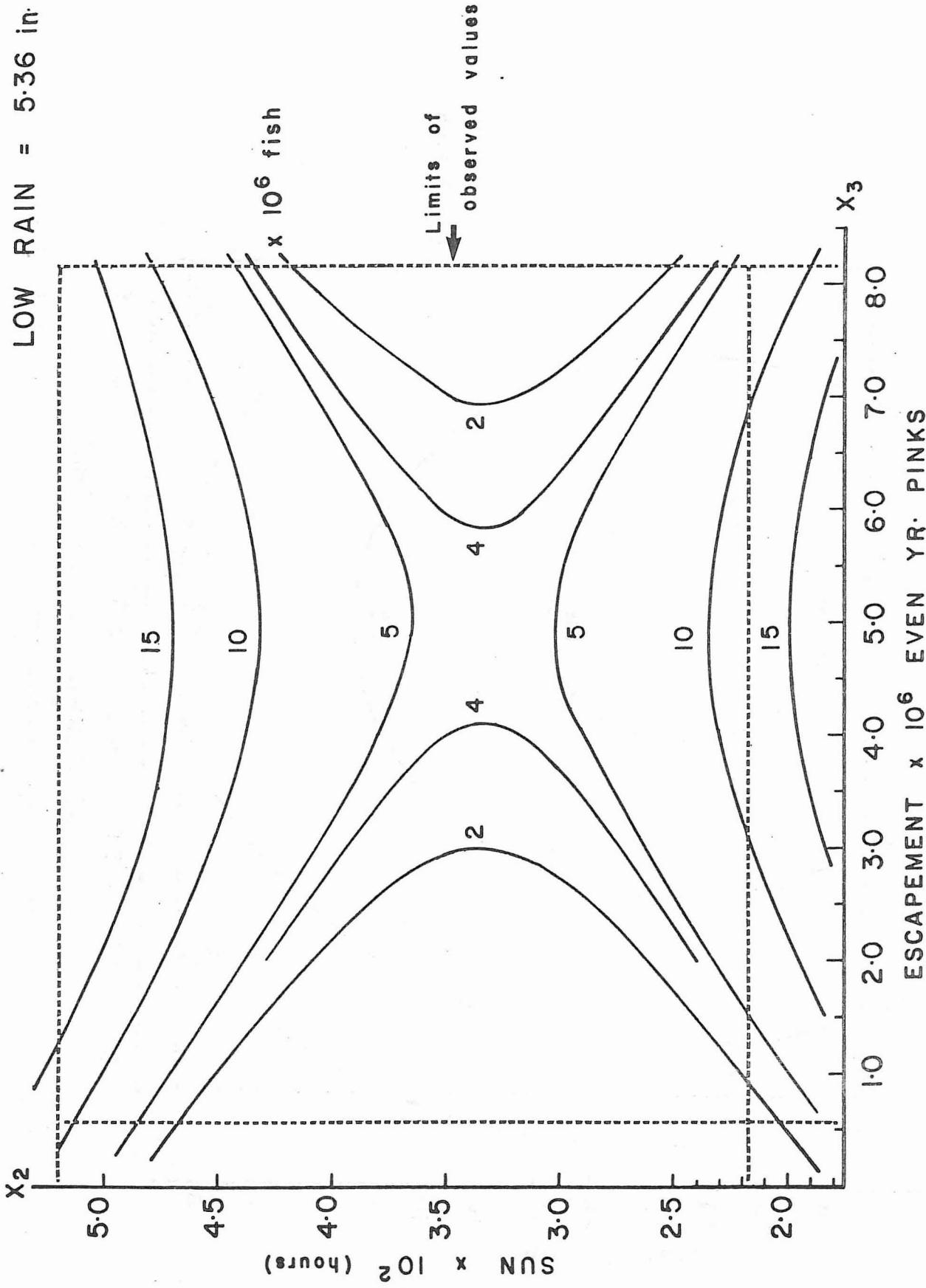


Fig. 11a. Central Area even year pink salmon recruitment stock contours for low rainfall.

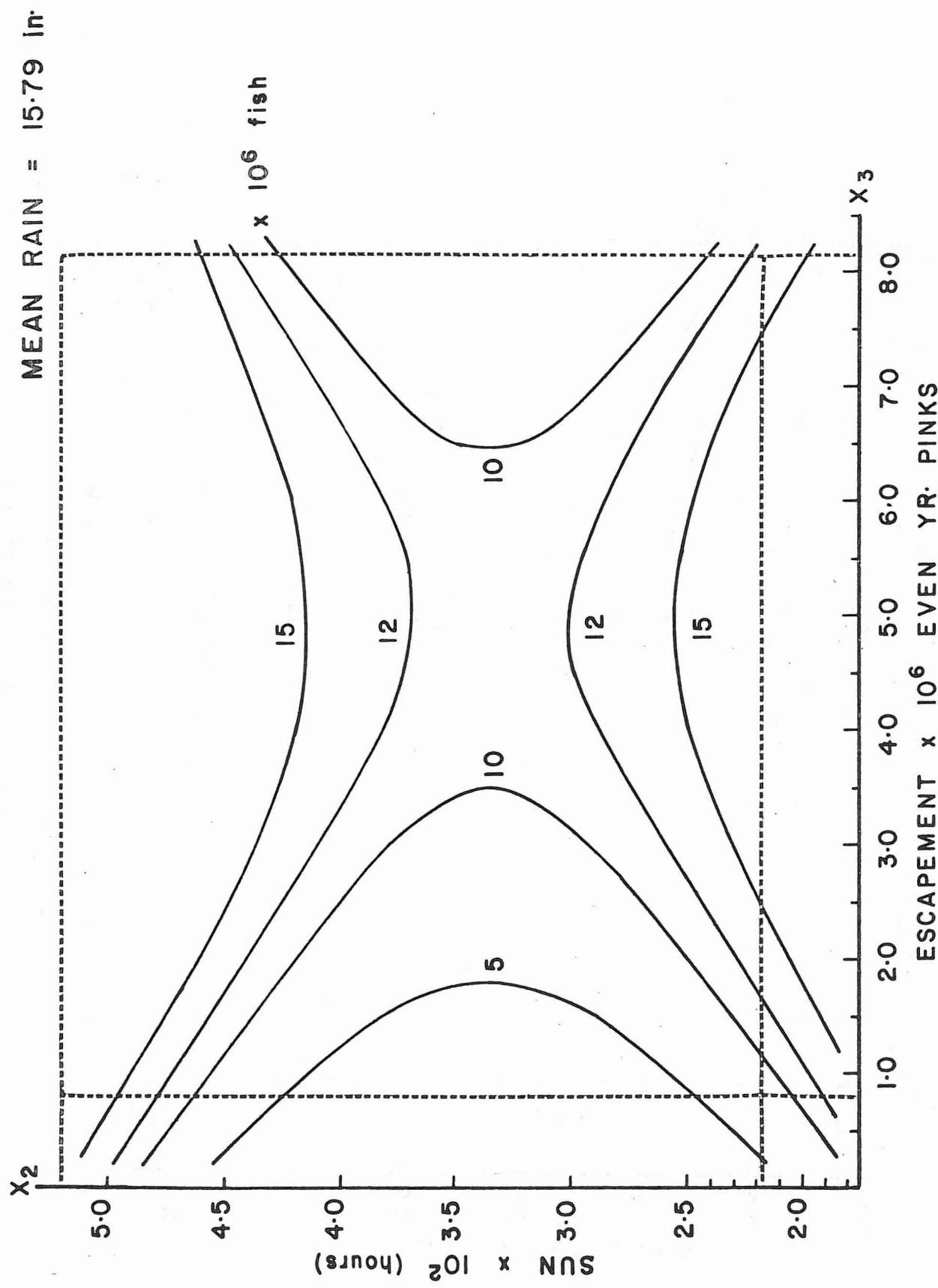


Fig. 11b. Central Area even year pink salmon recruitment stock contours for mean rainfall.

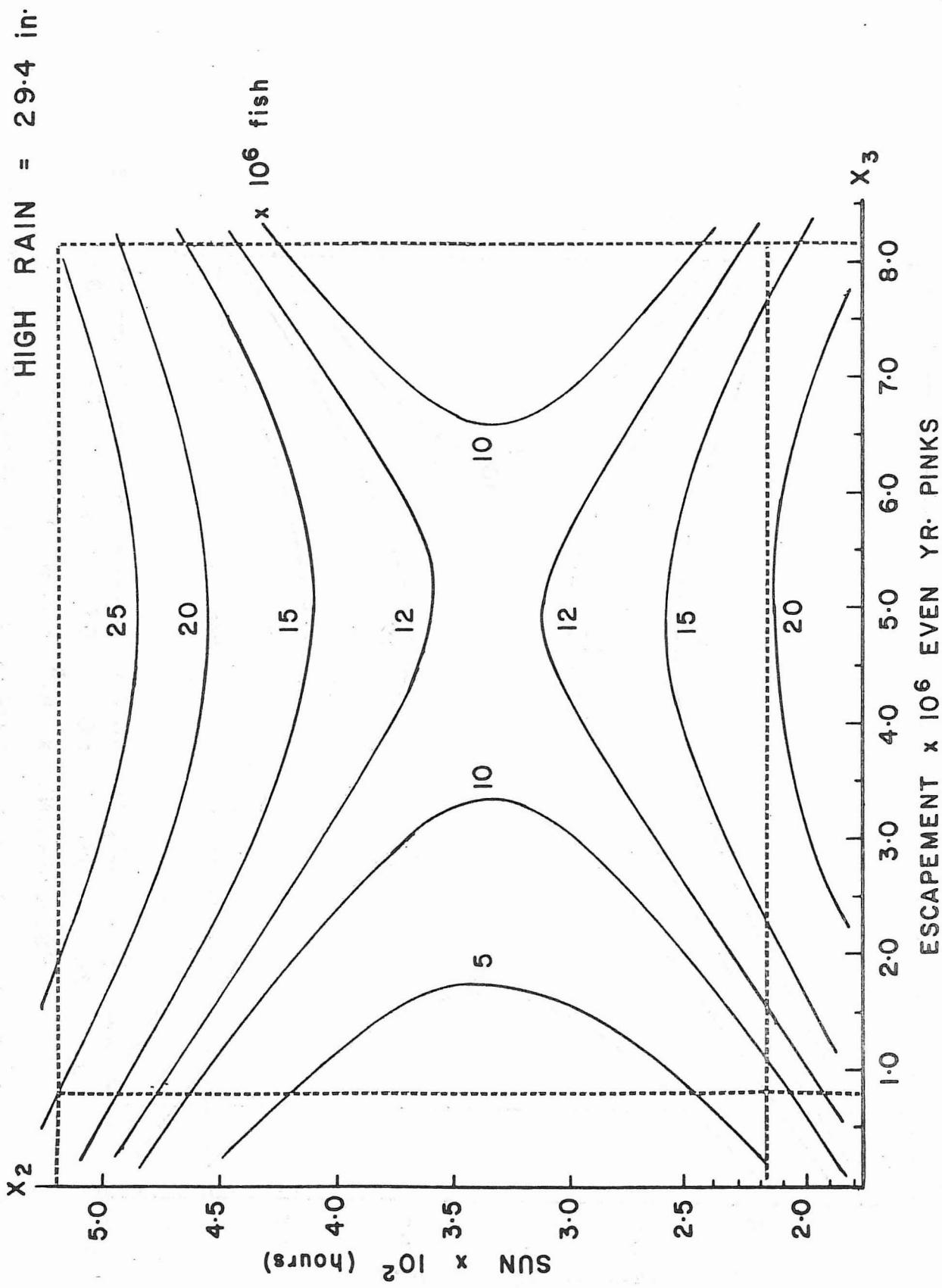


Fig. 11c. Central Area even year pink salmon recruitment stock contours for high rainfall.

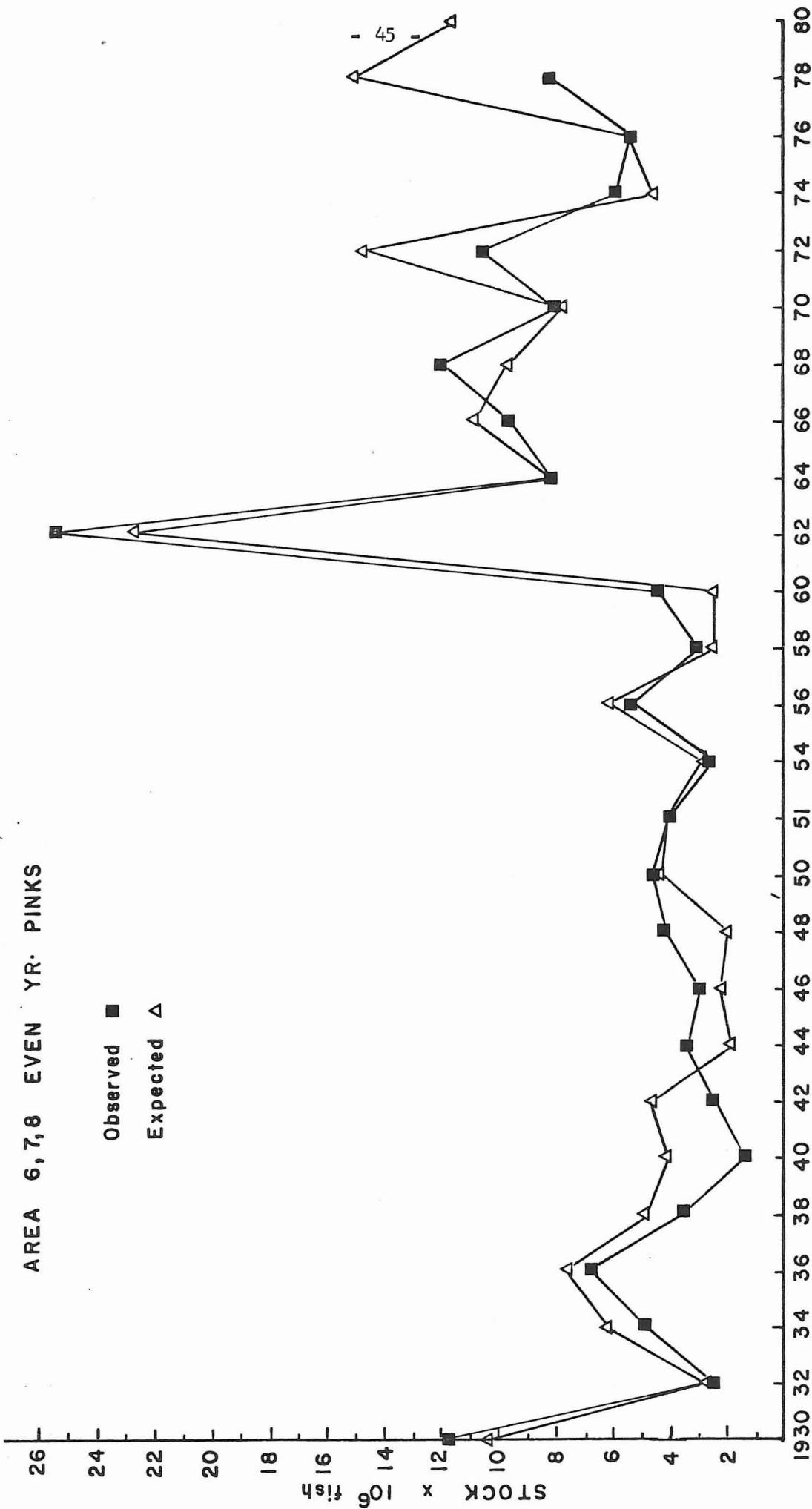


Fig. 12. Area 6,7,8 even year stocks observed and expected from the equation for the years 1930 to 1974 with predicted values for 1976, 78 and 80. The variables are hours of bright sunlight at Sandspit in July and August of the smolt year, July-August rainfall at Ocean Falls in the spawning year and escapement.



CENTRAL AREA (6, 7, 8) ODD YEAR PINK SALMON

RECRUITMENT YEARS 1931-73



CENTRAL AREA (6,7,8) ODD YEAR PINK SALMON

RECRUITMENT YEARS 1931-1973 (Fig. 13-16)

Variables

$\log(Y \times 100)$  = Areas 6,7,8 odd year recruitment (catch + escapement)  
in year<sub>n</sub> in  $10^6$  fish

$X_1$  = total July and August<sub>n-2</sub> rainfall at Ocean Falls in inches

$X_2$  = total July and August<sub>n-1</sub> hours of bright sunlight at Sandspit

$X_3$  = escapement in year<sub>n-2</sub>

Response function

$$\begin{aligned}\log(Y \times 100) = & -0.2217 + 0.0543X_1 + 0.9609X_2 + 0.8185X_3 - 0.001007X_1^2 \\ & - 0.1571X_2^2 - 0.1648X_3^2 \\ R^2 = 0.65 & \quad F = 3.889 \quad F_{.05} = 3.00 \quad F_{.01} = 4.82\end{aligned}$$

Processes

Processes at work are taken as those that affect the even year stocks except that mortality is multiplicative i.e. fractions of the fish present at any stage die rather than actual numbers of them.

Comment

Odd year and even year runs differ in weight and timing of the runs so that it is possible that the difference in response to hours of sunlight (transport) may be real (odd: sun - sun<sup>2</sup>; even: -sun + sun<sup>2</sup>). The lack of fit and greater uncertainty in the odd year is associated to a great extent with the year 1943. This year was one in which wartime circumstances could have had marked effects.

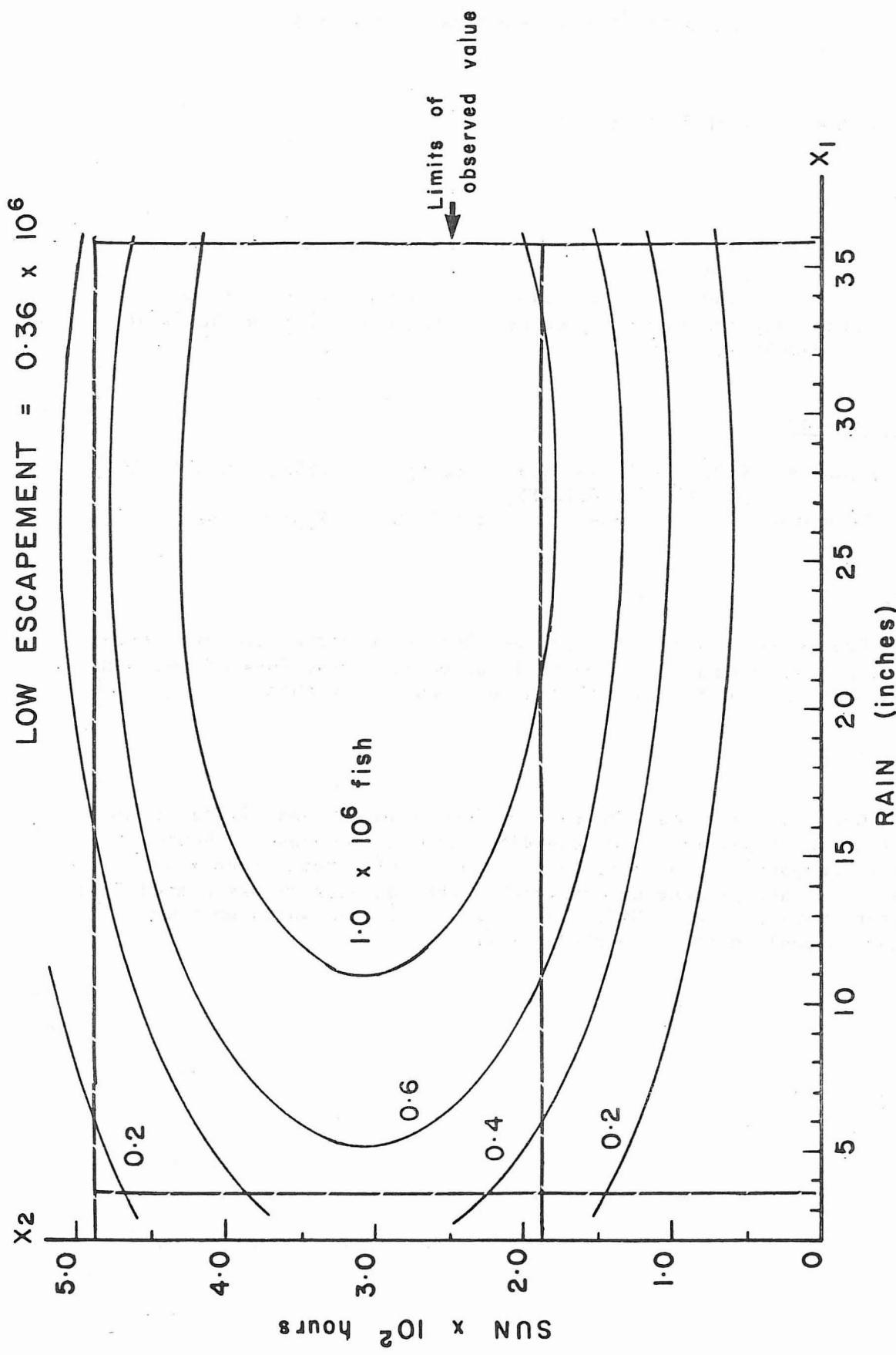


Fig. 13a. Contour diagrams of Central Area (6, 7, 8) pink salmon odd year recruitment stock with hours of bright sunlight at Sandspit in July and August of the smolt year and July-August rainfall at Ocean Falls in the spawning year for low escapement.

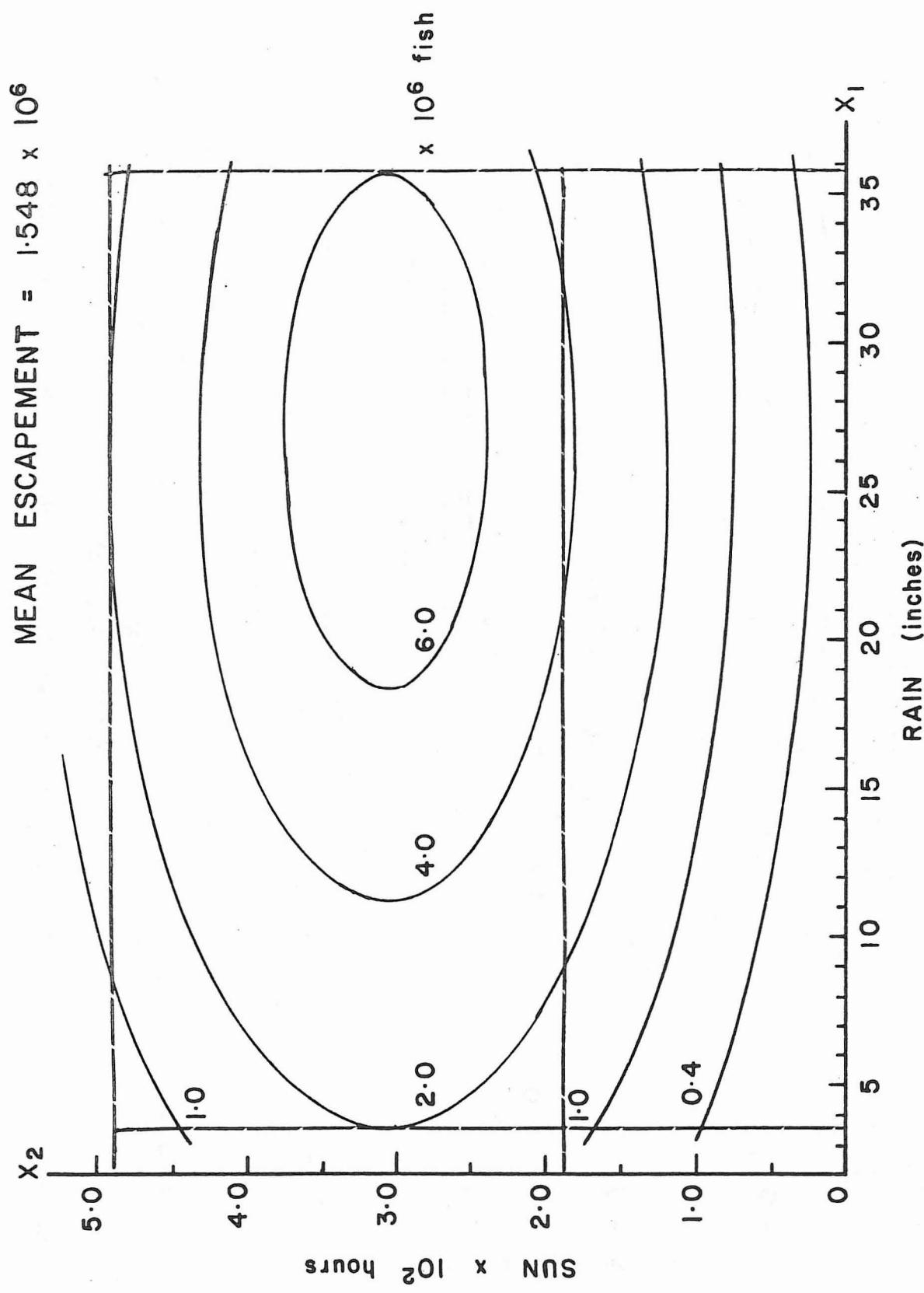


Fig. 13b. Central Area odd year pink salmon recruitment stock contours for mean escapement.

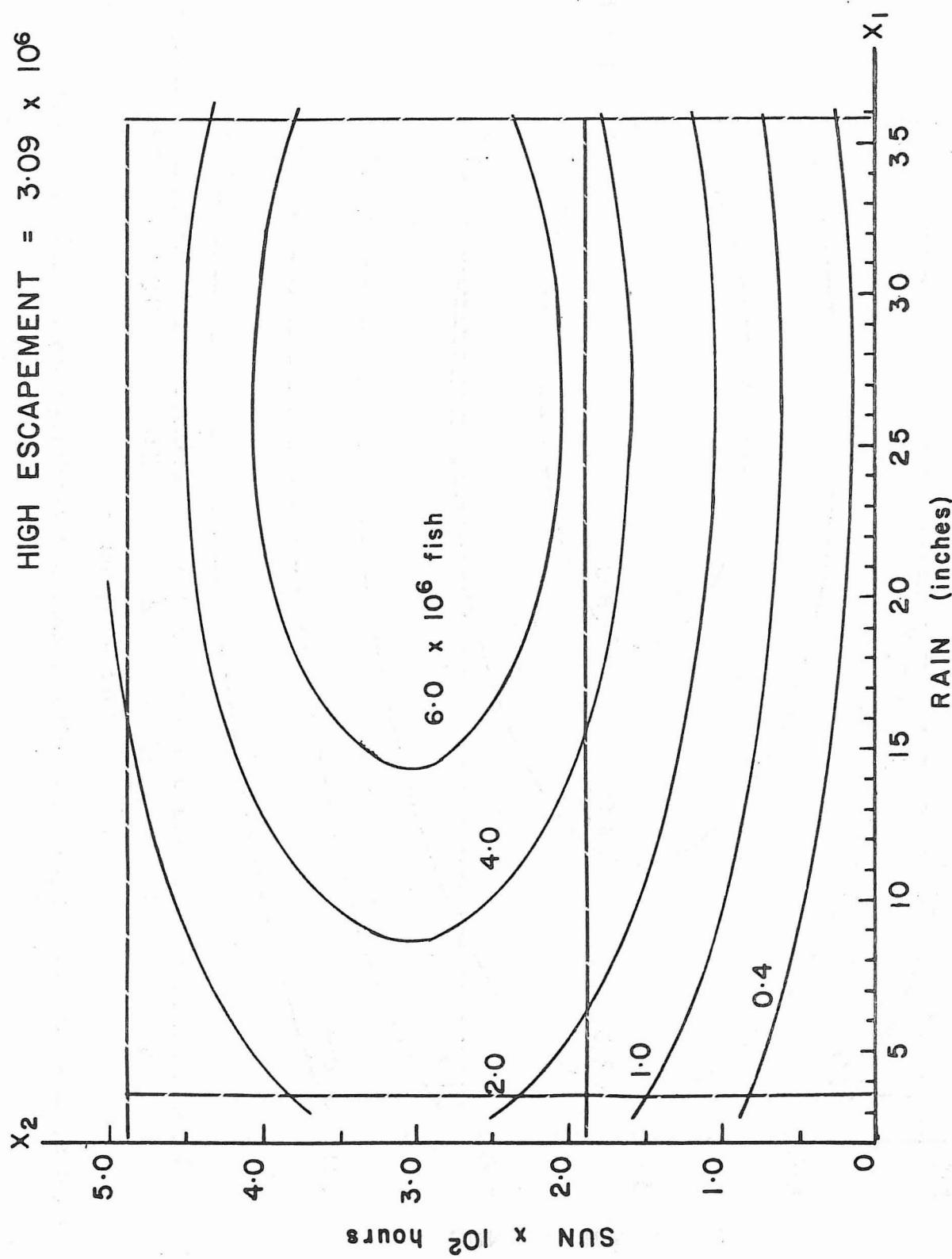


Fig. 13c. Central Area odd year pink salmon recruitment stock contours for high escapement.

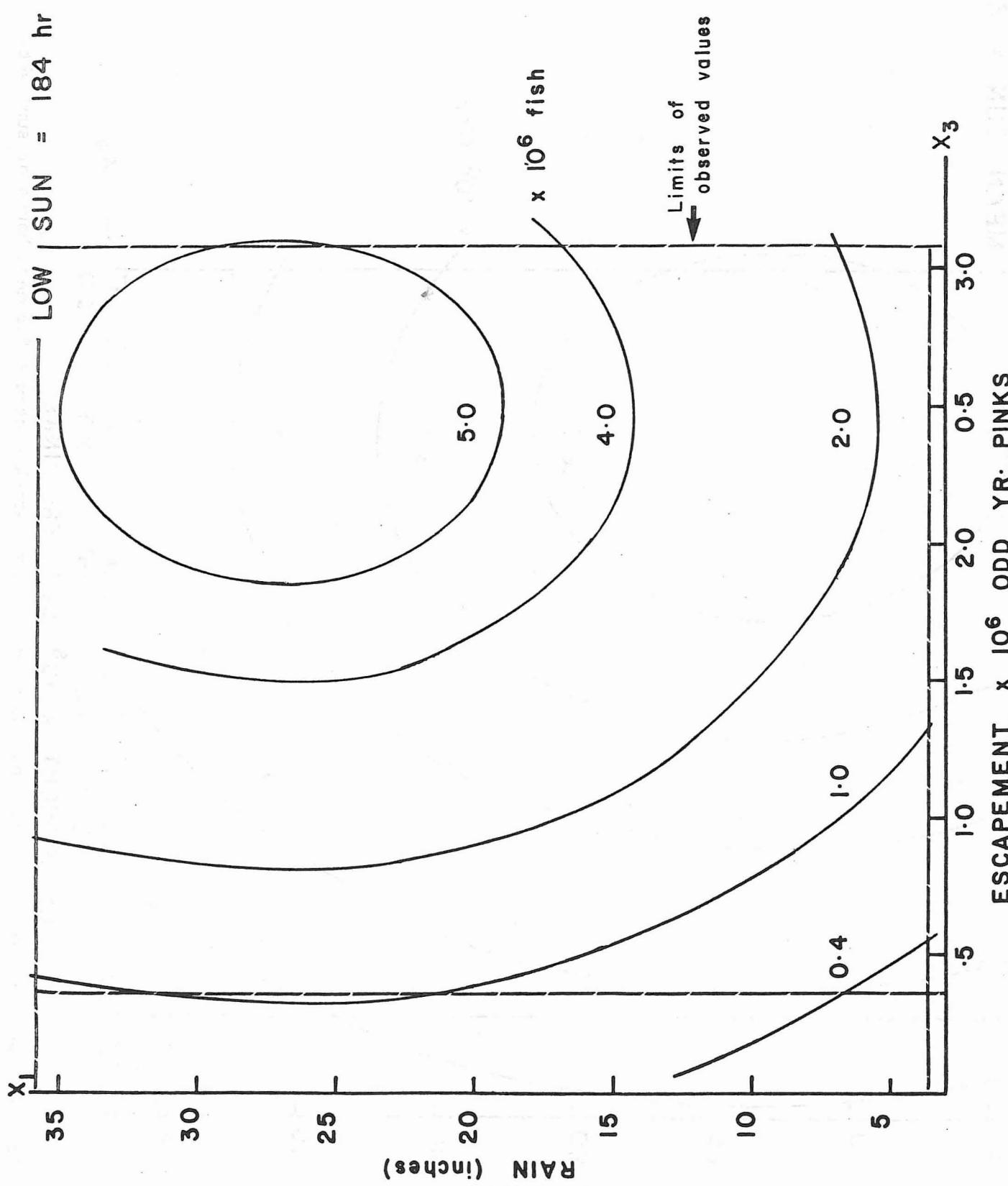


Fig. 14a. Central Area odd year pink salmon recruitment stock contours for low hours of sunlight.

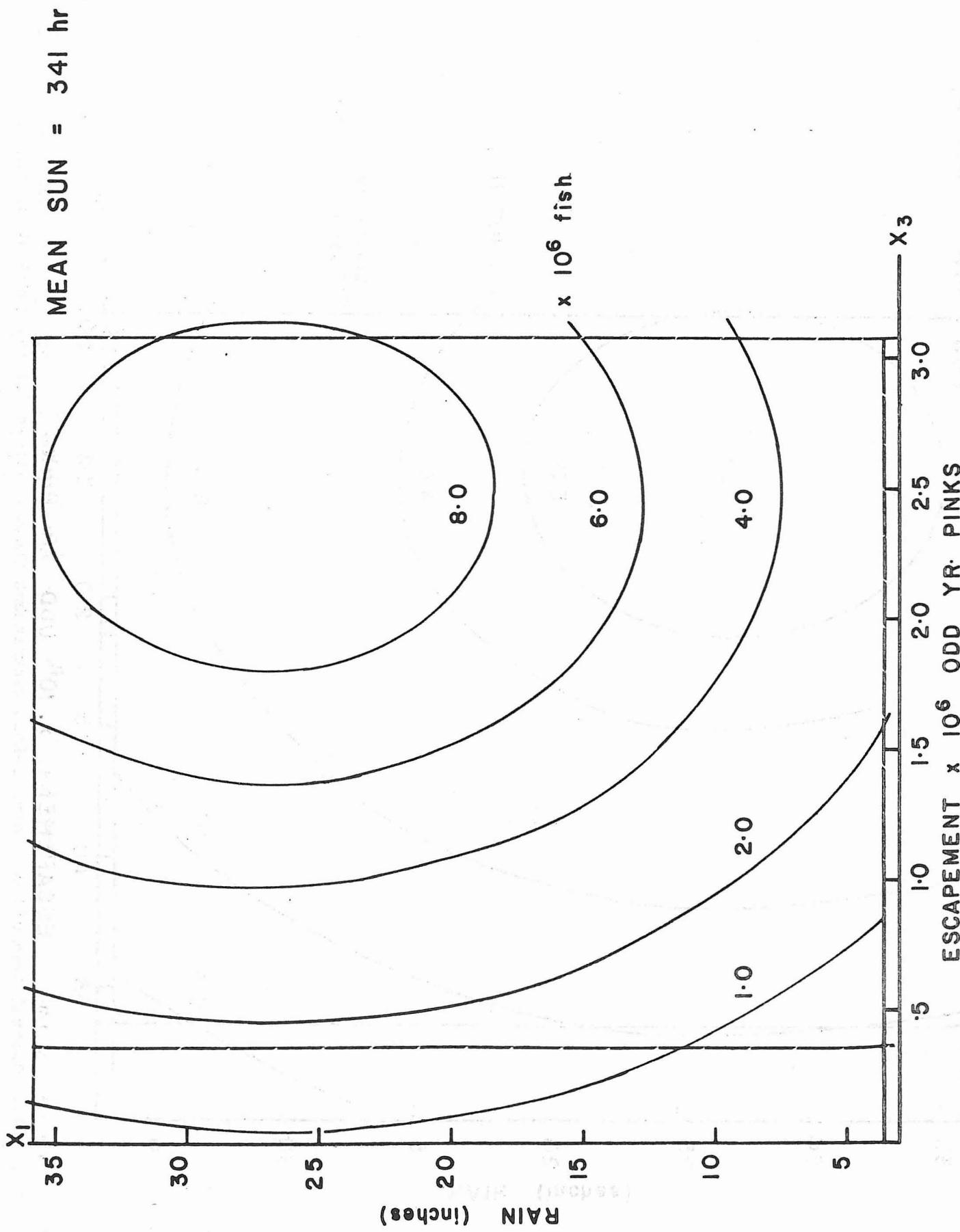
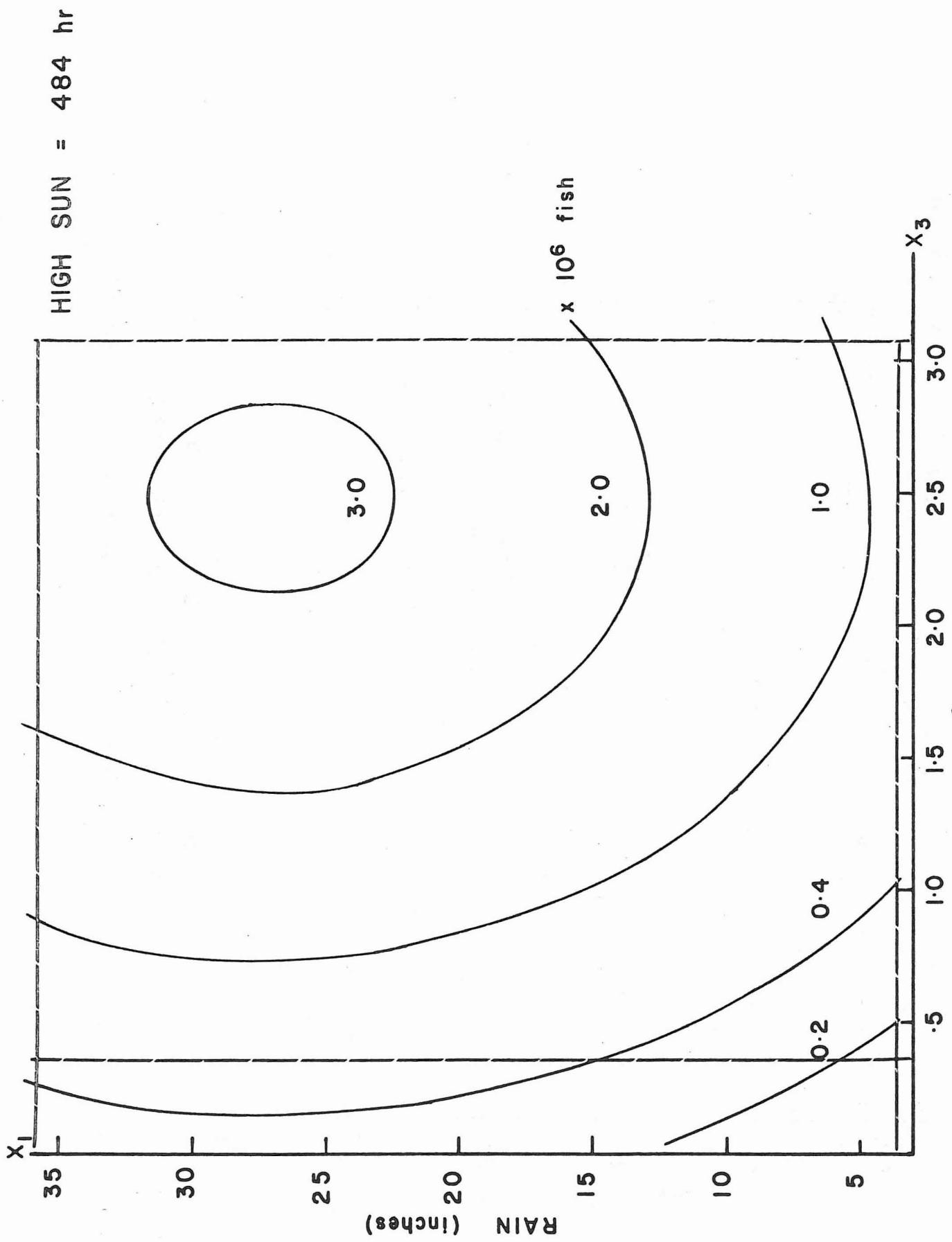


Fig. 14b. Central Area odd year pink salmon recruitment stock contours for mean hours of sunlight.



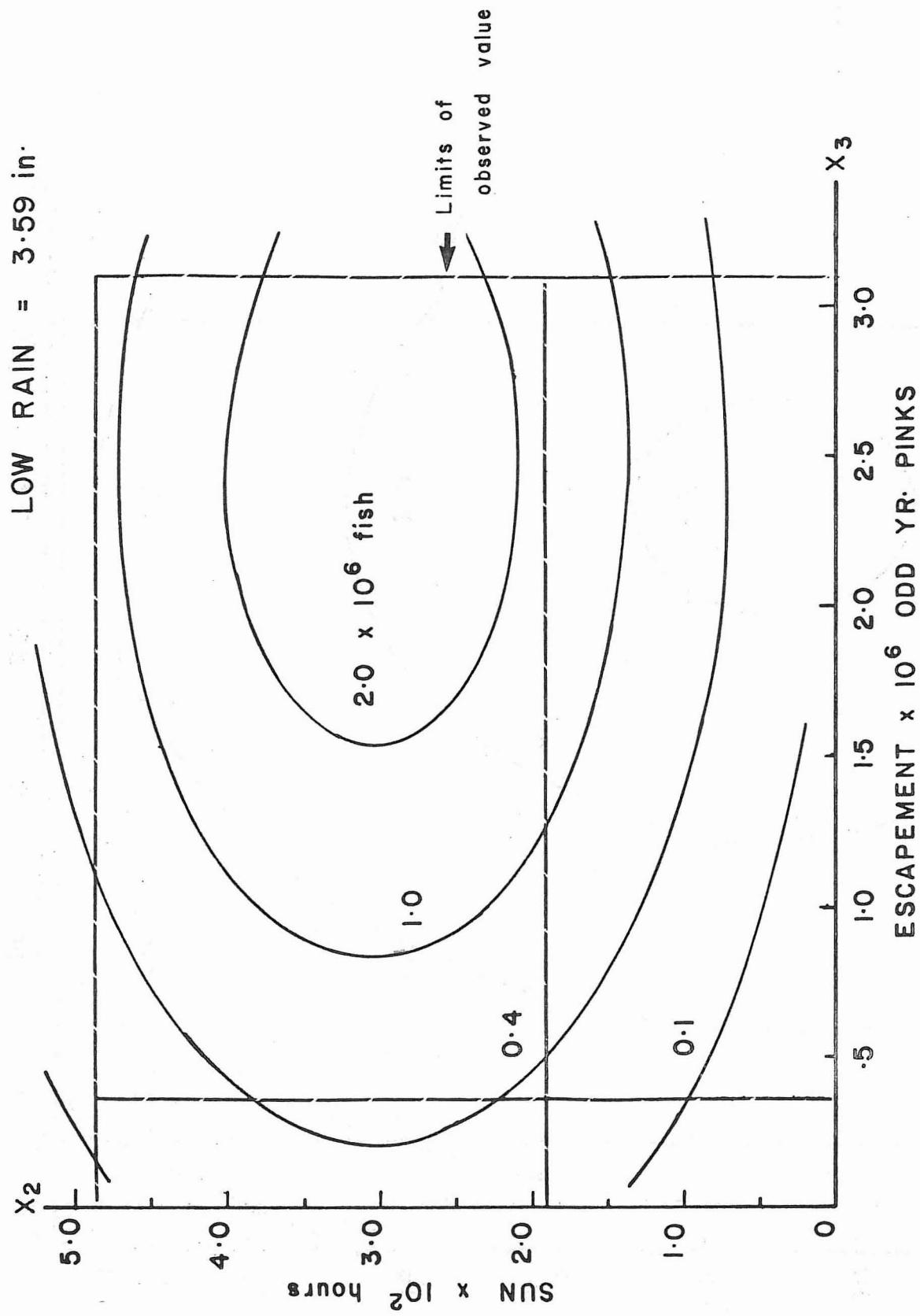


Fig. 15a. Central Area odd year pink salmon recruitment stock contours for low rainfall.

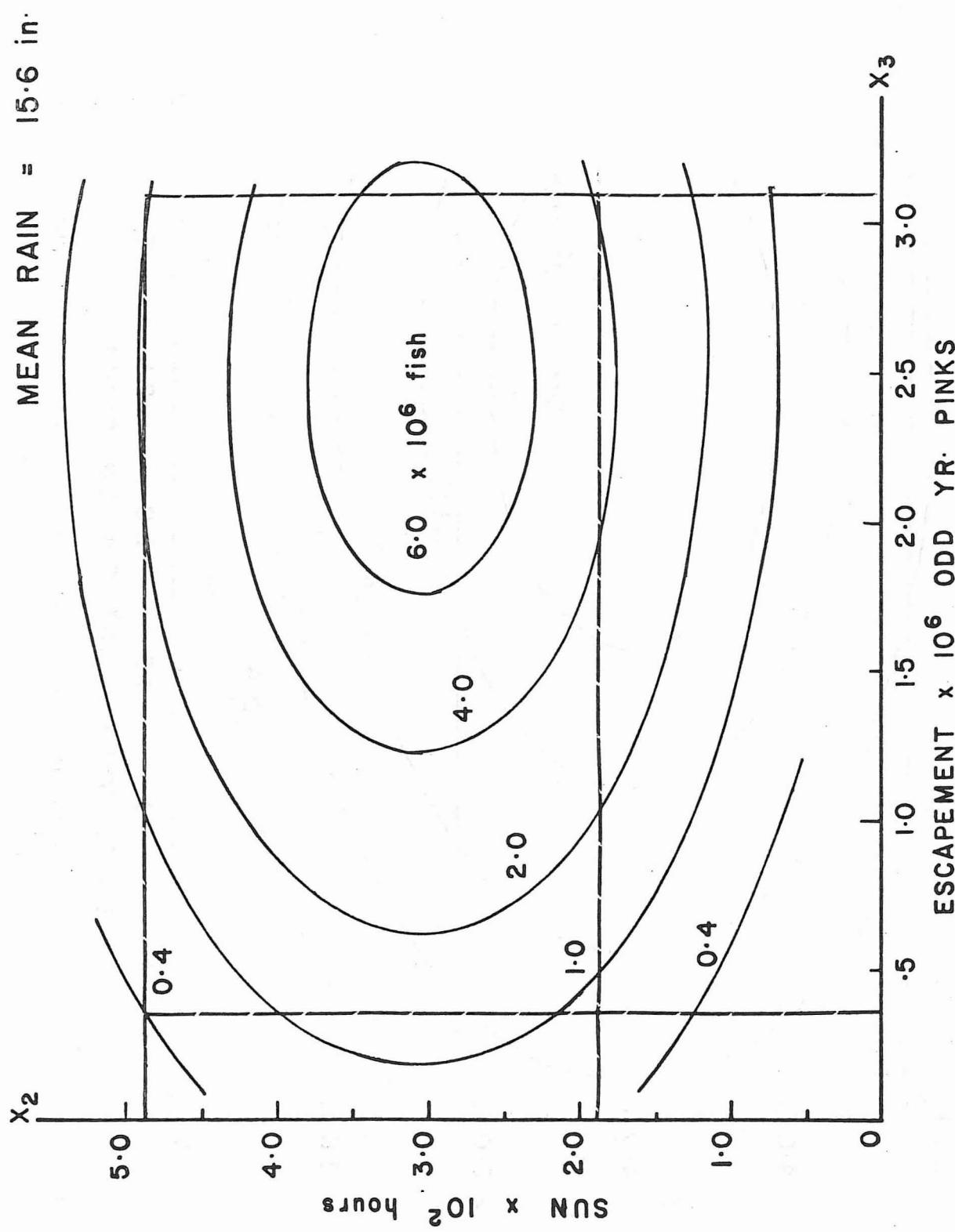


Fig. 15b. Central Area odd year pink salmon recruitment stock contours for mean rainfall.

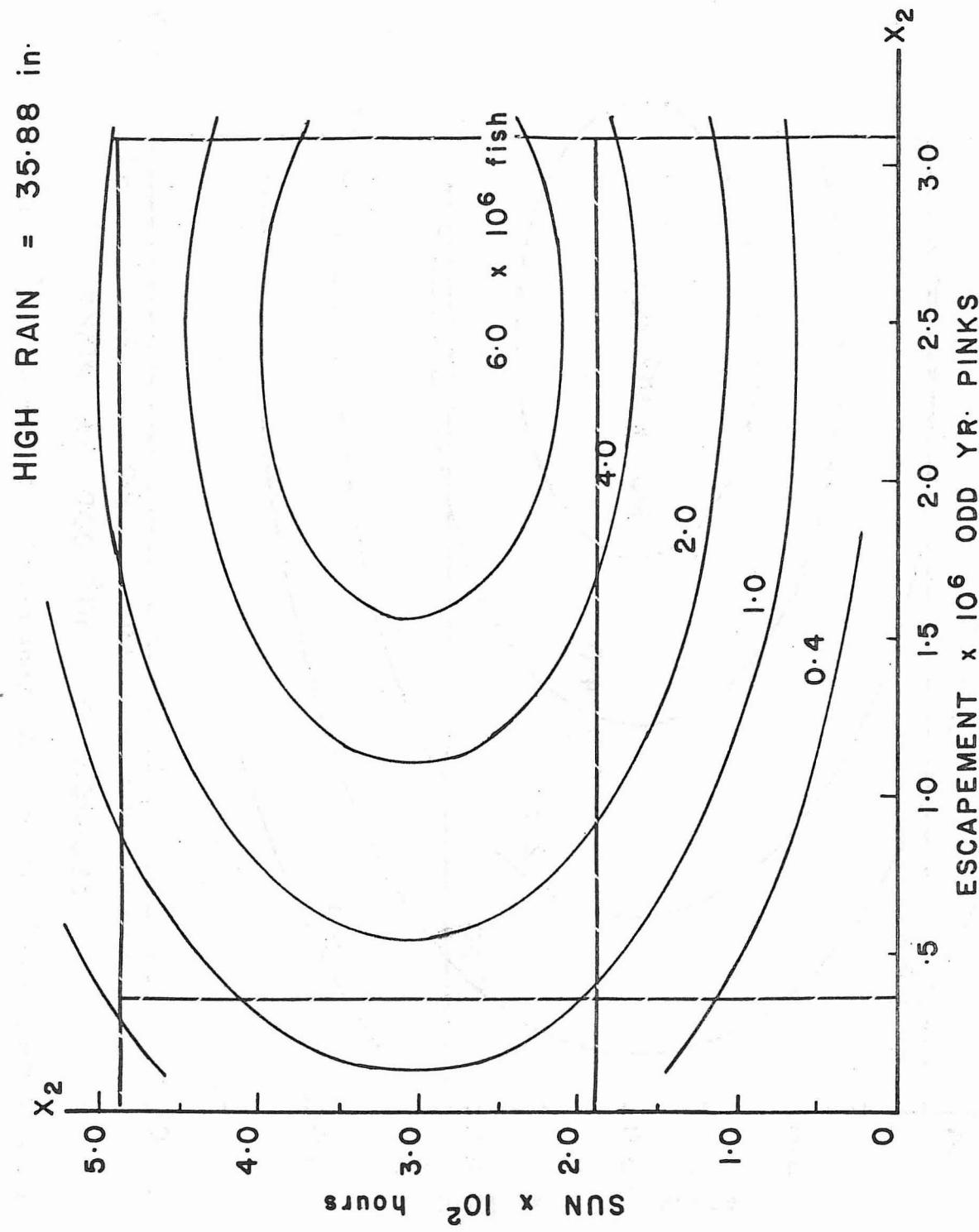


Fig. 15c. Central Area odd year pink salmon recruitment stock contours for high rainfall.

AREA 6,7,8 ODD YR. PINKS

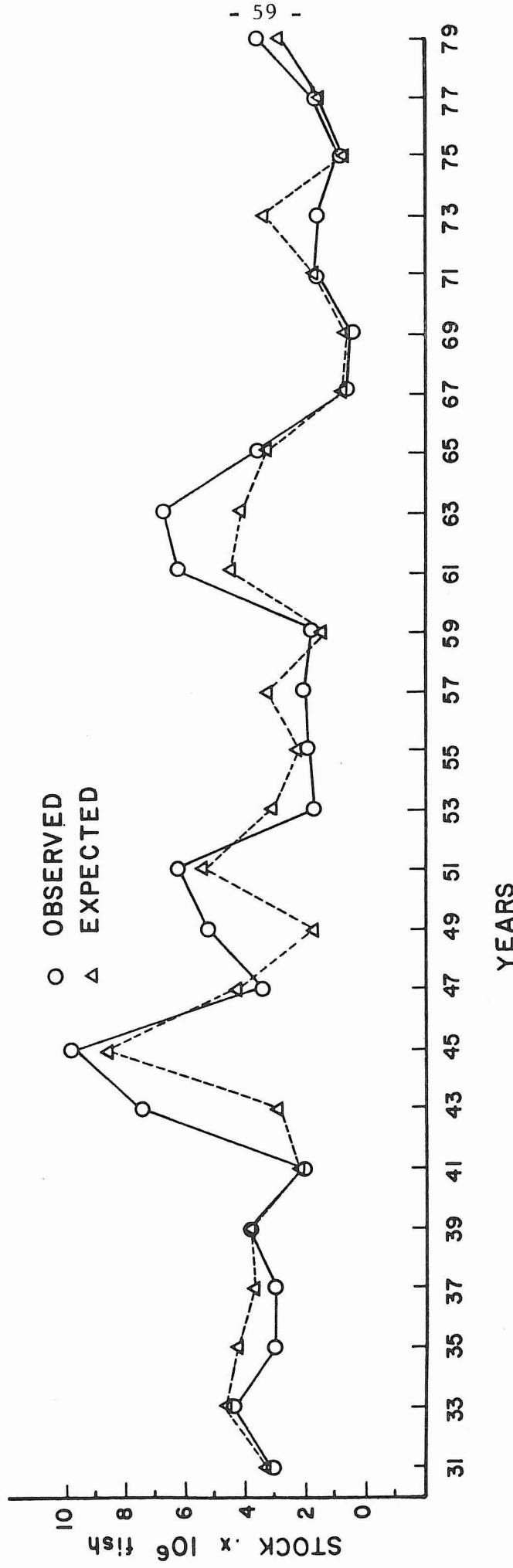
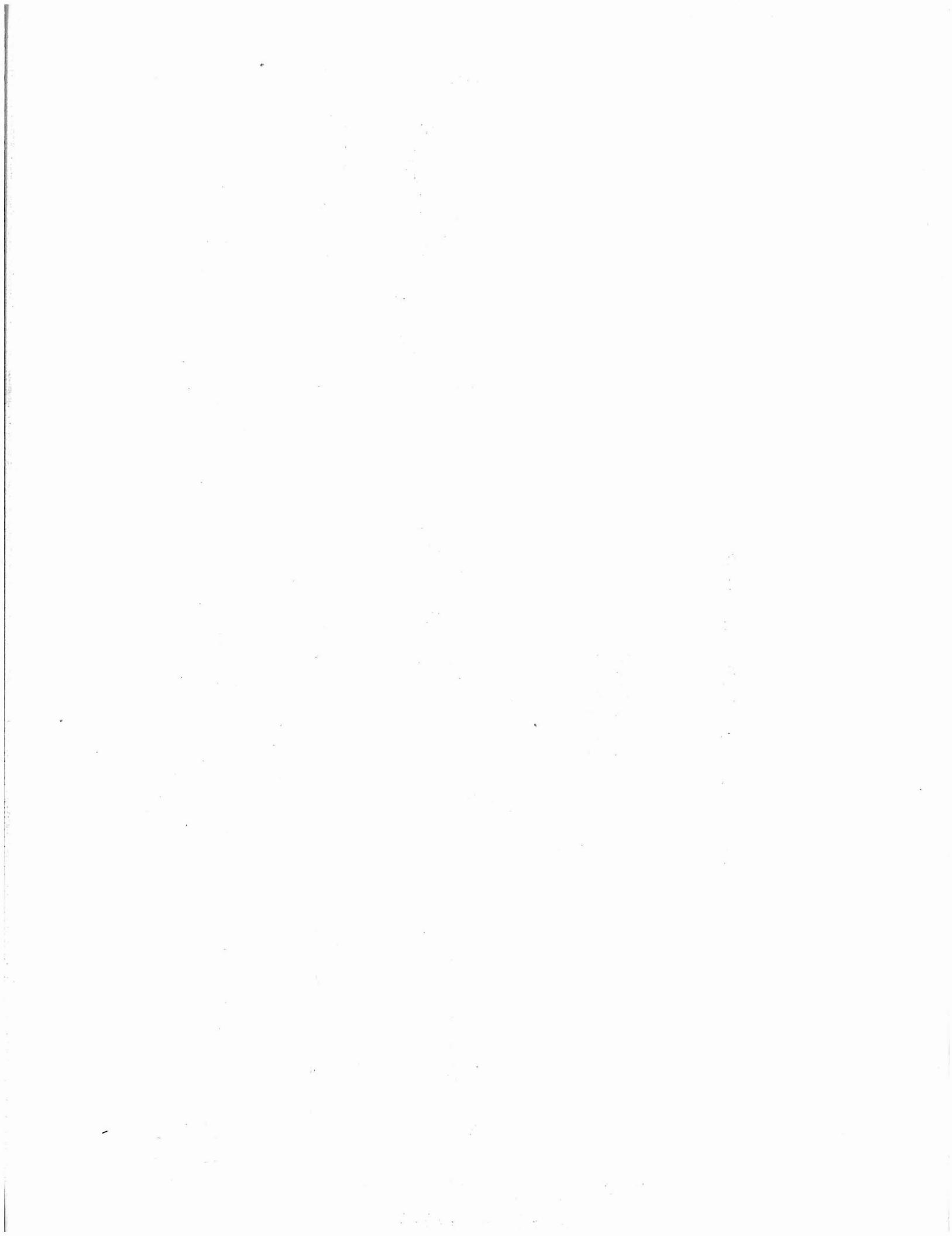


Fig. 16. Area 6,7,8 odd year observed stock and expected stock from the equation for the years 1931 to 1973 with predicted values for 1975, 77 and 79. Hours of bright sunlight at Sandspit in July and August of the smolt year, July-August rainfall at Ocean Falls in the spawning year and escapement are the predictive variates.



SKEENA RIVER SOCKEYE SALMON (4, 3X, 3Y)  
BROOD YEARS 1956-71. SMOLT YEARS 1958-73.



SKEENA RIVER SOCKEYE SALMON (4, 3X, 3Y)

BROOD YEARS 1956-1971 SMOLT YEARS 1958-1973 (Fig. 17-18)

Variables

$Y$  = total number of 3,4,5, yr-old fish returning from each smolt run  
in  $10^6$  fish

$X_1$  = number of smolts leaving Babine Lake in year<sub>n</sub> in  $10^6$  fish

$X_2$  = mean monthly salinity in ‰ at Cape St. James for July<sub>n-1</sub> to June<sub>n</sub>

$X_3$  = mean vertical velocity in meters per year across latitude 50°N  
between longitudes 150°W and 170°W for September<sub>n-2</sub> to August<sub>n-1</sub>

$X_4$  = mean sea level in feet at Prince Rupert for August<sub>n</sub> to July<sub>n+1</sub>

Response function

$$Y = 56.9735 + 0.010941X_1 - 2.9625X_2 + 0.57339X_3 + 3.01396X_4$$
$$R^2 = 0.81 \quad F = 11.427 \quad F_{.01} = 5.67$$

Processes

Age of mature fish is counted from brood year<sub>n-2</sub> on the assumption that all smolts are 2-yr-old. Sockeye caught in Areas 3X and 3Y are assumed to be Skeena stock. Each additional 10 million smolts produces about 100,000 more adults. Some process, which could be feeding by non-obligate predators such as sea birds, appears to prevent a large response to changes in smolt count. Salinity in the year preceding the smolt run could be a measure of movement and spread of coastal water masses that relate to such early mortality. Upwelling in the Gulf of Alaska is related to nutrient input to the upper layers of the general area where the smolts grow to maturity. A two year lag between primary production and large food items is assumed. Higher sea levels are related to northward coastal flow in Hecate Strait and Dixon Entrance and are an index of coastal conditions during the offshore migration of the young fish (Wickett and Ballantyne unpub.).

Comments

Predicted values for the brood years 1972 and 1973 are satisfactory. The failure of the 1974 brood may be related to the anomalous 1978 oceanographic conditions that altered the migration of the Fraser River sockeye and are suspected to have affected the Skeena pink salmon migration (see above).

$X_2$  MEAN SALINITY = 32.11

$X_4$  LOW SEA LEVEL = 12.38 ○

$X_4$  HIGH SEA LEVEL = 12.80 Δ

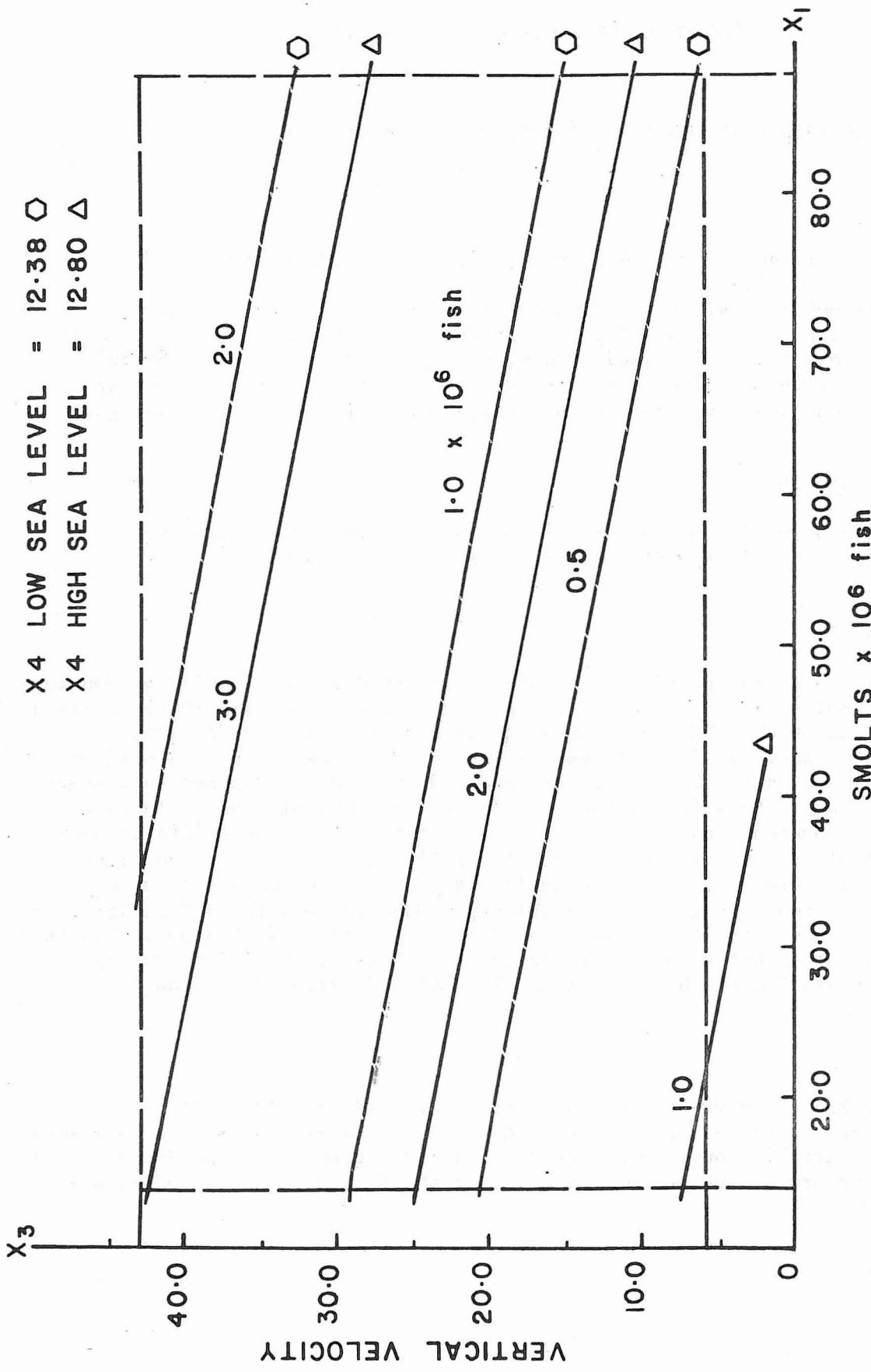


Fig. 17a. Contour diagrams of Skeena River (Area 4, 3X, 3Y) sockeye salmon 3, 4, 5 yr-old recruitment with vertical velocity in the Gulf of Alaska September<sub>n-2</sub> to August<sub>n-1</sub> and smolt output in year<sub>n</sub> at one level of Cape St. James salinity July<sub>n-1</sub> to June<sub>n</sub> and at two levels of Prince Rupert sea level August<sub>n</sub> to July<sub>n+1</sub>.

$$\begin{aligned}
 X_2 & \text{ MEAN SALINITY} = 32.11 \\
 X_3 & \text{ LOW VERTICAL VELOCITY} = 6.01 \circ \\
 X_3 & \text{ HIGH VERTICAL VELOCITY} = 43.18 \Delta
 \end{aligned}$$

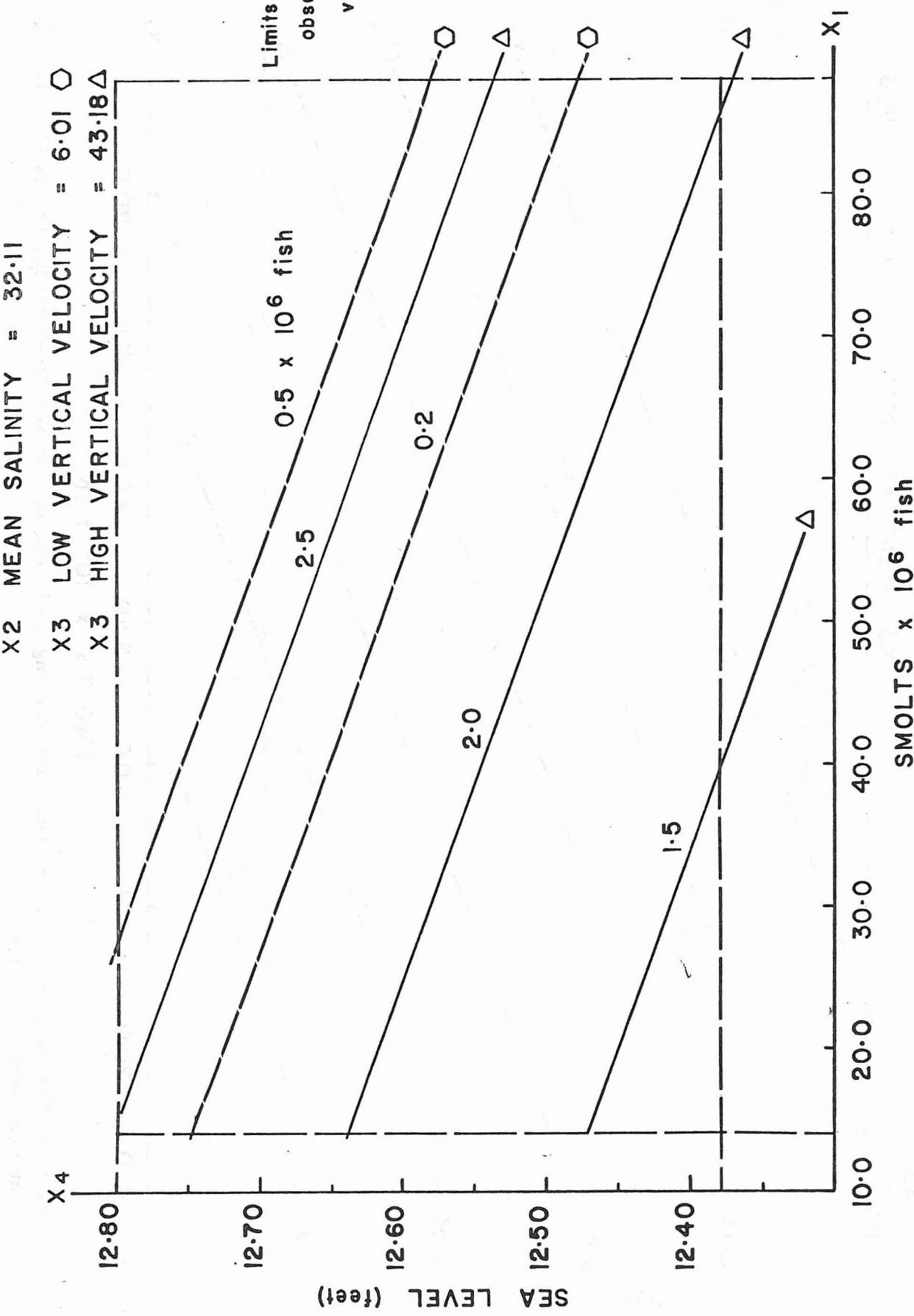


Fig. 17b. Skeena sockeye recruitment (total brood year return) with varying smolt output and sea level at mean salinity and two levels of vertical velocity.

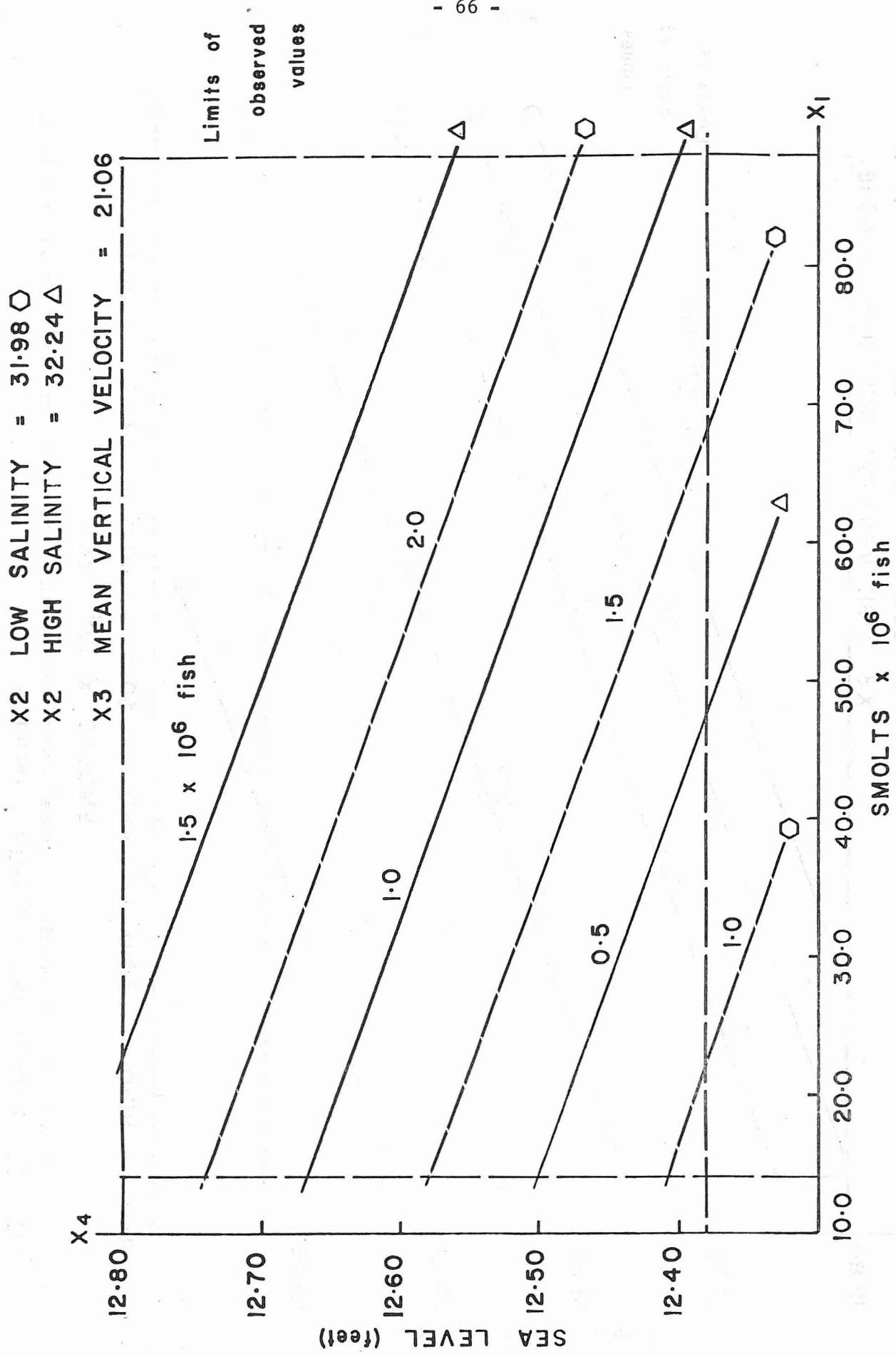


Fig. 17c. Skeena sockeye recruitment with varying smolt output and sea level at two levels of salinity and at mean vertical velocity.

$X_3$  LOW VERTICAL VELOCITY = 6.01 ○  
 $X_3$  HIGH VERTICAL VELOCITY = 43.18 △  
 $X_4$  MEAN SEA LEVEL = 12.63

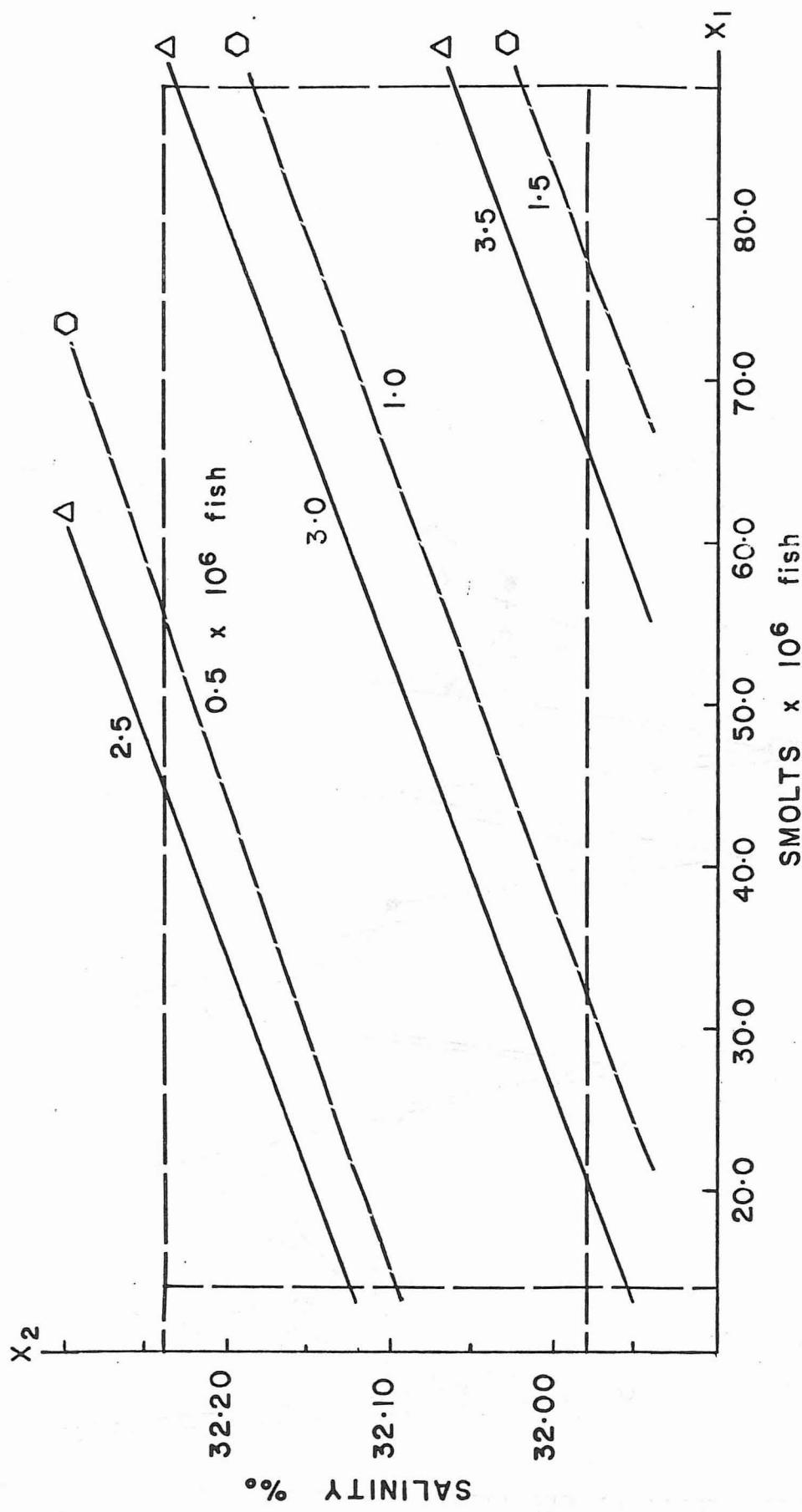


Fig. 17d. Skeena sockeye recruitment with varying smolt output and salinity at two levels of vertical velocity and at mean sea level.

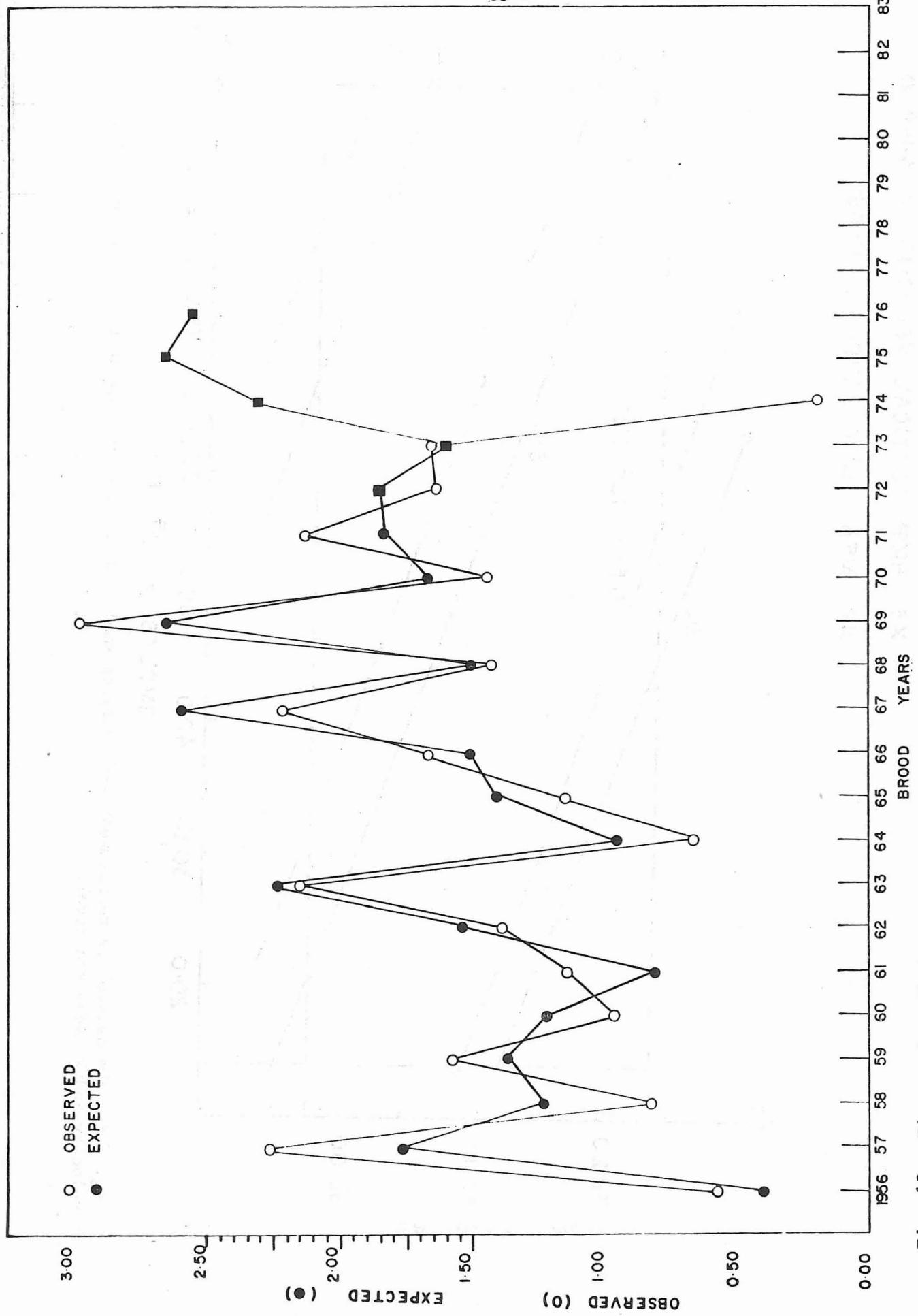


Fig. 18. Time series of observed and expected Skeena River sockeye 3+, 4 and 5 yr-old recruitment in Area 3X, 3Y and 4. Indices used are salinity, upwelling and sea level. For regression years 1956-71, eighty-one percent of the variance is associated with changes in smolt output and three environmental variates.

RIVERS INLET SOCKEYE SALMON

BROOD YEARS 1948-72



## RIVERS INLET SOCKEYE SALMON

BROOD YEARS 1948-1972 (Fig. 19-22)

### Variables

- $Y$  = sum of  $4_2$  catch and escapement in year $n+4$  and of catch and escapement of  $5_2$  fish in year $n+5$  in 1000's of fish  
 $X_1$  = escapement in year $n$ , which is the sum of the absolute values or of the midpoints of the letter codes for each stream in the spawning reports (B.C. 16) in 1000's of fish  
 $X_2$  = values of integrated total transport for  $50^{\circ}\text{N}$   $170^{\circ}\text{W}$  taken from Table 10 (Ballantyne and Wickett 1978) to give a mean value from July in year $n+3$  to June in year $n+4$  in  $10^5 \text{ t/sec}$   
 $X_3$  = mean values of sea level at Prince Rupert for August and September in year $n+2$  taken from Table 4 (Ballantyne 1978) in feet minus 12. (Table value minus the constant 12 to give the fractional parts of a foot)

### Response function

$$Y = 724.30 + 7.2466X_1 - 1.5450X_2 - 655.65X_3 - 0.0021266X_1^2 - 0.0052369X_2^2 + 5603.3X_3^2 + 0.0039281X_1X_2 - 13.878X_1X_3 - 11.442X_2X_3 \pm 514$$
$$R^2 = 0.78 \quad F = 5.897 \quad F_{.01} = 4.17$$

### Processes

The stock-recruitment curve is approximated by a parabola. Increased integrated total transport across  $50^{\circ}\text{N}$  latitude in the last year the 4-yr-olds are at sea indicates that a greater proportion of more southerly water is driven into the Gulf of Alaska. Since a number of predators such as salmon sharks and albacore migrate northward annually, it may be that northern transport increases the chances of the predators encountering and killing the eastward migrating 4-yr-old salmon. Fur seals in their southern migration through the Gulf may spend more time there and eat more salmon. Low sea levels result from northwesterly winds which cause offshore upper layer transport. On the other hand, high sea level indicates a convergence of the upper layers against the coast and an early end to the summer divergent condition. Low sea level could be associated with rapid offshore movement of smolts. With high sea level smolts may be kept longer within the hunting range of seabirds and at concentrations required by the birds. In addition, the convergent state is associated with advection of warm water that allows albacore to extend their northward feeding migration.

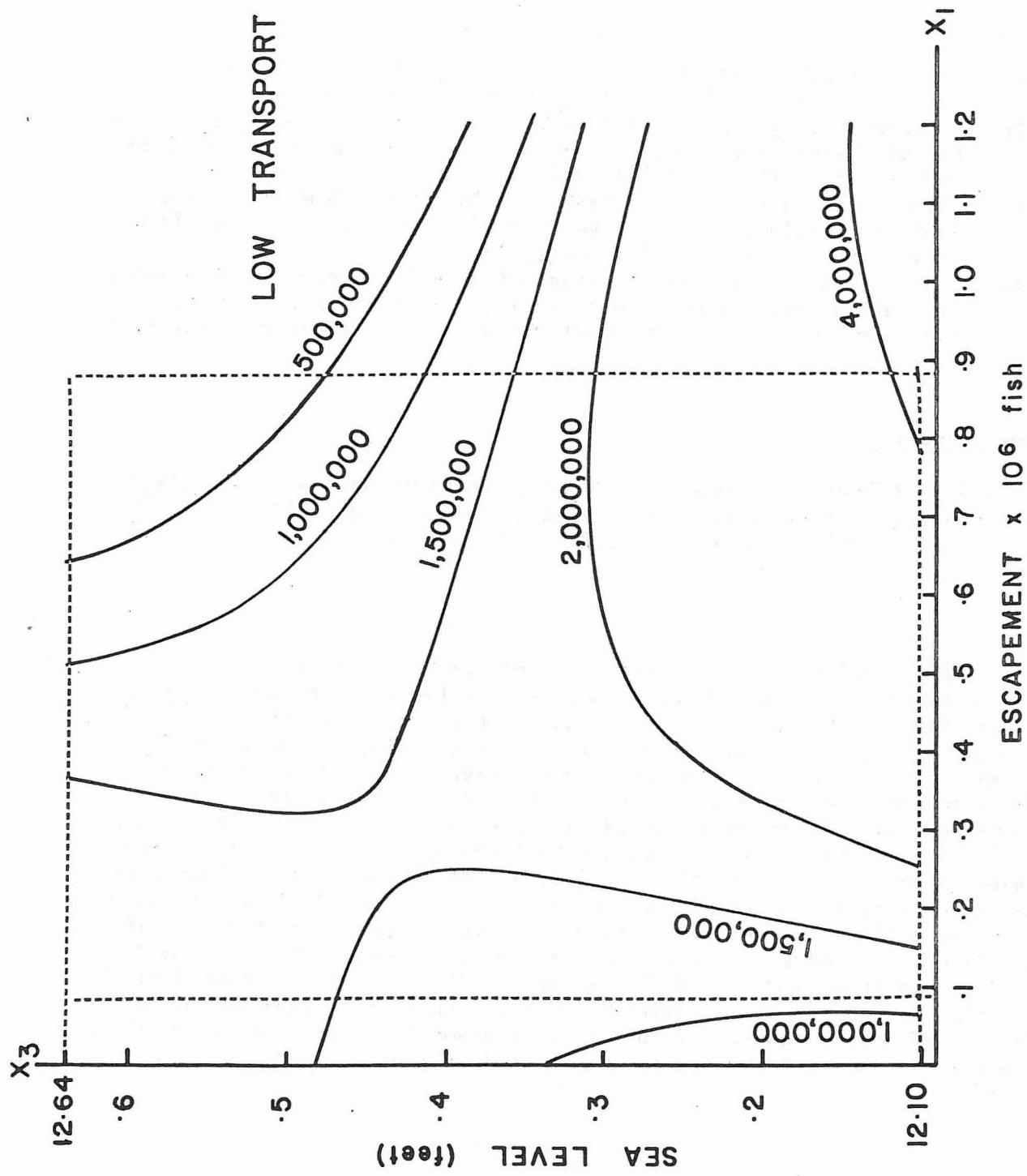


Fig. 19a. Yield chart of Rivers Inlet sockeye salmon for total catch and escapement of 4- and 5-year old adults and changes in Aug.-Sept. Prince Rupert sea level at a low value of northerly transport between the coast and 50°N 170°W during the 4-year-olds' last 12 months at sea. Dotted lines indicate the observed ranges of sea level and escapement.

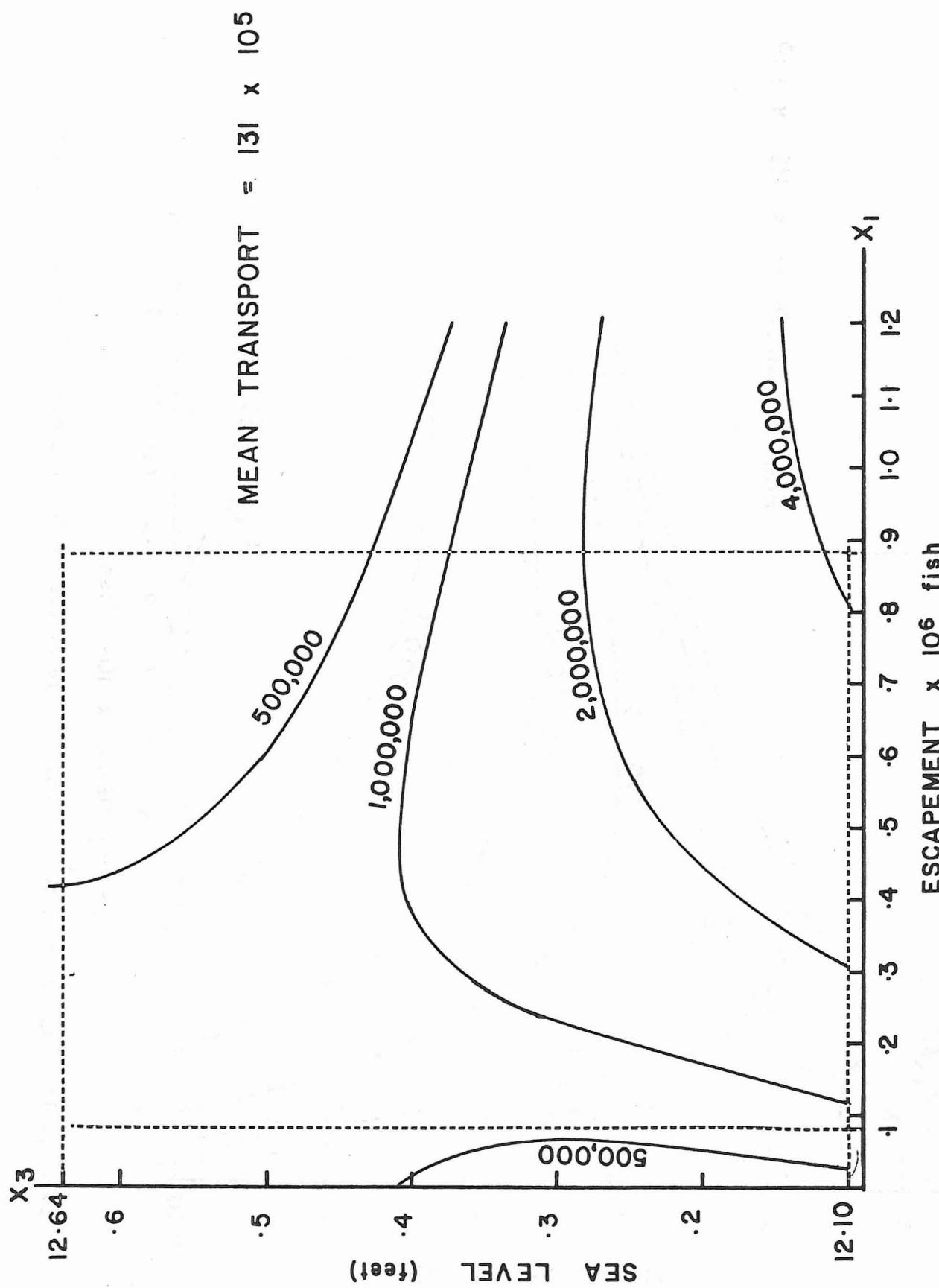


Fig. 19b. Yield chart of escapement against sea level for the mean value of transport.

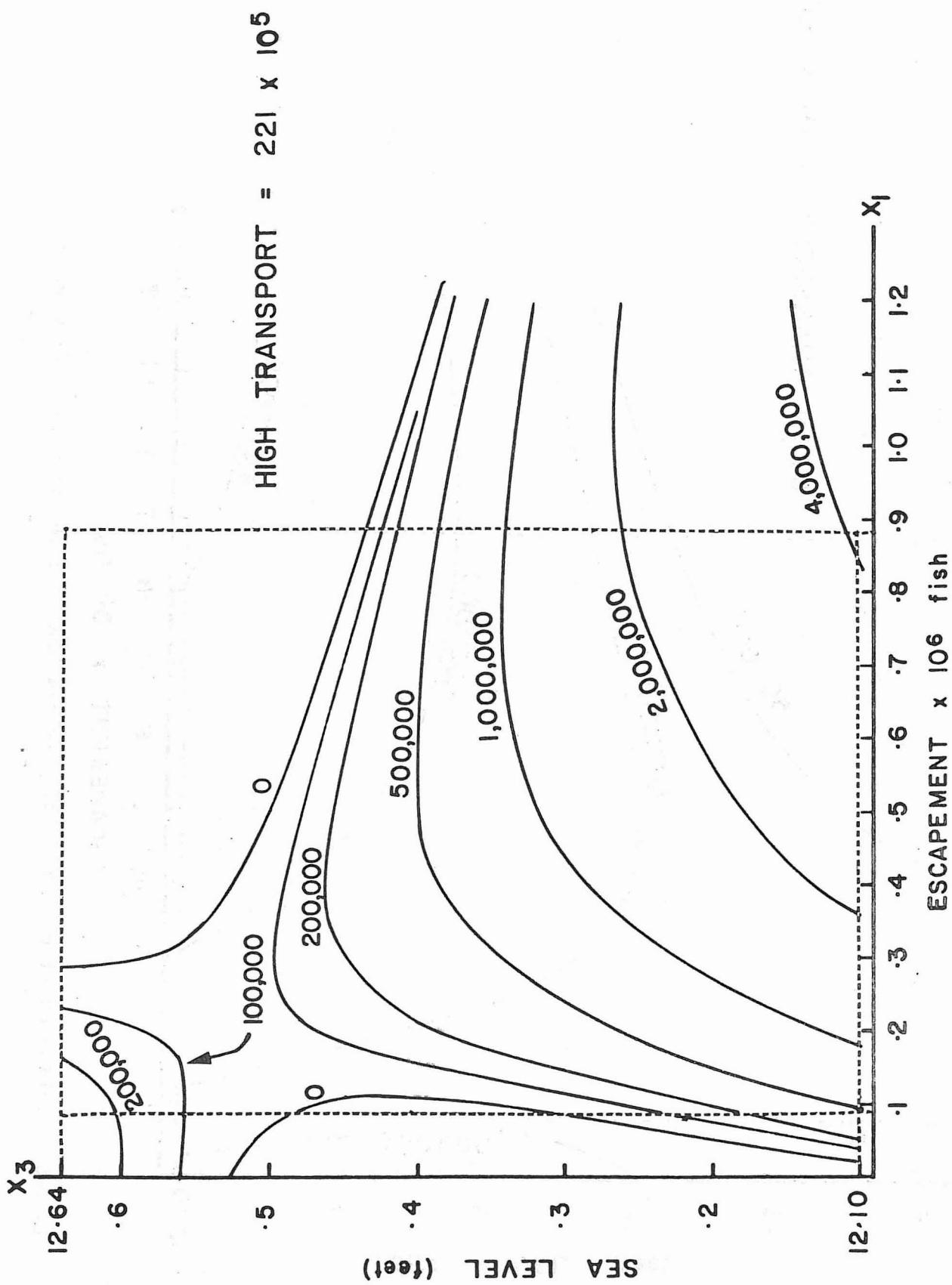


Fig. 19c. Yield chart of escapement against sea level for the highest observed value of transport.

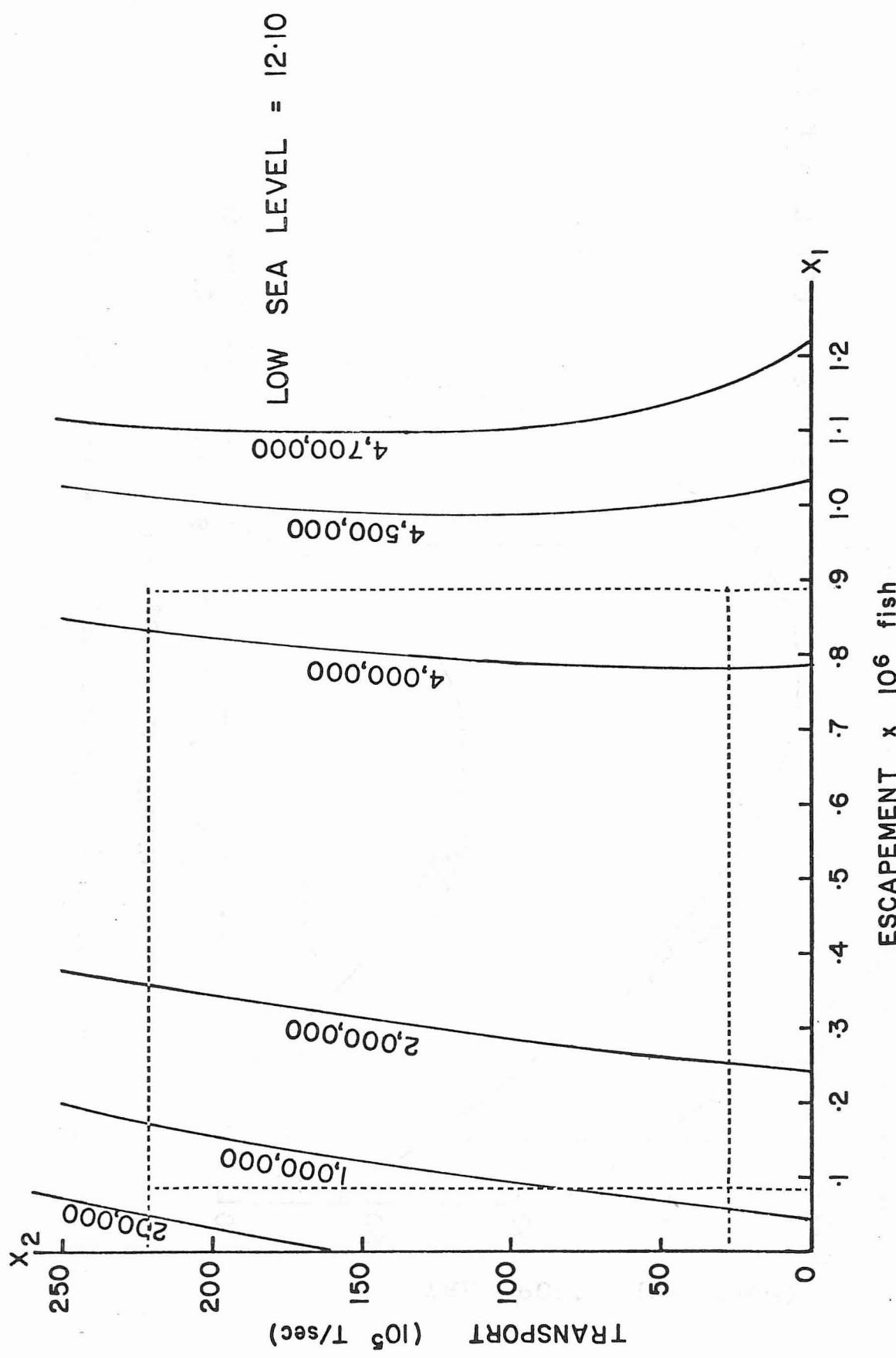


Fig. 20a. Yield chart of escapement against transport for the lowest August-September mean sea level at Prince Rupert. Dotted lines indicate observed ranges of escapement and transport.

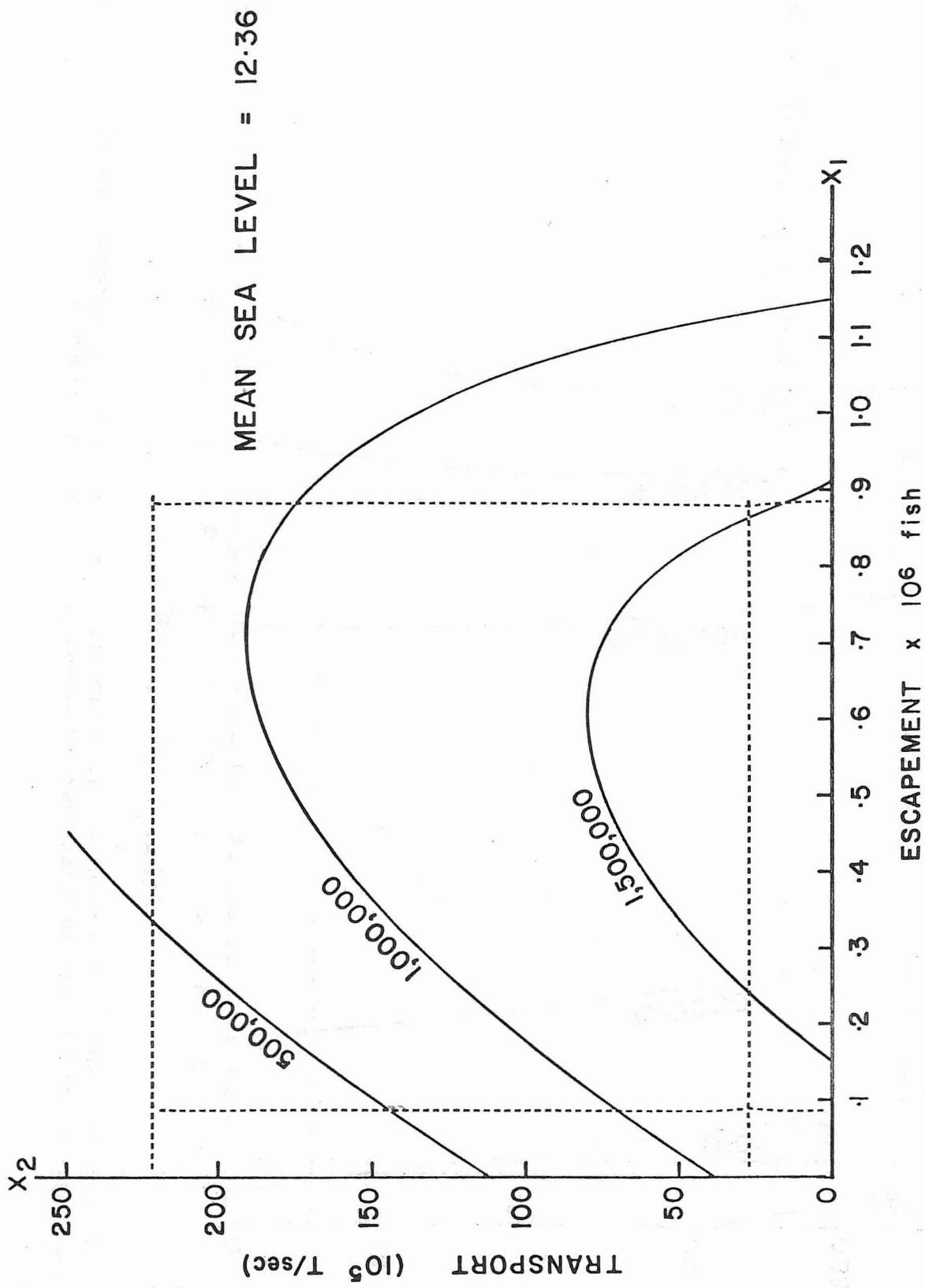


Fig. 20b. Yield chart of escapement against transport for the mean value of sea level.

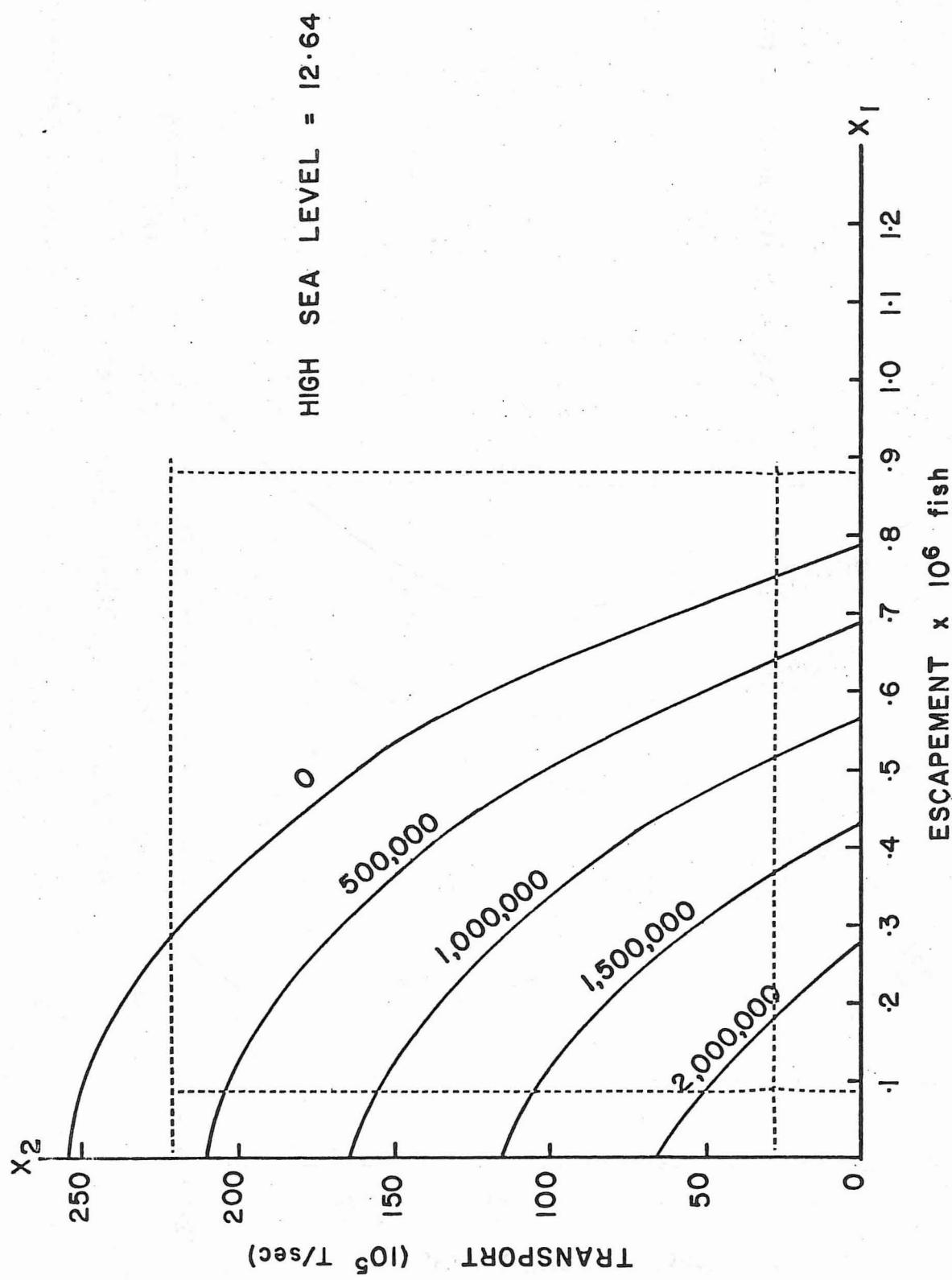


Fig. 20c. Yield chart of escapement against transport for the highest value of sea level. Note that yield drops with increased escapement under this condition.

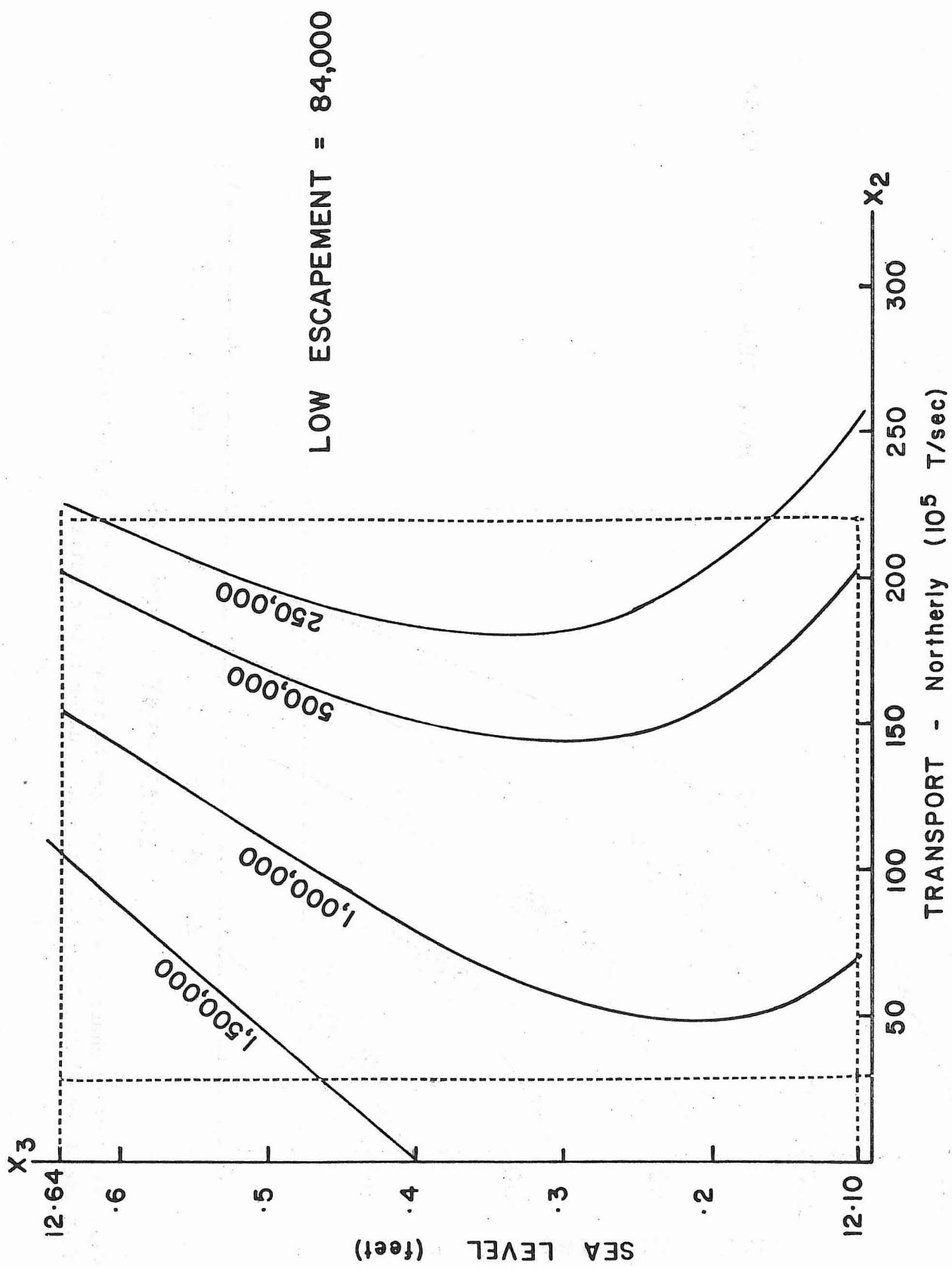


Fig. 21a. Yield chart for transport against sea level for the low value of escapement. Catches would be about 500,000 fish for mean ocean conditions.

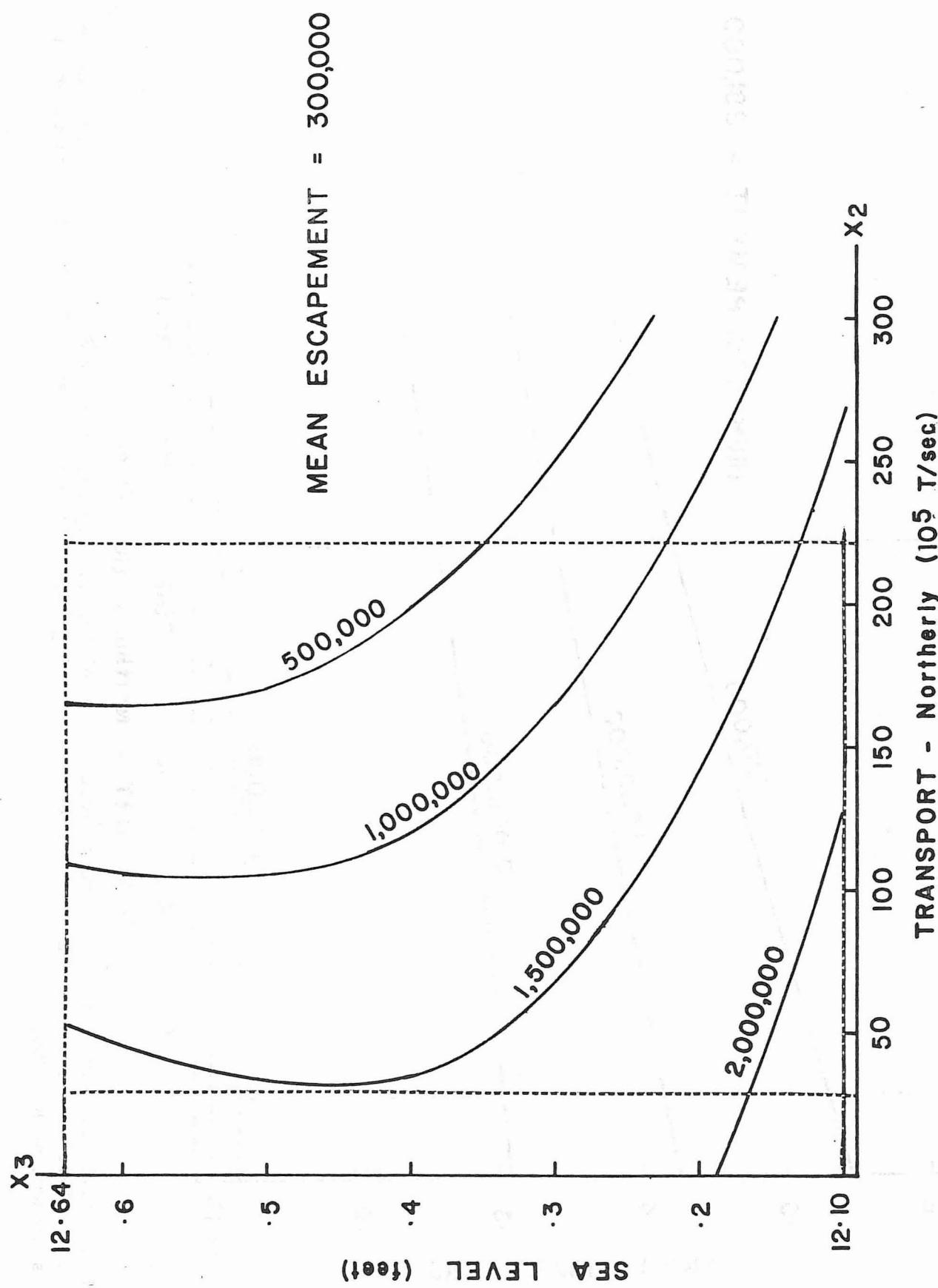


Fig. 21b. Yield chart for transport against sea level for the mean value of escapement. Catches would be about 800,000 fish for mean values of the ocean factors.

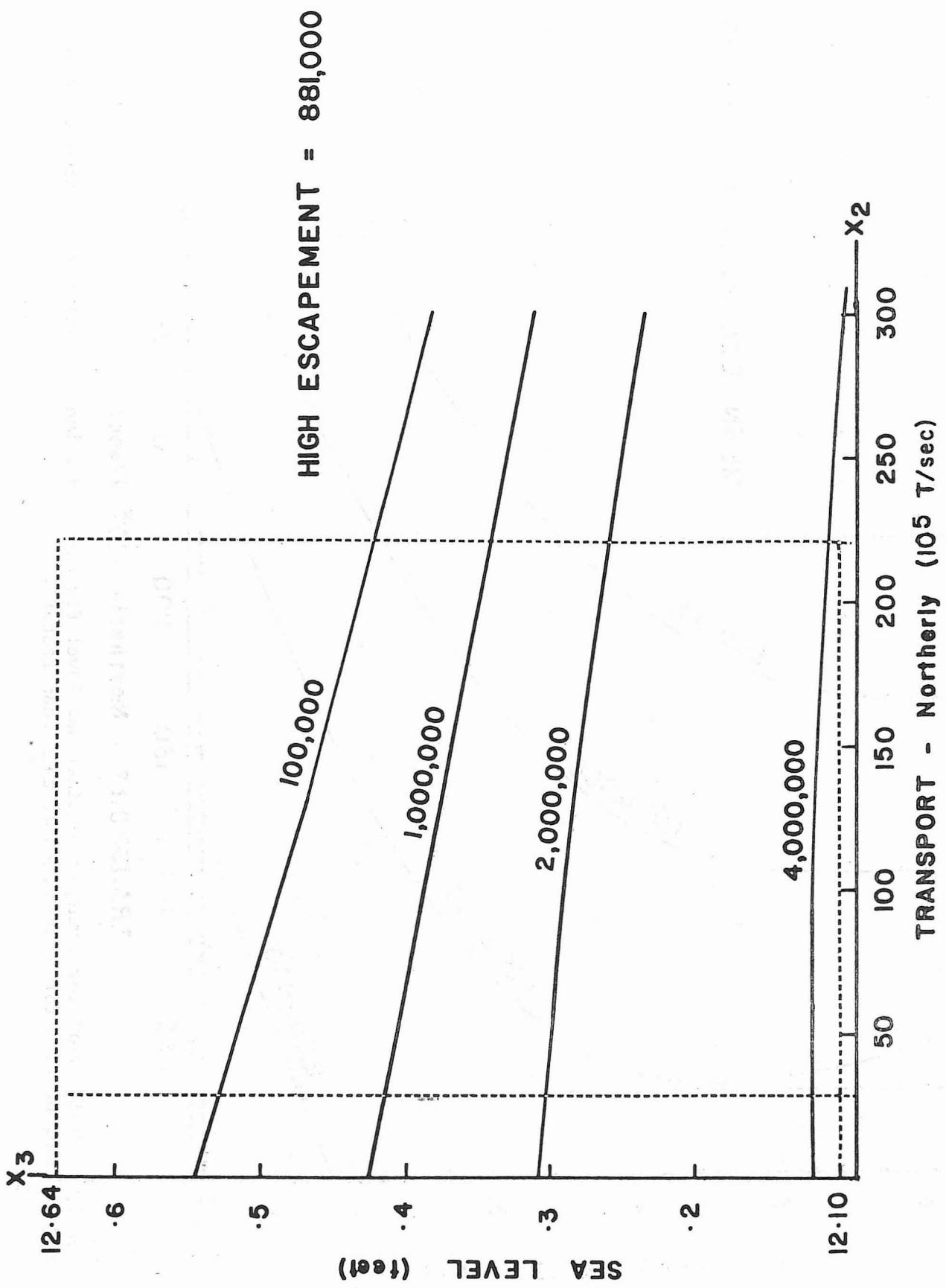


Fig. 21c. Yield chart of transport against sea level for the highest escapement observed. At mean values of sea level and transport the catch from the resulting 4's + 5's would be about 320,000 fish to maintain escapement of 880,000.

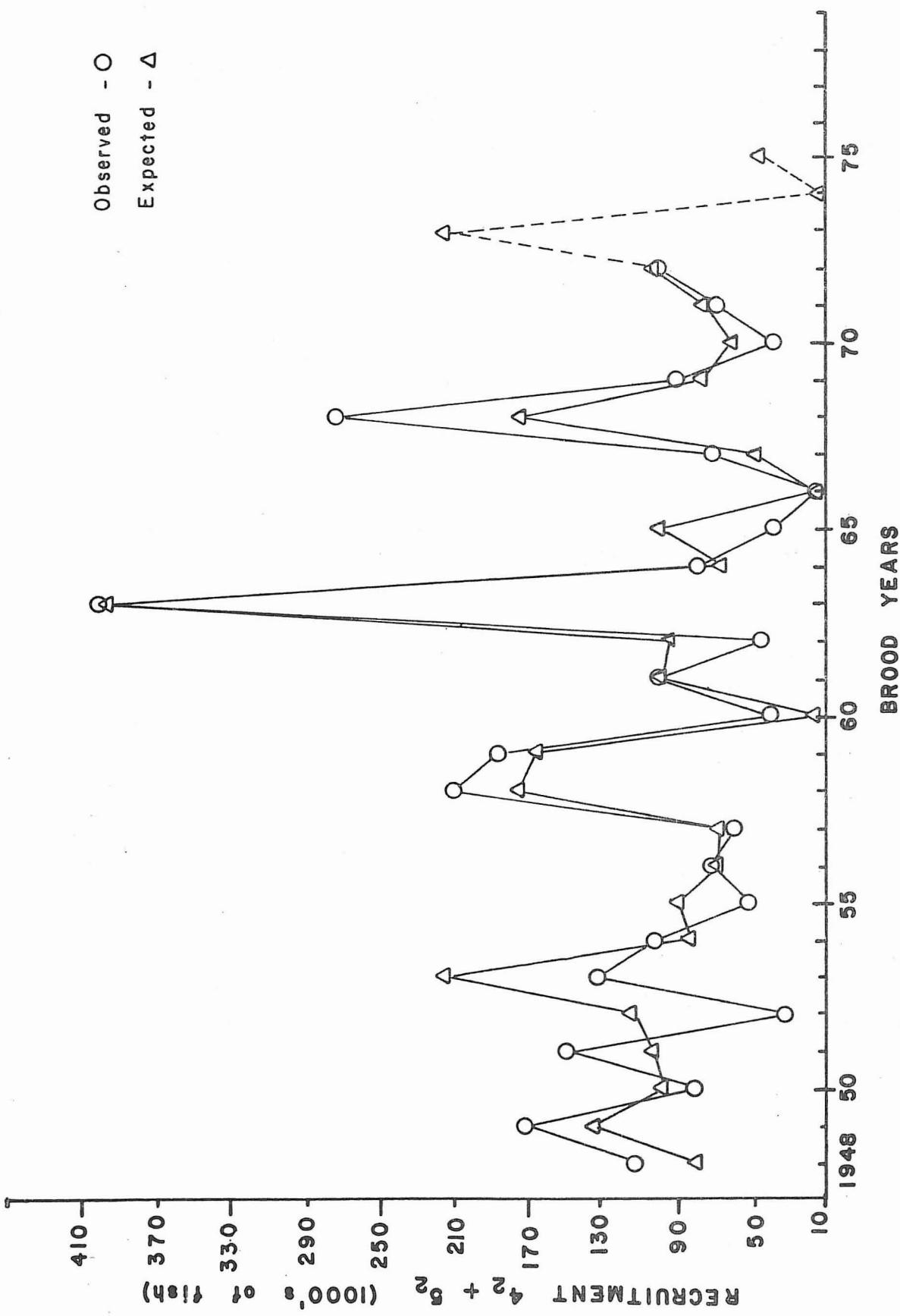


Fig. 22. Observed and expected recruitment of 4-year-old and 5-year-old Rivers Inlet sockeye salmon from 1948 to 1972 with predicted values for 1973-1975 brood years.

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