AN ABSTRACT OF THE DISSERTATION OF

Karl G. Brookins for the degree of Doctor of Philosophy in Fisheries Science presented on March 3, 1995. Title: Population Dynamics and Reproductive Ecology of the Redtail Surfperch *Amphistichus rhodoterus* (Embiotocidae)

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Howard F. Horton

Redtail surfperch (*Amphistichus rhodoterus*) catch has declined throughout their central California to Washington range. Research objectives determining if temperature affected reproduction, if recreational catch-per-hour (CPH) indexed abundance, if angler catch and effort data from the 1979 to 1986 Marine Recreational Fisheries Statistics Survey (MRFSS) were detailed enough to resolve CPH differences; and developing a population model based on MRFSS angler interview data; correlating abundance and recruitment with environmental factors; and making fishery management recommendations for redtail surfperch.

In the laboratory, 30- to 40-day exposure of gestating fish to ambient and ambient plus 3°C temperature affected offspring size and parturition timing. Horsefall Beach catches were recorded to the minute to determine the following: if handling time, inter-species hook competition, recording only successful anglers, rounding effort to 0.5 hrs., combining angler catches, or angling skill invalidated use of the total ratio estimate of CPH (TCPH) to index abundance; to determine if the Poisson Distribution was appropriate when modeling catch accumulation; and to estimate CPH resolution. Annual Horsefall Beach mortality was estimated from MRFSS catch-length and size at age data, and then combined with predicted gravidity to form a population model. Beards Hollow, Columbia River North Jetty, and Horsefall Beach recruit and abundance indexes were formed using MRFSS TCPH and length measurements; these indexes were correlated with annual catch, effort, and harbor seal abundance and with monthly wave height, wave period, sea surface temperature, and upwelling. TCPH can be used to index abundance and confidence intervals of ± 1 TCPH are estimated for *A. rhodoterus* surf fisheries at TCPH ≤3.3.

Kalaloch Beach, Damon Point, Westport Beach, Beards Hollow, Columbia River North Jetty, Jetty Sands, Freshwater Lagoons, and King Salmon (Buhne Point) fisheries were sustainable, but decreasing length of fish was common. Horsefall Beach fisheries captured prereproductive sizes extensively, and offspring production was below population replacement. Horsefall Beach recruitment correlated positively with June upwelling from when recruits were embryos, but not with catch or effort. Columbia River North Jetty abundance correlated with spring and fall environmental conditions of the previous 18-months. Female harvest restrictions are recommended when offspring production is below replacement levels.

Population Dynamics and Reproductive Ecology of the Redtail Surfperch *Amphistichus rhodoterus* (Embiotocidae)

by

Karl G. Brookins

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Karl G. Brookins, Author

DEDICATION

To the fish.

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CHAPTER 1

GENERAL INTRODUCTION

Estimated catch of redtail surfperch, *Amphistichus rhodoterus*, declined from 1979 to 1988 in Washington, Oregon, and California (Figure 1). This decline may reflect changes in the species' population dynamics. Evaluating the status of *A. rhodoterus* populations and making management recommendations may preserve the viability of the species and the recreational fishery. Recreational catch was used for the analysis because commercial catch is small, and no abundance or recruitment information is available. Tests were conducted to validate the use of recreational catch data for population analysis. Reproductive evaluation was also conducted to determine if current offspring production differs from the past.

The reasons for using recreational catch data to analyze *A. rhodoterus* fisheries are the following: 1) redtail surfperch abundance and recruitment information is not available; 2) Marine Recreational Fisheries Statistics Survey (MRFSS) data is available for most of the geographic range of *A. rhodoterus*; 3) additional catch information would be expensive to obtain because recreational fishermen are widely dispersed and highly mobile; 4) annual catch is

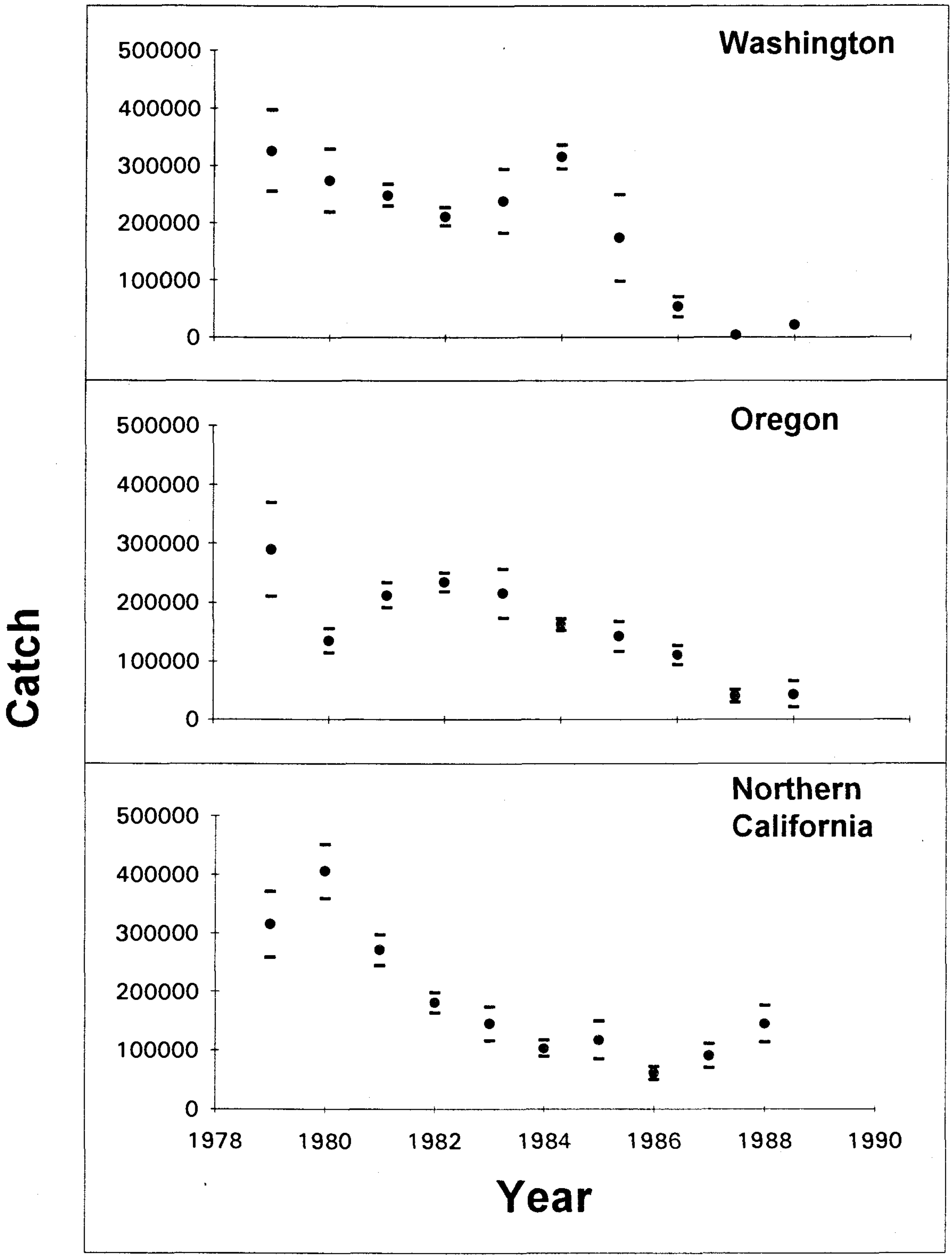

Figure 1. Estimated redtail surfperch catch plus or minus 1 standard error (USDC 1984a, 1984b, 1985, 1986, 1987, 1992a).

large enough to expect good representation in the survey; 5) some detailed historic information is available for comparison to MRFSS data; and 6) the MRFSS data for *A. rhodoterus* have not previously been analyzed at the population level. Methods and assumptions used in this study can be applied to other recreational species.

Amphistichus rhodoterus are viviparous fish that grow to 1.25 kg and reach the age of 9 years (Tarp 1952; Miller and Lea 1972; Bennett and Wydoski 1977). *Amphistichus rhodoterus* are common along sandy ocean beaches year-round and are captured in estuaries from March through August (Miller and Gotshall 1965; Gaumer et al. 1973; Culver 1980). Distributed from Avila Beach, CA, to Hope Island, B.C., this is the only North American marine embiotocid that does not inhabit Southern and Baja California waters (Tarp 1952; Miller and Lea 1972; Dentler and Grossman 1980; Peden and Hughes 1986). *Amphistichus rhodoterus* are iteroparous and after reaching sexual maturity at 3 or 4 years, parturiate annually (Bennett and Wydoski 1977). Females along the central Oregon coast contain fertilized eggs near the first of the year, gestate for 8 months, and give birth in August and September (Bennett and Wydoski 1977). Northern California populations have a similar reproductive schedule, except that parturition starts in July (Ngoile 1978).

Amphistichus rhodoterus are caught in recreational and commercial fisheries from Washington to California, with the principal commercial catch occurring in California (Lukas and Carter 1988; Oliphant et al. 1990). Recreational ocean catch is concentrated from spring to early fall and extends throughout the year depending on surf conditions. Ocean catch is mainly < age 4 or large males (Bennett and Wydoski 1977; Ngoile 1978). Estuarine fisheries occur in spring and early summer (Gaumer et al. 1973), with the catch consisting mostly of large gestating females (Bennett and Wydoski 1977; Ngoile 1978; Culver 1980). The recreational catch of *A. rhodoterus* is estimated to be second only to the catch of *Sebastes melanops* for Oregon marine species and holds similarly high ranks for the recreational catch in Washington and Northern California (USDC 1984a, 1984b, 1985, 1986, 1987). Estimated catch of *A. rhodoterus* from Oregon ranged between 90,000 and 200,000 fish for the early 1980's (USDC ibid.).

Throughout the research, attention was given to reproductive details because of close links between *A. rhodoterus* reproduction, life history, migration, and fisheries. The term *gravidity* (a count of embryos in the ovary) is used, rather than fecundity, because it relates to being pregnant and emphasizes the differences between gestation, being mature, or carrying mature eggs (Turner 1947; Miller 1984). Mating, copulation, fertilization, gestation, and parturition are used to identify specific conditions or points in the reproductive cycle (Tienhoven

1983). The timing and nature of these reproductive events are used to interpret correlations of environmental variables with fishery analysis results.

Fisheries analyses are based on abundance and recruitment estimates, but these estimates are expensive to gather for small, recreational, emerging, and difficult to sample fisheries. This dissertation demonstrates that recreational catch data can be used to form relative abundance indexes and then does for *A. rhodoterus*. Relative abundance is then correlated with environmental variables. Laboratory experiments in Chapter two demonstrate how one environmental variable, temperature, can influence *A. rhodoterus* reproduction; Chapter three describes a surf fishery and evaluates recreational fishery statistics for use in models and estimating abundance; Chapter four explores abundance and recruitment trends, correlating trends with environmental variables. The *A. rhodoterus* fisheries examined appeared to be at sustainable levels with the exception of Horsefall Beach. Future research should concentrate on pre-recruitment mortality, and migration at all ages.

This dissertation is the first to: (1) relate water temperature, and other environmental conditions to *A. rhodoterus* reproduction, population abundance, recruitment, and fisheries; (2) conduct broad geographic and >2-year analysis of *A. rhodoterus* populations and fisheries; (3)

document catch statistics and trends in the Pacific Northwest surf fishery; and (4) evaluate the applicability of using recreational catch per hour statistics to estimate *A. rhodoterus* abundance.

CHAPTER 2

THE EFFECT OF TEMPERATURE ON BROOD DEVELOPMENT AND PARTURITION IN REDTAIL SURFPERCH

INTRODUCTION

Physical environmental factors correlate with species distributions and biological processes such as reproduction (Terry and Stephens 1976; Bond 1979; Shrode et al. 1983; Bye 1984). Environmental temperature has been related to both distribution and reproduction of several surfperch species, but has not been studied in *A. rhodoterus* (Gordon 1965; Wiebe 1968; Terry and Stephens 1976; Shrode et al. 1983). Female *A. rhodoterus* move inshore and into estuaries during gestation, movements likely to bring females into warmer water (Morgan 1961; Bennett and Wydoski 1977; Ngoile 1978). This chapter examines the effect of environmental temperature on *A. rhodoterus* embryo development and birth. The objectives of this study were 1) to determine if temperature has an effect on *A. rhodoterus* embryo development; 2) to determine if temperature has an effect on parturition of *A. rhodoterus*; and 3) to determine if different temperatures experienced by gestating females could cause a shift in parturition timing.

Studies of parturition in surfperch concentrate on the relationship between the size of adults and the size of offspring, and on the timing of parturition as related to age of adults (Hubbs 1921; Carlisle et al. 1960; Wilson and Millemann 1969; Wares 1971; Bennett and Wydoski 1977; DeMartini et al. 1983; Schultz 1990). Researchers conducting typical experiments, including holding females in ambient water until parturition, do not report environmental conditions. Because temperature may influence embryo development, previous parturition timing and size analyses may be flawed (Hubbs 1921; Carlisle et al. 1960; Wilson and Millemann 1969; Bennett and Wydoski 1977; DeMartini et al. 1983; Schultz 1990). Specifically, experiments that tested the effect of water temperature on offspring development terminated prior to parturition (Wiebe 1968; this chapter), and experiments that included parturition do not examine holding temperature (Wilson and Millemann 1969; Bennett and Wydoski 1977). If holding temperature affects timing of parturition and size at birth, then previous experiments may mistakenly attribute results to factors other than temperature.

To determine the effect of temperature on *A. rhodoterus* reproduction, gestating females were held in tanks of different temperature and the size of embryos, the size of neonates, and timing of parturition were measured. Elevated water temperature resulted in increased *A. rhodoterus* embryo size, decreased weight at birth, and earlier parturition. Water temperature during gestation is a factor affecting *A. rhodoterus* reproduction and offspring size.

METHODS

Gestating *A. rhodoterus* were hook-and-line captured from wild populations 2 to 5 weeks prior to each experiment. Fish used in each experiment were captured from the same location over a period of two weeks. Mid-gestation experimental fish were captured in the Umpqua River Estuary. Late-Gestation and parturition experimental fish were captured between Seal Rock and Ona Beach State Park, Lincoln County, Oregon. Experimental fish were acclimated in flow-through ambient seawater at the Oregon State University, Hatfield Marine Science Center (HMSC) in Newport, Oregon for 2 to 4 weeks. Fish were fed three to five times a week, generally every other day. The diet was primarily shrimps (*Pandalus*, *Lissocrangon*, and *Callianassa*), and surf smelt (*Hypomesus*), with occasional additions of clams (*Mya*, and *Tresus*), mole crabs (*Emerita*), and mussels (*Mytilus*). Equal amounts of food per female were placed in each tank. Uneaten food was removed prior to the next feeding, except for live shrimps, which were left in tanks.

Fish were introduced to experimental tanks containing ambient seawater. Water temperature was then raised 1 - 2°C per day until treatment temperature was reached. Temperature was increased by passing the water through a bucket containing emersion heaters before holding it in a common, constant head tank. The heating system maintained the water approximately 3°C above ambient, but the ambient temperature varied. Water temperature was recorded every second or third day during the mid-gestation experiment.

Gestation Experiments

The mid-gestation experiment (May 23 to July 2) was conducted in 5, 300-liter flow-through tanks. Each tank contained three fish. Mean temperature per treatment was 14.3, 16.6, and 18.9°C, the lowest temperature determined by ambient seawater. Three fish were used for the lowest temperature treatment, and six fish each were used for the 16.6 and 18.9°C treatments. In each of the 16.6 and 18.9°C treatments, one fish showed no signs of having been impregnated and was eliminated from the analysis.

The late-gestation experiment (August 2 to September 6) was conducted in 6, 300-liter partially recirculating tanks. The late-gestation experiment was terminated at 36 days because of increased ambient water temperature and the possibility that the high temperatures would cause early parturition. The use of a partially recirculating experimental apparatus allowed better temperature control for heated water, but did not allow temperatures cooler than incoming seawater. Mean temperatures of the two treatments used were 11.9 (ambient) and 15.2°C. Six fish for each treatment were stocked, two per tank. Two fish, one from each treatment, showed no signs of impregnation and were excluded from the analysis. Additionally, one fish held at ambient temperature produced no live embryos. The inclusion or exclusion of this fish (and other dead embryos) had no affect on differences between experiments.

Adults were sacrificed, weighed, and measured at the termination of experiments (Appendix Table 35). Embryos were weighed to the nearest 0.1 g, body length measured to the nearest mm, and vitality recorded. Embryos described as "normal" were not stunted, did not show signs of external defects or reabsorption by the mother, and did not vary in color from other embryos of the same size. Conversions between total, fork, standard, and body lengths for neonate *A. rhodoterus* are given in Appendix D. Fulton-type condition factors (Anderson and Gutreuter 1983) and percent survival were calculated. Means for brood length, weight, condition and arcsine square root transformations of brood percent survival (Steel and Torrie 1980) were compared by analysis of variance (ANOVA). Only comparisons of live embryo length, weight, and condition were reported because dead embryos may include pre-experiment mortalities, and resorption starts quickly and can result in low weights for dead embryos.

Parturition Experiment

The parturition experiment was conducted in the same apparatus and manner as the late-gestation experiment. Parturition experiment females were randomly assigned a treatment and transferred to experimental tanks on July 15, 1992. One non-gestating *A. rhodoterus* was placed with each gestating female in experimental tanks because gestating females feed and behave more normally with companion fish. The temperature in heated water tanks was raised to 15°C over a 48-hour period. Tanks were checked daily for the presence of new offspring. When newborn *A. rhodoterus* appeared, they were removed to a separate holding tank and the date, viability, body length (BL), and wet weight recorded within 48 hours. Condition was calculated from length and weight (Anderson and Gutreuter 1983).

Length, weight, condition, percent survival, and number of days until birth (from start of the experiment) of each females' brood were tested by ANOVA and step-wise regression against female standard length (SL) and treatment. The median number of days to birth was compared using an unpaired t-test. Distributions of days until birth were compared with the Kolmogorov-Smirnov two sample test (Steel and Torrie 1980). A forward step-wise linear regression procedure was used to determine the relative importance of treatment and female SL in determining the size of offspring at birth and the timing of parturition. The significance level of all tests was set at alpha = 0.05. Statistical analysis was conducted using Statgraphics® statistical software (version 5.0).

RESULTS

Mid-gestation embryo development at 14.3°C appeared normal with 100% survival and healthy young. Highest temperature (18.9°C) during mid-gestation was associated with significantly decreased survival of embryos (Table 1). Late-gestation embryo development appeared normal at both temperatures, but mean embryo weight in the 15.2°C treatment was double that in the 11.9°C treatment after 36 days (Table 2). No temperature effect on embryo survival was noted during the late-gestation experiment. During both the mid- and late-gestation experiments mean temperatures in the range of 14.3 to 15.2°C produced normal embryos for the expected state of development. Other results of embryo development at different temperature experiments are displayed in Tables 1 and 2.

Seawater temperatures during the parturition experiment varied daily, averaged 12.3°C for ambient and 15.1°C for warmed water (Figure 2), and were significantly different. Two of the three females held at ambient temperature contained embryos. Three of the four females held in the warmed water gave birth to live young. Length of females was not statistically different between treatments, and averaged 286.5 (264, 309) and 252.3 (248, 243, 266) mmSL for ambient and heated treatments, respectively.

No significant differences were found between mean condition and percent survival of broods during the parturition experiment; significant differences were found for the number of days until birth (mode), the distributions of days to birth, and mean brood wet weight. The mean wet weight of living young was 7.61g for ambient and 5.65g for

Table 1. Mid-gestation experimental means, standard errors, and significance from ANOVA comparisons of mean brood condition, body length, wet weight, and percent survival. Abbreviations are K = condition, BL = body length, Wt = weight, PS = percent survival, NS = not significant, SE = standard error of mean, * significant at $p \leq 0.05$, ** significant at $p \leq 0.01$. Body length is the distance from the anterior end of the fish to the last scale on the tail.

Item	Significance	Treatment: Ambient	Heated 1	Heated 2
n: ♀♀(live embryos)		3(44)	5(31)	4(15)
Temperature (°C)				
mean	*	14.3	16.7	18.8
SE		0.24	0.26	0.20
K	NS			
mean		2.09	2.05	2.09
SE		0.071	0.113	0.179
BL	NS			
mean		31.9	28.7	27.6
SE		1.31	2.33	1.20
Wt	NS			
mean		0.679	0.508	0.450
SE		0.0707	0.1142	0.0630
PS	**			
mean		100.0	65.4	29.2
SE		0.00	0.11	0.06

Table 2. Late-gestation experiment means, standard errors, and significance for ANOVA comparisons of mean brood condition, body length, wet weight, and percent survival. Abbreviations are K = condition, BL = body length, Wt = weight, PS = percent survival, SE = standard error, NS = not significant, * significant at $p \leq .05$, ** significant at $p \leq .01$. Body length is the distance from the anterior end of the fish to the last scale on the tail.

Item	Significance	Treatment: Ambient	Treatment: Heated
n: ♀♀(live embryos)		5(56)	4(88)
Temperature (°C)	**		
mean		11.9	15.2
SE		0.345	0.225
K	*		
mean		1.967	2.208
SE		0.058	0.025
BL	**		
mean		47.1	50.8
SE		1.17	1.60
Wt	**		
mean		1.45	2.92
SE		0.136	0.310
PS	NS		
mean		80.2	70.4
SE		11.36	19.26

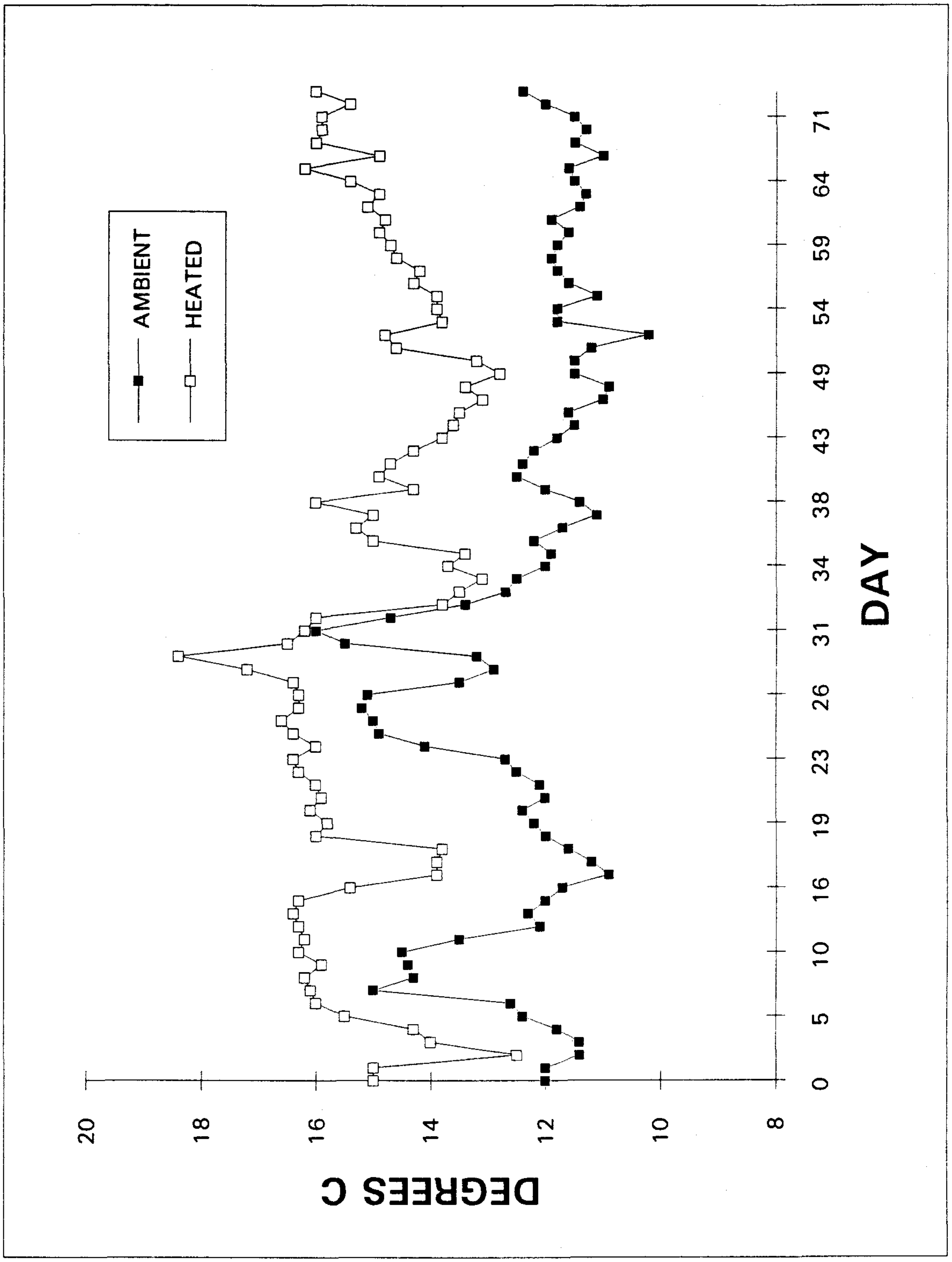

Figure 2. Daily water temperature measurements of ambient and heated tanks during parturition experiment with redtail surfperch. Water pressure changes on day 28 caused a decrease between treatment temperatures for 5 days until adjustments were completed.

heated treatments (Table 34). Mean brood body length was not different between treatments (p=0.056); 66.6 and 60.1 mm for ambient and heated treatments, respectively (Appendix Table 34). The average number of days to birth was 54 in ambient and 33 in heated treatments, respectively. This experiment was repeated during 1994, but only two fish (one from ambient treatment and one from heated) gave birth to live young. In this 1994 experiment, young born in the heated treatment were born sooner, and at a smaller size than the ambient treatment young; distributions of days until birth overlapped.

The F-to-enter for treatment (19.4) as a regression variable explaining offspring wet weight was larger than the F-to-enter for female SL (14.3). With both variables in the model, treatment was significant (p=0.00433) and Female SL was not (p=0.0563). The F-to-enter for treatment was also higher in regression models for offspring BL and mean day of birth for a brood, but neither of these regressions had a slope significantly different from zero.

DISCUSSION

Gestation Experiments

Mid-gestation temperatures averaging 18.8°C were associated with decreased survival of embryos (Table 1), indicating the physiological limits of *A. rhodoterus* reproduction were exceeded. The warmest and coolest water temperature experienced by gestating *A. rhodoterus* I have estimated from the literature are 15.0°C and 9.9°C (Gaumer et al. 1973; Karentz and McIntire 1977) (Appendix Tables 50, 51, 52). Mid-gestation experimental temperatures exceed this range. Late-gestation experimental temperatures were within the estimated temperature range of *A. rhodoterus* gestation and did not affect survival.

The decreased embryo survival at warmer temperatures during the mid-gestation experiment provides the basis for a physiological hypothesis explaining the southern range limit of *A. rhodoterus*. Water temperature is a barrier to dispersal of marine fish (Bond 1979), and the southern range limit of *A. rhodoterus*, Avila Beach, California, may be where water temperature limits embryo survival and adult reproduction. The near-shore surface temperature around Avila Beach ranges from 11 to 15°C, and for Port Hueneme and Santa Monica (the next reporting stations to the south) records include temperatures ranging from 12 to 20°C (USDC 1956). Embryo survival would be jeopardized at the higher end of this range. Additionally, embryos may be sensitive to temperature earlier in their development. Embryo development in *C. aggregata*, another viviparous embiotocid, was strongly affected by warm temperatures during early gestation (Wiebe 1968).

During late-gestation embryo length and weight significantly increased when water temperature was elevated on average from 11.9 to 15.2°C (Table 2). Therefore, during late-gestation, and probably mid-gestation, development of *A. rhodoterus* embryos would occur faster in estuaries than in the ocean because of warmer water in estuaries. Earlier parturition should take place in estuaries if birth occurs once embryos are fully developed. It follows that the difference between exposure to estuarine and open coastal temperatures would result in later parturition in neritic waters (assuming little or no migration). The magnitude and direction of the parturition shift between estuary and ocean would depend on the amount of time females were exposed to different temperature conditions.

The effects of gestation temperature on embryo development and parturition timing are likely to produce evolutionary and fishery consequences. Delayed *A. rhodoterus* parturition could limit the time available to complete other life processes, make pregnant females available to the fishery longer, and affect offspring survival. If females were available to the fishery longer, mortality and the unintended harvest of embryos (embryo by-catch) would increase. Both mortality and embryo by-catch could alter the dynamics of *A. rhodoterus* populations. Because parturition timing can be linked to survival, growth, reproduction, and habitat (via temperature), any change in estuarine catch of *A. rhodoterus* takes on greater importance.

Parturition Experiment

The main factor limiting the availability of female *A. rhodoterus* for the parturition experiment was the advanced gestational state of wild-caught females. Females collected for the parturition experiment were much closer (see below) to parturition than females sampled at the same time and location in previous years. Time to parturition predictions were based on visual inspection of abdominal enlargement and parturition timing. Females in the parturition experiment started giving birth 15 to 23 days after the experiment started, 4 weeks earlier than expected from the late-gestation and unreported experiments. The advanced gestational state of females was possibly the result of warm water associated with a El Niño Southern Oscillation (ENSO) event off Oregon during 1992. May, June, and July 1992 sea surface temperature anomalies were 1 to 2°C above normal (USDC 1992b, 1992c, 1992d). These 1992 observations of wild-caught females support the conclusion that faster embryo growth occurs with warmer water in the wild.

Mortality of embryos from the parturition experiment heated treatment was greater than in the ambient temperatures, although not significantly. Some of these mortalities may have been due to high temperatures in the heated tanks on day 28 and 29 (Figure 2). The female in tank 4 had higher embryo survival than other heated treatment females and gave birth prior to day 28 (Appendix Table 37). Temperature could be an important contributing factor to embryo mortality, but it was not demonstrated. Embryo mortality occurred in all parturition experiment broods and its effect on offspring production should be considered.

Number of offspring was less than would be predicted from the gravidity at length relationship (Chapter 4). Bennett and Wydoski (1977) also obtained fewer offspring from *A. rhodoterus* than expected (four of fourteen females gave birth and three of these four gave birth to less than the predicted number of young). Obtaining the number of offspring predicted from gravidity has been a consistent problem. The <100 percent survival of gestating embryos is of concern because gravidity would overestimate actual offspring production. Further research is recommended on embryo mortality and the effects of water temperature and female SL on *A. rhodoterus* reproduction.

Though minimal, the number of replicates used does not prevent the statistical analysis of these data; but the applicability of the results to *A. rhodoterus* in general must be carefully considered. There is a 10% (2/5 * 1/4) chance that the two fish picked for ambient temperature treatment would be the first to give birth without any experimental effects. However, a 21-day difference in mean day of parturition is not likely to be due to chance alone because the distributions of parturition dates as well as the modes of parturition date were found to differ (only slightly overlapping distributions). Significant differences in a second variable, wet weight, were also found. The chance of finding differences under these conditions with two independent variables involved is 1 in 100 (0.1 * 0.1). Parturition timing and size of offspring at birth are not independent variables as the parturition experiment demonstrates. Thus, the probability of these results occurring due to chance fall between 1 in 10 and 1 in 100. While there is a possibility that the effects observed are due to chance, the experimental results of the parturition experiment are most likely due to differences in temperature.

Female *A. rhodoterus* held in warmed water (mean temperature difference of 2.8°C) gave birth an average of 21 days sooner and produced 26% smaller offspring than females held at ambient temperatures. The timing of parturition in this experiment was consistent with the geographical pattern of surfperch being born earlier in lower and warmer latitudes (Odenweller 1975; Bennett and Wydoski 1977; Ngoile 1978). The offspring of females held in warmed water were similar in weight to those reported by Bennett and Wydoski (1977), whereas the offspring of females held at ambient temperatures were heavier. Bennett and Wydoski (1977) held their females in "ambient" seawater, but the temperature was not reported.

Female SL was used in the step-wise regression analyses of the experiment because, at the time of measurement, females were at different points in the recovery process after gestation and parturition. Comparison of female weight could potentially be misleading due to the differences in weight gain during recovery. Female SL is a better indicator of female size because SL is less likely than weight to change during gestation and recovery.

Water temperature is the most important variable in determining offspring wet weight in the parturition experiment based on the F-to-enter statistic. The small difference in the probabilities between temperature treatments and female SL indicates that female SL (size) may also play a role in determining the wet weight of offspring at birth.

Shifts in parturition timing of surfperch populations may be accounted for by changes in the age structure of females. Older surfperch are generally believed to reproduce earlier (Hubbs 1921; Carlisle et al. 1960; Triplett 1960; Swedberg 1965; Gnose 1967; Wilson and Millemann 1969; Ngoile 1978; Schultz 1990). However, these observations are flawed because reports of larger surfperch reproducing earlier do not consider environmental temperature, do not consider the movements of different aged females between disparate habitats (Gordon 1965; Bennett and Wydoski 1977), or are based on the size of embryos prior to parturition.

The sensitivity of birth size and timing to environmental temperature, the movement of embiotocids between areas with different thermal regimes (e.g. ocean and estuaries) (Morgan 1961; Smith 1967), and the segregation of female surfperch by size (Smith 1967; Gordon 1965; Bennett and Wydoski 1977; Ngoile 1978) are reasons why wild-caught embiotocids should not be used in experiments to determine size at, or timing of, parturition unless their thermal histories are known. Viable options are to study these variables in the wild or to hold females in the laboratory for the entire reproductive cycle.

Size of young at birth is believed to affect survival of *A. rhodoterus* and other fish (Bennett and Wydoski 1977; Pearcy 1992). The timing of parturition may also affect *A. rhodoterus* offspring. Timing of birth or hatching can affect survival in other "parental care" species such as deer, dwarf perch, and terns (Clutton-Brock et al. 1982; Schultz 1990; Burger and Gochfeld 1991). The evolutionary consequences of environmental temperature changes on *A. rhodoterus* offspring require further investigation.

CONCLUSION

Temperature during gestation affects the growth of *A. rhodoterus* embryos. Temperatures of 14 to 15°C had no effect on embryo survival and resulted in larger embryos than cooler temperatures. Temperature experienced before and during parturition can affect parturition timing and size of *A. rhodoterus* at birth. Cooler temperatures are expected to cause later parturition in ocean dwelling fish. Later parturition can result in less time for growth of both females before the next pregnancy, and neonates before winter. However, reduced neonate growth may be compensated for by a larger size of neonates born later. Embryo by-catch may increase due to longer exposure of gestating females to fishing mortality. In light of these results, embiotocid parturition size and timing experiments that do not consider thermal history of females likely are flawed. Differences between the survival rates of *A. rhodoterus* offspring born in estuaries and in the neritic zone needs further investigation.

CHAPTER 3

ANALYSIS OF SURF ANGLING CATCHES

INTRODUCTION

Recreational angling surveys are a valuable source of fisheries information because larger, older, and less abundant species from locations difficult or expensive to sample are targeted. A meaningful fishery analysis can be conducted using recreational angling statistics if their limitations are recognized. Constraints include the types of information available, the number of samples for different times and locations, and the completeness of the content for each sample. This chapter examines the constraints that limit researchers' ability to distinguish between catch per hour values (resolution) when analyzing the surf fishery of the Pacific Northwest. The constraints examined are handling time, gear saturation, competition for hooks, units for measuring effort, and the variance of catch per hour. Additionally, one recreational surf fishery is described and used to test if a Poisson distribution is appropriate for modeling the capture process.

Amphistichus rhodoterus is the primary catch of surf anglers from Northern California to Vancouver Island, British Columbia. Redtail surfperch catch rates from 0.0 to 4.7 fish per hour have been reported, with average catch rates of up to 1.86 fish per hour (Miller and Gotshall 1965; Bennett and Wydoski 1977; Culver 1980). Silver surfperch, *Hyperprosopon ellipticum*, are also commonly caught by surf anglers in these areas (Wydoski and Bennett 1973). The Marine Recreational Fishery Statistics Survey (MRFSS), conducted by the National Marine Fisheries Service from 1979 to 1986, included samples from shore anglers catching both *A. rhodoterus* and *H. ellipticum* in the sandy surf (USDC 1984a, 1984b, 1985, 1986, 1987).

Catch per unit effort (CPUE) is the recreational angling statistic of primary interest to fishery biologists and is usually measured as catch per hour (CPH)(Malvestuto 1983). The CPUE is used as an index of stock abundance and can be combined with other information to form indexes of recruitment or size-specific abundance (Beddington 1979; Malvestuto 1983; Richards and Schnute 1986; Bennett and Attwood 1991; Richards and Schnute 1992). Fluctuations in stock abundance correspond to those in CPUE; but the opposite does not always hold true (Peterman and Steer 1981; Bannerot and Austin 1983; Deriso and Parma 1987). The CPUE and stock abundance relationship varies considerably, and the mathematical relationship is only theoretically defined (Peterman and Steer 1981; Bannerot and Austin 1983).

Changes in CPUE relate to competition with other species, or the proportion of population caught by a standard gear (catchability coefficients) (Cushing 1975; Beddington 1979; Clark and Mangel 1979; Polovina 1986;

Deriso and Parma 1987). Stable CPUE with increases in population abundance can result from large handling times or gear saturation totally independent of any concurrent changes in stock abundance (Deriso and Parma 1987). Before using CPUE as an index of abundance, handling time, gear saturation, and competition for hooks by other species need to be examined. The variability associated with measuring CPUE using recreational angling statistics also needs examination in order to determine if enough resolution exists to conduct a discriminating fishery analysis.

Catch per hour can be measured or estimated in many ways (Crone and Malvestuto 1991). Statistical considerations define the Best Linear Unbiased Estimate (BLUE)(Cochran 1977). The BLUE for MRFSS *A. rhodoterus* catch statistics is the total ratio estimate of CPH (TCPH), total catch/total hours angling in a time interval (Chapter 4).

One drawback of using the class of variables including ratio estimates (versus using a mean or a regression estimate) is that ratio estimate distributions may be rather complicated and normal approximations of many statistical tests may not apply (Sokal and Rohlf 1969; Cochran 1977). Cochran (1977) found a jackknife variance estimate for ratio estimates to be promising and recommended further study. Smith (1980) found the jackknife variance estimate of TCPH superior to a regression estimate.

Recreational angling data collected to the nearest 1.0 min (time) at Horsefall Beach, Oregon, is used to determine if CPUE is an abundance index for *A. rhodoterus* recreational catch statistics. Confidence intervals of $\pm$ 1 fish per hour were found for TCPH, and a Poisson distribution was found appropriate for modeling catch in this fishery. Recreational angling statistics can be used to analyze *A. rhodoterus* surf fisheries as long as these confidence intervals are used and the same angling and analysis procedures followed.

METHODS

Horsefall Beach is located approximately 12 km north of the entrance to Coos Bay, Oregon. The paved access road behind the foredune (the only one south of Umpqua River access) makes Horsefall Beach unique within the 38.6 km of beach between the Coos and Umpqua River entrances. Horsefall Beach was chosen for study because of its reputation as a productive surf fishery, its proximity to an estuarine fishery, and its recommendation by fishery biologists overseeing the MRFSS.

Five anglers fished along an 8 km stretch of beach concentrating within 500 m of the Horsefall Beach parking area. The angling rig consisted of two hooks (size 4 to 8) baited with ghost shrimp, *Callianasa californica,* attached at approximately 30 cm intervals above a 28 to 57 g lead sinker. The gear used by angler 4 was not recorded. A variety of rods, reels, and wading boots were used by the different anglers. All trips were made between July 26 and September 9, 1987 during incoming tide. Morning, noon time, afternoon, and evening trips were included (Appendix C).

Start, catch and stop times were recorded to the nearest minute for each angling trip. Start was defined as when the bait entered the water, catch as when the catch was removed from the hook, and stop as when the line was removed from the water or when the last catch was unhooked. Species caught was recorded with each catch time. Angling time included soak time, gear retrieval, handling the catch, rebaiting, and redeploying gear. Time walking to, from, and between fishing locations or other non-angling time was not included in the analysis. From field records minutes angling per catch (MPC), catch (catch per trip), catch per minute (CPM, catch per trip/minutes per trip), catch per hour (CPH (= CPM * 60)), and timing of catch (relative to start and time of day) were calculated.

Monte Carlo Simulations

Monte Carlo simulations calculating TCPH were developed using QBASIC® programming language and personal computers (Appendix A). A total of 500 TCPH values were used for simulation distribution plots, with each TCPH value calculated from 16 trips randomly picked with replacement from sampled trips (Table 3). Average catch per trip simulations using 16 trips (randomly sampled from Table 3 with replacement) and 500 points for distribution plots were also run (Appendix A).

Table 3. Catch and effort values used for TCPH Monte Carlo simulations of the *Amphistichus rhodoterus* fishery and analysis. Hours listed are the next higher 0.5 h above the minutes fished. Time period abbreviations are N noon (midday), M morning, E evening, and A afternoon.

		Start	Time			Effort	
Trip	Date	Time	Period	Angler	Catch	Minutes	Hours
1	8-6	1045	N	1	8	150	2.5
2	8-7	0857	M	1	2	106	2.0
3	8-8	0800	M	3	1	147	2.5
4	8-8	0800	M	1	6	147	2.5
5	8-10	1952	E	1	6	63	1.5
6	8-11	1135	N	1	3	39	1.0
7	8-11	1900	E	1	6	103	2.0
8	8-12	1107	N	1	3	74	1.5
9	8-22	0759	M	1	1	146	2.5
10	8-31	1209	N	1	5	115	2.0
11	9-1	1322	A	1	16	135	2.5
12	9-1	1404	A	4	10	96	2.0
13	9-2	1647	A	1	9	56	1.0
14	9-5	1649	A	1	3	76	1.5
15	9-5	1649	A	5	4	76	1.5
16	9-9	0956	M	1	1	60	1.0

An angler skill simulation was also conducted using six skill levels derived from field data. For example, on 8-8-87, Anglers 1 and 3 caught 6 and 1 *A. rhodoterus*, respectively, in 147 min of angling (Appendix Table 44). Catches of 1, 2, 3, 4, 5, and 6 fish in 147 min were originally used as skill levels, but were adjusted upward to 6, 7, 8, 9, 10, and 11 fish (in 147 min) to have a mean similar to the Angler 1 simulation (Figure 3). Statistical

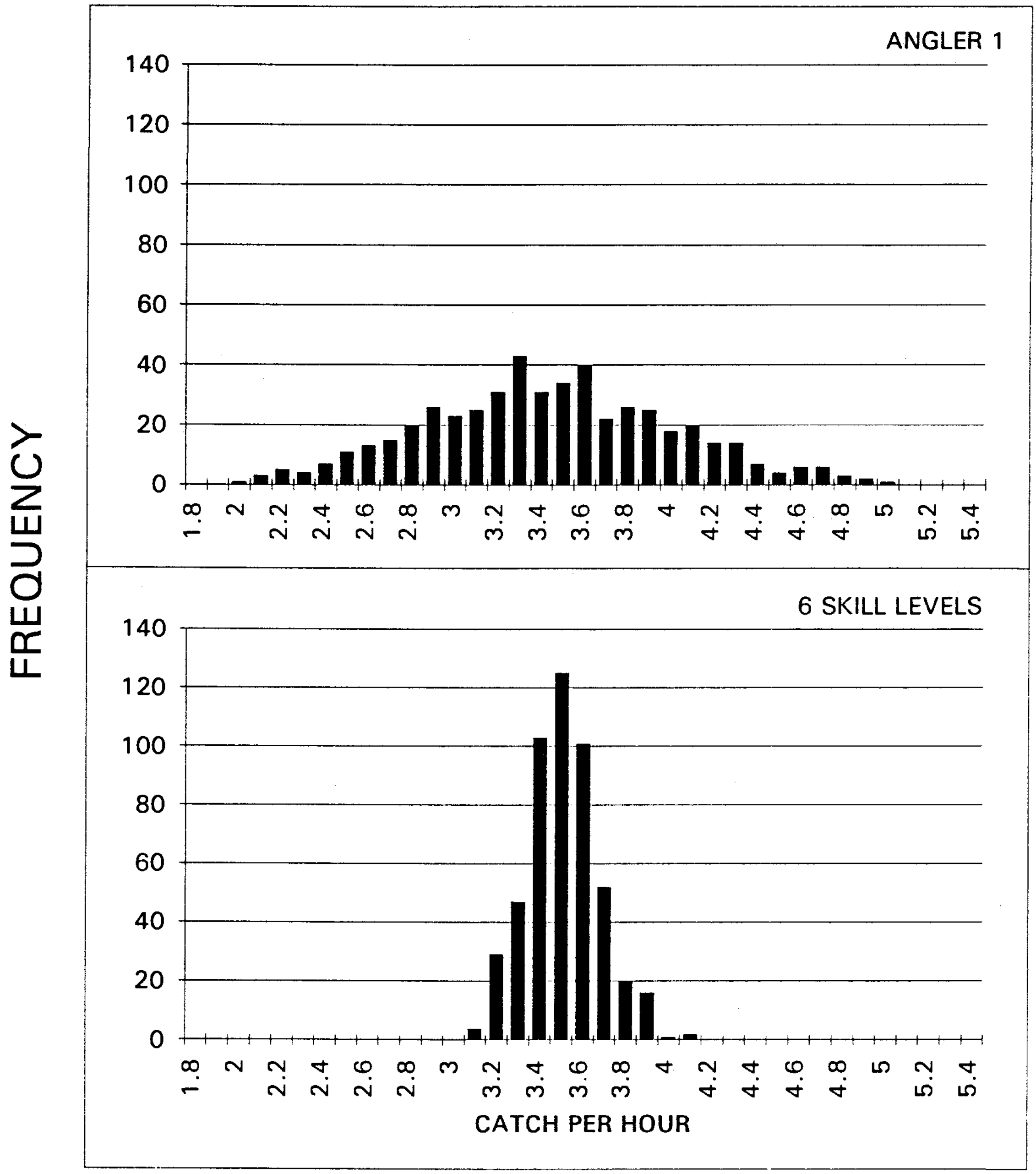

Figure 3. Distributions of the total ratio estimate of catch per hour (TCPH) generated by Monti Carlo simulation for a single angler on different days, and for six anglers catching 6, 7, 8, 9, 10, and 11 fish in 147 min (6 skill levels). Angler 1 was the author. Each graph represents 500 TCPH values each calculated from 16 angler trips.

analysis was conducted using Statgraphics® statistical software version 5.0, and by hand. The G-test ($p \leq 0.05$) was used for comparing distributions (Zar 1974). Statistical power of G-tests was determined using chi-square methods of Cohen (1977). A similar amount of time (2278 min) was spent angling for *A. rhodoterus* in Coos Bay (late May through early August, 1987). Only one redtail surfperch was caught, so comparing the estuary and surf fisheries was not attempted. A concurrent beach seine survey of Coos Bay (March through October, 1987) captured hundreds of surfperch similar in size to surf caught *A. rhodoterus*, but only 13 *A. rhodoterus* (methods in Fisher and Pearcy, 1989).

RESULTS

Fishery Description

Eighty four *A. rhodoterus*, 39 *H. ellipticum*, 30 staghorn sculpin, *Leptocottus armatus*, 2 shiner perch, *Cymatogaster aggregata*, and 4 Dungeness crab, *Cancer magister*, were caught in 21 surf angler trips totaling 2292 min of angling (Appendix Table 44). Trips ranged from 39 to 291 min. Harbor seals, *Phoca vitulina,* were noted at the water surface within 100 m of the bait on five occasions. Two anglers were present when one harbor seal was spotted. Catches of *C. magister* and *C. aggregata* were not included in the statistical examination because of low sample sizes. On average 2.2, 1.0, and 0.8 *A. rhodoterus*, *H. ellipticum*, and

L. armatus, respectively, were captured per hour of fishing. Catch rates ranged from a low of 0.0 fish per hour for all species to a high of 9.6, 12.0, and 4.66 for *A. rhodoterus*, *H. ellipticum*, and *L. armatus*, respectively. Five trips were unsuccessful at capturing *A. rhodoterus*, while this was the only species caught on five other trips. *Amphistichus rhodoterus* were caught at a higher rate than the other species on five of the trips, at the same rate as another species on three trips, and at a lower rate than other species on three trips (Table 4).

Table 4. Catch per hour of species from the Horsefall Beach surf fishery during 1987.

Date	Angler	All	*Amphistichus rhodoterus*	*Hyperprosopon ellipticum*	*Leptocottus armatus*
7-26	1	1.9			1.88
8-6	1	4.4	3.20	0.80	0.40
8-7	1	2.3	1.13		1.13
8-8	2	1.0		1.00	
8-8	3	0.8	0.41		0.41
8-8	1	2.9	2.45		0.41
8-10	1	5.7	5.71		
8-11	1	4.6	4.62		
8-11	1	8.1	3.50		4.66
8-12	1	2.4	2.43		
8-14	1	1.2			1.18
8-15	1				
8-22	1	1.6	0.41		1.23
8-23	1	0.5			0.49
8-31	1	14.6	2.61	12.0	
9-1	1	12.4	7.11	4.89	0.44
9-1	4	8.7	6.25	0.63	1.86
9-2	1	9.5	9.46		
9-5	1	3.2	2.37	0.79	
9-5	5	3.2	3.16		
9-9	1	2.0	1.00		1.00

Catches occurred from 1 to 106 min after baits entered the water with 5 and 4 min being the most common for *A. rhodoterus* and *H. ellipticum*, respectively (Figure 4). *Leptocottus armatus* were most commonly caught 6 and 8 min after the bait entered the water (Figure 4). The frequency of MPC for *A. rhodoterus* was $\geq$ frequency of MPC of all other species, except for 1 and 17 min (Figure 4). No significant relationship was found between MPC and the elapsed fishing time. All species were caught two or three times within one minute of the bait entering the water. Consistent patterns of CPH were not found for individuals angling at the same location and time (Table 5). The ratios of individual angler catchability coefficients varied with species and anglers (Table 6). Timing of catch between anglers fishing simultaneously did not follow a consistent pattern (Appendix Table 44). Catch per hour varied between angling trips, with the highest values occurring within a few days of the full moon (Figure 5). The TCPH was lowest in morning and highest in afternoon trips (Table 3).

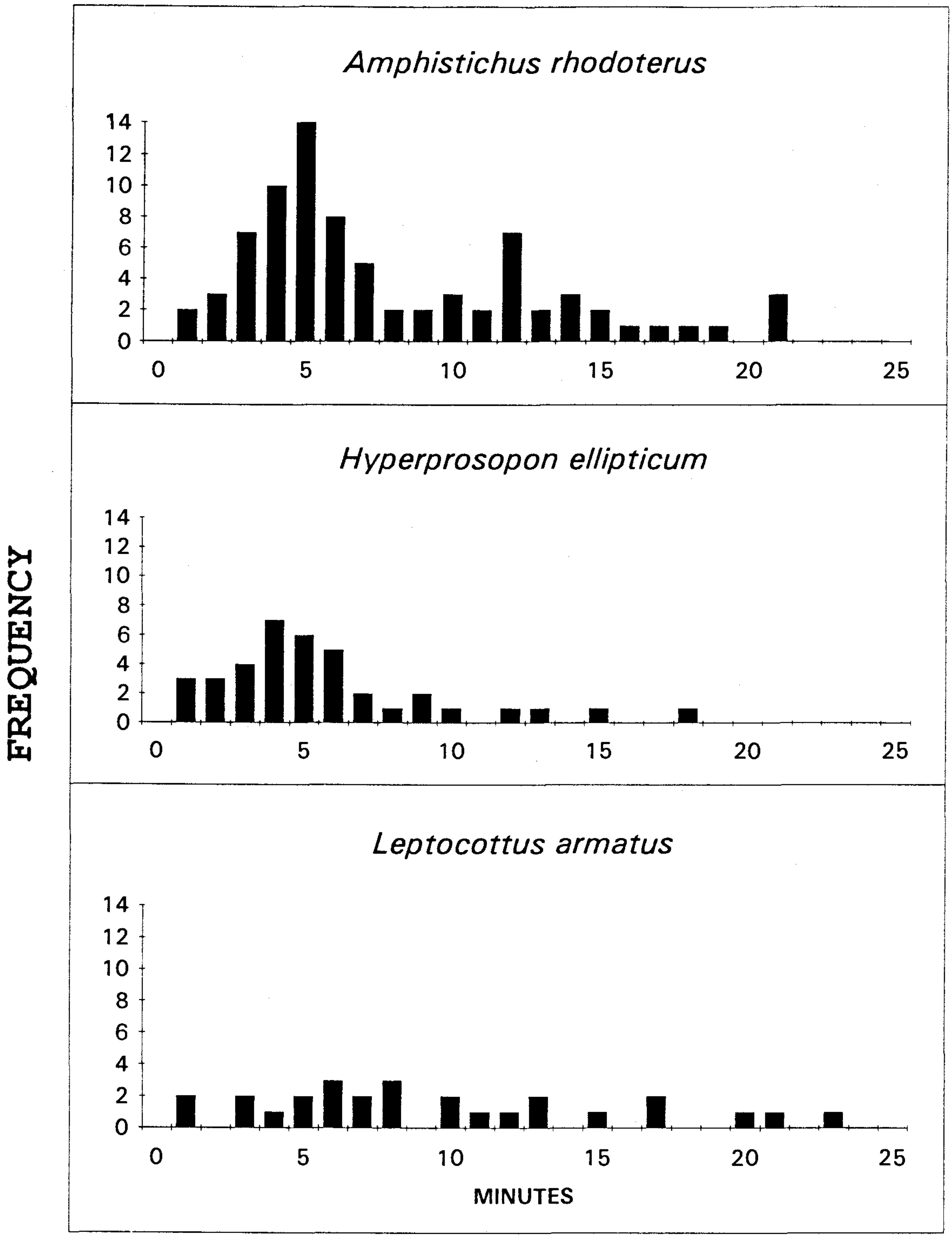

Figure 4. Frequency distribution of minutes per catch for the three most commonly caught species at Horsefall Beach, Oregon during 1987.

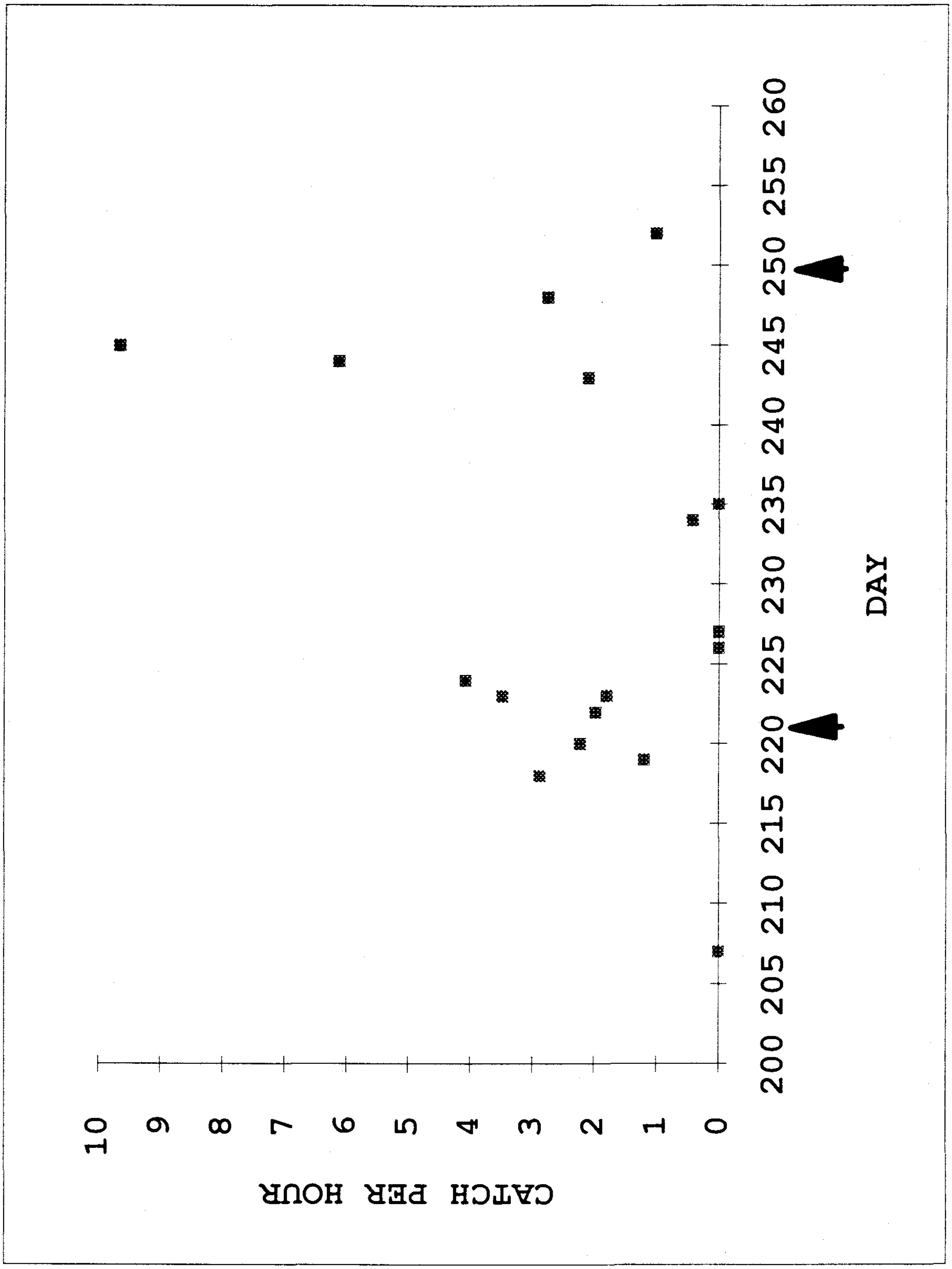

Figure 5. Catch per hour of *A. rhodoterus* at Horsefall Beach, Oregon for 1987. Arrows indicate the full moons on day 221 (August 9th) and day 250 (September 7th).

Table 5. Comparison of catch per hour and number of fish caught for anglers fishing simultaneously at Horsefall Beach, Oregon during 1987. The number of fish caught is listed as (N).

Date and Angler	Minutes Fished	Catch Per Hour (N) *A. rhodoterus*	*H. ellipticum*	*L. armatus*
8-8-87				
1	147	2.449 (6)	(0)	0.408 (1)
2	60	(0)	1.000 (1)	(0)
3	147	0.408 (1)	(0)	0.408 (1)
9-1-87				
1	135	6.576 (16)	4.521 (11)	0.411 (1)
4	96	6.252 (10)	0.625 (1)	1.875 (3)
9-5-87				
1	76	2.368 (3)	0.789 (1)	(0)
5	76	3.158 (4)	(0)	(0)

Table 6. Ratios of species-specific catchability coefficients calculated for angling pairs fishing simultaneously at Horsefall Beach, Oregon during 1987.

Anglers	Catchability Coefficient Ratio *A. rhodoterus*	*H. ellipticum*	*L. armatus*
1:2			
1:3	6.0		1.0
1:4	1.052	7.233	0.219
1:5	0.75		

Catch of any one species was not significantly correlated with the catch of another. Simultaneous catch of fish of the same species occurred four times for *A. rhodoterus*, six times for *H. ellipticum*, and once for *L. armatus* (Appendix D). Simultaneous catch of *A. rhodoterus* with *H. ellipticum* occurred four times, and with *L. armatus* twice (Appendix D). No other simultaneous catch of fish occurred. The catch frequency of zero, one, and two fish at a time was not statistically different from the Poisson distribution when species are considered individually or combined (G-test, p= 0.05)(Appendix C).

Monte Carlo Simulations

The simulated TCPH distribution using one angler over time is considerably broader and flatter than the distribution representing six angler skill levels equally (Figure 3). For the simulation of six skill levels, 95.4% of the TCPHs fall between 3.2 and 3.8, a range of 0.6 CPH, while 95.0% of Angler 1 TCPH's fall between 2.4 and 4.6, a range of 2.2 CPH. The simulated TCPH distribution using all anglers is slightly broader and the mean higher when minutes angling is used to measure effort as compared to rounding effort up to the next highest half-hour (Figure 6). The mean of simulated TCPHs calculated by minutes angling was 3.2, and 95.8% of the values fall between 2.1 and 4.6, a range of 2.5 CPH. The mean of simulated TCPHs calculated by rounding hours fished to the half-hour was 2.9, and 96.0% of the values fall between 1.9 and 3.9, a range of 2.0 CPH. Average catch per trip values were between 3.6 and 7.6 for 95.6% of simulated trips.

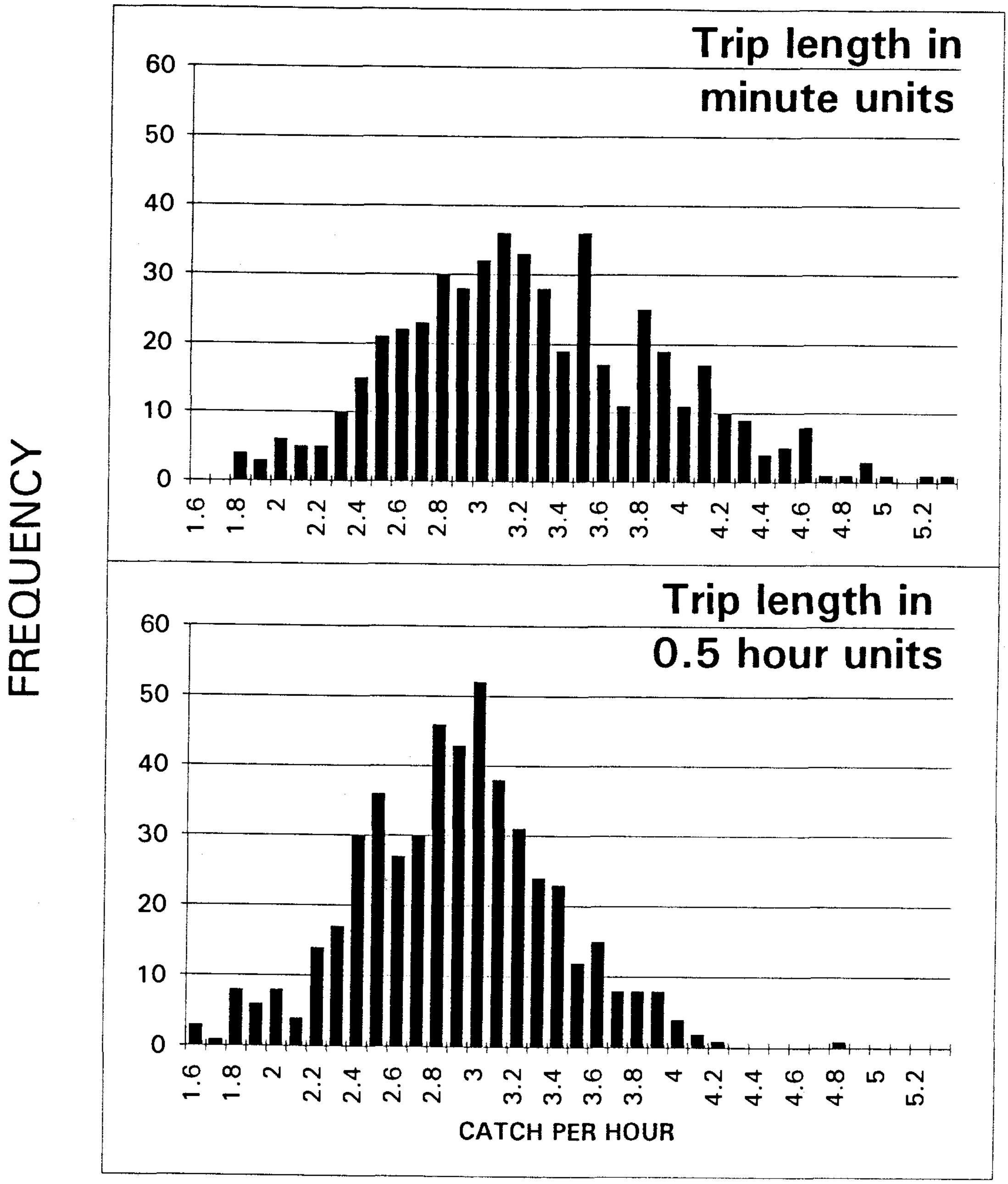

Figure 6. Distributions of the total ratio estimate of catch per hour (TCPH) generated by Monte Carlo simulation for all angler trips with trip duration recorded as minutes angling and trip duration rounded to the next higher one-half hour. Each graph represents 500 TCPH values each calculated from 16 angler trips.

DISCUSSION

Fishery Description

The average catch rate of 2.2 *A. rhodoterus* per hour is higher than reported from other studies (Miller and Gotshall 1965; Culver 1980), but is expected as other studies included non-angling time effectively increasing the time per trip slightly. The 2.2 fish per hour is a minimum of three times the catch rates used in analysis of CPUE and stock density for other species by Peterman and Steer (1981), and Bannerot and Austin (1983). The use of frequency of zero catches for an index of abundance as recommended by Bannerot and Austin (1983) would be ineffective because unsuccessful trips would be at this catch rate (<2.5% of trips based on catch per trip simulations).

The higher *A. rhodoterus* catch near the time of full moon can not at this time be explained by any hypothesis more substantial than coincidence or lycanthropy. Two full moons occurred during field sampling, but the magnitude and timing of high catch rates were not the same in both cases. Perhaps *A. rhodoterus* concentrate in certain areas to exploit rich feeding areas developed during spring neap tidal and sediment transport cycles. But this fails to explain why similar increases in catch rate do not occur near the time of new moon.

Higher catch rates occurred later in the day, but could reflect a bias towards more frequent morning samples early in this study. A seasonal change cannot be excluded as a possible cause of higher afternoon catch rates.

Handling Time and Gear Saturation

Handling time was $\leq$1 min (Figure 4). *A. rhodoterus* do not fight extensively, are most often hooked in the lip, and once in hand, are usually placed in a collection bin quickly. This result is consistent with other anglers' performance but may be biased toward the handling time of the author (Appendix Table 44).

Gear saturation (no hooks available when fish are available) can result in constant CPUE especially at high population levels (Beddington 1979; Deriso and Parma 1987). The low handling time and the top catch rate of 14.6 fish per hour indicated that the gear was not saturated.

Handling time does bias the CPUE stock density relationship. An overall catch rate of 4.1 fish per hour and a 1 min handling time per fish (4.1 fish in 55.9 min soak time) calculates to a CPH of 4.4, a 6.8% average underestimate bias due to the inclusion of handling time in angling time. This bias is present in all *A. rhodoterus* recreational angling statistics including the MRFSS. The handling time bias increases as the catch rate increases and vice versa.

The handling time bias also relates to variations in the handling time of other species. Corrections in *A. rhodoterus* TCPH for handling time at catch rates below 6 fish of all species per hour (equivalent to 3.3 *A. rhodoterus* per hour in this study) are 10% or less. Without knowing the catch of other species or the exact handling time, TCPH corrections below values of 6 are not recommended because the correction would be 10% or less. Any time systematically counted as effort but not spent as soak time leads to a bias (Beddington 1979). In this study, non-soak time was included in the time between a catch and starting (soaking) again.

Competition for Hooks

Catch of a competing species can result in changes in CPUE not due to changes in abundance (Polovina 1986; Deriso and Parma 1987). In this fishery, *A. rhodoterus* were caught in approximately equal number to all other species combined. The catch of all species combined did not saturate the gear. *Amphistichus rhodoterus* were caught at a lower rate than other species on only 3 of the 16 trips, and catch rates of all species were not significantly related. Distributions of MPC for other species were similar to *A. rhodoterus*, or had higher modal values. Redtail surfperch had higher frequencies of MPC in most minute categories than did other species. Lastly, handling time was not a large percentage of the time spent fishing for any species. Competition by other species for hooks could be a factor on individual trips, but on average was not a large factor affecting *A. rhodoterus* TCPH. Although unlikely, competition for hooks may be a factor in the MRFSS *A. rhodoterus* data and needs to be considered.

Monte Carlo Simulations

Three features of data used for the Monte Carlo simulations need explanation. First, no unsuccessful trips (24% of all trips) were used in the simulations because the MRFSS data included only successful trips and this analysis aims to estimate the resolution of the MRFSS data. Second, the successful trip CPH range (0.4 to 4.6) was similar to MRFSS Horsefall Beach CPH range (Appendix Table 31). Third, 16 trips is similar to or smaller than MRFSS Horsefall Beach sample sets (Appendix Table 30). The resolution of the fishery analysis based on the simulations would be conservative due to the size of the sample set and the high variance associated with a wide range of CPH values. Using a high variance would be a conservative estimate for the resolution of MRFSS data. Questions about how MRFSS survey methods affect TCPH can be addressed because CPM data are more accurate than MRFSS data.

Simulated TCPH frequency distributions depict that a range of skill levels contributes less variance to the TCPH statistic than is characteristic of one angler's skills over 46 d (Figure 2). A small amount of variance is added when the three trips by other anglers are added to the 13 Angler 1 trips (Figure 5). The main source of variance in the TCPH simulation data was from a single angler over time.

In the MRFSS interviews, fishing trips were rounded to the half hour with the predictable results of decreasing the variance (less options for effort estimates and thus less variance) and decreasing the mean TCPH (by increased effort as catch remained constant). A careful study of the relationship between angling time and trip time in recreational surveys would better define the resolution of TCPH values. The confidence intervals predicted from trips without rounded hours were only 0.5 fish per hour wider than when hours were rounded. A careful study of how angling time and trip time relate when recreational surveys are conducted would better define the resolution of the TCPH values. Based on the values of approximately 95% of the TCPH simulations, confidence intervals of the mean plus or minus one fish per hour are recommended when 16 trips are sampled. The bias due to inclusion of handling time is small compared to TCPH confidence intervals.

The TCPH variance would increase if different categories of trips were more successful than others, and were sampled disproportionately. Trip success would vary if searching efficiency changes or something like learning occurs during the trip, making longer trips more successful than shorter ones (Beddington 1979). The TCPH variance could also increase due to local depletion of the resource over the length of a trip. Success itself may influence trip length. In this study no supporting evidence was found correlating the trip length with catch (success) and no pattern of success early or late in the trip was found. Trip success could change if angling location was chosen on the basis of another angler's success. In this study, angling location was chosen before arriving at the beach.

Disproportionate numbers of skilled anglers can affect TCPH. A non-statistical comparison of angler skill was possible for this study. In the case of *A. rhodoterus*, Angler 3 was less successful than the other anglers (Table 5). Angler 3 attributes his lack of success to the assistance he was giving his wife, Angler 2 (C. Sharpe, Oregon State University, Department of Fish and Wildlife, personal communication). Catch differences for other species were not consistent between anglers (Table 5) and were probably the result of subtle knowledge, gear, or technique differences rather than skill. The addition of trips by anglers other than Angler 1 to TCPH simulations slightly increased the variance and did not increase the range of catch and hours used in calculating TCPH. The variance associated with anglers of different skill levels does not appear to be of large consequence when TCPH is measured over long time intervals.

Catch Model

The Poisson Distribution has been used to model catch processes (Kirkwood 1979; Deriso and Parma 1987; Sampson 1988). A test of the appropriateness of these distributions have not been conducted. The *A. rhodoterus* surf fishery data can be used to test the Poisson model because use of multiple hooks results in the catch of more than one fish at a time (a key part of the Poisson Distribution). Deriso and Parma (1987) provide a model for fishing a line with two baited hooks, but model the second hook as a "back-up bait supply". At Horsefall Beach during 1987, hooks often caught fish simultaneously; 17 of 136 catches had fish on both hooks. By measuring catch on the scale of minutes (the handling time), the frequencies of 0, 1, and 2 catches are integers allowing for statistical tests. Catch frequencies were not significantly different from the Poisson Distribution (Appendix C) demonstrating the appropriateness of this distribution for modeling the fishery.

Resolution

Resolution of *A. rhodoterus* recreational surf fishery analysis using TCPH was affected by two main factors: confidence limits for the estimate, and handling time bias. Handling time bias is expected to be 10% or less for catch rates lower than 3.3 *A. rhodoterus* per hour. Confidence intervals (95%) were ± one fish per hour at TCPH=3. Thus, the analysis resolution was dominated by the confidence intervals, and TCPH differences of greater than two fish per hour are likely significant.

CONCLUSION

The dominant species caught by surf anglers was *A. rhodoterus* with *H. ellipticum* and *L. armatus* each captured at roughly half the rate of *A. rhodoterus*. Competition for hooks and gear saturation were not important factors in controlling CPH in the Horsefall Beach fishery. Handling time of all species caught introduces a negative bias, generally less than 10%, in CPH values. Confidence limits for *A. rhodoterus* TCPH are mean $\pm$ one fish per hour at catch rates of 3.3 *A. rhodoterus* per hour: The Poisson distribution is suitable for use in modeling Horsefall Beach *A. rhodoterus* surf angling.

CHAPTER 4

POPULATION AND FISHERY STATUS OF REDTAIL SURFPERCH, *Amphistichus rhodoterus*, BASED ON DATA FROM THE RECREATIONAL CATCH

INTRODUCTION

Births, deaths, emigration, and immigration regulate population. These factors can be combined into a population model to hindcast abundance for correlation with known significant events, to forecast abundance and age structure, and to test the effects of management decisions before implementation. This chapter evaluates and uses the angler interview information from the Marine Recreational Fishery Statistics Survey (MRFSS) to construct an *Amphistichus rhodoterus* population model and two indexes; abundance and relative abundance of recruits. The indexes are correlated with several environmental variables to determine if population changes are related to changes in the environment. The goal of this chapter is to provide information to improve management, with models and indexes being a convenient method to combine and summarize the data.

Marine Recreational Fishery Statistics Survey

The goal of the MRFSS was to obtain estimates of participants, catch, and effort by recreational fishermen in the marine waters of the United States (USDC 1984a, 1984b, 1985, 1986, 1987). Information was collected by two complementary surveys -- a telephone survey of households, and an intercept survey of fishermen (USDC ibid.). Sampling effort of the west coast states was based on the square root of the coastal populations with state sampling effort apportioned to counties based on the square root of population (Jerry Butler, Oregon Department of Fish and Wildlife, personal communication). Sampling effort was divided into six, 2-month waves (JAN/FEB, MAR/APR,... NOV/DEC) for each of four fishing modes (beach/bank, man-made structures, charter boats, and private/rental boats) based on expected relative effort in each mode (USDC ibid; Jerry Butler, Oregon Department of Fish and Wildlife, personal communication). Interviewers selected sampling locations based on goals for county, wave, and mode, but several sites often had to be visited to reach interview goals (Elaine Stewart, Oregon Department of Fish and Wildlife, personal communication). Seventy-five percent of sampling effort was on weekends and holidays. Every nth angler was interviewed when a large number of anglers were present with n being selected by the interviewer (USDC ibid.).

The essential elements for the formation of an age structured population model using MRFSS data are population abundance, size distribution, offspring production, and length at age. A continuous 7-year series, 1979 to 1985, of

A. rhodoterus abundance and size distributions were available for Horsefall Beach, Oregon from the MRFSS. Gravidity and length at age was determined from fish caught at Horsefall Beach during 1987 (Chapter 3), and other Oregon locations from 1987 to 1992. Comparable gravidity, length at age, and size distributions were available for the central Oregon coast, Northern California, and Washington (Bennett and Wydoski 1977; Ngoile 1978; Culver 1980).

Offspring Production

To interpret the MRFSS data, the *A. rhodoterus* population segments producing offspring need to be identified, and the number of offspring produced by each quantified. For viviparous *A. rhodoterus*, the number of mature fish is not the concern; rather the percentage of the population that are gestatory needs to be identified and quantified. No current information is available and such information is vital to using the MRFSS data in a population model.

The percentage of *A. rhodoterus* that are gestatory has not been recorded during recent fishery surveys, so must be estimated from another variable. Sexual maturation and gravidity can be related to length, which is one of the most commonly available fishery statistics. MRFSS length at harvest data are used to estimate gravidity and offspring production for population models.

Length Frequencies

Length frequency distributions can be tabulated from catch or catch per unit effort (CPUE) statistics. Length frequency distributions based on CPUE weight each hour of fishing equally, while distributions based on catch weight each fish equally. Anderson and Gutreuter (1983) recommend the use of CPUE for analysis of population length frequencies without describing the differences between catch- and CPUE-based methods. In this chapter, the differences between methods were compared using computer modeled data, and the results used to analyze *A. rhodoterus* populations sampled by the MRFSS.

Length frequency distributions of catch were examined to determine if population changes other than total abundance occurred. Changes in length frequency distributions can occur for any number of reasons including availability, ontogenetic migration, and fishing mortality. But, specific changes can be predicted as a fishery of an unexploited resource develops. Generally, the length frequency distribution of an unexploited fishery resource includes all sizes (ages) of fish with the smallest being the most abundant and larger fish progressively less so. This was the length frequency distribution for *A. rhodoterus* in the late 1960's and 1970's (Bennett and Wydoski 1977; Ngoile 1978). When a fishery starts, the length frequency distribution begins to change as fish are caught. The distributions for several years reflect a relative decrease in the number of larger fish. Often the largest sizes no longer occur in samples because their likelihood of being captured (death) increases with exposure to the fishery. The shift to smaller fish can continue until the remaining population no longer produces enough offspring to replace itself. Things to look for in length frequency distributions are the presence and relative abundance of larger fish and the distribution's position relative to the size where reproduction sustains the present population.

TCPH

Catch per unit effort is commonly used as a relative abundance index, and a general relationship between CPUE and stock abundance has been shown for other recreational species (Beddington 1979; Peterman and Steer 1981; Bannerot and Austin 1983; Malvestuto 1983; Quinn 1985; Richards and Schnute 1986; Bennett and Attwood 1991; Richards and Schnute 1992). The total ratio estimate of CPH (TCPH) is the total catch divided by the total effort during any time period, and will be used as a relative abundance index. Computer simulations estimate the bias in TCPH due to the exclusion of unsuccessful anglers in the data, and examine the behavior of the TCPH jackknife variance estimator under recreational fishery sampling conditions (Cochran 1977; Smith 1980).

Explanations for population decreases and shifts toward a population unable to reproduce itself are varied. Many of the population changes noted can be explained by migration or natural sources of mortality. Natural sources of mortality can be density dependent or density independent, and modifying fishing mortality has little effect on populations controlled by density independent mortality. Angling proves to not be correlated to these changes, and halting angling may not change population trends. However, angling for a population that is below optimal levels, no matter what the cause, complicates any attempt at recovery.

Six factors that may explain changes in *A. rhodoterus* recruitment and abundance are: density dependant factors, temperature during gestation, wave height (directly influencing feeding or indirectly influencing the amount of detritus available for the beach ecosystem), upwelling (directly producing food, or indirectly producing kelp which fuels detrital based ecosystems), angling effort, predation by harbor seals.

The correlation of these environmental variables with recruitment and abundance attempts to identify the following: if *A. rhodoterus* recruitment and abundance are controlled by density dependant factors; which environmental factors help control *A. rhodoterus* recruitment and abundance; and the age or life stage when environmental factors act on *A. rhodoterus* recruitment and abundance.

The *A. rhodoterus* fisheries examined were the largest sampled by the MRFSS and were all, with the exception of Horsefall Beach, sustainable. Relative abundance was most closely correlated with the spring and fall physical environmental conditions of the previous 18 months. Recruitment index was most closely correlated with June upwelling 2 years previous. Evaluation of *A. rhodoterus* population and fishery status using recreational catch data required using additional reproductive and ageing information. Examination of the Horsefall Beach *A. rhodoterus* fishery for overharvest after 1986 was recommended.

METHODS

MRFSS Angler Interview Data

Oregon MRFSS angler interview data were obtained from Elaine Stewart, Oregon Department of Fish and Wildlife, Newport, Oregon. Washington and California MRFSS angler interview data were obtained from Russell Porter, Pacific States Marine Fisheries Commission, Portland, Oregon. Records of *A. rhodoterus* catches were copied from the angler interview data into a data set including only *A. rhodoterus* (Appendix A). Monthly angling statistics, July 1979 through December 1989, were calculated for all locations with *A. rhodoterus* capture records (Appendix A). Using these monthly statistics, the survey coverage was insufficient for a meaningful monthly analysis.

Annual length-frequency distributions, catch, and effort were tabulated for locations in Washington and Oregon with 80 or more measured lengths, and with 50 or more measured lengths for California (Appendix A). Length-frequency distributions were based on relative catch (TCPH times the fraction of the annual sample at each 1 cm length). For Washington, the following locations and MRFSS site numbers were included: Columbia River North Jetty (4) and Beard's Hollow (6) in Pacific County; Westport Beach (27) and Damon Point (35) in Gray's Harbor County; and Kalaloch Beach (51) in Jefferson County (Figure 7). Oregon locations were Horsefall Beach (76) in Coos County and Jetty Sands (3) in Clatsop County (Figure 7). California locations were Freshwater Lagoon (23205) and King Salmon (23216)(Buhne Point, Humboldt Bay) in Humboldt County (Figure 7). Populations were defined as the *A. rhodoterus* captured at a given location. Unique length frequency distributions for the locations listed above supported the individuality of populations. Information from other locations was examined, but was not included in the written text because of low sample sizes (Appendix A).

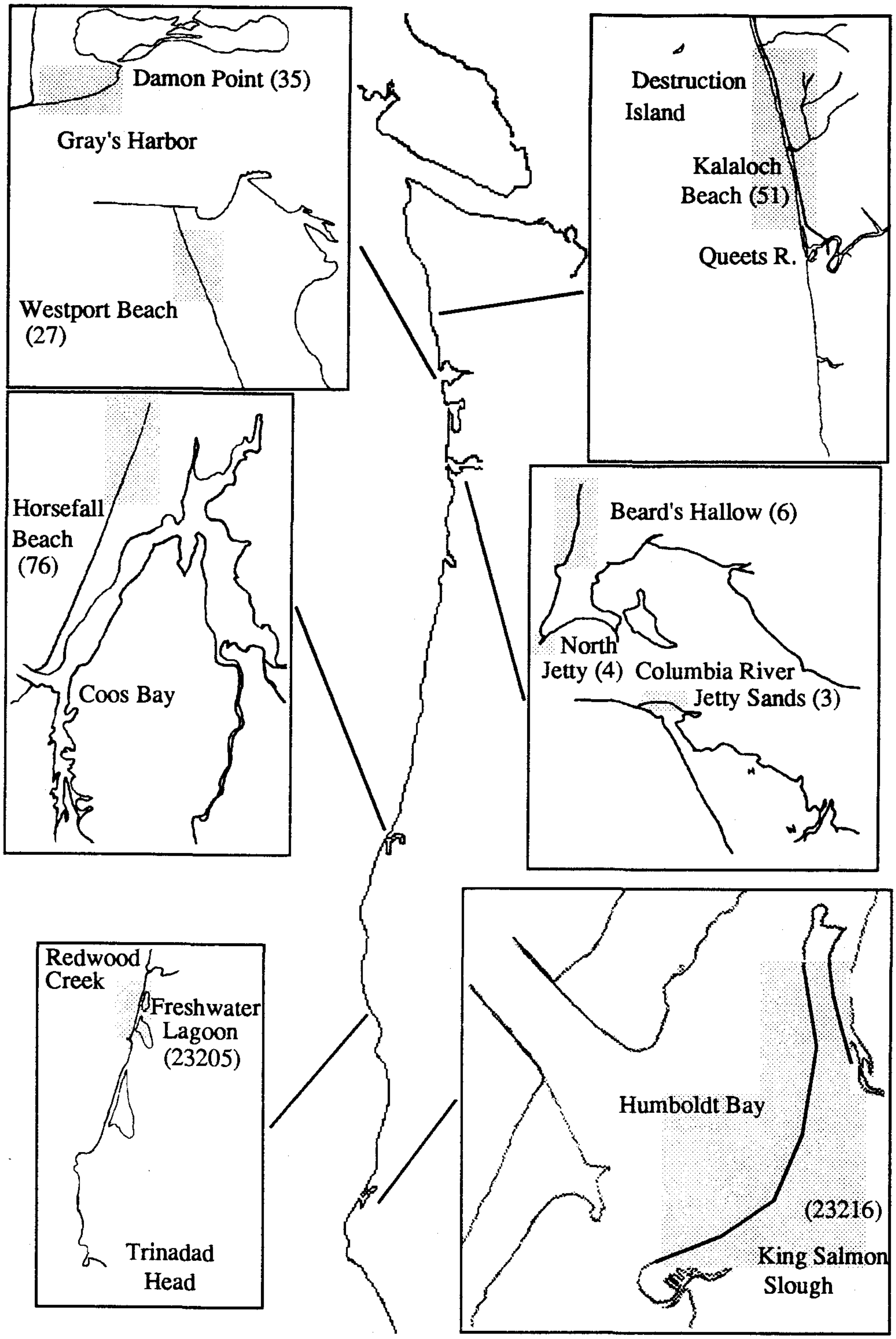

Figure 7. *Amphistichus rhodoterus* sample locations from the Marine Recreational Fishery Statistics Survey for which data were analyzed. Shaded areas are approximate boundaries. Area maps are not to scale.

Computer Simulations

A computer model, the Core Model, was developed to simulate the Horsefall Beach *A. rhodoterus* surf fishery and was modified to study the effects of data constraints on length frequency distributions, sample bias, and TCPH variance. The Core Model randomly determined the duration of each fishing trip (effort) and then simulated angling for that length of time while tabulating catch. Effort for each trip (hours fished) was randomly picked from a normal distribution of 0.5-h intervals with a mean of 3 h and standard deviation of 1.17. For example, the *A. rhodoterus* surf zone fishery at Horsefall Beach had a mean monthly hours per trip of 2.87 and a standard deviation of 1.17 for July to November 1979, 1980, and 1981 (Appendix A). Once the number of hours was selected, hours were converted to minutes for use as a parameter in generating catch. Catch was generated by randomly sampling a Poisson distribution of catch per minute (CPM) for each minute of simulated fishing effort. Zero, one, or two fish were the simulated catch possibilities for each minute fished, with the probability of catching two simulated fish being the sum of the expected probabilities of catching two to six fish at one time. Including the probabilities of catching more than six fish at once did not change the overall probability above the tenth significant digit. Trip catch and effort were then used to generate data for either length frequencies, TCPH, or TCPH variance. The number of angling trips simulated by the core model varied depending on the comparison.

Length frequency data were simulated by a Length Frequency Model that used catch from the Core Model. Average catches of 50 and 100 were simulated with the exact numbers (N) determined by the model as outlined below. The Length Frequency Model randomly selected a CPH between 0.5 and 6.5 fish per hour and then calculated the number of trips needed to simulate catch of approximately N=50 or N=100 fish. The number of trips was calculated by dividing N by three times the mean catch rate and adding one (e.g. 100 fish/(3 h per trip * X fish per h) + 1). This number of trips was then used to generate catch stochastically using the Core Model as outlined above. Next, catch length data from a known distribution was randomly assigned to each simulated trip. The known length distribution was 1, 5, 12, 13, 10, 11, 9, 9, 12, 8, 4, 3, 2, 2, 1, 1 for 17- to 32-cm fish, and was similar to but not based on actual length frequency observations. Length data was then used to compare catch and CPUE based length frequency distributions.

The two length frequency estimators tested were the total catch for each 1 cm in length (frequency), and the total CPH for each 1 cm in length. The total CPH was calculated as the sum of CPH for each fish in each 1 cm size group (1 fish/hours for the trip when caught). Comparisons were based on correlation of catch and CPH in the 17- to 32-cm length categories with the original distribution (length for length with 16 lengths per correlation), and on G-tests of the log-likelihood ratios (Zar 1974; Steel and Torrie 1980). Statistics were calculated for each run of 100 length frequency model runs at N=50 and N=100. Mean correlation coefficients were calculated for each 100 runs and a paired t-test was used to evaluate if the differences between correlation coefficients were significantly different from zero.

A second modification of the Core Model, the TCPH Bias Model, simulated how the TCPH was affected when unsuccessful trips were excluded from calculations, and when only one hook was fished. Catch and effort generated by the Core Model was used to calculate TCPH using only successful trips and then using all trips. Successful trips were defined as trips during which at least one fish was captured. A range of mean catch rates (0.2, 0.4, ... 6.0) was simulated for comparison. The model was run using 7, 14, 21, 28, and 35 angler trips so that the catch and effort values associated with a lower number of trips were included in the sample used in calculations for the next higher number of trips (progressively). Multiples of 7 best mimicked the 1979 to 1989 MRFSS Horsefall Beach *A. rhodoterus* annual sample totals (Appendix A). As catch and effort were generated for the two-hook simulation, catch was also generated for a one-hook simulation. Successful trip TCPH was regressed (using an exponential model) against the difference between successful and all angler TCPHs for mean catch rates of 0.4

to 1.2 fish per hour and 35 trips. This regression equation was then used to predict bias-corrected TCPH values for the MRFSS.

The jackknife variance estimate for TCPH (Cochran 1977; Smith 1980) was also simulated by using a modified Core Model, the TCPH Variance Model. The TCPH Variance Model calculated the TCPH sample based on 7, 14, 21, 28, and 35 trips progressively so that each TCPH value included all previous trips. Samples of 4, 7, and 10 TCPH values were used progressively to calculate the TCPH jackknife variances (Cochran 1977). Samples of 4, 7, and 10 TCPH values included the range of annual TCPH values available from different MRFSS locations. Mean catch rates of 0.6, 1.2, 1.8, 2.4, and 3.0 were used. Jackknife variance estimates were also calculated using the annual TCPH samples from the MRFSS.

Age At Length

Amphistichus rhodoterus were captured by hook-and-line at Horsefall Beach from July through September 1987. Most angling was conducted within 500 m of the Horsefall Beach parking area, but fish captured within 8 km of the parking area were included in the analysis. Fish were collected by the author, research assistants, and other anglers who would permit their catch to be sampled. Total, fork, and standard lengths (TL, FL, and SL, respectively) were measured to the nearest mm and recorded along with capture information on envelopes into which scale samples were placed. Scales were removed from the side of fish as described by Bennett and Wydoski (1977). Total length measurements not taken because of fin damage were estimated from standard length measurements and conversion relationships developed by Bennett and Wydoski (1977).

Scales were examined with a compound microscope at a magnification of 25X. A graduated ocular lens was used to measure distances to birth marks, each annulus, and scale edges. Measurements were made along the anterior radius of the scale. Annuli were best identified by cutting over of the circuli on the dorsal ventral scale axis. Three to fifteen scales from each fish were used to determine age, and a single scale was measured. Age was rechecked three times and scale measurements were rechecked twice. A subsample of 13 scales (three each of ages 2 to 4, and one age 0) were examined for confirmation of aging procedure by Howard Horton, Professor Emeritus of Fisheries, Oregon State University. Back-calculations were based on modifications of the Fraser-Lee procedure using biological intercepts (Campana 1990). Biological intercepts are the fish length and scale radius at initial scale formation. The SL at scale formation and initial scale radius were estimated from data obtained from mid-gestation experiment embryos (Chapter 2). Estimates were based on the presence and absence of scales on embryos of different size (Appendix Table 60).

The formation and relative location of the first winter annulus on scales was confirmed for six *A. rhodoterus* born on Horsefall Beach and held at the Hatfield Marine Science Center Aquarium.

Gravidity

Female *A. rhodoterus* were captured from the Oregon coast by angling, beach seining, and gill netting. Total number of embryos was either counted after dissection or after birth and later verified by dissection. The TL and SL were recorded to the nearest mm; when TL was not measurable, SL was converted to TL using the relationship in Bennett and Wydoski (1977). Data were divided into either Lincoln County or Coos and Douglas counties because of overlap with Bennett and Wydoski (1977) and geographic proximity of samples in the two regions. Lincoln County samples were collected between Seal Rock and Yaquina Bay, the main ocean surf area sampled by Bennett and Wydoski (1977). Other samples were collected in Coos and Douglas counties, mainly from Horsefall Beach, but also in the Umpqua and Coos estuaries. Regression slopes and intercepts of female TL versus gravidity were compared using methods of Sokal and Rohlf (1981). Regressions were also compared to data contained in the appendix of Bennett (1971). For comparison with past studies, regressions excluded non-gravid fish. Non-gravid fish were included in regressions for the current data, but only if the fish length was ≥ the length of the smallest gravid fish. Minimum length of gravidity was defined as the length at which the gravidity at length regression line crossed y=1 (females carry one embryo) and was determined mathematically.

Population Models

Age Structured Model

Annual *A. rhodoterus* length frequency distributions from Horsefall Beach for 1979 to 1985 were obtained from the MRFSS. Annual bias-corrected TCPH was used to estimate relative population abundance. The TCPH bias due to using only successful anglers was corrected using both the regression equation from the TCPH Bias Model and the measured TCPH.

One-year-old fish, a small part of the MRFSS data, were not included in the model because the age class was apparently not completely vulnerable to recreational anglers. Two-year-old fish, 17- to 21-cm, were identified using size at age, back-calculated length, and length frequency plots presented later in this chapter. Fish three years old and older were grouped together as these age classes could not easily be identified based on size at age, back-calculated length, or length frequency distributions. (Attempts to use each cohort identification method for distinguishing age 3 and 4 fish resulted in population models similar to the one described here). Offspring production (age 0 fish) per 100 fish was determined based on the percent of CPH in each 1-cm size group and the gravidity at length regression equation for *A. rhodoterus* (e.g. 335 mm for the 33-cm size group). A sex ratio of 1:1 was assumed, requiring offspring production to be reduced by a factor of one-half. Numbers presented for age groups 2 and 3+ were calculated by multiplying the annual percent of the total population in the group by the TCPH. Annual mortality was calculated as the difference in cohort abundance from year to year.

Average Mortality Model

The percent of the total population sampled for each age was determined using the length at age relationship for female *A. rhodoterus* from this chapter (ages 1-4), and from Bennett and Wydoski (1977) (ages 5 and up). Lower length cutoffs were 19, 23, 27, 30, 32, 35, 38, and 40 cm TL for ages 2 through 9, respectively. The oldest age group representing <0.5% of the annual length sample was used as the *maximum age* for that year. The range of annual cohort mortality rates that would result in 0.5 to 1.0% survival to this maximum age (acting on age 2 and older fish) was determined mathematically and termed the *average 2+ mortality* (Appendix Table 63). The doubling of the percentage of fish surviving to age X (from <0.5% to 0.5-

1.0%) when calculating mortality rates accounted for the fact that the largest fish are females and the assumption that a similar number of males to survived to the maximum age. The average 2+ mortality was used in the Average Mortality Model to calculate the affect of mortality rate and the timing of mortality on population abundance.

The Average Mortality Model started with a population of 2,000 and ran for 35 years. Offspring production was calculated by entering the average female size at age for each age group into the gravidity at length equation, multiplying by the sex ratio (fraction of the population which was female), and summing for all age groups:

$$O = SR * \sum(G_a * N_a) \quad \text{for } a = 3 \text{ to } 9$$

O is the annual offspring production,

SR is the percent of the population that is female,

G_a is the mean gravidity at age a,

N_a is the number at age a.

Gravidity at age was calculated as:

$$G_a = (.203 * TL_a) - 46.1$$

TL_a is the mean female total length at age a.

Number survival to the next age class was calculated for each age class as:

$$N_a = N_{(a-1)} * (1 - m_a)$$

m_a is the mortality between age a-1 and age a.

Egg and embryo mortality was not modeled separately from the loss of adults because prebirth mortalities were excluded from gravidity analyses. The mortality of female fish included loss of any gestating embryos (embryo by-catch if the mortality was due to harvest). Mortality at age and timing of mortality (pre or post birth) were varied using the Average Mortality Model to determine the effect of these changes on population abundance. The model was used with constant mortality at all ages prior to parturition to make management recommendations.

Fishery Recruitment

A recruit index was formulated for the nine MRFSS locations. The index was calculated by multiplying TCPH by the fraction of the population in the most abundant year class. Age 2 fish were considered recruits in Oregon and Washington, and the age class defined as fish measuring 17 to 21 cm TL. Age 3 fish were considered recruits in California, and defined as fish measuring from 20 to 25 cm TL. The abundance of age 3+ fish was used as the parental stock size (Appendix E) and was lagged two years in Oregon and Washington stock recruit correlations. Stock recruit regressions were not made for California locations due to insufficient [less than 5] data points.

Environmental Correlations

Correlations of the recruitment index and TCPH for selected sites were made with monthly sea surface temperature, upwelling, significant wave height, and peak wave period; and with annual surfperch angling trips, commercial catch, and harbor seal counts (Appendix E). Beards Hollow, Columbia River North Jetty, and Horsefall Beach recruit indexes and annual TCPH values were used because they had five or greater years sampled. Correlations were also computed for monthly sea surface temperature and upwelling lagged 1 and 2 years previous to recruit indexes and TCPH year. Sea surface temperature data from Neah Bay, Washington, Charleston, Oregon, and Trinidad Beach, California were used (Scripps 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1986, 1994a, 1994b, 1994c). Upwelling indexes for 42°, 45°, and 48°N were obtained from Pete Lawson, Oregon Department of Fish and Wildlife, Newport Oregon (see Bakun 1973). Wave data from off Humboldt Bay, California, and off the Columbia River were provided by Sig Larson, Marine Minerals Management Service, Camarillo, California. Recreational angling trips were calculated using estimated total trips and percent of trips fishing for *A. rhodoterus* and surfperch from the MRFSS summaries (USDC 1984a, 1984b, 1985, 1986, 1987). Commercial catch statistics from Oregon (Lukas and Carter 1988) and from California (Gloria Hawks, California Department of Fish and

Wildlife, Long Beach, California) were used. Harbor seal, *Phoca vitulina*, counts used were made during June and July 1979 to 1984 at Shell Island, Cape Arago (15 km south of the Coos Bay entrance) (Brown 1988; Harvey et al. 1990).

Mean monthly significant wave height and peak wave period data from off Humboldt Bay and the Columbia River were used for correlations. Data from buoys 46010 and 46029 were combined for the Columbia River area, and from buoys 46022 and 30340 for the Humboldt Bay area (Earle and Eckard 1988). Wave data from months that were sampled by both buoys in an area were regressed using a linear model and the regression equation used to convert values from the smaller data sets to appropriate values for larger data sets. Data from buoys 46029 and 30340 were used to fill in months not sampled by buoys 46010 and 46022. For wave period at the Columbia River, two regression outliers (January 1985 and March 1986) were excluded from the overlapping sample month regressions.

Combinations of environmental variables were correlated to demonstrate that environmental variables were not random variables. Significant wave height and wave period were correlated for each month at each location and between locations (2 variables * 2 locations * 12 months = 48 correlations). Sea surface temperature and upwelling data for each month, and adjacent months were correlated between the three sea surface temperature and upwelling locations (678 correlations). Three different lags of 1 year each were used for sea surface temperature and upwelling resulting in 2034 correlations (3 * 678).

RESULTS

MRFSS Length Frequency Distributions

Kalaloch Beach (Figure 8)

Length frequency distributions of relative CPH from 1981, 1982, 1983, and 1985 were compared. The majority of the catch was in the 18- to 33-cm sizes for all years. The 30-cm size was most abundant during 1981 and 1982, and the 19- to 22-cm sizes second. The highest abundance during 1983 was the 30- to 31-cm size, though sizes less than 20 cm were common. Fish 37- to 40-cm in length were captured during 1981 and 1982. The 18- to 20-cm sizes were the most common lengths during 1985. Fish larger than 32 cm and 30 cm were absent during 1983 and 1985, respectively. Few 23- to 27-cm length fish were sampled during 1982. The TCPH ranged from 1.43 to 3.96 for 1981, 1982, 1983, and 1985, was lowest in 1982 and 1983, and highest in 1985 (Table 7).

Damon Point (Figure 9)

Length frequency distributions of relative CPH from 1982 through 1985 were compared. The 39- and 40-cm size groups were well represented in the 1982 sample, but did not

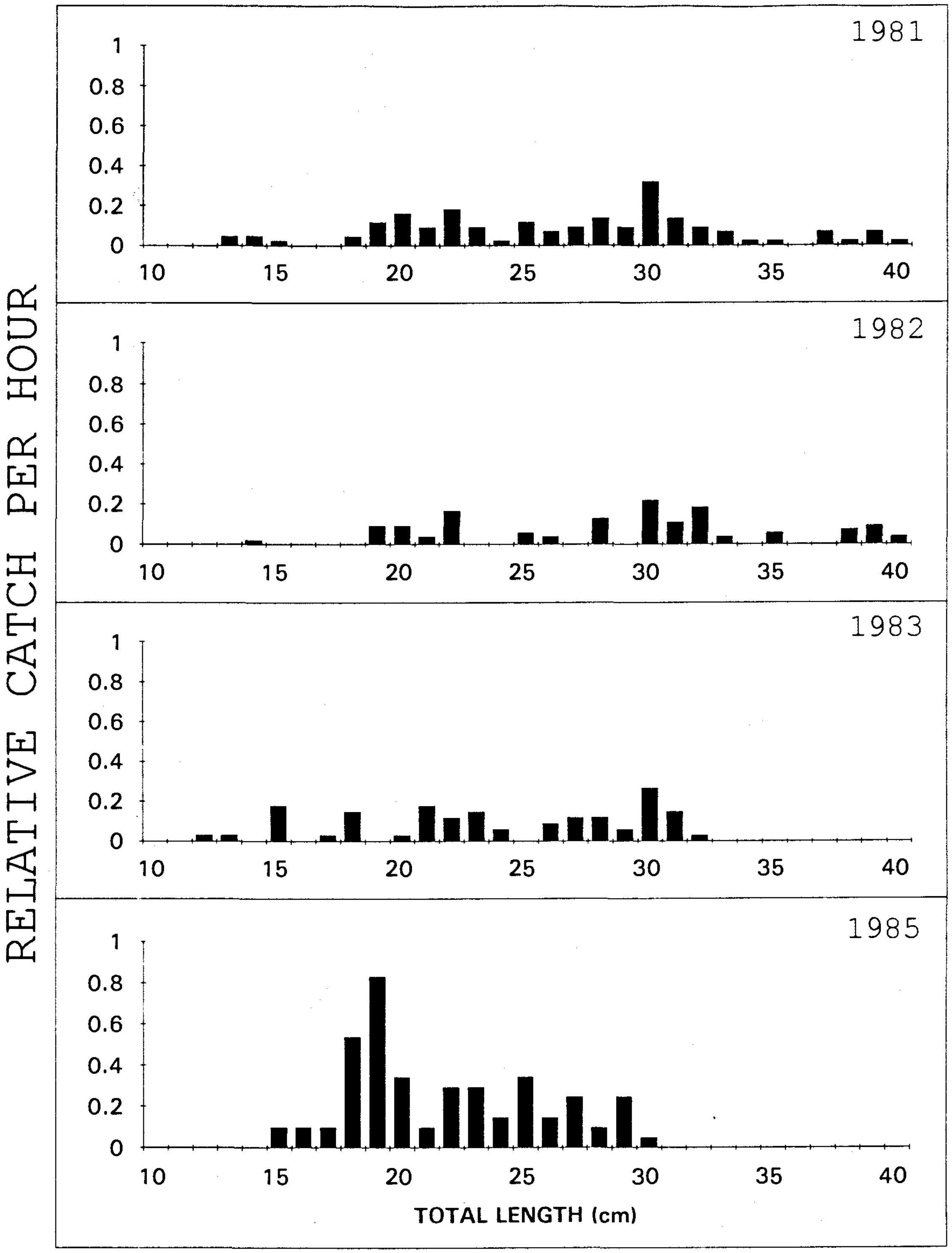

Figure 8. Relative catch per hour of redtail surfperch sampled at Kalaloch Beach, Washington. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

Table 7. Total ratio estimate of catch per hour (TCPH) and jackknife variance estimates for annual *Amphistichus rhodoterus* catch computed from the Marine Recreational Fishery Statistics Survey data base (Russell Porter, Pacific States Marine Fisheries Commission, Portland, Oregon).

Location	Year	TCPH	Jackknife Variance
Kalaloch Beach			
	1981	2.17	
	1982	1.43	
	1983	1.77	
	1985	3.96	
	mean	2.27	0.081
Damon Point			
	1982	1.58	
	1983	2.43	
	1984	1.88	
	1985	1.15	
	mean	1.76	0.061
Westport Beach			
	1982	5.43	
	1983	2.11	
	1984	4.94	
	1985	2.33	
	mean	3.70	0.973
Beards Hollow			
	1979	3.34	
	1980	2.38	
	1982	1.62	
	1984	1.64	
	1985	1.57	
	mean	2.11	0.085
Columbia River North Jetty			
	1979	2.86	
	1980	2.74	
	1981	1.81	
	1984	0.80	
	1985	2.34	
	mean	2.11	0.166

Table 7. continued.

Total ratio estimate of catch per hour (TCPH) and jackknife variance estimates for annual *Amphistichus rhodoterus* catch computed from the Marine Recreational Fishery Statistics Survey data base (Russell Porter, Pacific States Marine Fisheries Commission, Portland, Oregon).

Location	Year	TCPH	Jackknife Variance
Jetty Sands			
	1981	1.12	
	1983	1.15	
	1984	1.29	
	1985	1.47	
	mean	1.26	0.005
Horsefall Beach			
	1979	3.13	
	1980	2.05	
	1981	3.07	
	1982	0.60	
	1983	1.37	
	1984	2.22	
	1985	1.33	
	mean	1.97	0.085
Freshwater Lagoon			
	1979	1.15	
	1981	0.89	
	1984	1.51	
	1985	1.04	
	mean	1.15	0.010
King Salmon			
	1980	1.09	
	1982	1.88	
	1986	0.67	
	mean	1.21	0.016

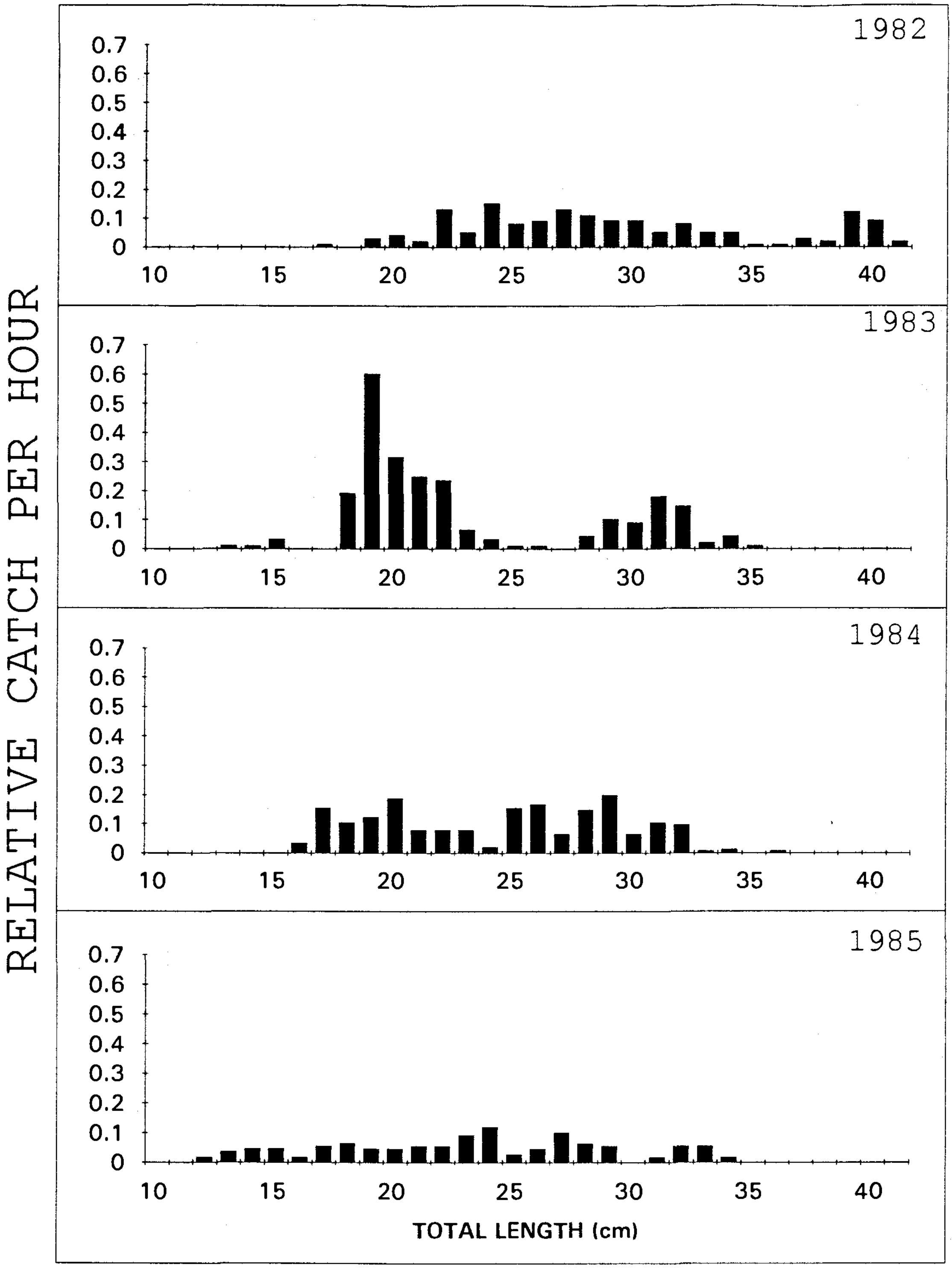

Figure 9. Relative catch per hour of redtail surfperch sampled at Damon Point, Washington. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

appear in subsequent years. Fish from 17 to 34 cm made up most of the catch after 1982. An abundant 19- to 22-cm size group was apparent during 1983. The TCPH ranged from 1.15 to 2.43, was lowest in 1985, and highest in 1983 (Table 7).

Westport Beach (Figure 10)

Length frequency distributions of relative CPH were compared for 1982 through 1985. The 17- to 29-cm sizes dominated the catch in all years. The mean length of the catch decreased from 1982 to 1985. The 1985 relative CPH was highest in the 21- and 22-cm sizes. The high-low range of TCPH was 5.43 in 1982 and 2.11 in 1983 (Table 7).

Beard's Hollow (Figure 11)

Length frequency distributions of relative CPH were compared for 1979, 1980, 1982, 1984, and 1985. The 1979 catch was the only year that included a large proportion of less than 18-cm fish. The bulk of the catch for all other years was in the 18- to 37-cm sizes. The 32+ cm sizes were absent from the catch in 1984. The TCPH ranged from 1.57 to 3.34 and gradually decreased over the years sampled (Table 7).

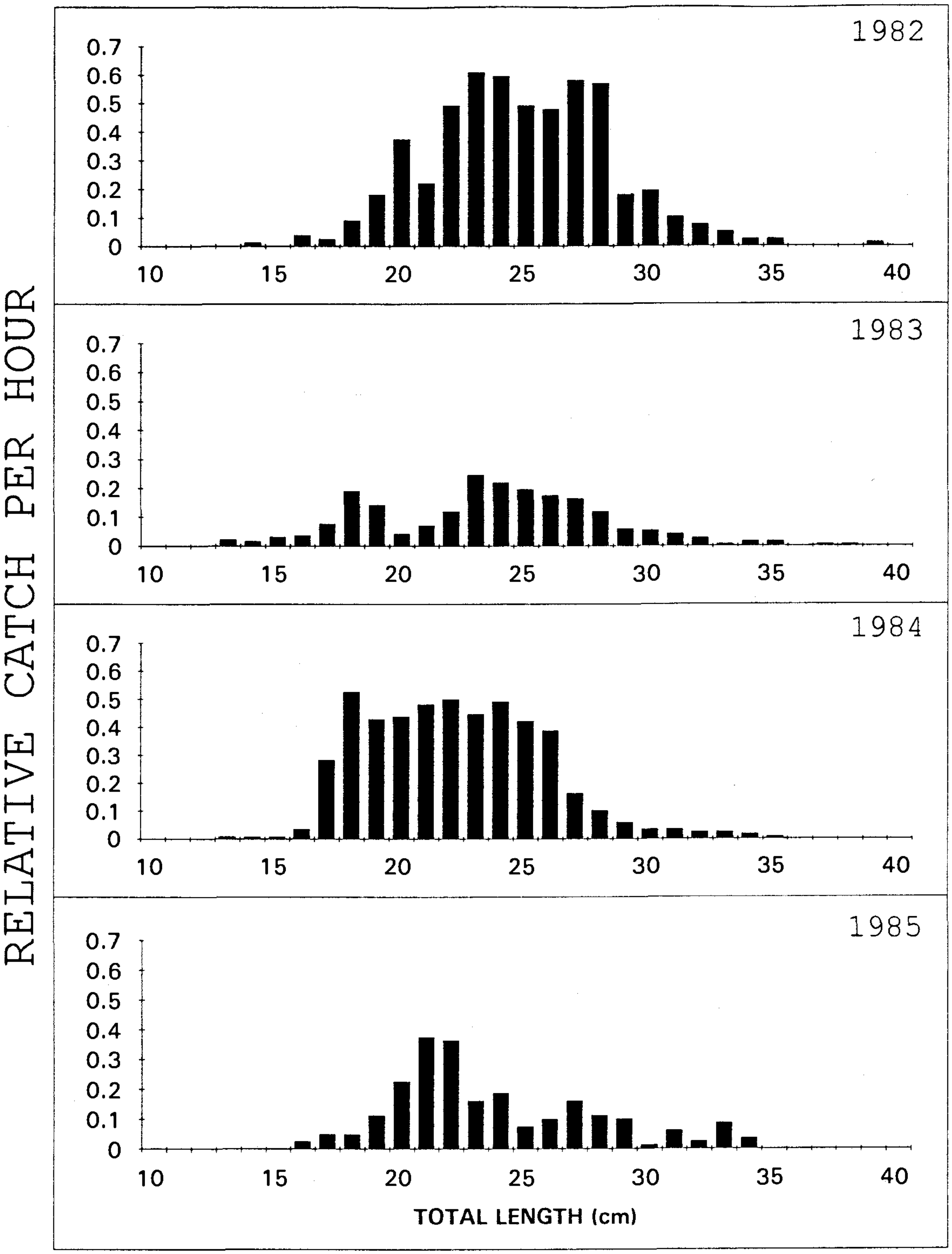

Figure 10. Relative catch per hour of redtail surfperch sampled at Westport Beach, Washington. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

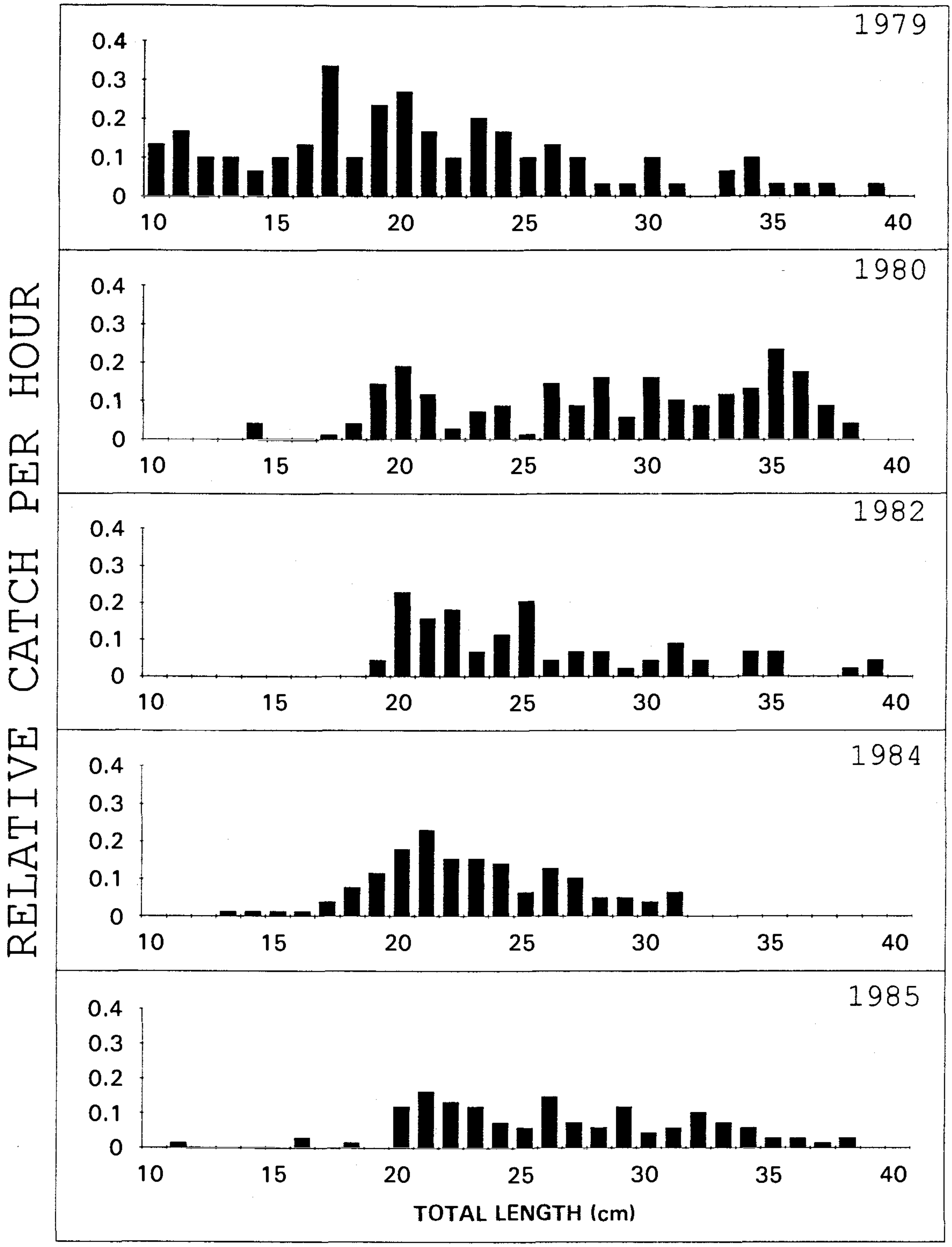

Figure 11. Relative catch per hour of redtail surfperch sampled at Beard's Hollow, Washington. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

Columbia River North Jetty (Figure 12)

Length frequency distributions of relative CPH for 1979, 1980, 1981, 1984, and 1985 were compared. The catch was generally highest in the 19- to 22-cm size range, and decreased for larger sizes. The bulk of the catch was in the 18- to 36-cm sizes. During 1979, the 10- to 16-cm sizes were regularly caught but were nearly absent in all other years. The TCPH ranged from 2.86 to 0.80 and decreased from 1979 to 1984 (Table 7).

Jetty Sands (Figure 13)

Length frequency distributions of relative CPH from 1981, 1983, 1984, and 1985 were compared. The bulk of the catch was in the 15- to 36-cm sizes for 1981, in the 13- to 33-cm sizes for 1983, and in the 17- to 31-cm sizes for 1984 and 1985. Smaller sizes contributed more to catch than did larger sizes during 1983 through 1985. Relative contributions of different sized groups were similar during 1981. The large catch of 13- to 14-cm sizes during 1983 was unique. Fish larger than 31-cm decreased in abundance between 1981 and 1983, and between 1984 and 1985. The TCPH ranged from 1.12 to 1.47 and increased over the years sampled (Table 7).

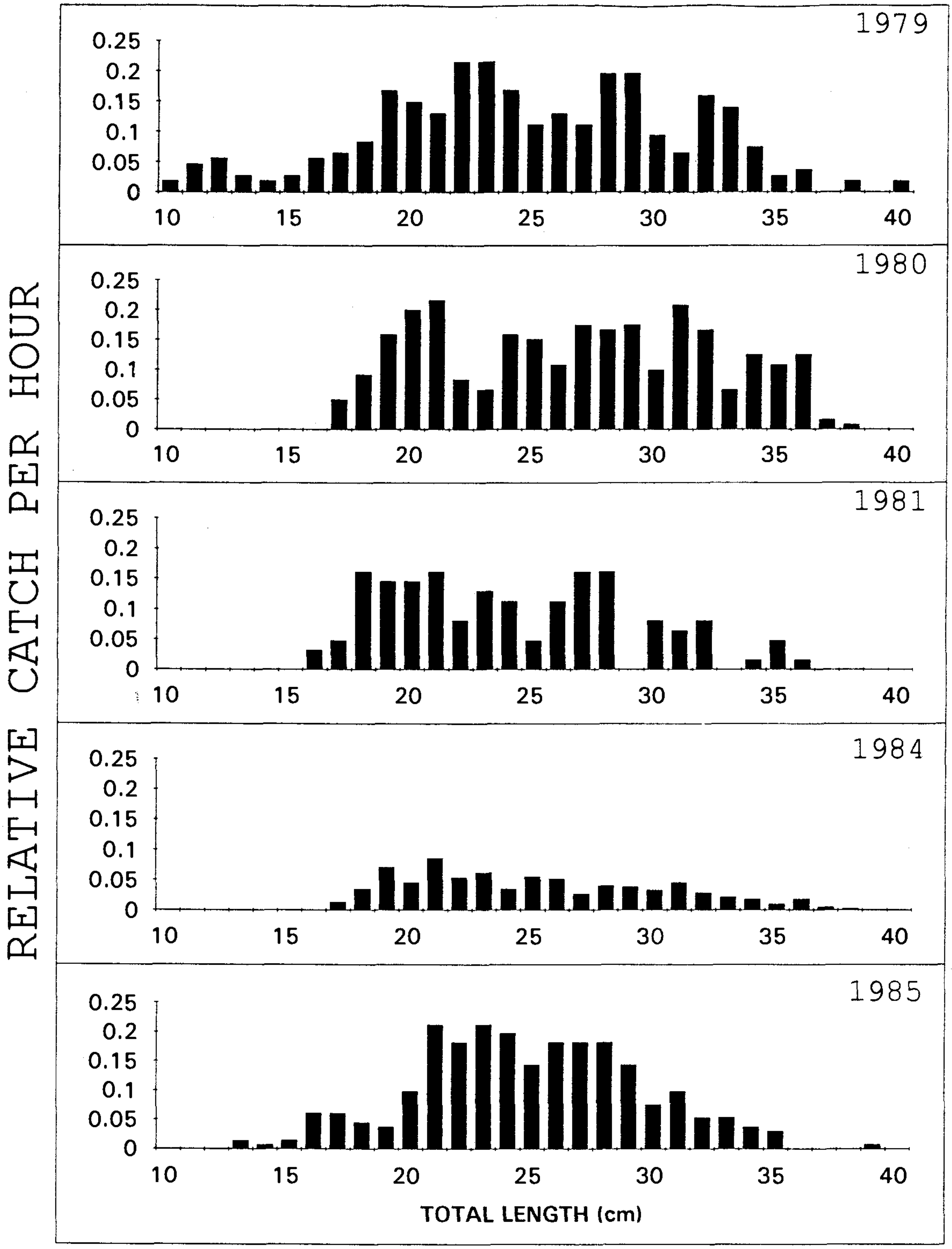

Figure 12. Relative catch per hour of redtail surfperch sampled at Columbia River North Jetty. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

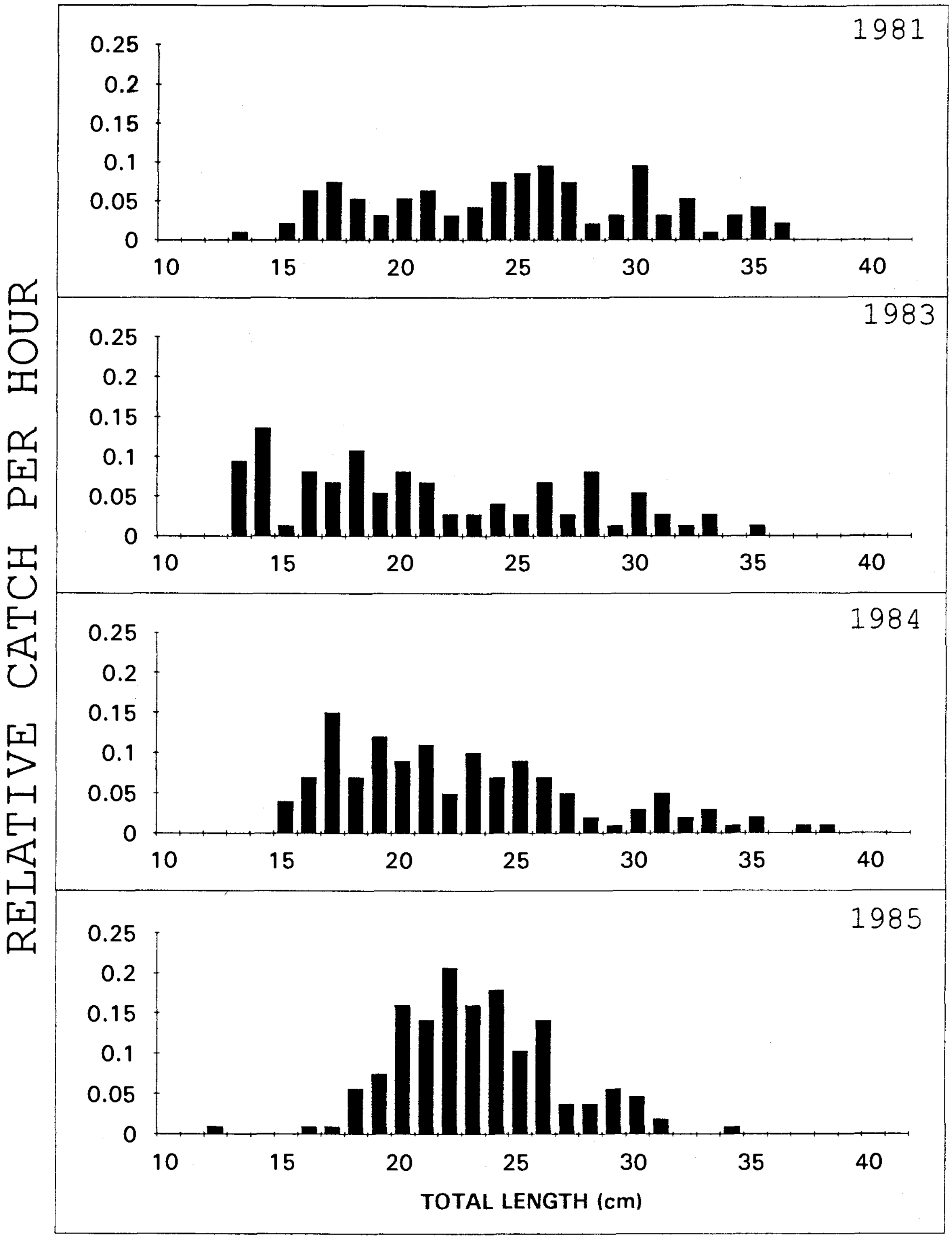

Figure 13. Relative catch per hour of redtail surfperch sampled at Jetty Sands, Oregon. Data from the Marine Recreational Fishery Statistics Survey (Elaine Stewart, Oregon Department of Fish and Wildlife, Newport, Oregon).

<u>Horsefall Beach</u> (Figure 14)

This location was the most consistently sampled for *A. rhodoterus* in the MRFSS. Length frequency distributions of relative CPH from 1979 through 1985 were compared. The main catch was 18 to 28 cm in length with some catches measuring 29 to 32 cm. Few catches were over 32 cm in length, and catches centering around the 19- and 25-cm sizes were dominant. Catch was highest in the 19- to 21-cm sizes and decreased at larger sizes during 1979, 1981, and 1983. During 1980, catches peaked at 25 cm and rapidly decreased at larger sizes. Total relative CPH was low at this location during 1982. The TCPH ranged from 3.13 in 1979 to 0.60 in 1982 and a non-significant decline occurred from 1979 to 1985 (Table 7). Few fish were recorded from this location during 1986 and 1987, only 4.4% of the 1979 to 1987 total.

<u>Freshwater Lagoon</u> (Figure 15)

Length frequency distributions of relative CPH from 1979, 1981, 1984, and 1985 were compared. The majority of catch occurred in the 21- to 34-cm sizes for all years. Highest catch for all years occurred in the 23- to 27-cm sizes. Some catches above 34-cm occurred during 1981 and 1984. Catch of 17- to 19-cm sizes occurred during 1979. The smallest size of catch was 20, 19, and 21 cm for 1981,

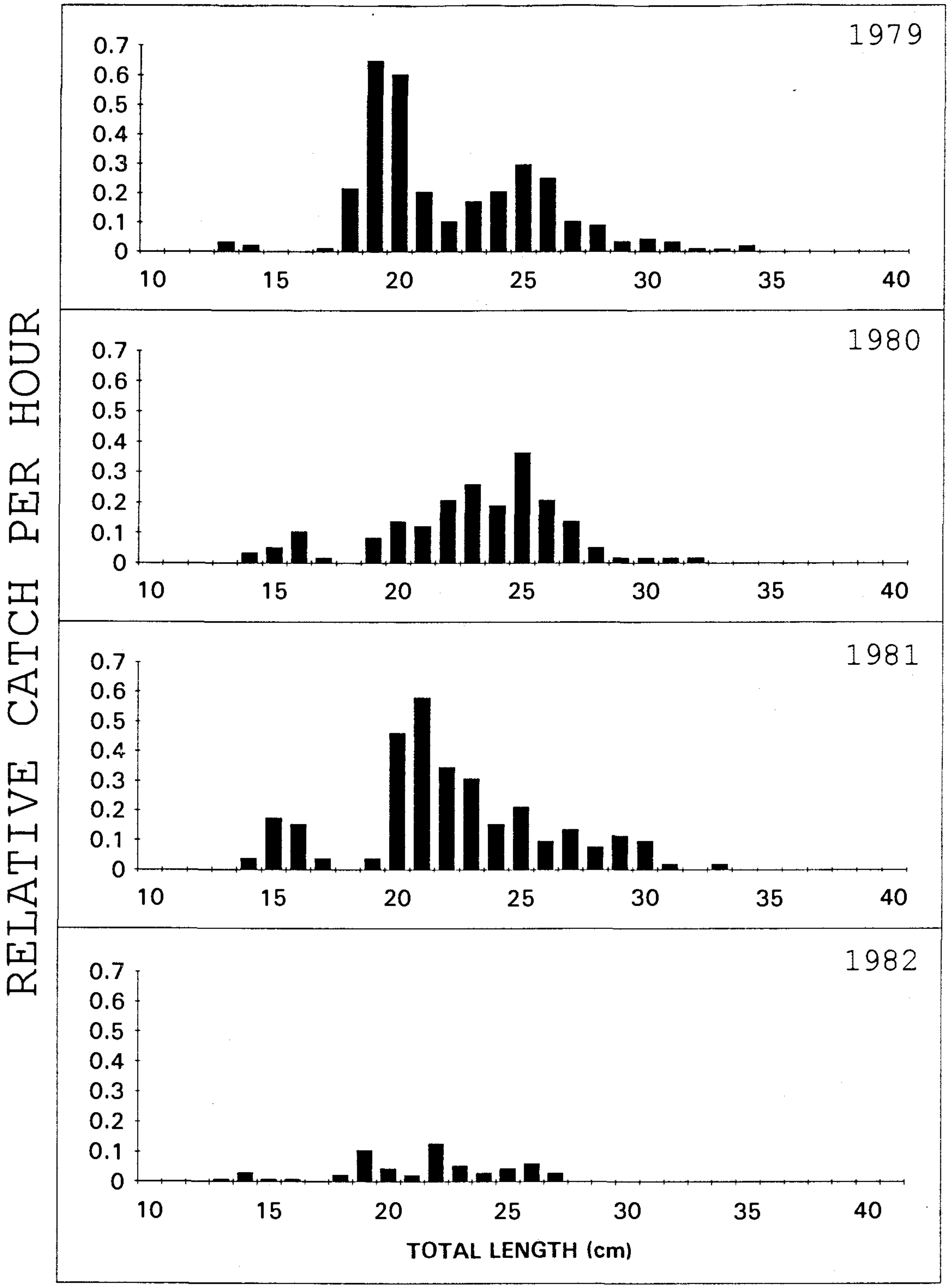

Figure 14. Relative catch per hour of redtail surfperch sampled at Horsefall Beach, Oregon. Data from the Marine Recreational Fishery Statistics Survey (Elaine Stewart, Oregon Department of Fish and Wildlife, Newport ,Oregon).

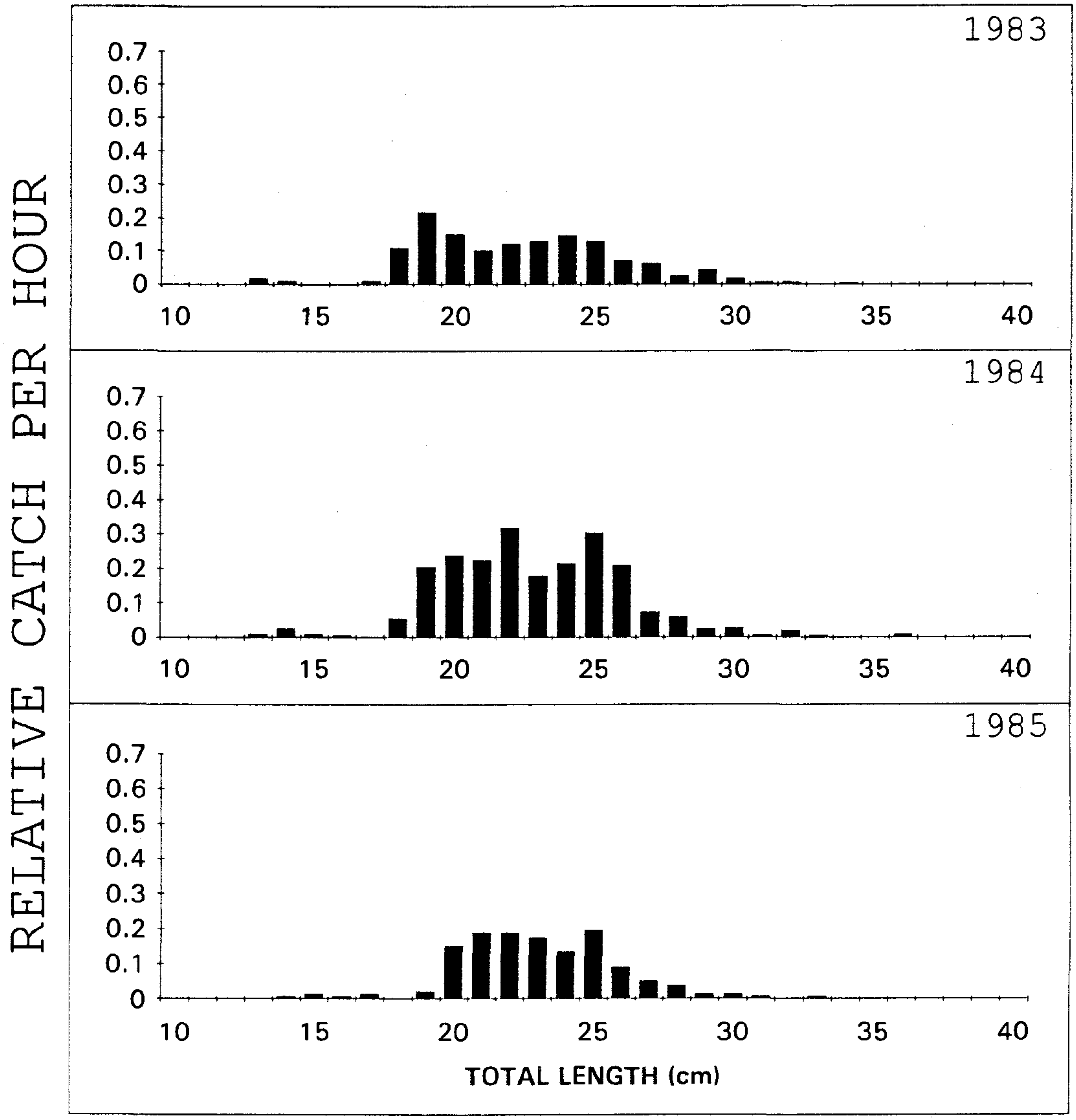

Figure 14. continued.

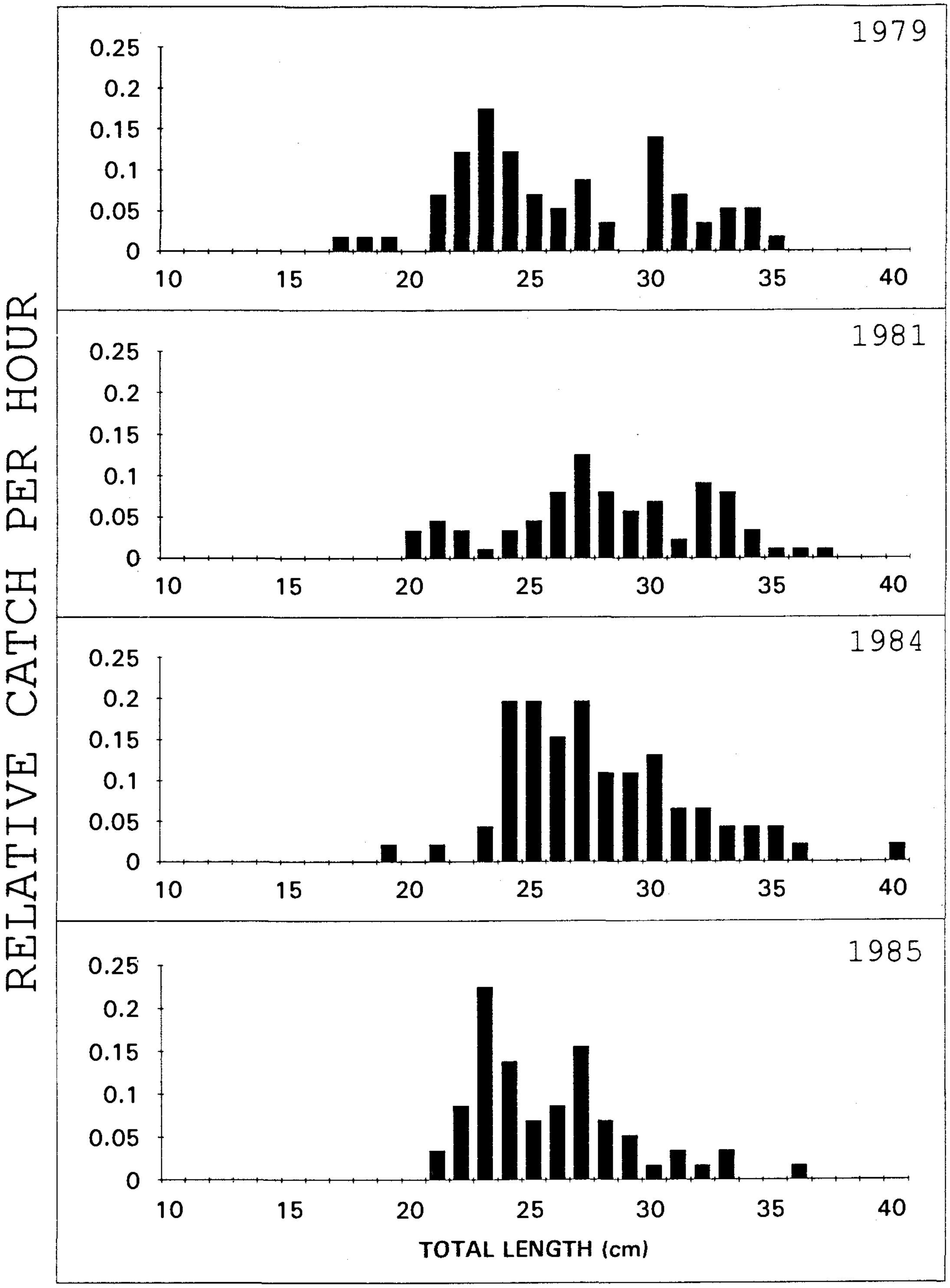

Figure 15. Relative catch per hour of redtail surfperch sampled at Freshwater Lagoons, California. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

1984, and 1985, respectively. The TCPH ranged from a low of 0.89 in 1981 to a high of 1.51 in 1984 (Table 7).

King Salmon (Figure 16)

Frequency distributions of relative CPH from 1980, 1982, and 1986 were compared. Highest catch occurred in the 25- to 30-cm size for all years, and most of the catch was in the 22- to 33-cm sizes. Fish below 18 and above 36 cm were not recorded. This location was unique among all MRFSS sampling sites for *A. rhodoterus* because the catch occurred from December through April and not in late spring and summer (Appendix A). The TCPH was 1.09, 1.88, and 0.67 for 1980, 1982, and 1986, respectively (Table 7).

MRFSS BLUE Estimator (Figure 17)

A plot of *A. rhodoterus* catch per trip from 1979 to 1986 MRFSS Horsefall Beach data verses hours per trip generally agrees with Cochran's (1977) criteria for using a ratio estimate of CPH (depicting a straight line relation through the origin and variance of catch per trip roughly proportional to hours per trip).

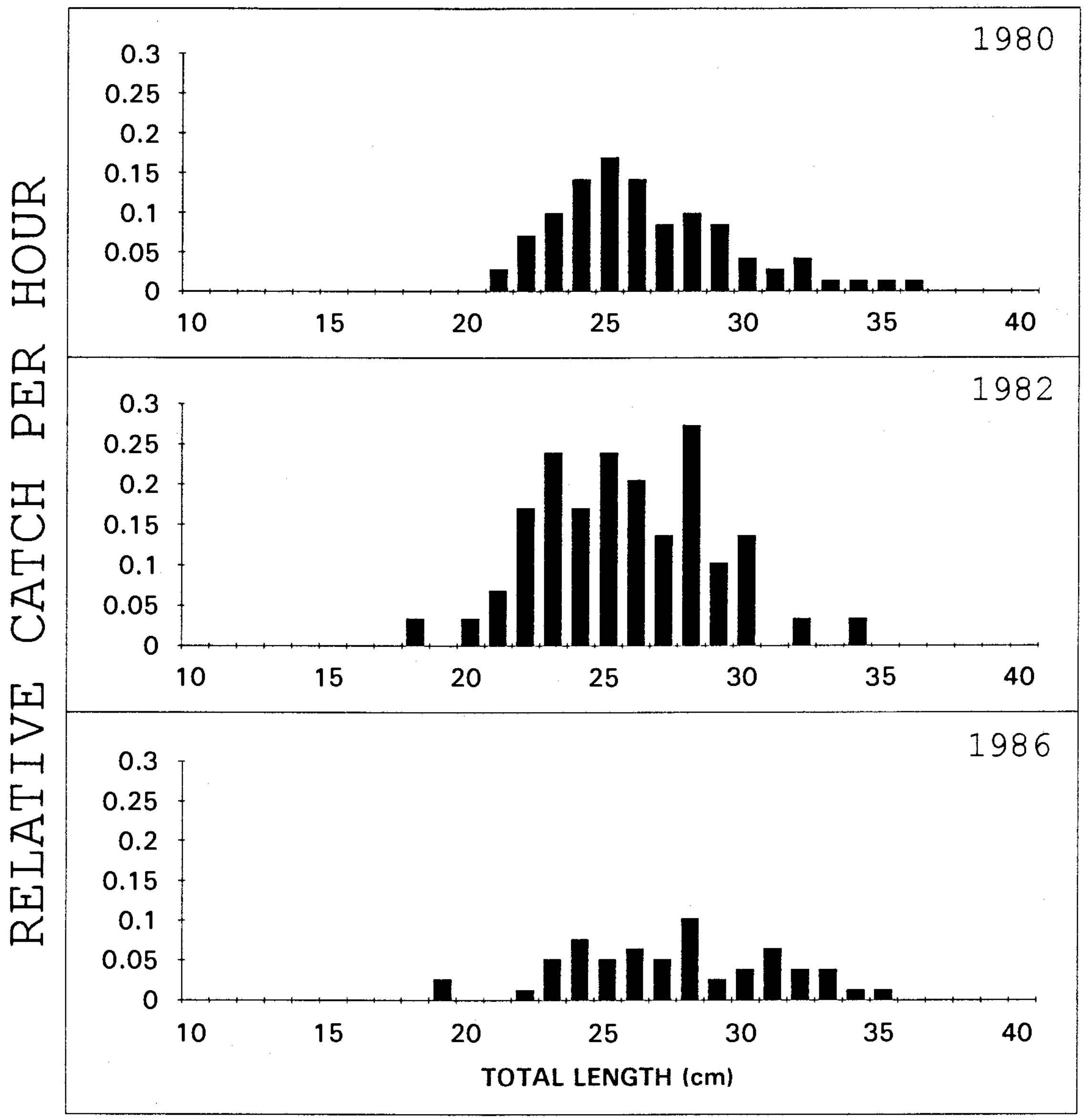

Figure 16. Relative catch per hour of redtail surfperch sampled at King Salmon, California. Data from the Marine Recreational Fishery Statistics Survey (Pacific States Marine Fisheries Commission, Portland, Oregon).

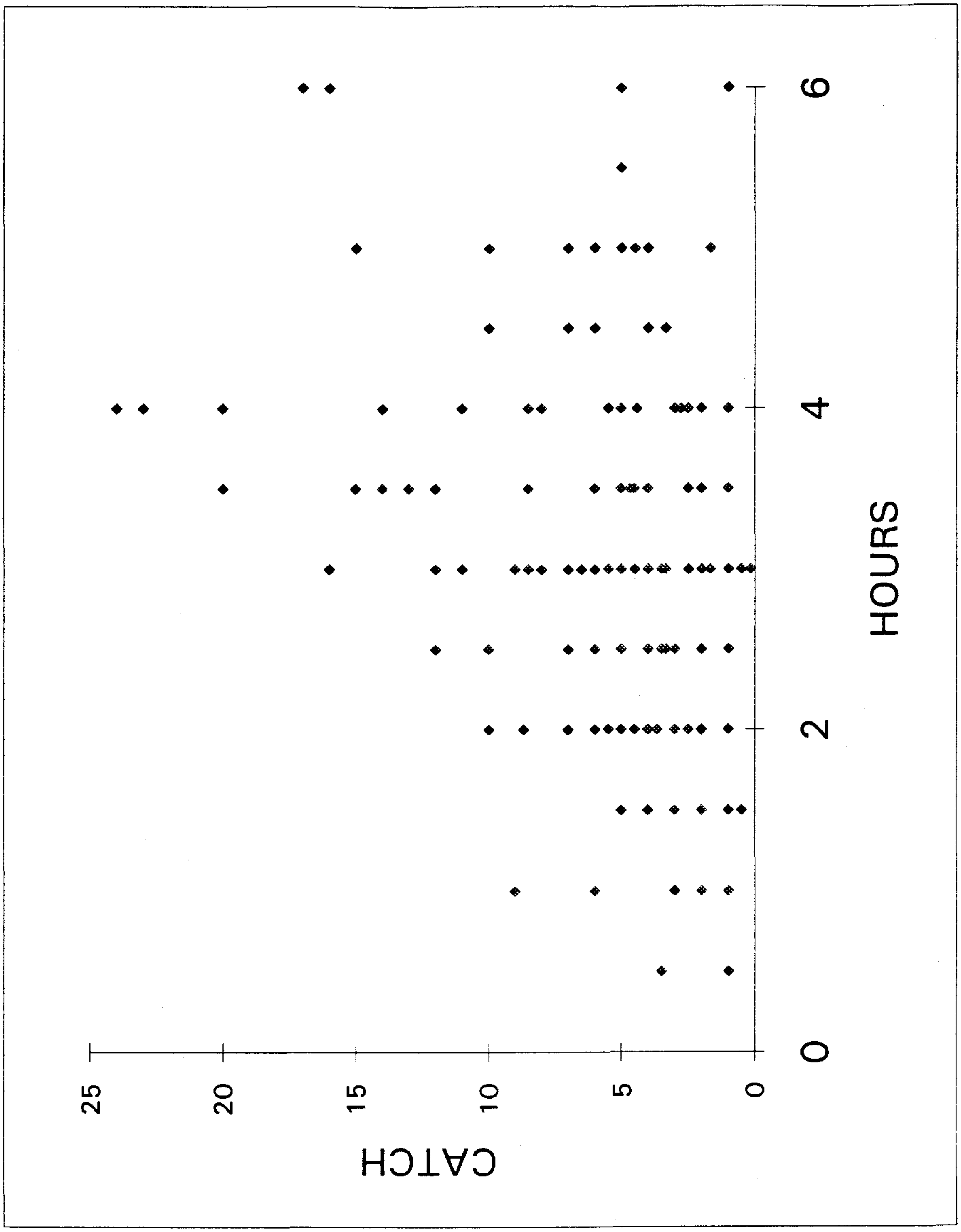

Figure 17. *Amphistichus rhodoterus* catch and hours fishing per trip at Horsefall Beach, Oregon for 1979 to 1986. Data from the Marine Recreational Fisheries Statistics Survey (Elaine Stewart, Oregon Department of Fish and Wildlife, Newport, Oregon).

Computer Simulations

Length Frequencies (Table 8)

Correlations of numbers in size groups of a known population with simulated population sample statistics (catch and CPH) ranged between 0.80 and 0.89 (Table 8). Differences between correlation coefficients of the two sample statistics were not significantly different from zero. Distributions of both statistics were not significantly different from the known distribution of lengths.

Table 8. Means of correlation coefficients between a known population, simulated catch (Catch R), and simulated catch per hour (CPH R) including the results of testing if catch and CPH correlation coefficients were significantly different.

Number	Mean			
of Fish	Catch R	CPH R	Difference	Probability
50	0.8267	0.8024	0.0150	0.0593
100	0.8937	0.8788	0.0243	0.0573

TCPH Bias (Figure 18)

Simulated TCPH values generally corresponded to the initial CPH data used to model them; but visual inspection indicates that variance increased as the number of simulated trips decreased. A positive bias at low CPH

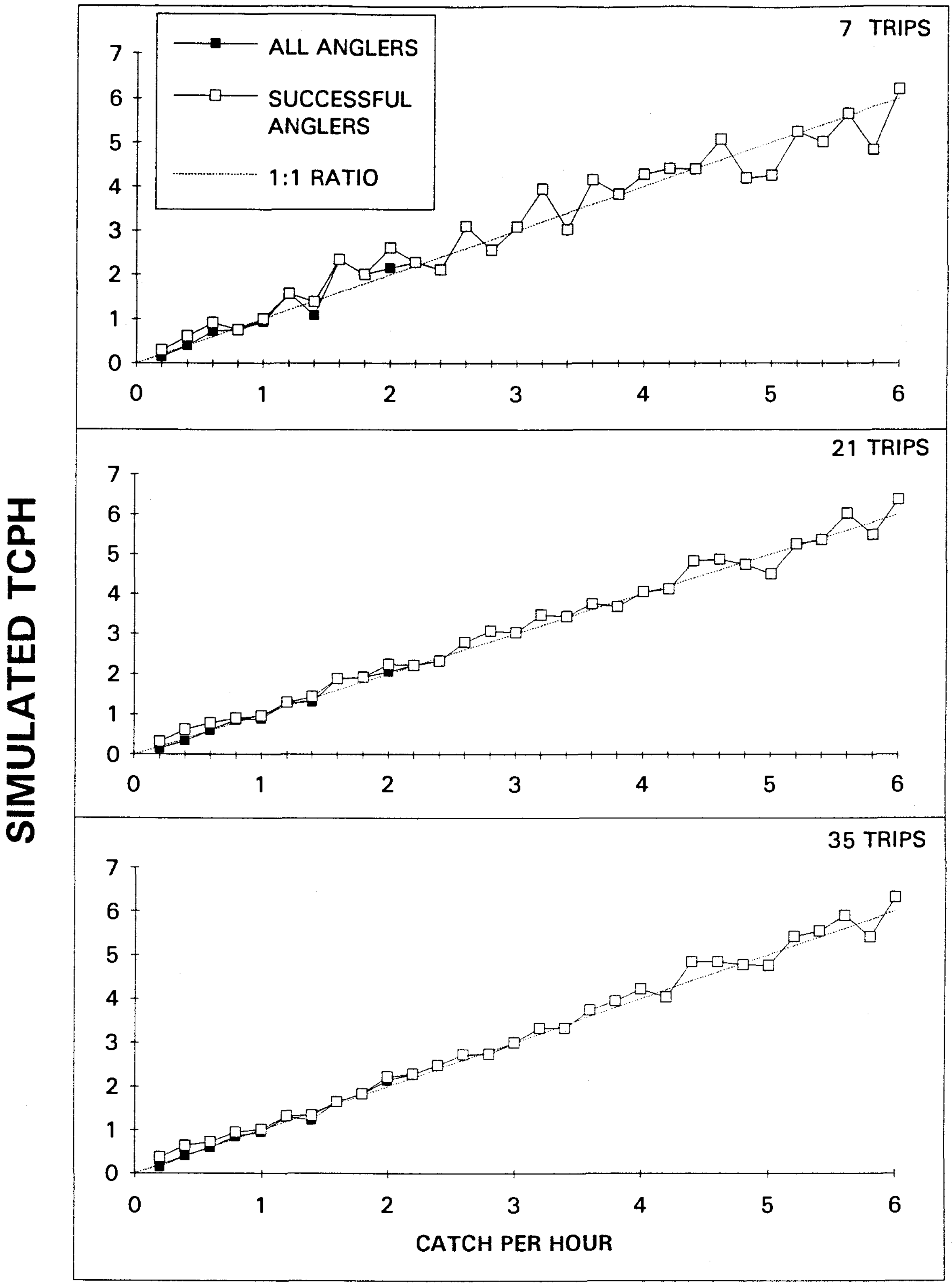

Figure 18. Simulated TCPH calculated using all and only successful anglers, and using 7, 21, and 35 trips. A 1:1 line is shown for comparison.

was found when only successful anglers were used to calculate TCPH for all simulations. Results of another model using means of angler CPH instead of TCPH were similar. The regression relationship between successful angler TCPH and the difference between all and successful angler TCPHs for initial CPH values ranging from 0.4 to 1.2 was:

$$CPH = EXP((-2.359 * TCPH) - 0.296)$$

(R = -0.9575, slope prob. = 0.00268, intercept NS, N = 5). When only one hook was simulated, a negative bias in TCPH ranged from 1.2 to 5% for TCPH values between 2.2 and 6.0, respectively.

<u>TCPH Variance</u> (Figure 19)

Jackknife variance estimates for TCPH calculated from the model data were mostly below 0.02 CPH. Variance calculated using only seven trips was larger than when more trips were included. Maximum jackknife TCPH variance was always below 0.04 when using 14 or more trips, and the average TCPH jackknife variance was always below 0.02 fish per hour. Jackknife TCPH variance calculated from the MRFSS ranged from 0.0048 to 0.1666 except for Westport Beach which was 0.9731 (Table 7).

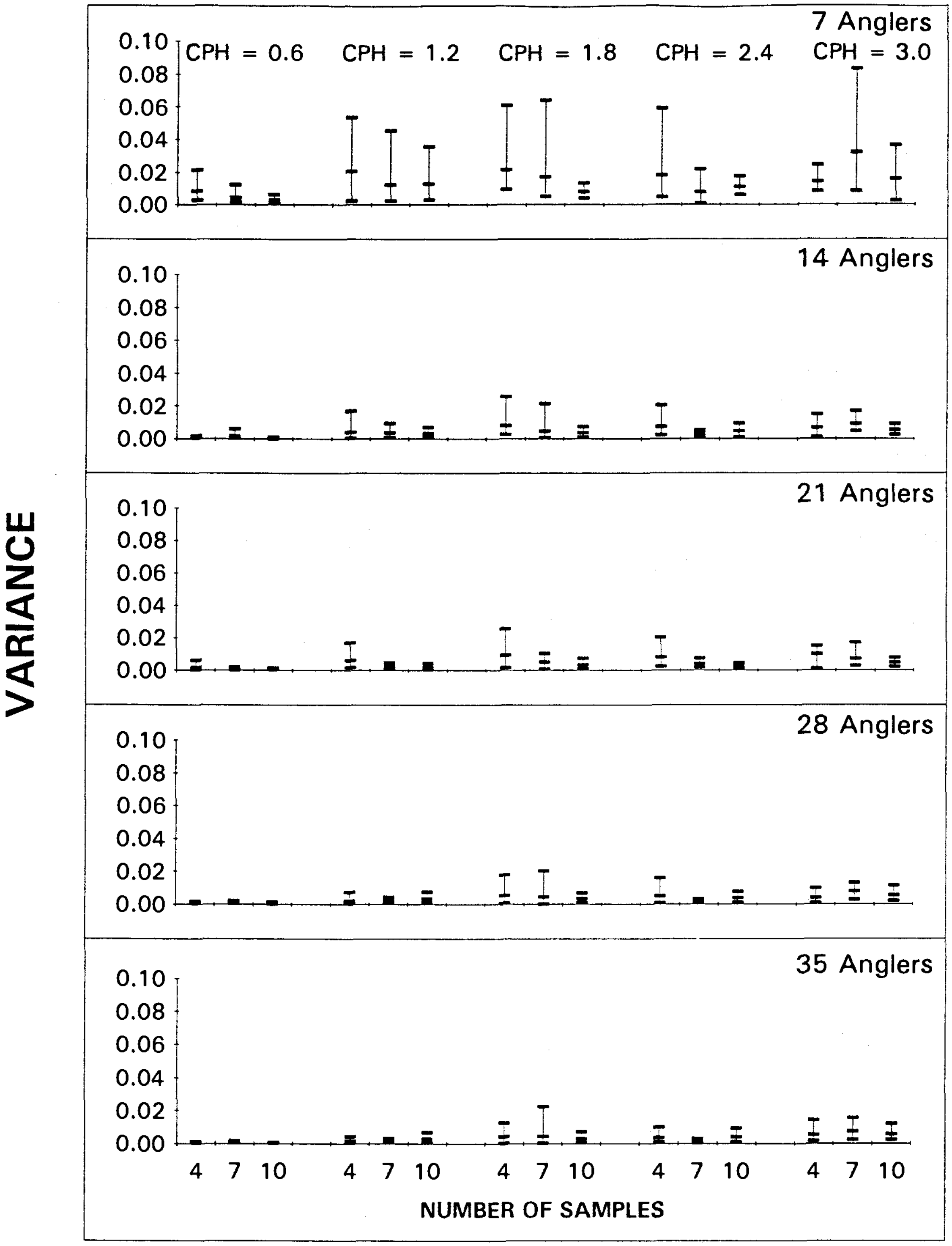

Figure 19. Maximum, average, and minimum jacknife variance for the total ratio estimator of catch per hour (TCPH) as produced by a redtail surfperch surf fishery computer simulation.

Length at Age (Table 9)

The first winter annulus and a parturition mark were found on scales of 6 *A. rhodoterus* examined in August 1994, 12 months after their 1993 birth on Horsefall Beach. An initial scale formation radius of 0.084 mm (3 ocular units), and an embryo SL of 21 mm at scale formation were estimated from mid-gestation embryos (Appendix F).

Scale radius was linearly related to standard length for all fish sampled (Figure 20). The size of fish at capture overlapped for all age groups except age 1 (Table 9). The average length back-calculated from annulus formation was 100.4, 163.6, 226.4, and 268.6 mm for annuli 1 through 4, respectively, and varied between cohorts (Table 10).

Gravidity (Table 11)

Significant relationships were found between length and gravidity for samples collected in Lincoln County but not for those from Coos and Douglas counties. The length regression slopes for all the samples combined were not significantly different from data of Bennett (1971). Coos and Douglas County samples included gravid *A. rhodoterus* between 213 to 308 mm TL. Lincoln County samples included gravid fish up to 377 mm TL. Some Coos and Douglas County fish had larger gravidity for their size than fish of a similar size from Lincoln County (Figure 21). The gravidity

Table 9. Number of *Amphistichus rhodoterus* of given total length (TL) and age at capture from Horsefall Beach, Oregon during late summer 1987.

TL cm	Age 1-2	2-3	3-4	4-5
15	4			
16	7			
17	3			
18				
19	1			
20		3		
21		11	1	
22		9	1	
23		3	4	
24			5	
25			5	
26				4
27			3	3
28			2	1
29				
30				1
31				1

Table 10. Average back-calculated total length at annulus formation for *Amphistichus rhodoterus* captured at Horsefall Beach, Oregon during 1987.

Cohort	N	Birth Mark	Annulus 1	2	3	4
1983	10	65	102	183	242	269
1984	21	65	102	170	219	
1985	26	64	94	151		
1986	15	67	108			
1987	1	65				

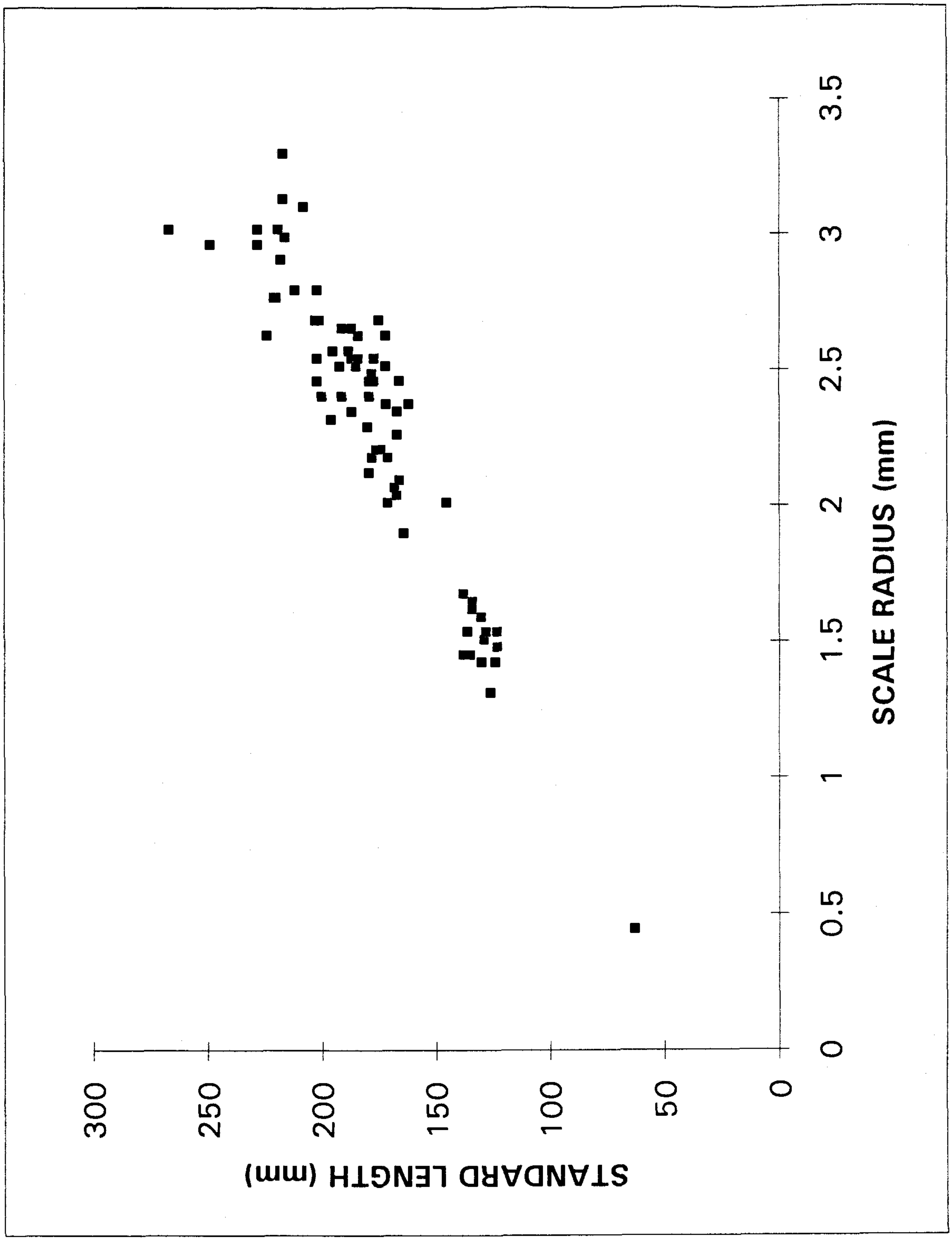

Figure 20. The relationship of length at capture and scale radius for *A. rhodoterus* collected from Horsefall Beach, Oregon during the summer of 1987.

by length regression for Lincoln, Coos, and Douglas counties combined (regression H, Table 11) intersected the gravidity equals 1 line at 232 mm TL.

Table 11. Relationships of *Amphistichus rhodoterus* gravidity to total length. Gravidity is defined as the number of embryos in the ovary. Sources for A and C=Bennett (1971); B=Culver 1978; D=Culver 1980; and E, F, G, and H=this study. All regression slopes are significantly different from zero ($p \leq 0.05$) unless noted by (NS). All regressions exclude non-gravid females except (H) which includes non-gravid females if they had reached 213 mm (the length of the smallest gravid *A. rhodoterus* observed).

Location	Year	Slope	Intercept	R	N
A. Copalis Beach	1970	.206	-48.5	.83	18
B. Damon Point	1978	.231	-53.1	.83	30
C. Oregon Coast	1967-69	.210	-48.6	.84	168
	1968	.208	-46.3	.91	51
D. N. California	1976	.16	-31.1	.60	140
E. Lincoln Co.	1987-92	.242	-58.0	.84	35
F. Coos and Douglas Co.	1987-92	.061 NS	- 6.6	.32	27
G. E & F Combined	1987-92	.180	-38.5	.79	62
H. E & F Combined (including 0's)	1987-92	.203	-46.1	.74	72

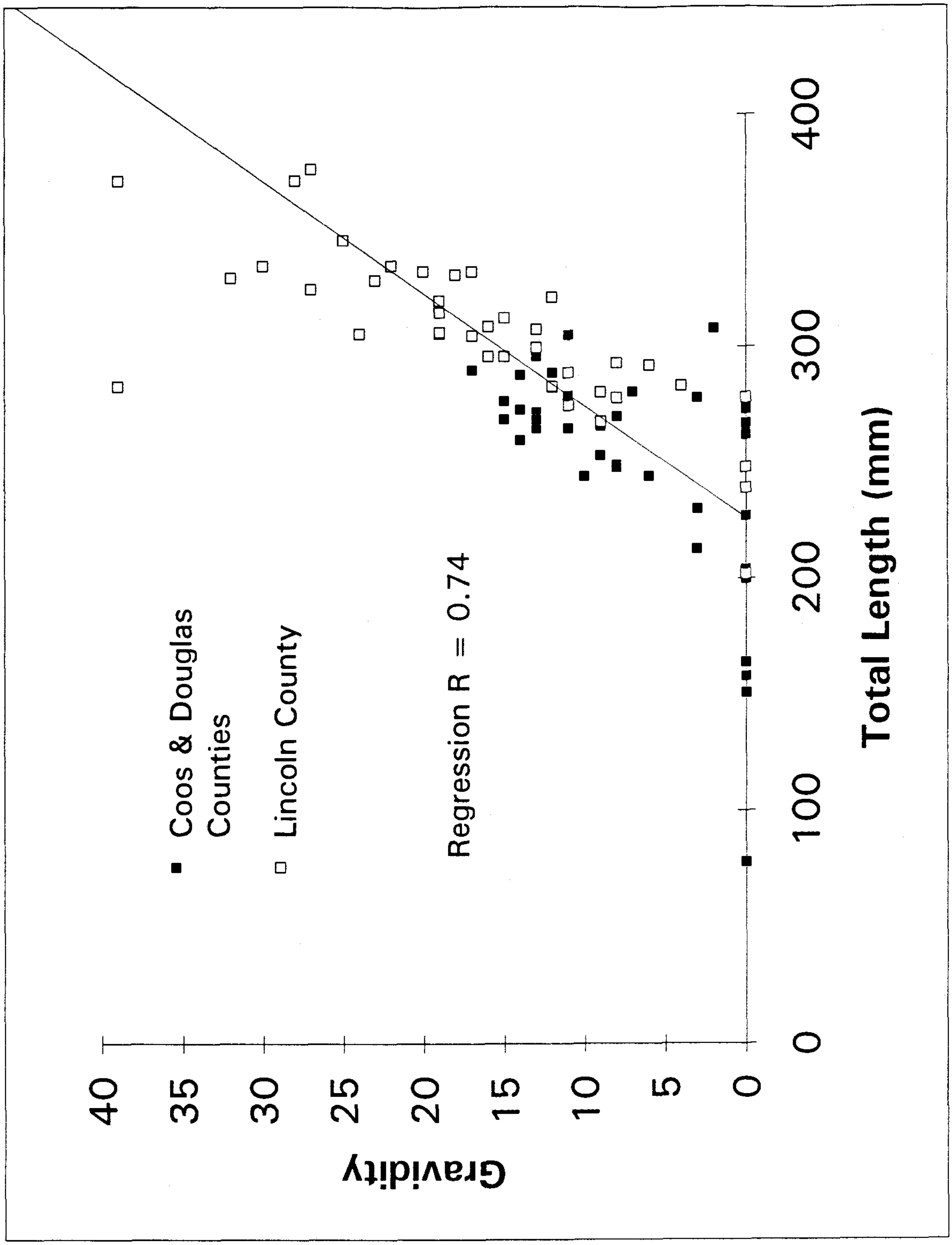

Figure 21. Gravidity at length relationship of *A. rhodoterus* captured in Coos, Douglas, and Lincoln counties, Oregon, from 1987 to 1992. The regression line shown is for all fish longer than the smallest gravid fish captured (213 mm). Gravidity is the number of embryos in the ovary.

Population Models

Age Structured Model

The Age Structured Model and other models that attempted to distinguish abundance of individual age classes produced survival rates in excess of 100%. The high survival during 1982 to 1984 made the model results unrealistic. In the Age Structured Model, 123% and 116% of fish age 2 and older survived to the next age during 1982 and 1983, respectively. Survival of predicted offspring to age 2 was 82% for the 1982 cohort, most likely because this year had the lowest abundance estimate for reproductive aged fish (Age 3+).

Average Mortality Model

The annual maximum age of *A. rhodoterus* sampled by the MRFSS from Horsefall Beach was 8, 7, 7, 6, 7, 8, and 8 years for 1979 to 1985, respectively. Age 2+ mortality of 0.725 to 0.675, 0.650 to 0.600, and 0.575 to 0.550 per year would result in maximum ages of 6, 7, and 8 years, respectively (Appendix Table 63). An age 2+ mortality of 0.583 and age 0 or 1 mortality of 0.330 maintained a stable Average Mortality Model abundance when mortality occurred before parturition. An age 2+ mortality of 0.675 and age 0 and 1 mortality of 0.330 maintained stable Average Mortality Model abundance when mortality occurred after parturition.

Mortality of 0.570 per year for all ages after parturition resulted in a stable population. The Average Mortality Model simulated populations declines gradually over a number of years after initial drops in abundance (Figure 22). Mortality of 0.489 per year for all ages prior to parturition resulted in a stable population with 49, 25, 13, 7, 3, 2, 1, and 0% of the fish sampled in ages 2 to 9, respectively (age 1 fish excluded from percentage calculations).

<u>Fishery Recruitment</u> (Table 12)

The recruit index ranged from 0.102 to 2.16 with no significant trends over time for any station. The only locations with a significant correlation between the recruitment index were Horsefall Beach and Beard's Hollow (R=0.9552, N=5, p=0.0113). Horsefall Beach recruit index was not significantly correlated with parental stock size.

The Horsefall Beach recruit index had a significant, positive correlation with Horsefall Beach TCPH (R=0.8694, N=7, p = 0.0110). Other correlations of TCPH and recruit indexes between Beards Hollow, Columbia River North Jetty, and Horsefall Beach were not significant ($p \leq 0.05$).

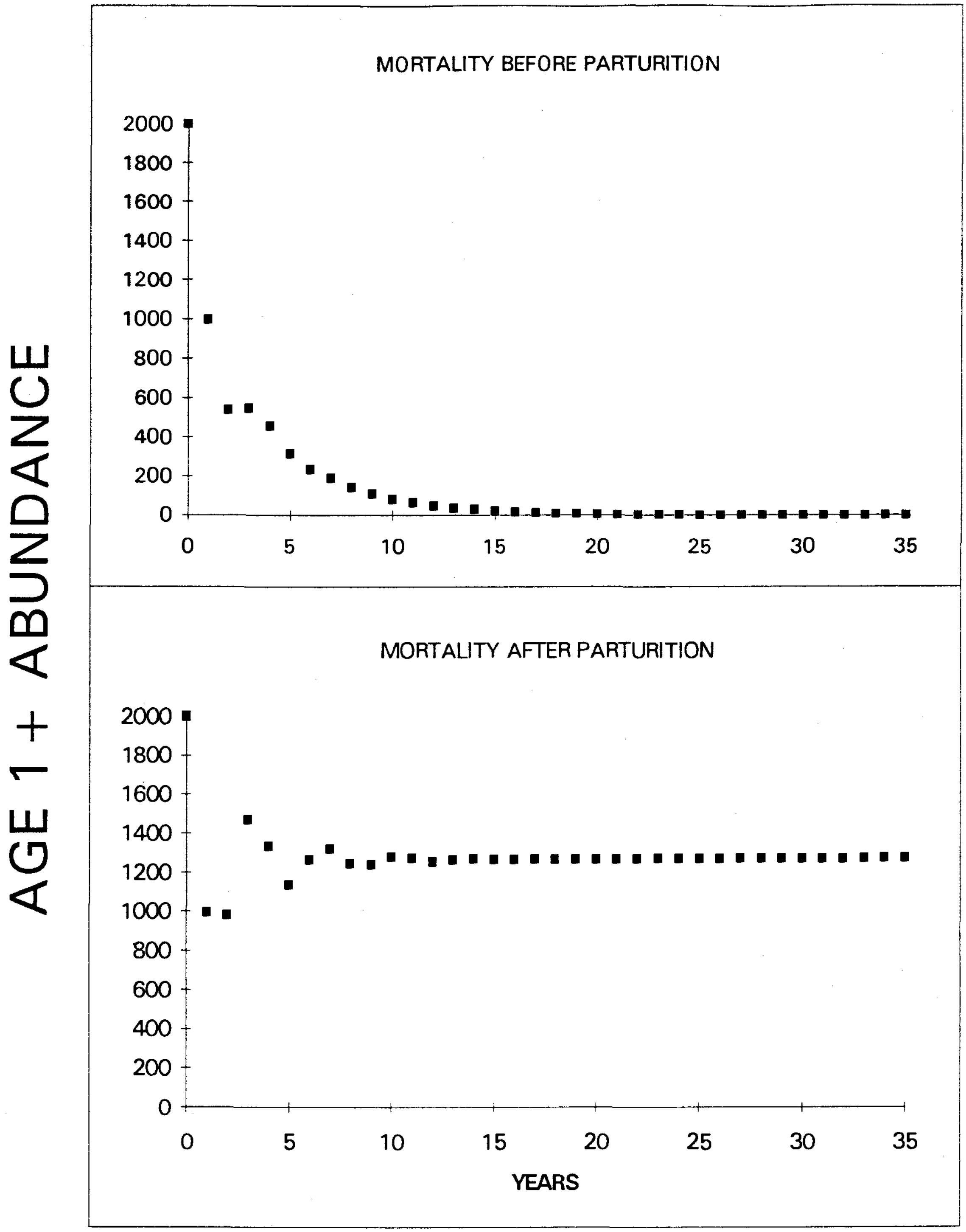

Figure 22. Redtail surfperch abundance predictions from the Horsefall Beach, Oregon Average Mortality Model. These Average Mortality Model results were based on annual mortality rates of 0.675 and 0.330 for ages 2+ and <2, respectively.

Table 12. Recruitment indexes of *Amphistichus rhodoterus* locations sampled by the Marine Recreational Fishery Statistics Survey. Recruitment index was calculated as the percentage of the populations which were recruits (age 2 in Oregon and Washington; age 3 in California) times the total ratio estimate of annual catch per hour.

	Year							
Location	1979	1980	1981	1982	1983	1984	1985	1986
Kalaloch Beach			0.411	0.220	0.384		1.907	
Damon Point				0.102	1.363	0.646	0.269	
Westport Beach				0.892	0.525	2.160	0.814	
Beards Hollow	1.113	0.514		0.434		0.641	0.296	
Columbia River North Jetty	0.602	0.718	0.663			0.251	0.456	
Jetty Sands			0.364		0.425	0.481	0.337	
Horsefall Beach	1.691	0.365	1.120	0.197	0.585	0.720	0.378	
Freshwater Lagoon	0.558		0.205			0.350	0.555	
King Salmon		0.510		0.923				0.193

Environmental Correlations

Of 211 environmental variables 108 had at least one highly significant correlation with another environmental variable in 2082 correlation attempts (Appendix E). Approximately 21 (2082*.01) of these 108 correlations would be expected to be significant if the environmental variables were random numbers. Thus, TCPH and recruit index correlations were actually made with no more than 124 random variables (211-(108-21)).

The number of significant and highly significant correlations from Beards Hollow and Horsefall Beach data are not statistically different from predicted with 124 random variables (Chi-square test). Beards Hollow and Horsefall Beach correlations are described because the true number of independent environmental variables is unknown. The number of significant and highly significant correlations from Columbia River North Jetty is much greater than would predicted from 124 random variables (Chi-square test). This is due to the large number of highly significant correlations.

Significant correlations with environmental variables were most numerous with upwelling and temperature variables. Wave height, wave period, commercial catch, recreational catch, recreational trips, and harbor seal numbers did not correlate well with the abundance (TCPH) or recruit indexes. The physical environmental factors, not the biological factors or fishing activities, were more closely related to *A. rhodoterus* abundance and recruitment.

<u>Recruit Index</u> (Table 13a, 13b)

Recruitment indexes were mainly correlated with sea surface temperature and upwelling index during March through June and August through October. For the same month and location, slopes of upwelling and temperature correlations were opposite. Beards Hollow and Horsefall Beach recruitment indexes were often correlated with environmental variables in the same month. Columbia River North Jetty recruitment index was correlated with environmental variables in different months than Beards Hollow and Horsefall Beach, or correlated with the same type of variable, but with opposite slope. Beards Hollow and Horsefall Beach recruitment indexes were positively correlated with upwelling during June and October, and negatively correlated with upwelling in August and September. Columbia River North Jetty recruitment was negatively correlated with temperature (positive with upwelling) except in September when the correlation reversed.

All recruitment indexes were correlated with upwelling from May or June of two years previous. Beards Hollow and Horsefall Beach recruitment indexes were correlated with fall temperature or upwelling one year previously. Columbia

Table 13a. Statistics from significant correlations of recruitment index and environmental variables. Data types are upwelling index (UP), sea surface temperature (SST), and average significant wave height (WH). Environmental data, recruitment indexes, and years sampled at locations are listed in Appendix E.

Location	Month	Year Lag	Data	R	N	Probability
			Beard's Hollow			
Charleston	OCT	-1	SST	-0.9415	5	0.0168
42°N	OCT	-1	UP	0.9394	5	0.0177
45°N	JUN	-2	UP	0.9328	5	0.0207
45°N	SEP	0	UP	-0.9194	5	0.0271
45°N	AUG	-1	UP	-0.9144	5	0.0297
42°N	JUN	0	UP	0.9111	5	0.0314
Trinidad Beach	APR	-1	SST	0.8957	5	0.0398
48°N	SEP	0	UP	-0.8925	5	0.0416
42°N	JUN	-2	UP	0.8842	5	0.0465
			Columbia River North Jetty			
Trinidad Head	MAY	-1	SST	-0.9883	5	0.0015
Neah Bay	MAR	-1	SST	-0.9781	5	0.0039
Neah Bay	MAY	0	SST	-0.9770	5	0.0042
48°N	MAR	-1	UP	0.9765	5	0.0043
Neah Bay	MAY	-1	SST	-0.9672	5	0.0071
45°N	MAR	-1	UP	0.9662	5	0.0074
Neah Bay	APR	-1	SST	-0.9438	5	0.0159
Neah Bay	AUG	-1	SST	-0.9287	5	0.0226
Trinidad Beach	AUG	0	SST	-0.9274	5	0.0232
Neah Bay	OCT	-1	SST	0.9179	5	0.0279
42°N	MAR	-1	UP	0.9018	5	0.0364
48°N	MAY	-2	UP	-0.9005	5	0.0371
42°N	SEP	-1	UP	-0.8863	5	0.0452
42°N	DEC	0	UP	-0.8831	5	0.0471
			Horsefall Beach			
Charleston	SEP	0	SST	0.9418	7	0.0015
Charleston	OCT	-1	SST	-0.9213	7	0.0032
42°N	JUN	-2	UP	0.9062	7	0.0049
Charleston	AUG	0	SST	0.8921	6	0.0169
42°N	JUN	0	UP	0.8128	7	0.0263
Trinidad Beach	NOV	-1	SST	-0.8075	7	0.0281

Table 13b. Correlations of environmental variables and recruit index arranged by location and time lag. Trinidad Beach (T), Charleston (C), Neah Bay (N) are sea surface temperature sampling locations. Upwelling index locations are 42°N, 45°N, and 48°N Along the United States west coast. Negative and positive correlations are indicated by the respective mathematical symbols. Significant (*) and highly significant (**) linear correlations are also indicated.

Environmental variable Lagged -2 years		Beards Hollow	Columbia River North Jetty	Horsefall Beach
MAY	Upwelling		-48*	
JUN	Upwelling	+45*,+42*		+42**

Environmental variable Lagged -1 years		Beards Hollow	Columbia River North Jetty	Horsefall Beach
MAR	Temperature		-N*	
MAR	Upwelling		+42*,+45**,+48**	
APR	Temperature	+T*	-N*	
MAY	Temperature		-T**,-N**	
AUG	Temperature		-N*	
AUG	Upwelling	-45*		
SEP	Upwelling		-42*	
OCT	Temperature	-C*	+N*	-C**
OCT	Upwelling	+42*		
NOV	Temperature			-T*

Environmental variable Lagged 0 years		Beards Hollow	Columbia River North Jetty	Horsefall Beach
MAY	Temperature		-N**	
JUN	Upwelling	+42*		+42*
AUG	Temperature		-T*	+C*
SEP	Temperature			+C**
SEP	Upwelling	-45*,-48*		
DEC	Upwelling		-42*	

River North Jetty recruitment index was correlated with temperature and upwelling during spring and late-summer to early-fall one year previously. Beards Hollow and Horsefall Beach recruitment indexes correlated with June 42°N upwelling and September temperature or upwelling of the same year. Columbia River North Jetty recruitment index was correlated with May and August temperature of the same year. Environmental variables were cross correlated when more than one variable correlated with a recruitment index.

<u>Abundance Index</u> (Table 14a, 14b)

Significant correlations with abundance were less common than with recruitment. Significant correlations followed the same temporal pattern as recruitment for Beards Hollow and Horsefall Beach and a different pattern for Columbia River North Jetty. Columbia River North Jetty abundance had a highly significantly positive correlation with February upwelling one year previously and March upwelling of the same year, and a highly significant negative correlation with September upwelling of the previous year.

Table 14a. Statistics from significant correlations of TCPH with environmental variables for *Amphistichus rhodoterus*. Data types are upwelling index (UP), sea surface temperature (SST), and average significant wave height (WH). Environmental data is listed in Appendix E. Years sampled at each location and TCPH values are listed in Table 8.

Location	Month	Year Lag	Data	R	N	Probability
			Beard's Hollow			
45°N	Aug	-1	UP	-0.9745	5	0.0049
42°N	APR	-2	UP	0.9457	5	0.0151
42°N	JUN	-2	UP	0.9279	5	0.0230
Trinidad Beach	OCT	-1	SST	-0.8958	5	0.0397
48°N	MAY	-2	UP	-0.8932	5	0.0412
Charleston	OCT	-2	SST	-0.8798	5	0.0491
			Columbia River North Jetty			
45°N	FEB	-1	UP	0.9961	5	0.0003
45°N	MAR	0	UP	0.9936	5	0.0006
45°N	SEP	-1	UP	-0.9915	5	0.0009
48°N	MAR	0	UP	0.9762	5	0.0044
42°N	FEB	-1	UP	0.9732	5	0.0052
42°N	SEP	-1	UP	-0.9641	5	0.0081
45°N	MAY	-2	UP	-0.9416	5	0.0168
45°N	DEC	0	UP	-0.9349	5	0.0197
42°N	DEC	0	UP	-0.9110	5	0.0315
45°N	OCT	-2	UP	0.8952	5	0.0401
48°N	MAY	0	UP	0.8790	5	0.0469
			Horsefall Beach			
48 °N	SEP	0	UP	-0.8418	7	0.0175
Trinidad Beach	JUN	0	SST	-0.8385	7	0.0184
45°N	JUN	-2	UP	0.8385	7	0.0184
Charleston	OCT	-1	SST	-0.8290	7	0.0211
Humboldt Bay	DEC	0	WH	-0.9270	5	0.0234
Columbia R.	MAR	0	WH	-0.8579	6	0.0289
42°N	JUN	-2	UP	0.7626	7	0.0462
45°N	SEP	0	UP	-0.7593	7	0.0477

Table 14b. Correlations of environmental variables and TCPH arranged by location and time lag. Trinidad Beach (T), Charleston (C), Neah Bay (N) are sea surface temperature sampling locations. Upwelling index locations are 42°N, 45°N, and 48°N Along the United States west coast. Negative and positive correlations are indicated by the respective mathematical symbols. Significant (*) and highly significant (**) linear correlations are also indicated.

Environmental variable Lagged -2 years		Beards Hollow	Columbia River North Jetty	Horsefall Beach
APR	Upwelling	+42*		
MAY	Upwelling	-48*	-45*	
JUN	Upwelling	+42*		+42*,+45*
OCT	Temperature	-C*		
OCT	Upwelling		+45*	

Environmental variable Lagged -1 years		Beards Hollow	Columbia River North Jetty	Horsefall Beach
FEB	Upwelling		+42**,+45**	
AUG	Upwelling	-45**		
SEP	Upwelling		-42**,-45**	
OCT	Temperature	-T*		-C*

Environmental variable Lagged 0 years		Beards Hollow	Columbia River North Jetty	Horsefall Beach
MAR	Upwelling		+45**,+48**	
MAY	Upwelling		+48*	
JUN	Temperature			-T*
SEP	Upwelling			-45*,-48*
DEC	Upwelling		-42*,-45*	

DISCUSSION

CPUE and Abundance

Amphistichus rhodoterus abundance was not available for this study and CPUE (TCPH) was used as an index of abundance. Catch per unit effort is related to abundance of other species (Beddington 1979; Kirkwood 1979; Peterman and Steer 1981; Richards and Schnute 1986; Polovina 1986; Bannerot and Austin 1987; Deriso and Parma 1987), but certain factors may cause CPUE not to be proportional to abundance. Chapter 3 demonstrated how handling time, gear saturation, competition for hooks, combining data from anglers of different skill, and recording effort in 0.5 units would affect TCPH values from the Horsefall Beach fishery. The factors reviewed in Chapter 3 did not have a large enough effect to cause non-proportionality in the CPUE (TCPH) population abundance relationship given the resolution of TCPH values. Bias associated with using only successful anglers in TCPH calculations, the applicability of 1987 Horsefall Beach studies to the entire MRFSS, and changes in availability and vulnerability are possible causes of non-proportionalities between CPUE and population abundance.

Use of only successful anglers in the TCPH calculations (TCPH bias) was determined using the TCPH Bias Model. All TCPH values below 1.2 *A. rhodoterus* per hour were corrected using TCPH Bias Model predictions. Thus, TCPH bias is not a part of the data reported.

The 1987 Horsefall Beach sampling captured fish of similar size and at similar rates to 1979 to 1985 MRFSS Horsefall Beach samples (Figures 14, 15; Appendix A), and thus are likely to be applicable to the MRFSS Horsefall Beach samples. Conclusions about TCPH from other MRFSS locations based on the 1987 Horsefall Beach samples require review of competition for hooks and gear saturation.

The MRFSS estimated the catch of *H. ellipticum* to be less (usually much less) than 2/3 and 1/3 of the catch of *A. rhodoterus* in Northern California and Oregon (1979 to 1986), respectively, and almost no catch of *H. ellipticum* occurred in Washington (USDC 1984a, 1984b, 1985, 1986, 1987). The catch of *L. armatus* was estimated to be higher than the catch of *A. rhodoterus* by the MRFSS. However, based on the relative catch of these two species reported in Chapter 3, *L. armatus* was assumed not to out-compete *A. rhodoterus* for hooks during the 1979 to 1989 surf fisheries sampled by the MRFSS. The catch of all species reported in the MRFSS is not likely to saturate the angling gear. Competition for hooks and gear saturation do not appear to be a factor affecting the CPUE abundance relationship for *A. rhodoterus* in MRFSS surf fisheries. Thus, conclusions based on 1987 Horsefall Beach data are applicable to other ocean beaches sampled by the MRFSS (Kalaloch Beach, Westport Beach, Beards Hollow, and Freshwater Lagoon). Conclusions based on 1987

Horsefall Beach data are applicable to Damon Point, Jetty Sands, and King Salmon fisheries because these fisheries are dominated by *A. rhodoterus* and catch rates are similar to Horsefall Beach (Allen et al. 1970; Gaumer et al. 1973; Culver 1980). Starry flounder, *Platichthys stellatus*, were caught slightly more often than *A. rhodoterus* at Columbia River North Jetty (Culver 1978), but because catch rates of the two species were similar and would not have saturated the gear, conclusions based on 1987 Horsefall Beach data are assumed to be appropriate for Columbia River North Jetty.

Availability (the proportion of the population in the area sampled) and vulnerability could be causing the annual changes in TCPH for the MRFSS data. This study assumes constant availability, or at least a stochastic equivalent (e.g. normally distributed). Clark and Mangel (1979) found changes in availability could change (or not) CPUE and stock abundance relationships in tuna stocks depending on model assumptions. Although tuna schools may be a good model for *A. rhodoterus*, information on population movements (other than gestating females discussed below) is unknown. The best argument against availability changes causing annual changes in TCPH is that if a portion of the population was moving out of the sampling area they should appear in increased sample sizes from adjacent areas, and this was not found (Appendix A). Vulnerability is not likely to have changed, based on the consistency of gear and tactics used in recreational surf angling.

Factors that are known to cause non-proportionality in the CPUE population abundance relationship were not large enough to prevent the use of MRFSS TCPH as an index of *A. rhodoterus* abundance. Thus, changes in TCPH calculated from MRFSS angler interviews are assumed to represent local *A. rhodoterus* population changes.

Marine Recreational Fishery Statistics Survey

Interstate Comparison

Washington locations had the widest range and largest number of *A. rhodoterus* lengths sampled. California locations had less catch below 20 cm in length than did other states, and annual TCPH values lower than for other states (Figure 16 and 17; Table 7). Annual TCPH ranged from 0.80 to 5.43 for Washington locations, 0.6 to 3.12 for Oregon locations, and 0.67 to 1.88 for California locations (Table 7). Based on this broad scale of information, Washington had the most fisheries, highest representation of large fish, and highest abundance (TCPH). These factors translate to Washington having larger and less highly exploited *A. rhodoterus* populations. California locations had lower abundance and intermediate sized fish.

Intrastate Comparison

Washington fisheries were in satisfactory to good condition overall, with some signs of apparent decline. The 1985 harvest levels, though sustainable for most Washington populations, were high enough that management changes could restore Kalaloch Beach, Damon Point, and Westport Beach fisheries to the early MRFSS levels. Increasing effort levels would contribute to further declines.

Most Oregon locations had too few samples to be included suggesting that *A. rhodoterus* fisheries were in poor condition. Horsefall Beach, the most consistently sampled fishery by the MRFSS, was dependant on prereproductive fish and abundance (TCPH) was declining. The Jetty Sands fishery was stable. Management changes are recommended for Horsefall Beach.

Low annual TCPH and sample numbers were noted for California when compared to other states (Table 7). Catches of large and age 2 sized *A. rhodoterus* were not documented in California, but were important components of past studies (Miller and Gotshall 1965; Ngoile 1978). Recruitment to the fishery did not occur until age 3. The average size of the fish in the catch was far below the average size in past studies (Miller and Gotshall 1965; Appendix A). Research into locating age 2 and large fish is recommended. Management changes should be considered if these age 2 and large fish cannot be located or are present in low numbers.

TCPH and Population Age Changes

At Horsefall Beach, a decrease in the annual TCPH was noted when a single cohort formed a large percentage of the fishery for two successive years (Table 7, Figure 14). Cohorts were recruited to the fishery at about 19 cm and were about 25 cm in length during the next year (Figure 14, Table 9). Strong recruitment in 1979 and 1981 resulted in an alternation of higher and lower annual TCPH values at Horsefall Beach (Table 7). The decrease in annual TCPH as a cohort ages was not surprising because as a fished cohort ages its contribution to catch would be expected to decline. The importance of decreasing TCPH with cohort age is in reference to the assumption that as TCPH decreases population abundance decreases. In this analysis, changes in annual TCPH which have an associated change in catch size distribution will be evaluated in relation to the catch size distribution before assuming a change in the total population size.

In addition to size at recruitment, size at first reproduction, size at age, and growth curves of the two sexes are helpful in analyzing length-frequency distributions. The minimum length of *A. rhodoterus* gravidity was calculated to be 23 cm TL. Male *A. rhodoterus* mature smaller, at lengths <20 cm TL; male reach a maximum reported size of 32 cm TL; females can reach 40+ cm TL; females reach 31 cm TL at age 6; thus, 32 cm and over fish are assumed to be older females (Bennett and Wydoski 1977; Ngoile 1978).

Kalaloch Beach

The highest TCPH occurred in 1985 and reflects the relative dominance of smaller fish (Figure 8). Prereproductive sizes constituted the greatest part of the 1985 catch. If this prevalence of prereproductive fish continued in the fishery, eventually a drop in the reproduction of this population would be expected. However, the relative dominance of smaller fish in 1985 may also be related to a very successful year class. A successful year class should be apparent in catches from future years; but fewer than 80 trips were sampled at this location during 1986 and any "success" of the 1985 recruits was lost within one year (Appendix A).

The majority of the Kalaloch Beach relative CPH was distributed between the 18- to 33-cm sizes indicating that the fishery occurred on several year classes and was viable at the 1985 level (Figure 8). The increasing catch of smaller fish would continue if fishing mortality increased above 1985 levels. The catch of fish larger than 32 and 30 cm during 1981 and 1982 and the lack of these sizes during

1983 and 1985 indicates that something was preventing the fish from reaching large sizes at this location (Figure 8). The loss of these size groups to the fishery in only 5 years could be the result of fishing mortality, high natural mortality levels or migration.

Damon Point

Damon Point is known for catches of larger older females (Culver 1980). The catch of 39- and 40-cm fish during 1982 and lack of their presence for the next three years at Damon Point (Figure 9) defines a change in the population. The 39-cm and over *A. rhodoterus* are within 2 cm of the maximum size reported for the species (Miller and Lea 1972). The fact that no 39-cm or larger fish were captured for three years after 1982, while fish with the potential to grow to this size were captured, indicates that something was preventing the surfperch from reaching full size. Prereproductive sizes progressively became more common in the catch after 1982 and reproductive size classes were always well represented.

Culver (1980) gave catch rates for 1977 and 1978, and a length frequency plot for 1978 from this location. The catch rates were in the same range as those calculated from the MRFSS for 1982 to 1985. Female *A. rhodoterus* dominated the catch during 1978 (Culver 1980) and this female length frequency plot was similar to the 1984 and 1985 cumulative

CPH length frequency distribution reported here. Thus, conditions in the Damon Point fishery during 1982 and 1983 seemed to be abnormal and returned to a normal condition during 1984 and 1985. The 1985 size distribution and catch were likely maintainable but increasing catch of prereproductive sizes may be a long term problem.

Westport Beach

The decreased catch of 27- and 28-cm sizes and increased catch of 18- and 22-cm sizes at Westport Beach (Figure 10) correspond to an increase in the percentage of prereproductive fish caught. Some fish above 28 cm were caught but an overall shift to smaller fish in the fishery occurred. The range of sizes caught remained stable over the sample period and length distribution changes were relatively small compared to changes at other Washington locations. This fishery should be monitored for a continuation of these shifts to smaller sizes, but appeared viable at the 1985 levels.

Beards Hollow

The Beards Hollow fishery improved between 1979 and 1985 (Figure 11). The lack of 32-cm and over fish during 1984 did not continue in 1985, and the relative importance of 21-cm and over sizes to the catch increased. The annual

TCPH decline over the period sampled is attributed to the increasing importance of larger fish in the catch.

Columbia River North Jetty

At Columbia River North Jetty, the broad size range of the catch and decrease in the 10- to 16-cm sized catch from 1979 and 1984 (Figure 12) indicated a viable, possibly expanding, fishery. The population abundance (annual TCPH) was more stable than all Washington and Oregon locations except for Jetty Sands (the Oregon side of the Columbia River jetties) (Table 7). This fishery is the best example of a broad size based, historically consistent, and viable *A. rhodoterus* fishery.

Jetty Sands

The Jetty Sands population abundance remained relatively stable during the MRFSS while the size range of the catch narrowed. Smaller sized fish were recorded for 1983 than for 1981, but the relative contribution of these smaller sizes decreased to less than 1981 levels during 1984 and 1985 (Figure 13). The population abundance as measured by annual TCPH was very stable, only changing 0.35 over the sample years (Table 7).

Horsefall Beach

A decrease in population abundance, though not significant, was observed at Horsefall Beach. The catch was alternating between primarily prereproductive sizes (19-cm) and first year reproductive sizes (25-cm) from 1979 to 1982, and fish >28 cm were uncommon (Figure 14). The 1986 and 1987 MRFSS did not sample enough fish at Horsefall Beach to make the information usable in this analysis; a small sample would be the logical extension of a decline in population. Decreasing annual TCPH for years with similar length frequency distributions indicated that population abundance was decreasing. Because of the lack of 32-cm and larger sized fish and the large catches of prereproductive fish on alternate years, the reproduction from this location was limited.

Freshwater Lagoon

The consistent catch of 21- to 34-cm size fish at Freshwater Lagoon was interesting in light of the fact that after 1979 no fish smaller than 19 cm were sampled (Figure 15). The fishery may have depended mainly on migration fish or perhaps angler only kept larger fish. The lack of sizes larger than 34 cm indicated older, highly fecund females were not caught and likely were not contributing to reproduction. The population abundance as indicated by annual TCPH was reasonably stable compared to other MRFSS locations examined.

King Salmon

The catch at King Salmon occurred earlier in the year than at any other location. Miller and Gotshall (1965) reported the best *A. rhodoterus* catches here were from October to May, and Allen et al. (1970) recorded catch rates of slightly over 1.0 *A. rhodoterus* per hour for February 20, 1964. The high catch rates in winter may reflect an attraction to the area's power plant cooling water discharge, although no attraction to the warmest part of the discharge was found by Allen et al. (1970).

The population abundance was low and decreased between 1982 and 1986, and there was an absence of fish smaller than 18 cm and larger than 35 cm (Figure 16). The absence of these sizes was similar to Freshwater Lagoon suggesting that a limited number of smaller fish and older females were present in the area. It is plausible that low recruitment was limiting the fishery at King Salmon. The lack of larger fish indicated that fish were not reaching full size possibly due to fishing mortality, natural mortality, migration, or other factors. In general, the population abundance and size distribution at King Salmon was stable, but a decrease between 1982 and 1986 occurred.

BLUE Estimate

Because the Horsefall Beach catch per trip and hours pre trip relationship (Figure 17) fit the criteria outlined in Cochran (1977), the total ratio estimate of CPH (TCPH) is "hard to beat" (Cochran 1977, p. 160) as the superior Best Linear Unbiased Estimator (BLUE) of CPH.

Estuaries

Damon Point and the Columbia River stations were technically inside estuaries; but they were not considered typical of past estuarine catch areas due to association with jetties and proximity to an estuary entrance. King Salmon was the only estuary location not in close proximity to the entrance. Samples at King Salmon depicted a decreasing population and sizes well below the 816 g average (= 30 cm TL) reported for California in the late 1950's and early 1960's (Miller and Gotshall 1965; Figure 16).

Many other estuarine locations were sampled by the MRFSS, but *A. rhodoterus* were uncommon (Appendix A). The few *A. rhodoterus* estuarine samples contrasted with the large catches of this species in Oregon estuaries in 1971 (Gaumer et al. 1973). An examination of several years of the MRFSS angler interview data base for any surfperch species sampled from Coos and Siuslaw estuary locations revealed many surfperch were sampled but few were *A. rhodoterus*. The only conclusion reached regarding estuarine fisheries was that few *A. rhodoterus* were sampled from inside estuaries. This conclusion implies that *A. rhodoterus* no longer extensively utilize estuaries.

Gravidity

The *A. rhodoterus* gravidity at length relationship was not statistically different from the past and variation was similar to the past. The Lincoln County regression slope was larger than any previously reported and the Coos, Douglas, and Lincoln counties combined regression slope was the second smallest reported (Table 11). It is not likely that any of the available regression relationships from Washington and Oregon are significantly different because the slopes of these regressions fall between two regressions which are not significantly different. The Northern California regression is also not likely to be significantly different because the slope is close to the lower range of Oregon regression slopes, and the California data had the poorest fit of the significant regression slopes ($R = 0.6$). The gravidity at length relationship for *A. rhodoterus* was stable both over time and geographic range.

Three differences in the Coos and Douglas County gravidity data stand out from Lincoln County data. First, Coos and Douglas County gravidity data did not form a regression with a slope significantly different from zero. This is likely to result from the narrow range of lengths sampled (213 to 308 mm). A significant regression slope would be expected if longer fish were sampled (Figure 21). Second, the two smallest, gravid *A. rhodoterus* ever recorded were sampled in these counties (230 and 213 mm). Ngoile (1978) and Bennett (1971) both sampled over twice the number of females but did not record pregnant fish this small. Studies with larger sample sizes would be predicted to contain more of the small pregnant fish if these were only rare, but expected occurrences. A hypothesis that *A. rhodoterus* from these areas mature at smaller sizes is supported by this finding, but cannot be tested. These two fish, especially the 213 mm fish, contributed to the nonsignificant regression slope by raising the 200- to 250-mm average gravidity as the regression line passes through closely spaced points in the 250- to 300-mm sizes. Third, many of the Coos and Douglas County *A. rhodoterus* gravidities were higher than Lincoln County gravidities for similar lengths (Figure 21). Higher gravidity at length could result from maturity occurring at smaller sizes in Coos and Douglas counties than in Lincoln County. Although there are two indicators that fish may mature at a smaller size in the Coos and Douglas County areas, the lack of appropriate samples prevents statistical comparison.

Non-gravid fish longer than 213 mm TL (length of smallest gravid fish) were included in the gravidity at length relationship (regression H, Table 11) in order to determine the length at which the population of female *A.*

rhodoterus should be considered gravid (*minimum length of gravidity*). A regression that included non-gravid fish equal or greater in length to the smallest gravid fish was the best way to estimate the mean population value. Including the Coos and Douglas County data in the regression admittedly decreased the regression slope and forced the length of gravidity to a minimum. The value of y=1 was the best single point for setting the minimum length of gravidity because any fish which carried less than 1 embryo could not be considered gravid and using y=0 (the mathematical length of gravidity) required the use of a difficult to interpret point in a step function which was forced to be an endpoint for a regression relationship.

The minimum length of gravidity for *A. rhodoterus* was 23 cm (232 mm). This was the most conservative estimate for minimum length of gravidity available from these data as exclusion of Coos and Douglas County samples could not be justified statistically. This minimum length can be used in management decisions as the length at which female *A. rhodoterus* are considered gravid if other reproductive information is unavailable. Slight seasonal adjustments for the minimum length of gravidity would be appropriate, but were not determined here.

Offspring Production

Studying only gestatory fish assumes that males do not limit the population's reproductive output. Available evidence supports the assumptions that male *A. rhodoterus* are not decreasing in abundance relative to females, are polygamous, and do not limit the reproductive output of females. For male *A. rhodoterus* to limit reproductive output, numbers of males (relative to females) or their ability to mate successfully would need to be limiting. Male *A. rhodoterus* mature sooner and are smaller than females (Bennett and Wydoski 1977; Ngoile 1978). The catch is mostly of lengths that would be mature fish if they were males (USDC 1984a, 1984b, 1985, 1986, 1987). In the most intensively studied surfperch, *Cymatogaster aggregata*, males mate with multiple females (Shaw and Allen 1977; Darling et al. 1980); the same is likely for *A. rhodoterus*. Non-gravid females and those carrying fewer embryos than predicted from past studies are uncommon (Table 11; Bennett and Wydoski 1977; Figure 21).

Population offspring production is dependant on the gravidity of females in the population and their abundance. Gravidity increased at a rate of 0.2 embryos per mm of length once maturity was reached. A >30-fold increase in gravidity is expected over a maximum female reproductive length span of 240 to 410 mm. This >30-fold increase in gravidity over the length span of *A. rhodoterus* emphasizes the importance of larger females to the production of offspring. However, offspring production must not be considered without also factoring in abundance information of different sizes of fish.

In general, viviparous fish would be expected to have intermediate survivorship curves with abundance decreasing more linearly than oviparous fish (McNaughton and Wolf 1979). Using the numbers and ages of female *A. rhodoterus* captured as a vertical survivorship sample, the ages contributing most to offspring production were calculated (Appendix Table 65). Ages 7 and under for Oregon and ages 6 and under for Northern California were estimated to produce greater than 10% of the offspring in the past (Bennett and Wydoski 1977; Ngoile 1978)(Table 65). These ages correspond to average lengths of less than 357 mm and 340 mm, respectively. The use of the number at age samples to represent survivorship could introduce error into the analysis, but correlation coefficients for the decreasing numbers at age were 0.97 and 0.94 for Bennett and Wydoski (1977) and Ngoile (1978), respectively. These survivorship curves are time and location specific and could be concave without the effects of the concurrent fisheries. Sample bias and variation in cohort survival can also affect the analysis. The best available estimate is that survivorship is linearly related to age (at least from age 2 or 3 onward), and that 4- to 7-year old fish contribute the most offspring production. Older fish may also contribute significantly if they represent more than 1 to 2% of the population.

Population Models

The Horsefall Beach population of *A. rhodoterus* was chosen to model because of the amount of information available from the MRFSS, the low cost to collect additional information, and the simplicity of the fishery. Age structured Horsefall Beach population models did not produce realistic annual cohort mortalities, but the Average Mortality Model demonstrated that Horsefall Beach population mortality was below sustainable levels. If all mortality occurred after parturition in early September, then the population may have been above replacement level in 1982, but not for other years. If all mortality occurred prior to parturition, then the population was below replacement from 1979 to 1985. Timing of mortality with respect to parturition at Horsefall Beach would be between these extremes.

Most *A. rhodoterus* recorded by the MRFSS were captured prior to parturition and thus some of the mortality of age 2+ fish occurred before parturition. The timing of natural mortality is unknown, but is likely to occur throughout the year. A model with at least some of the mortality prior to parturition is appropriate, and as the proportion of mortality prior to parturition increases the sustainable level of mortality decreases. Mortality is near sustainable levels for Horsefall Beach making information on the timing of mortality vital to the fishery's management.

The mortality rate prior to age 2 is also an unknown for *A. rhodoterus*. Mortality of fish in the ocean is generally highest at small sizes, and a rate of 0.33 for ages 1 and 2 may be an underestimate. Coho salmon, *Oncorhynchus kisutch*, experience an annual mortality rate of 0.83 their first year in the ocean off Oregon, and are larger (approximately 40 g) than neonate *A. rhodoterus* (Fisher and Pearcy 1988; Pearcy 1992). O-group plaice, *Pleuronectes platessa*, experience a mortality rate of 50% or greater per month in shallow surf nursery areas off Scotland (Poxton et al. 1982; Poxton and Nasir 1985). If mortality rates are higher than 0.33 for *A. rhodoterus* prior to age 2, which appears likely, then the Horsefall Beach population cannot sustain itself. Factors contributing to mortality prior to age 2 are discussed in the recruitment section.

The sensitivity of the Horsefall Beach Average Mortality Model to timing of mortality and parturition indicates that offspring production is near the replacement level. The bulk of 1979 to 1985 Horsefall Beach offspring production would have been produced by age 3 and 4 fish, which is fewer age classes than reported for previous studies where females from ages 4 to 7 produced 10% or more of the offspring per age class (Bennett and Wydoski 1977; Ngoile 1978; Appendix G). Both abundance and age structure have changed over time, so the actual numbers of young produced may not have changed as much as the age of the mothers.

A closed population is assumed for these models even though the cohesiveness of *A. rhodoterus* as a population along the open beach between the Coos and Umpqua rivers is unknown. Tagged and recaptured surfperch of other species have been documented to move only a few miles from the release location, and have been captured near the release location one year later (Morgan 1961; Smith 1967). However, movement along a uniform sandy stretch like Horsefall Beach is not likely to violate the closed population assumption as long as all fish along the same uninterrupted beach define the population. Movements offshore are possible, but *A. rhodoterus* have not been documented deeper than 18 m (Miller and Lea 1972). Catch of *A. rhodoterus* by commercial boats in California increased (landings data, Gloria Hawks, California Department of Fish and Wildlife, Long Beach, California), but fishermen may be moving onshore instead of fish moving offshore.

The movements most likely to violate the closed population assumption are those in and out of estuaries by older females (Bennett and Wydoski 1977; Ngoile 1978). *Amphistichus rhodoterus* were captured in Coos Bay during 1987, and some migration into Coos Bay from the Horsefall Beach population is likely. The migration of larger, older females away from Horsefall Beach into Coos Bay should not bias the maximum age estimates for the area, because the mature females collected in Coos Bay during 1987 were found to be age 4 or less. Few *A. rhodoterus* were sampled from Coos Bay by the MRFSS indicating little or no bias due to migration into the bay. Using the angling catch rates of fish inside and outside the estuary as a guide (1 and 83 fish in a similar number of hours; Chapter 3), the abundance of *A. rhodoterus* at Horsefall Beach is likely underestimated by 1.2% due to females migrating into Coos Bay. Any violation of the closed population assumption at Horsefall Beach because of fish moving into Coos Bay is small, and any violation due to movements along the ocean beach is unlikely.

The length at age relationship of fish measured during the MRFSS is not known and the estimates used could also bias the model. The length at age relationship may have been the problem with the Age Structured Model. The Average Mortality Model used the most conservative length at age information available, which if in error would tend to place *A. rhodoterus* in the next higher age class than was appropriate. This conservative approach had the effect of predicting minimum average mortality of age 2 and older fish. It is not likely that the length at age relationship used would overestimate average mortality.

The Average Mortality Model demonstrates that the Horsefall Beach *A. rhodoterus* population was near, but below a sustainable mortality level from 1979 to 1985. If the model parameters were overly conservative, the population was likely declining; if they were not conservative enough, the population could be increasing. Both TCPH and recruit index generally declined over this period supporting the idea of a population decrease, but the trends were not significant.

If a decrease in population abundance were occurring, the Average Mortality Model predicted exponential decline over 5 to 15 years (Figure 22). Because of this gradual decline a significant reduction in abundance may not be found for several years. The best *A. rhodoterus* information from the MRFSS spans only 7 years, which may not be long enough to show a significant trend, especially when a relative index is used to estimate abundance. Indications are that mid 1980's abundance was lower than in the 1958 to 1971 period for Oregon and California (Miller and Gotshall 1965; Gaumer et al. 1973). More information about age specific mortality and its timing, and ocean beach migration are needed for the development of a more predictive population model.

The Average Mortality Model demonstrated that accurate *A. rhodoterus* population estimates over several years are needed to find a significant population decline because of the exponential nature of population changes. The largest *A. rhodoterus* annual abundance reductions will occur in the first few years, and the largest annual abundance increases will occur years after any change in mortality. If abundance estimates are not available during the first few years of a decline and are collected later, population reductions may not be significantly different for several years. This may be the case for *A. rhodoterus* in California and Oregon where abundance appeared to be high in the 1950's through 1970's, but relative abundance information was not available until 1979 (Miller and Gotshall 1965; Gaumer et al. 1973; USDC 1984a). Many factors that could potentially influence *A. rhodoterus* abundance have changed since the 1950's through the 1970's. Angling effort has likely increased, upwelling has weakened, ocean temperatures have been warmer, and marine mammals have increased in abundance.

<u>Environmental Correlations</u>

Theoretically, *A. rhodoterus* reproduction and recruitment may be regulated by density dependant factors, because these viviparous fish produce relatively large and fully functional young. However, density dependant factors did not appear to be affecting *A. rhodoterus* recruitment because stock size and recruitment were not significantly correlated, and because recruitment was correlated with density independent factors. Recreational angling, commercial catch, and harbor seal abundance also were not related to *A. rhodoterus* recruitment and abundance. Temperature during gestation was shown to affect embryo development (Chapter 2), and may be related to the correlation between upwelling and recruitment at Horsefall Beach and Beards Hollow. Because on average there were more than 1.24 (0.01 * 124 random variables) highly significant and 6.2 (0.05 * 124) significant environmental correlations per recruit index and TCPH value (Tables 13a, 13b, 14a, 14b), the correlations outlined below were not purely the result of random chance. Correlations that were due to random chance cannot be distinguished using this analysis.

Beards Hollow and Horsefall Beach correlations were similar in pattern between recruited and abundance indexes. Although the number of these correlations was not different than expected, the consistency of pattern would not be expected from random variables. Both these locations are sandy beaches north of an estuary entrance and the consistency in the correlation may result from the similar locational characteristics.

Horsefall Beach and Beards Hollow recruitment indexes were negatively correlated with the previous years, October sea surface temperature in Charleston, and positively correlated with June upwelling 2 years previously (Table 13a, 13b). October is usually the end of warm fall ocean temperatures and the start of more dynamic colder conditions in the Pacific Northwest surf zone. Second-winter survival of recruits may be linked to the environmental temperature during October, but the average October sea surface temperature ranged only 0.95°C over the study at Charleston, and the correlation is likely to be of little biological significance (Appendix E). The correlation of recruit index with September sea surface temperature of the same year is probably a coincidence because recruits were a large part of the catch from May through August at these locations, and because most of the year's catch occurs before September. Two-year-old recruits would be gestating embryos during June two years previously, and either temperature or parental food availability could affect their growth. Cool temperatures during gestation slow embryo growth and may affect offspring survival (Chapter 2). Thus, gestation environment may affect recruitment as well as embryonic growth and parturition.

Columbia River North Jetty recruitment strongly correlated with March upwelling (positive) of the previous year and May temperature (negative) of the same and previous year. The spring transition from winter into upwelling conditions occurs at this time of year and the production of food in strong upwelling years is the most likely cause of strong *A. rhodoterus* recruitment. The May temperature range is <2.0°C (Appendix Table 50).

Columbia River North Jetty abundance is strongly positively related to upwelling during spring and negatively to early fall upwelling. Because temperature was not a strong correlate, upwelling associated changes in food abundance are a likely mechanism controlling *A. rhodoterus* abundance. Upwelling's influence on the surf zone food web during seasonal transitions should be investigated.

Both abundance and recruitment at Columbia River North Jetty are strongly correlated with upwelling variables. The value of the upwelling variables themselves were related to the 1983 El Niño Southern Oscillation (ENSO). The March 1979 and 1983 45°N upwelling index values were the low and high extremes (Appendix Table 54). Therefore, abundance at Columbia River North Jetty was strongly influenced by El Niño probably through upwelling during March 1983.

El Niño Southern Oscillation

The 1982-83 ENSO could have affected the *A. rhodoterus* populations and fisheries throughout the species range. Changes in productivity, survival, and range of fish species are common during temperature anomalies associated with ENSO events (Pearcy and Schoener 1987; Pearcy 1992), and temperature is known to affect surfperch distribution (Wiebe 1968; Terry and Stephens 1976; Shrode et al. 1983). The 1982, 1983, and 1984 MRFSS interview data stand out as the most nontypical of the records from 1979 to 1989. The 1982 Damon Point length frequency was different from the more common length frequencies sampled in 1978, 1984, and 1985 (Figure 9; Culver 1980). Strong recruitment occurred at Damon Point and Westport Beach during 1983 and 1984, respectively (Table 12). Low recruitment occurred during 1982 and 1984 for Horsefall Beach and Columbia River North Jetty, respectively (Table 12). Columbia River North Jetty and Beards Hollow in 1983 and Columbia River North Jetty in 1982 had fewer fish sampled than were taken in the years before and after the ENSO event (Appendix A). High TCPH (abundance) occurred at Damon Point during 1983. Low TCPH occurred at Columbia River North Jetty during 1984 and at Horsefall Beach during 1982. While there is no direct link established, it appears that the 1982 to 1983 ENSO had an effect on *A. rhodoterus* populations in Oregon, Washington, and California from 1982 to 1984. The *A. rhodoterus* population changes possibly related to ENSO events were strong recruitment at Damon Point, and smaller populations at Horsefall Beach (1982) and Columbia River North Jetty (1984). These population changes at Horsefall Beach and Columbia River North Jetty may have been due to changes in recruitment.

Fishery Recommendations

Harvest restrictions at locations where replacement level of offspring production does not occur is recommended. The recommended harvest restriction is no catch of "female" *A. rhodoterus* at the given location or in adjacent estuaries until three consecutive years of replacement offspring production have occurred. "Female" *A. rhodoterus* are defined as any fish having a straight margin to the anal fin (see below). Harvest restrictions should be implemented after three consecutive years of less than replacement levels of reproduction so the population can stabilize. Restrictions designed to maintain higher levels of offspring production are unwarranted because recruitment is not related to parent stock size, but to physical environmental variables. For more stringent actions, management goals would need to be clearly defined.

The recommended conditions used to determine replacement level include gravidity and growth levels as used in the Average Mortality Model, no migration, constant mortality throughout life, and mortality prior to parturition. Assuming the same mortality for all ages may underestimate the mortality of young fish. Mortality of small fish is often higher than for older fish (Pearcy 1992; Pepin 1993); *A. rhodoterus* produce fully functional young (5 to 8 g), and a more linear decrease in numbers with time would be expected than for oviparous fish (McNaughton and Wolf 1979). Pepin (1993) found that individual larval survival rate was nearly constant for a species regardless of size, but that among species, where a larger size range exists, mortality decreased with increasing size. Assuming that all *A. rhodoterus* mortality occurs prior to parturition is an oversimplification, but is closer to reality than assuming all occurs after parturition. The no migration assumption should be further investigated, but recovery of other large, tagged embiotocids has generally been within a few miles of the release point (Morgan 1961; Smith 1967).

Restricting harvest of "female" *A. rhodoterus* would restrict the harvest to mature males. Adult female *A. rhodoterus* cannot be distinguished from juveniles while mature males can easily be distinguished from either adult females or juveniles due to the formation of a notch in the anal fin margin during maturation (Bennett and Wydoski 1977). At least one anal fin ray of mature male *A. rhodoterus* (numbers 11-14, most often number 12) is much shorter than other rays (K.G. Brookins, Oregon State University, unpublished data). No harvest of "female" *A. rhodoterus* would have little effect on the harvest of males because male *A. rhodoterus* develop the anal fin notch at approximately 15 to 20 cm TL (Bennett and Wydoski 1977) and most of the harvest is 20 cm or larger (Figures 8 to 16). Hook-and-line catch-and-release of females is not expected to cause much mortality based on survival of females used in Chapter 2 experiments.

Management guidelines to identify population replacement level can be generated from the Average Mortality Model. Using the recommended conditions, a mortality rate of 0.489 resulted in an equilibrium *A. rhodoterus* population over 35 years. This 0.489 mortality rate would be an ideal management guideline, but would require additional research. Using the size and age structure of the equilibrium population would be an easier guideline because much of the size information is already collected in recreational surveys. In the equilibrium population, the percentages of the age 2 to 9 fish at each age are 49, 25, 13, 7, 3, 2, 1, and 0, respectively. The recommended guide for evaluating *A. rhodoterus* populations is the percentage of age 5 fish should be at least 7% of the age 2 to 9 fish in an equilibrium population. Unfortunately, populations are not likely to be at equilibrium and evaluations should be based on the abundance of a cohort at age 5 being at least 7% of that cohorts abundance at age 2. Serious bias could be introduced by strong or decreasing recruitment if survival of different cohorts are compared.

Annually, populations should be randomly sampled for 200 fish resulting in sampling limits of ±0.5%. The fishery can be the source of the fish as long as their collection is representative of the population in the area. For example, fishery collections from March through September may not be representative because large females are expected to be in estuaries. With uninterrupted, annual population age samples, the age 5 fish can be compared to their recruitment cohort size and not the recruitment for the year in which they were sampled. This type of population sampling would be large enough to estimate mortality for the younger ages in the fishery, though much larger samples would be needed to estimate mortality at older ages.

CONCLUSION

Washington *A. rhodoterus* populations and fisheries were in the best condition, while the California fisheries were in the poorest. Few *A. rhodoterus* were sampled from estuaries. All large fisheries sampled by the MRFSS were sustainable (except for Horsefall Beach), but the size of fish caught was declining at many locations. *Amphistichus rhodoterus* gravidity at length was stable between 1968 and 1992 over most of the species' geographic range.

Successful angler TCPH has a positive bias below an average catch rate of 1.2 fish per hour and single hook TCPH has a negative bias starting at about 1.2 fish per hour. The jackknife variance for TCPH when applied to MRFSS data for *A. rhodoterus* resulted in 8 out of 9 confidence intervals of less than ± 1 fish per hour. *Amphistichus rhodoterus* length frequencies were not statistically different when calculated using catch or CPH data generated from a typical recreational marine fishery survey.

The MRFSS data was useable for an average mortality model of recruited age classes, but not usable for an age structured model. More information about age specific mortality and migration is needed to form a predictive population model. The 1992 to 1993 El Niño probably acted to increase recruitment at Damon Point and decrease population size at Horsefall Beach and Columbia River North Jetty. Recruit index was correlated with June upwelling two years previous, and the population abundance index was correlated with spring and fall seawater temperature and upwelling. Though most *A. rhodoterus* fisheries appear sustainable, responsive management is recommended when populations fall below replacement levels.

REFERENCES

Allen, G.H., L.B. Boydstun, and F.G. Garcia. 1970. Reaction of marine fishes around warmwater discharge from an atomic steam-generating plant. The Progressive Fish-Culturist 32(1):9-16.

Anderson, R.O., and S.J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 283-300 in L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Bakun, A. 1973. Coastal upwelling indices, west coast of North America, 1946-1971. NOAA Technical Report NMFS SSRF-671.

Bannerot, S.P., and C.B. Austin. 1983. Using frequency distributions of catch per unit effort to measure stock abundance. Transactions of the American Fisheries Society 112:608-617.

Beddington, J.R. 1979. On some problems of estimating population abundance from catch data. Report of the International Whaling Commission 29:149-154.

Bennett, B.A., and C.G. Attwood. 1991. Evidence for recovery of a surf-zone fish assemblage following the establishment of a marine reserve on the southern coast of South Africa. Marine Ecology Progress Series 75:173-181.

Bennett, D.E. 1971. Biology of the redtail surfperch (*Amphistichus rhodoterus*) from the central Oregon coast. M.S. Thesis, Oregon State University, Corvallis.

Bennett, D.E., and R.S. Wydoski. 1977. Biology of the redtail surfperch (*Amphistichus rhodoterus*) from the central Oregon coast. U.S. Fish and Wildlife Service, Technical Paper 90:1-23.

Bond, C.E. 1979. Biology of fishes. W.B. Sanders Co. Philadelphia, Pennsylvania.

Brown, R.F. 1988. Assessment of pinniped populations in Oregon, April 1984 to April 1985. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Processed Report 88-05.

Burger, J., and M. Gochfeld. 1991. The common tern. Columbia University Press, New York, New York.

Bye, V.J. 1984. The role of environmental factors in the timing of reproductive cycles. Pages 187 to 205 in G.W. Potts and R.J. Wootton, editors. Fish reproduction: strategies and tactics. Academic Press Inc., London.

Campana, S.E. 1990. How reliable are growth back-calculations based on otoliths? Canadian Journal of Fisheries and Aquatic Sciences 47: 2219-2227.

Carlisle, J.G., Jr., J.W. Schott, and N.J. Abramson. 1960. The barred surfperch (*Amphistichus argenteus* Agassiz) in Southern California. Fish Bulletin Number 109, California Department of Fish and Game, Sacramento.

Clark, C.W., and M. Mangel. 1979. Aggregation and fishery dynamics: a theoretical study of schooling and the purse seine tuna fisheries. Fishery Bulletin (U.S.) 77(2):317-337.

Clutton-Brock, T.H., F.E. Guiness, and S.D. Albon. 1982. Red deer: behavior and ecology of two sexes. University of Chicago Press, Chicago.

Cochran, W.G. 1977. Sampling techniques, 3d ed. John Wiley and Sons, Inc. New York, New York.

Cohen, J. 1977. Statistical power analysis for the behavioral sciences. Academic Press, Inc., Orlando, Florida.

Crone, P.R., and S.P. Malvestuto. 1991. Comparison of five estimators of fishing success from creel survey data on three Alabama reservoirs. Pages 61-66 in D. Guthrie, J.M. Hoenig, M. Holliday, C.M. Jones, M.J. Mills, S.A. Moberly, K.H. Pollock, and D.R. Talhelm, editors. Creel and angler surveys in fisheries management. Symposium 12, American Fisheries Society, Bethesda, Maryland.

Culver, B. 1978. 1977 recreational fisheries at the Columbia River north jetty. Washington Department of Fisheries, Progress Report No. 63.

Culver, B. 1980. The 1977 and 1978 recreational fishery for redtail surfperch (*Amphistichus rhodoterus*) at Damon Point, Washington. Washington Department of Fisheries, Progress Report Number 118.

Cushing, D.H. 1975. Marine ecology and fisheries. Cambridge University Press, Cambridge, Massachussets.

Darling, J.D.S., M.L. Noble, and E. Shaw. 1980. Reproductive strategies in the surfperches. I Multiple insemination in natural populations of the shiner perch, *Cymatogaster aggregata*. Evolution 34(2):271-277.

DeMartini, E.E., T.O. Moore, and K.M. Plummer. 1983. Reproductive and growth dynamics of *Hyperprosopon argenteum* (Embiotocidae) near San Diego, California. Environmental Biology of Fishes 8(1):29-38.

Dentler, J.L., and G.D. Grossman. 1980. A geographic record for the redtail surfperch, *Amphistichus rhodoterus*. California Fish and Game 66(4):242.

Deriso, R.B., and A.M. Parma. 1987. On the odds of catching fish with angling gear. Transactions of the American Fisheries Society 116:244-256.

Earle, M.D., and J.P. Eckard, Jr. 1988. Coastal wave statistical data base, volume 2. Outer Continental Shelf Study. Minerals Management Service 88-0019.

Fisher, J.P., and W.G. Pearcy. 1988. Growth of juvenile coho salmon (*Oncorhynchus kisutch*) off Oregon and Washington, USA, in years of differing coastal upwelling. Canadian Journal of Fisheries and Aquatic Sciences 45:1036-1044.

Fisher, J.P., and W.G. Pearcy. 1989. Distribution and residence times of juvenile fall and spring chinook salmon in Coos Bay, Oregon. Fishery Bulletin, U.S. 88:51-58.

Gaumer, T., D. Demory, and L. Osis. 1973. 1971 Oregon estuary resource use studies. Fish Commission of Oregon, 1973-1974 (12 volumes).

Gnose, C.E. 1967. Ecology of the striped seaperch, *Embiotoca lateralis*, in Yaquina Bay, Oregon. M.S. Thesis, Oregon State University, Corvallis.

Gordon, D.C. 1965. Aspects of the life history of *Cymatogaster aggregata* Gibbons. M.S. Thesis, University of British Columbia, Vancouver.

Harvey, J.T., R.F. Brown, and B.R. Mate. 1990. Abundance and distribution of harbor seals (*Phoca vitulina*) in Oregon, 1975-1983. Northwest Naturalist 71(3):65-71.

Hubbs, C.L. 1921. The ecology and life-history of *Amphigonopterus aurora* and of other viviparous perches of California. Biological Bulletin 40:181-209.

Karentz, D., and C.D. McIntire. 1977. Distribution of diatoms in the plankton of Yaquina estuary, Oregon. Journal of Phycology 13:379-388.

Kirkwood, G.P. 1979. The net catcher day as a measure of effort. Report of the International Whaling Commission 29:163-165.

Lukas, J., and C. Carter. 1985. 1983 pounds and value of commercially caught fish and shellfish landed in Oregon. Oregon Department of Fish and Wildlife, Portland, Oregon.

Lukas, J., and C. Carter. 1988. 1986 pounds and value of commercially caught fish and shellfish landed in Oregon. Oregon Department of Fish and Wildlife, Portland, Oregon.

Lukas, J., and C. Carter. 1993. 1991 pounds and value of commercially caught fish and shellfish landed in Oregon. Oregon Department of Fish and Wildlife, Portland, Oregon.

Malvestuto, S.P. 1983. Sampling the recreational fishery. Pages379-419 in L.A. Nielsen and D.L. Johnson, editors Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

McNaughton, S.J., and L.L. Wolf. 1979. General ecology, 2nd ed. Holt, Rinehart and Winston, New York, New York.

Miller, P.J. 1984. The tokology of gobioid fishes. Pages 119-153 in G.W. Potts and R.J. Wootton, editors. Fish reproduction: strategies and tactics. Academic Press Inc., London.

Miller, D.J., and D.W. Gotshall. 1965. Ocean sportfish catch and effort from Oregon to Point Arguello, California. Fish Bulletin Number 130, California Department of Fish and Game, Sacramento.

Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Fish Bulletin Number 157, California Department of Fish and Game, Sacramento.

Morgan, A.R. 1961. Siletz Bay surf perch tagging. Fish Commission of Oregon Research Briefs 8(1):5-13.

Ngoile, M.A.K. 1978. Biology of the redtail surfperch, *Amphistichus rhodoterus*, in Northern California. M.S. Thesis, Humboldt State University, Arcata, California.

Odenweller, D.B. 1975. The life history of the shiner surfperch, *Cymatogaster aggregata* Gibbons, in Anaheim Bay, California. Pages 107-115 in E.B. Lane and C.W. Hill, editors. The marine resources of Anaheim Bay. Fish Bulletin Number 165, California Department of Fish and Game, Sacramento.

Oliphant, M.S., P.A. Gregory, B.J. Ingle, and R. Madrid. 1990. California marine fish landings for 1977-1986. Fish Bulletin Number 173, California Department of Fish and Game, Sacramento.

Pearcy, W.G. 1992. Ocean ecology of North Pacific salmonids. Washington Sea Grant, University of Washington Press, Seattle.

Pearcy, W.G., and A. Schoener. 1987. Changes in the marine biota coincident with the 1982 - 1983 El Niño in the northeastern subarctic Pacific Ocean. Journal of Geophysical Research 92(c13):14417-14428.

Peden, A.E., and G.W. Hughes. 1986. First records, confirmatory records, and range extensions of marine fishes off Canada's west coast. Canadian Field Naturalist 100(1):1-9.

Pepin, P. 1993. An appraisal of the size-dependent mortality hypothesis for larval fish: comparison of a multispecies study with an empirical review. Canadian Journal of Fisheries and Aquatic Sciences 50:2166-2174.

Peterman, R.M., and G.J. Steer. 1981. Relation between sport-fishing catchability coefficients and salmon abundance. Transactions of the American Fisheries Society 110:585-593.

Polovina, J.J. 1986. A variable catchability version of the Leslie model with application to an intensive fishing experiment on a multispecies stock. Fishery Bulletin (U.S.) 84(2):423-428.

Poxton, M.G., and N.A. Nasir. 1985. The distribution and population dynamics of O-group plaice (*Pleuronectes platessa* L.) on nursery grounds in the Firth of Forth. Estuarine Coastal and Shelf Science 21:845-857.

Poxton, M.G., A. Eletheriou, and A.D. McIntyre. 1982. The population dynamics of O-group flatfish on nursery grounds in the Clyde Sea area. Estuarine Coastal and Shelf Science 14:265-282.

Quinn, T.J., II. 1985. Catch-per-unit-effort: a statistical model for Pacific halibut (*Hippoglossus sterolepis*). Canadian Journal of Fisheries and Aquatic Sciences 42:1423-1429.

Richards, L.J., and J.T. Schnute. 1986. An experimental and statistical approach to the question: is CPUE an index of abundance? Canadian Journal of Fisheries and Aquatic Sciences 43:1214-1227.

Richards, L.J., and J.T. Schnute. 1992. Statistical models for estimating CPUE from catch and effort data. Canadian Journal of Fisheries and Aquatic Sciences 49:1315-1327.

Sampson, D.B. 1988. Fish capture as a stochastic process. Journal du Conseil International pour l'Exploration de la Mer 45: 39-60.

Schultz, E.T. 1990. Why do small dwarf perch breed late? The cause and consequences of breeding schedule variation in female *Micrometrus minimus*. Ph.D. Dissertation, University of California, Santa Barbara.

Scripps Institution of Oceanography. 1978. Surface water temperatures at shore stations, United States west coast 1977. SIO reference 78-16.

Scripps Institution of Oceanography. 1979. Surface water temperatures at shore stations, United States west coast 1978. SIO reference 79-9.

Scripps Institution of Oceanography. 1980. Surface water temperatures at shore stations, United States west coast 1979. SIO reference 80-11.

Scripps Institution of Oceanography. 1981. Surface water temperatures at shore stations, United States west coast 1980. SIO reference 81-30.

Scripps Institution of Oceanography. 1982. Surface water temperatures at shore stations, United States west coast 1981. SIO reference 82-17.

Scripps Institution of Oceanography. 1983. Surface water temperatures at shore stations, United States west coast 1983. SIO reference 83-16.

Scripps Institution of Oceanography. 1984. Surface water temperatures at shore stations, United States west coast 1983. SIO reference 84-26.

Scripps Institution of Oceanography. 1986. Surface water temperatures at shore stations, United States west coast 1985. SIO reference 86-18.

Scripps Institution of Oceanography. 1994a. Surface water temperatures at shore stations, [Online]. Available FTP:NEMO.UCSD.EDU Directory:/PUB/SHORE/PAST_YEARS File:CHARLEST.T.

Scripps Institution of Oceanography. 1994b. Surface water temperatures at shore stations, [Online]. Available FTP:NEMO.UCSD.EDU Directory:/PUB/SHORE/PAST_YEARS File:TRIN_BCH.T

Scripps Institution of Oceanography. 1994c. Surface water temperatures at shore stations, [Online]. Available FTP:NEMO.UCSD.EDU Directory:/PUB/SHORE/PAST_YEARS File:NEAH_BAY.T

Shaw, C.R., and J. Allen. 1977. The reproductive behavior of the female shiner perch, *Cymatogaster aggregata*, family Embiotocidae. Marine Biology 40:81-86.

Shrode, J.B., L.J. Purcell, and J.S. Stephens, Jr. 1983. Ontogeny of thermal preference in four species of viviparous fishes (Embiotocidae). Environmental Biology of Fishes 9(1):71-76.

Smith, A.K. 1967. Population dynamics and ecology of the embiotocids of Humboldt Bay, California. M.S. Thesis, Humboldt State College, Arcata, California.

Smith, S.J. 1980. Comparison of two methods of estimating the variance of the estimate of catch per unit effort. Canadian Journal of Fisheries and Aquatic Sciences 37:2346-2351.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Co., San Francisco, California.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry. Second edition. W.H. Freeman and Co., San Francisco, California.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill, New York, New York.

Swedberg, S.E. 1965. Age-fecundity relationships in the striped seaperch *Embiotoca lateralis* from Yaquina Bay, Oregon. M.S. Thesis, Oregon State University, Corvallis.

Tarp, F.H. 1952. A revision of the family Embiotocidae (the surfperches). Fish Bulletin Number 88, California Department of Fish and Game, Sacramento.

Terry, C.B., and J.S. Stephens, Jr. 1976. A study of the orientation of selected embiotocid fishes to depth and shifting seasonal vertical temperature gradients. Bulletin of the Southern California Academy of Science 75:170-182.

Tienhoven, A. 1983. Physiology of vertebrates. Cornell University Press, Ithaca, New York.

Triplett, E.L. 1960. Notes on the life history of the barred surfperch, *Amphistichus argenteus* Agassiz, and a technique for culturing embiotocid embryos. California Fish and Game 46:433-439.

Turner, C.L. 1947. Viviparity in teleost fishes. The Scientific Monthly 65:508-518.

(USDC) U.S Department of Commerce, Coast and Geodetic Survey. 1956. Surface water temperatures. Special Publication No. 280.

(USDC) U.S. Department of Commerce. 1984a. Marine recreational fishery statistics survey, Pacific Coast, 1979-1980. Current Fisheries Statistics No. 8321.

(USDC) U.S. Department of Commerce. 1984b. Marine recreational fishery statistics survey, Pacific Coast, 1981-1982. Current Fisheries Statistics No. 8323.

(USDC) U.S. Department of Commerce. 1985. Marine recreational fishery statistics survey, Pacific Coast, 1983-1984. Current Fisheries Statistics No. 8325.

(USDC) U.S. Department of Commerce. 1986. Marine recreational fishery statistics survey, Pacific Coast, 1985. Current Fisheries Statistics No. 8328.

(USDC) U.S. Department of Commerce. 1987. Marine recreational fishery statistics survey, Pacific Coast, 1986. Current Fisheries Statistics No. 8393.

(USDC) U.S. Department of Commerce. 1992a. Marine recreational fishery statistics survey, Pacific Coast, 1987 -1989. Current Fisheries Statistics No. 9205.

(USDC) U.S. Department of Commerce. 1992b. Oceanographic Monthly Summary 7(5):7.

(USDC) U.S. Department of Commerce. 1992c. Oceanographic Monthly Summary 7(6):7.

(USDC) U.S. Department of Commerce. 1992d. Oceanographic Monthly Summary 7(7):7.

Wares, P.G. 1971. Biology of the pile perch, *Rhacochilus vacca*, in Yaquina Bay, Oregon. U.S. Fish and Wildlife Service, Technical Paper 57.

Wiebe, J.P. 1968. The effects of temperature and day length on the reproductive physiology of the viviparous seaperch *Cymatogaster aggregata* Gibbons. Canadian Journal of Zoology 46:1207-1219.

Wilson, D.C., and R.E. Millemann. 1969. Relationships of female age and size to the embryo number and size in the shiner perch, *Cymatogaster aggregata*. Journal of the Fisheries Research Board of Canada 26:2339-2344.

Wydoski, R.S., and D.E. Bennett. 1973. Contributions to the life history of the silver surfperch (*Hyperprosopon ellipticum*) from the Oregon coast. California Fish and Game 59:178-190.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall International, Inc., London.

APPENDIXES

APPENDIX A

EXPLANATION OF APPENDED DISKETTES

Three 3.5-inch high density computer diskette are included with this dissertation. Diskettes 1 and 2 contain *Amphistichus rhodoterus* fishery statistics calculated from data collected by the 1979 to 1989 Marine Recreational Fisheries Statistics Survey (MRFSS). The third diskette contains computer programs and will be explained below.

The fishery statistics were calculated using programs written by the author, and copies of programs are available from the author. All statistics were calculated month by month, and annual statistics are calculated from monthly values. Number of interviews sampling *Amphistichus rhodoterus* and number of length observations were summed monthly. Total hours fished is the sum for all interviews of hours per interview. Mean hours fished was calculated by totaling the hours per interview and dividing by the number of interviews. Catch was calculated as the sum of catch per interview (average catch per interview when >1 angler was represented by an interview). This causes the sampled catch to be underestimated, but is more accurate in determining mean catch and catch per hour. Mean catch is catch divided by the number of interviews. Catch per hour (CPH) was calculated by dividing catch per trip by the number of hours sampled. The total ratio estimate of CPH (TCPH) was calculated by dividing total monthly catch by total hours fished in that month. Mean catch per hour was calculated by summing CPH for all interviews and dividing by the number of interviews. Average length was calculated by summing lengths of measured fish and dividing by the number of observations. Standard deviations (STD) were calculated following Steel and Torrie (1980).

The data is stored in three directories A:\WAS (414,540 bytes), A:\ORE (771,505 bytes), and A:\CAL (1,082,410 bytes). A:\ORE is split between diskettes 1 and 2. All files in each directory has a file extension (.___ at the end of the file name) which identifies which state the information is from. Washington, Oregon and California file extensions are WAS, ORE, and CAL, respectively, and contain 470, 873, and 1,224 files, respectively. Statistics for each location within a state are contained in 13 files, one statistic per file. Files names identify the location and the statistic. Locations are represented as the number in the file name and the statistic by one or two letters. The letters C, H, R, S, L, O, and W stand for Catch, Hours fished, catch per hour (Rate), Standard deviation, Length, number of Observations, and Weighted mean (TCPH), respectively. Thus a file with the name and extension 76LO.ORE contains the length observations for location 76 in the state of Oregon. Files in these state directories are arranged as month-by-year tables. Months are arranged in columns starting with January on the left. Rows are years chronologically top to bottom. Number of interviews, number of length observations, hours fished and catch tables contain an extra row at the bottom of the table which contains the totals for the MRFSS survey. Other data formats are available from the author.

Listed below are the files on the third appended disk (Table 15) and a brief description of each (Table 16)

Table 15. Directory of diskette 3 as would be seen after a Disk Operating System (DOS) dir command. Each file is a BASIC computer program, data file, or EXCEL® 4.0 spreadsheet.

File Name	Extension	Size Bytes	Formation Date	Time
CPUEBIAS	BAS	3434	07-23-94	11:26p
NMODEL2	BAS	3567	07-22-94	11:23p
AVMMDL	XLS	60757	02-16-95	5:04p
TCPHBIAS	BAS	3640	09-16-94	5:33p
TCPHVAR2	BAS	7311	09-22-94	4:33p
RNDC2AG	BAS	403	11-14-94	9:39a
RNDCATCH	BAS	460	11-10-94	10:19p
RNDCCAT	BAS	334	11-17-94	10:10p
RNDCKARL	BAS	449	11-12-94	9:34p
RNDCRHRS	BAS	461	11-14-94	12:05p
RTSTAT89	BAS	5007	11-20-92	3:11p
RTSTATS	ORE	4643	09-30-92	10:39a
RTSTATWA	BAS	4736	08-18-93	1:59p
RTSTATSC	BAS	6299	09-16-93	11:56p
RTTABLE4	BAS	5182	11-21-92	2:23p
RTTABLEC	BAS	5654	09-14-93	3:38p
RTTABLES	BAS	8094	10-06-92	4:17p
NMFSRTWA	BAS	1338	10-10-90	9:41p
NMFSRT88	BAS	1323	10-24-90	8:11p
NMFSRT89	BAS	1329	11-09-92	4:34p
WA505779	ORE	51456	01-27-88	11:16a
NMFSRT2	BAS	1513	07-05-90	5:27p
NMFSSP	BAS	1501	11-30-93	12:39p
LCPE	BAS	1968	02-06-93	2:44p
LCPEYR	BAS	1940	02-10-93	1:57p
QTR182	011	35712	04-12-89	7:44a
	28 file(s)		218511 bytes	

Table 16. Short descriptions of files and programs on appended diskette 3.

CPUEBIAS.BAS is a QBASIC® computer program that generates mean catch per hour data using the Core Model to simulate successful angler trips and all angler trips.

NMODEL2.BAS is a QBASIC® computer program that generates catch and CPH based length frequency data from a known distribution (Length Frequency Model).

AVMMDL.XLS is an EXCEL® 4.0 spreadsheet containing the Horsefall Beach average mortality model.

TCPHBIAS.BAS is a QBASIC® computer program that generates TCPH data using the Core Model to simulate successful angler trips and all angler trips (TCPH Bias Model).

TCPHVAR2.BAS is a QBASIC® computer program that generates TCPH jackknife variance data using the Core Model (TCPH Variance Model).

RNDC2AG.BAS is a QBASIC® computer program that generates Monte Carlo simulated TCPH data using 6 angler skill levels.

RNDCATCH.BAS is a QBASIC® computer program that generates Monte Carlo simulated TCPH data from all successful Horsefall Beach trips during 1987 (Chapter 3).

RNDCCAT.BAS is a QBASIC® computer program that generates Monte Carlo simulated catch per trip data.

RNDCKARL.BAS is a QBASIC® computer program that generates Monte Carlo simulated TCPH data using Angler 1's successful trips.

RNDCRHRS BAS is a QBASIC® computer program that generates Monte Carlo simulated TCPH data using all successful 1987 Horsefall Beach trips, but having the hours fished rounded to the next higher hour.

RTSTAT89.BAS is a GWBASIC® computer program that calculates redtail surfperch fishery statistics for MRFSS 1989 data formats.

RTSTATS.ORE is a GWBASIC® computer program that calculates redtail surfperch fishery statistics for MRFSS Oregon data formats.

RTSTATWA.BAS is a GWBASIC® computer program that calculates redtail surfperch fishery statistics for MRFSS Washington data formats.

Table 16. continued.

RTSTATSC.BAS is a GWBASIC® computer program that calculates redtail surfperch fishery statistics for MRFSS California data formats.

RTTABLE4.BAS is a GWBASIC® computer program that takes the output from a RTSTAT__.BAS program and puts it in tabular form.

RTTABLEC.BAS is a GWBASIC® computer program that takes the output from a RTSTAT__.BAS program and puts it in tabular form.

RTTABLES.BAS is a GWBASIC® computer program that takes the output from a RTSTAT__.BAS program and puts it in tabular form.

NMFSRTWA.BAS is a GWBASIC® computer program that searches MRFSS Washington data files for redtail surfperch records and transfers them to a redtail surfperch only data base.

NMFSRT88.BAS is a GWBASIC® computer program that searches MRFSS 1988 data files for redtail surfperch records and transfers them to a redtail surfperch only data base.

NMFSRT89.BAS is a GWBASIC® computer program that searches MRFSS 1989 data files for redtail surfperch records and transfers them to a redtail surfperch only data base.

WA505779.ORE is a MRFSS data base file containing angler interview records for wave 5 (September and October) 1979 from Lincoln County, Oregon.

NMFSRT2.BAS is a GWBASIC® computer program that searches some types of MRFSS Oregon data files for redtail surfperch records and transfers them to a redtail surfperch only data base.

NMFSSP.BAS is a GWBASIC® computer program that searches MRFSS data files for surfperch (Embiotocid) records.

LCPE.BAS is a GWBASIC® computer program that uses monthly MRFSS data files to generate monthly length frequencies.

LCPEYR.BAS is a GWBASIC® computer program that uses annual MRFSS data files to generate annual length frequencies.

QTR182.011 is a MRFSS data base file containing angler interview records from Coos County during first quarter of 1982.

Table 17. Washington locations where *Amphistichus rhodoterus* were recorded by the Marine Recreational Fishery Statistics Survey.

Number	Observations	Name
1	0	Chinook boat ramp
2	22	Ilwaco boat basin
3	20	Port Beanery boat ramp
4	326	Columbia River, north jetty
6	167	Beard's Hollow
7	3	Seaview Beach
8	105	Long Beach
9	25	Ocean Park Beach
13	32	Washaway Beach
14	3	Grayland Beach
15	4	Astoria Bridge
17	51	Cranberry road
18	56	Klipson Beach
20	0	Unidentified
25	14	Unidentified
26	74	Twin Harbors Beach
27	493	Westport Beach
28	103	Grays Harbor, south jetty
29	55	Halfmoon Bay
30	16	Westport groin jetties
32	82	Westport boat basin
33	2	Westport boat ramp
34	2	Elk River Bridge
35	268	Damon Point
36	210	Grays Harbor, north jetty
37	45	Ocean Shores Beach
38	17	Ocean City Beach
39	0	Copalis Beach
40	0	Pacific Beach
51	99	Kalaloch Beach
53	1	South Beach, Jefferson County
54	0	Unidentified
275	1	Cornet Bay ramp and pier
515	1	Don Armeni ramp
535	10	Unidentified
612	3	Old Town Dock, Tacoma

Table 18. Oregon locations where *Amphistichus rhodoterus* were recorded by the Marine Recreational Fishery Statistics Survey.

Number	Observations	Name
2	158	Columbia River, south jetty
3	108	Columbia River, jetty sands
4	76	Clatsop County beaches
10	1	Nehalem State Park
15	63	Tillamook estuary north jetty
16	1	Tillamook " Garibaldi moorage
17	103	Tillamook " Hobsonville Point
19	117	Cape Mears
20	17	Short Beach
21	16	Oceanside
27	111	Pacific City
34		Siletz River estuary, county ramp
36		Government Point to Depoe Bay
39		Otter Rock to Devils Punchbowl
40	2	Yaquina Head
42	10	Yaquina Bay, north jetty
43	59	Yaquina Bay, south jetty
44		Yaquina Bay, city docks
46		Yaquina Bay, Coquille Pt.-Yaquina Marina
48		Yaquina Bay, Marker 25 to Fowler's
50		Yaquina Bay, South Beach Marina - HMSC
53	83	Seal Rock to Lost Creek
54		Alsea Bay up to HWY 101
56		Waldport to Yachats
57	68	Yachats, Tablerocks
58	9	Yachats to Neptune State Park
59	1	Neptune State Park to Bob Creek
60	14	Stonefield Beach
62		Stonfield Beach to Devils Elbow
65	172	Siuslaw River, north jetty
66		Siuslaw River, city docks
67	19	Siuslaw River, south jetty
68	4	Florence to Reedsport
69	85	Umpqua, south jetty
72	53	Umpqua, C. G. Dock to Social Security Beach
74	2	Umpqua, Coast Guard Park
75	172	Umpqua, adjacent to south jetty
76	930	Umpqua River to Coos Bay
77	12	Coos Bay, south jetty
78	6	Coos Bay, roadfill
79	6	Coos Bay, Charleston waterfront
80	2	Coos Bay, Charleston bridge
82		Coos Bay, Empire

Table 18. continued.

Number	Observations	Name
83	17	Coos Bay, Pony Slough ramp
87	2	Coos Bay, Ford's dock
88	1	Coos Bay, Haynes Inlet
89		Bastendorf Beach
90	2	Sunset Bay to Cape Arago
91	92	Coquille estuary, north jetty
92	372	Coquille estuary, north side
93	16	Coquille estuary, city docks
94	50	Whiskey Run
95	92	Coquille estuary, south jetty
96	68	Beach south of Coquille estuary
97	25	Coquille estuary, Bullard's ramp
98		Cape Blanco
101	19	Sisters Rock to Frankport
102	81	Rogue River, north jetty
104		Rogue River, city docks
105	232	Rogue River, south jetty
106		Gold Beach to Cape Ferrelo
107		Cape Ferrelo to Chetco River
108		Chetco River, north jetty
109		Chetco River docks
110	20	Chetco River, south jetty
111	1	Brookings to California
125	16	Unidentified

Table 19. California locations where *Amphistichus rhodoterus* were recorded by the Marine Recreational Fishery Statistics Survey.

Number	Observations	Name
Alameda County		
1100	4	Berkeley Marina ramp
Del Norte County		
15100	3	Crescent City, public fish access
15112	1	Ship to Shore Resort
15200	21	Lopez Cr. to Pyramid Point
15201	19	Smith River to Lake Talawa outlet
15202	8	Pt. St. George to north breakwater
15212	1	Unidentified
15218	57	South breakwater to Nickel Cr.
15219	10	Footsteps Rock to False Klamath Rock
15232	12	Kamph Park
15302	4	Crescent City, public fishing pier
15303	8	Crescent City, south jetty
Humboldt County		
23103	5	Fields Landing boat ramp
23105	1	King Salmon landing sites
23108	1	Seaplane boat ramp, Somoa
23118	40	Crab Park boat launch
23204	72	Fern Canyon to Prairie Cr. State Park
23205	79	Freshwater Lagoon, Redwood Cr.-Sharp Pt.
23208	3	Trinidad Head to Little River
23209	79	Mad River Beach
23210	9	North spit
23211	56	South spit
23212	39	VABM8 to Eel River
23213	75	Eel River to Centerville Beach Park
23214	5	Point Delgada to Dead Mans Gulch
23215	2	Eureka Slough to west of KINS radio tower
23216	77	King Salmon, KPAN R. tower - Coast Guard cutter dock
23218	1	Unidentified
23222	25	Sharp Point to Big Lagoon outlet
23223	4	Megwil Point to Trinidad Head
23227	16	Humboldt Bay, Coast Guard boundary to Mad River Slough
23304	10	Humboldt Bay, north jetty
23305	10	Eureka, private docks and piers
23306	57	Humboldt Bay, south jetty
23308	11	Fields Landing, docks and piers
23309	8	Seaplane boat ramp, Samoa
23313	27	Eureka Slough, railroad trestle

Table 19. continued.

Number	Observations	Name
Marin County		
41201	24	Abbott's Lagoon to Pt. Reyes National Seashore
41202	37	Pt. Reyes Nat. Seashore to Coast Guard reservation
41205	6	Bolinas Lagoon to Stinson State Beach
41206	5	Stinson State Beach to Rocky Pt.
41211	20	Estero San Antonio through Dillon Beach
41215	4	Elephant Rock to Abbott's Lagoon
41218	5	Tom's Pt. to North Shore Boat Works
41220	30	Drakes Beach
41224	1	Sam's Pt. to Tom's Pt.
41301	1	Paradise Beach fishing pier
Mendocino County		
45100	1	Noyo Mooring Basin launch
45200	27	Little Juan Cr. to DeHaven Cr.
45201	4	DeHaven Cr. to Bell Point
45202	14	Abalobadiah Cr. to Ten Mile R.
45203	9	Sand Hill Lake outlet to Pudding Cr.
45204	9	Noyo R. to Point Cabrillo
45206	5	HWY 1 Big River bridge to Albion R.
45207	1	Gelchell Gulch to Bourns Landing
45209	37	Usal
45210	2	Elk
45211	68	Mancester
45300	25	Noyo Harbor, north and south jetties
45301	1	Noyo Harbor docks
45302	1	Point Arena pier
Monterey County		
53205	1	Pajaro River to Salinas River
San Francisco County		
75203	11	Baker Beach to Lobos Cr.
75207	4	Sloat BLVD to San Mateo County Line
75210	8	Lobos Cr. to Lookout Point Park, east end
75303	1	Pier 7, foot of Broadway
San Luis Obispo County		
79200	10	Old Creek to Atascadero State Beach, north end
79205	1	Oso Flaco Lake outlet to Santa Barbara County line
79305	1	Pismo Beach pier

Table 19. continued.

Number	Observations	Name
San Mateo County		
81200	0	Fisherman Park, off Airport Blvd.
81202	1	Pillar Point to Half Moon Bay jetty
81204	0	Lobitos Cr. to Tunitas Cr.
81213	0	Rockaway Beach, sand area
81215	3	Pedro Valley Beach, north to San Pedro Cr.
81222	9	Magnolia Rd. to Redondo Beach Drive
81224	12	San Gregorio Cr. to Pompanio Cr.
81226	1	Pescadero Beach
81237	15	Pescadero Point to Lake Lucerne outlet
81301	2	Pacifica Pier
81305	1	Princeton Harbor, east jetty
Santa Cruz County		
87201	2	Sunset Beach, north to Pajaro River
87203	3	Old Davenport Pier to Wilder Creek
87204	10	Aptos Creek to La Selva Creek
87209	1	San Mateo county to Old Davenport Pier
Sonoma County		
97200	2	Russian Gulch to Russian River
97201	4	Russian River to off Peaked Hill
97202	0	Gualala River to Gualala Point
97210	0	Salt Point to Stockhoff Creek
97217	2	Furlong Gulch to Duncan Point
97220	10	Marshal Gulch to Salmon Cr.
97221	43	Salmon Cr. to Mussel Point
97223	2	North Breakwater to Pinnacle Rock
97224	1	Pinnacle Rock to Marin County
97301	0	Bodega Harbor, north jetty

EXAMPLES OF DISKETTE FILES

Location 76, Horsefall Beach Oregon, files are presented as examples because they contain the most data, and because some readers may wish to review these data due to population declines noted in Chapter 4. Washington and California files have the same format. The basic file format is a matrix where rows represent years and columns represent months. In files where it was appropriate, column totals were placed in a final row. The row and column labels are not included in the file in order to facilitate use of the data by computer. Rows represent the years 1979 to 1989, top to bottom, with the last row being the sum of each column. Columns represent the months January to December, left to right. The arrangement of rows and columns are shown in Table 21.

Table 20. Contents of file A:\ORE\76C.ORE, monthly sampled catch numbers for location 76 in Oregon, Horsefall Beach.

0	0	0	0	0	0	53	199	193	0	5	0
0	0	0	0	17	19	12	93	55	0	0	0
0	0	0	7	0	43	284	123	0	0	0	0
0	0	2	0	0	68	15	53	1	3	0	0
0	16	0	25	214	105	100	127	0	0	0	0
0	7	2	0	2	133	273	237	114	11	0	0
0	7	0	14	10	11	58	55	263	0	6	9
0	0	0	0	0	46	18	4	0	0	0	0
0	0	0	0	0	0	45	32	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	7	0	0	0	0
0	30	4	46	243	425	859	930	626	14	11	9

Table 21. Contents of file A:\ORE\76C.ORE with month column, and year row labels.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
79	0	0	0	0	0	0	53	199	193	0	5	0
80	0	0	0	0	17	19	12	93	55	0	0	0
81	0	0	0	7	0	43	284	123	0	0	0	0
82	0	0	2	0	0	68	15	53	1	3	0	0
83	0	16	0	25	214	105	100	127	0	0	0	0
84	0	7	2	0	2	133	273	237	114	11	0	0
85	0	7	0	14	10	11	58	55	263	0	6	9
86	0	0	0	0	0	46	18	4	0	0	0	0
87	0	0	0	0	0	0	45	32	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	0	0
89	0	0	0	0	0	0	1	7	0	0	0	0
SUM	0	30	4	46	243	425	859	930	626	14	11	9

Table 22. Contents of file A:\ORE\76XC.ORE, monthly means of catch per trip for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 11 and 12, November and December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989. A sum of the columns is not included as a row.

0.00	0.00	0.00	0.00	0.00	0.00	7.60	11.06	21.44	0.00	4.50	0.00
0.00	0.00	0.00	0.00	5.67	2.42	2.45	6.65	7.83	0.00	0.00	0.00
0.00	0.00	0.00	7.00	0.00	8.50	10.92	10.25	0.00	0.00	0.00	0.00
0.00	0.00	1.00	0.00	0.00	6.78	2.90	6.63	1.00	1.50	0.00	0.00
0.00	16.00	0.00	3.53	14.26	9.53	5.85	7.48	0.00	0.00	0.00	0.00
0.00	2.17	1.67	0.00	1.00	4.74	8.26	13.94	8.79	3.67	0.00	0.00
0.00	3.50	0.00	2.02	3.33	1.83	3.83	5.50	6.93	0.00	2.00	3.00
0.00	0.00	0.00	0.00	0.00	7.63	3.60	2.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	6.43	10.67	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	1.00	7.00	0.00	0.00	0.00	0.00

Table 23. Contents of file A:\ORE\76CS.ORE, standard deviation of monthly mean catch per trip for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 9-12, September-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.000	0.000	0.000	0.000	0.000	0.000	5.640	5.980
10.415	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	4.933	1.990	2.718	6.300
5.505	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	0.000	4.637	12.670	7.896
0.000	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	0.000	5.615	2.632	5.090
0.000	0.707	0.000	0.000				
0.000	0.000	0.000	3.918	9.436	6.089	4.517	7.414
0.000	0.000	0.000	0.000				
0.000	1.041	0.000	0.000	0.000	4.877	7.905	11.723
4.684	2.363	0.000	0.000				
0.000	0.707	0.000	0.748	0.764	0.753	2.938	3.100
3.642	0.000	1.000	1.000				
0.000	0.000	0.000	0.000	0.000	3.121	3.647	1.414
0.000	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	0.000	0.000	6.241	7.371
0.000	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000				

Table 24. Contents of file C:\ORE\76H.ORE, monthly total of hours angling sampled for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 9-12, September-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989. The last row is the sum of each column.

0.0	0.0	0.0	0.0	0.0	0.0	20.0	63.5	28.5	0.0	3.0	0.0
1.5	0.0	0.0	5.0	12.0	11.5	10.0	40.0	13.5	29.0	0.0	0.0
0.0	0.0	0.0	1.5	0.0	18.5	83.0	38.0	0.0	141.0	0.0	0.0
0.0	0.0	7.5	0.0	0.0	203.1	13.0	24.0	1.0	4.5	0.0	0.0
0.0	4.0	0.0	15.5	43.0	39.0	58.5	55.5	0.0	0.0	0.0	0.0
0.0	8.0	4.5	0.0	5.0	81.0	108.5	65.5	32.5	10.5	0.0	0.0
0.0	3.5	0.0	17.0	9.5	17.5	55.0	33.0	129.0	0.0	7.0	7.5
0.0	0.0	0.0	0.0	0.0	20.0	11.5	6.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	23.0	8.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	4.0	2.0	0.0	0.0	0.0	0.0
1.5	15.5	12.0	39.0	69.5	390.6	386.5	335.5	204.5	185.0	10.0	7.5

Table 25. Contents of file A:\ORE\76XH.ORE, monthly mean of hours per trip for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 9-12, September-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.000	0.000	0.000	0.000	0.000	0.000	2.857	3.528	3.167	0.000	3.000	0.000
1.500	0.000	0.000	2.500	4.000	1.438	2.000	2.857	1.929	2.636	0.000	0.000
0.000	0.000	0.000	1.500	0.000	3.700	3.192	3.167	0.000	3.205	0.000	0.000
0.000	0.000	3.750	0.000	0.000	20.310	2.600	3.000	1.000	2.250	0.000	0.000
0.000	4.000	0.000	2.214	2.867	3.545	3.441	3.265	0.000	0.000	0.000	0.000
0.000	2.667	4.500	0.000	2.500	2.893	3.288	3.853	2.500	3.500	0.000	0.000
0.000	1.750	0.000	2.429	3.167	2.917	3.667	3.300	3.395	0.000	2.333	2.500
0.000	0.000	0.000	0.000	0.000	3.333	2.300	3.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	3.286	2.667	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	4.000	2.000	0.000	0.000	0.000	0.000

Table 26. Contents of file A:\ORE\76HS.ORE, standard deviation of monthly mean of hours per trip for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 9-12, September-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.000	0.000	0.000	0.000	0.000	0.000	1.180	0.977	1.904	0.000	0.000	0.000
0.000	0.000	0.000	0.000	1.000	0.678	0.935	0.969	0.673	1.247	0.000	0.000
0.000	0.000	0.000	0.000	0.000	1.037	0.960	1.174	0.000	1.042	0.000	0.000
0.000	0.000	0.354	0.000	0.000	25.833	0.548	1.558	0.000	0.354	0.000	0.000
0.000	0.000	0.000	0.699	0.855	1.254	1.171	1.200	0.000	0.000	0.000	0.000
0.000	0.289	0.000	0.000	0.707	1.150	1.369	1.272	0.890	0.000	0.000	0.000
0.000	0.354	0.000	1.018	0.577	0.801	0.794	1.059	0.807	0.000	0.289	0.500
0.000	0.000	0.000	0.000	0.000	0.753	0.274	0.707	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1.075	0.289	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 27. Contents of file C:\ORE\76L.ORE, monthly mean length of *Amphistichus rhodoterus* sampled for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 11 and 12, November and December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.0	0.0	0.0	0.0	0.0	0.0	221.6	228.4	217.9	0.0	229.6	0.0
0.0	0.0	0.0	0.0	243.6	242.8	206.8	229.0	242.0	0.0	0.0	0.0
0.0	0.0	0.0	210.6	0.0	230.3	216.2	235.5	0.0	0.0	0.0	0.0
0.0	0.0	263.0	0.0	0.0	219.0	239.4	212.3	165.0	0.0	0.0	0.0
0.0	260.5	0.0	237.1	224.7	232.4	210.2	231.5	0.0	0.0	0.0	0.0
0.0	251.8	243.2	0.0	367.5	234.0	227.8	235.9	234.8	238.2	0.0	0.0
0.0	0.0	0.0	258.7	267.2	258.3	226.9	249.7	225.9	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	273.1	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	242.3	251.3	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	251.0	245.0	0.0	0.0	0.0	0.0

Table 28. Contents of file A:\ORE\76LO.ORE, number of *Amphistichus rhodoterus* length observations from for location 76 in Oregon, Horsefall Beach. Columns represent months. Rows represent years, 1979 to 1989, and the last row is a sum of each column.

0.	0.	0.	0.	0.	0.	34.	163.	68.	0.	9.	0.
0.	0.	0.	0.	14.	15.	15.	50.	25.	0.	0.	0.
0.	0.	0.	7.	0.	34.	59.	59.	0.	0.	0.	0.
0.	0.	1.	0.	0.	51.	7.	19.	1.	0.	0.	0.
0.	10.	0.	25.	72.	92.	95.	111.	0.	0.	0.	0.
0.	10.	5.	0.	2.	135.	184.	45.	50.	16.	0.	0.
0.	0.	0.	16.	9.	6.	23.	7.	117.	0.	0.	0.
0.	0.	0.	0.	0.	10.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	19.	20.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	1.	7.	0.	0.	0.	0.
0.	20.	6.	48.	97.	343.	437.	481.	261.	16.	9.	0.

Table 29. Contents of file A:\ORE\76LS.ORE, standard deviation of monthly mean length for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 8-12, August-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.000	0.000	0.000	0.000	0.000	0.000	30.277
41.872	25.358	0.000	33.091	0.000		
0.000	0.000	0.000	0.000	25.452	29.958	38.090
48.574	28.247	0.000	0.000	0.000		
0.000	0.000	0.000	12.934	0.000	29.592	42.529
40.724	0.000	0.000	0.000	0.000		
0.000	0.000	0.000	0.000	0.000	25.159	28.283
48.530	0.000	0.000	0.000	0.000		
0.000	21.188	0.000	37.632	32.808	31.101	32.598
35.763	0.000	0.000	0.000	0.000		
0.000	47.623	8.228	0.000	2.121	35.193	31.165
22.876	25.522	38.792	0.000	0.000		
0.000	0.000	0.000	32.576	11.410	13.995	28.677
7.847	33.188	0.000	0.000	0.000		
0.000	0.000	0.000	0.000	0.000	29.430	0.000
0.000	0.000	0.000	0.000	0.000		
0.000	0.000	0.000	0.000	0.000	0.000	24.021
22.760	0.000	0.000	0.000	0.000		
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000		
0.000	0.000	0.000	0.000	0.000	0.000	0.000
37.678	0.000	0.000	0.000	0.000		

Table 30. Contents of file A:\ORE\76O.ORE, number of angler interviews recording *Amphistichus rhodoterus* at location 76 in Oregon, Horsefall Beach. Columns represent months. Rows represent years, 1979 to 1989, and the last row is the sum of each column.

0	0	0	0	0	0	7	18	9	0	1	0
1	0	0	2	3	8	5	14	7	11	0	0
0	0	0	1	0	5	26	12	0	44	0	0
0	0	2	0	0	10	5	8	1	2	0	0
0	1	0	7	15	11	17	17	0	0	0	0
0	3	1	0	2	28	33	17	13	3	0	0
0	2	0	7	3	6	15	10	38	0	3	3
0	0	0	0	0	6	5	2	0	0	0	0
0	0	0	0	0	0	7	3	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	0	0	0	0
1	6	3	17	23	74	121	102	68	60	4	3

Table 31. Contents of file A:\ORE\76XR.ORE, monthly mean catch per hour for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 9-12, September-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.000	0.000	0.000	0.000	0.000	0.000	2.734	3.172	8.956	0.000	1.500	0.000
0.000	0.000	0.000	0.000	1.489	1.719	1.048	2.126	4.367	0.000	0.000	0.000
0.000	0.000	0.000	4.667	0.000	2.317	3.216	3.464	0.000	0.000	0.000	0.000
0.000	0.000	0.268	0.000	0.000	14.086	1.050	2.216	1.000	0.700	0.000	0.000
0.000	4.000	0.000	1.869	4.754	2.761	1.704	2.133	0.000	0.000	0.000	0.000
0.000	0.811	0.370	0.000	0.417	1.626	2.564	3.453	3.753	1.048	0.000	0.000
0.000	2.083	0.000	0.976	1.048	0.622	1.052	1.750	2.246	0.000	0.867	1.256
0.000	0.000	0.000	0.000	0.000	2.501	1.540	0.629	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	2.045	3.844	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	3.500	0.000	0.000	0.000	0.000

Table 32. Contents of file A:\ORE\76RS.ORE, standard deviation of monthly mean catch per hour for location 76 in Oregon, Horsefall Beach. Columns represent months; columns 9-12, September-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.000	0.000	0.000	0.000	0.000	0.000	2.042	1.709	6.223	0.000	0.000	0.000
0.000	0.000	0.000	0.000	1.360	0.908	0.612	1.598	2.630	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	1.004	3.275	2.723	0.000	0.000	0.000	0.000
0.000	0.000	0.025	0.000	0.000	15.796	0.820	1.234	0.000	0.424	0.000	0.000
0.000	0.000	0.000	1.946	2.824	1.578	1.056	1.612	0.000	0.000	0.000	0.000
0.000	0.400	0.000	0.000	0.118	1.436	2.047	2.737	2.159	0.675	0.000	0.000
0.000	0.825	0.000	0.556	0.082	0.151	0.857	1.020	1.690	0.000	0.416	0.512
0.000	0.000	0.000	0.000	0.000	1.474	1.431	0.323	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	2.397	2.237	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 33. Contents of file A:\ORE\76WR.ORE, monthly weighted mean catch per hour (TCPH) figures for location 76 in Oregon, Horsefall Beach. Weighted means were calculated as total catch for the month divided by hours expended catching the fish. Columns represent months; columns 8-12, August-December, are wrapped around because of margin limitations. Rows represent years, 1979 to 1989.

0.00	0.00	0.00	0.00	0.00	0.00	2.65	3.13
6.77	0.00	1.67	0.00				
0.00	0.00	0.00	0.00	1.42	1.65	1.20	2.33
4.07	0.00	0.00	0.00				
0.00	0.00	0.00	4.67	0.00	2.32	3.42	3.24
0.00	0.00	0.00	0.00				
0.00	0.00	0.27	0.00	0.00	0.33	1.15	2.21
1.00	0.67	0.00	0.00				
0.00	4.00	0.00	1.61	4.98	2.69	1.71	2.29
0.00	0.00	0.00	0.00				
0.00	0.88	0.44	0.00	0.40	1.64	2.52	3.62
3.51	1.05	0.00	0.00				
0.00	2.00	0.00	0.82	1.05	0.63	1.05	1.67
2.04	0.00	0.86	1.20				
0.00	0.00	0.00	0.00	0.00	2.30	1.57	0.67
0.00	0.00	0.00	0.00				
0.00	0.00	0.00	0.00	0.00	0.00	1.96	4.00
0.00	0.00	0.00	0.00				
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00				
0.00	0.00	0.00	0.00	0.00	0.00	0.25	3.50
0.00	0.00	0.00	0.00				

APPENDIX B

MEASUREMENTS, COUNTS, AND CONDITION INDEX

OF EXPERIMENTAL FISH

Table 34. Data used in the analysis of *Amphistichus rhodoterus* parturition experiment. The column head abbreviations are number of live-born offspring (N), offspring survival, mean wet weight in grams (WWT), mean body length (BL) (mm), mean condition factor ((WWT)*10EXP4)/(BL)EXP3 = (K), and mean brood birth day.

		Offspring		MEAN			
Tank	Treat-ment	N	Sur-vival	WWT	BL(mm)	K	Birth day
4	heated	9	9/13	5.683	62.1	2.4269	23.3
5	ambient	18	18/20	7.182	65.8	2.5163	62.3
6	ambient	14	14/27	8.056	67.4	2.6266	44.6
7	heated	1	1/11	5.230	57.0	2.8241	44.0
8	heated	3	3/29	6.047	61.3	2.6207	39.3

Table 35. Size of female *Amphistichus rhodoterus* measured after parturition experiment. The abbreviations used are standard length (SL), body length (BL), fork length (FL), and total length (TL). Wet weight (WWT) is considered an inaccurate measure of the true size of these fish because of the poor condition of females after parturition (Bennett and Wydoski 1977).

			Lengths (mm)				
Tank	Treat-ment	Fish Number	SL	BL	FL	TL	WWT (g)
4	heated	92014	248				425.0
5	ambient	92012	264	274	306		660.6
6	ambient	92011	309		331	377	771.6
7	heated	92009	243	251	280	295	438.5
8	heated	92008	266	269	309		522.0

Table 36. Mean brood values for *Amphistichus rhodoterus* mid- and late-gestation embryo development experiments.

Female	Embryos		Mean		
ID #	Count	Number Normal	Weight (g)	Body Length (mm)	Condition Index
Mid-gestation experiment					
Treatment 14.3° C					
89024	17	17	0.658	30.9	22.2
89025	14	14	0.811	34.5	19.9
89026	13	13	0.569	30.3	20.5
Treatment 16.6° C					
89018	13	13	0.900	36.8	18.1
89027	10	4	0.338	25.0	21.6
89028	6	5	0.288	25.2	17.8
89029	13	5	0.630	31.0	21.1
89031	8	4	0.385	25.3	23.8
Treatment 18.9° C					
89019	11	1	0.220	24.0	15.9
89020	15	7	0.513	28.4	21.7
89022	14	5	0.448	29.3	21.6
89023	8	2	0.595	28.5	24.4
Late-gestation experiment					
Treatment 11.9° C					
91100	15	15	1.65	42.8	21.1
91101	17	16	1.76	43.9	20.7
91102	9	5	0.96	37.2	18.7
91103	8	8	1.41	42.8	18.0
91110	19	12	1.47	41.9	19.9
Treatment 15.2° C					
91104	19	19	3.00	51.7	21.7
91105	39	39	3.76	54.9	22.8
91106	24	14	2.4	47.9	21.9
91107	16	16	2.52	48.6	21.9

Table 37. Neonate *Amphistichus rhodoterus* data from the parturition experiment. Day is the day of birth from the start of the experiment, WWT is wet weight, offspring which were born are entered as 1 in the born column, and those removed from their mothers by dissection as 0. Fish which were alive after birth or dissection are classified as 1 in the live column and those dead as 0. Treatment is recorded as 0 for ambient and 1 for heated. Tank is the tank number of the mother. Total, fork, body, and standard lengths are recorded as TL, FL, BL, and SL, respectively.

WWT	DAY	BORN	LIVE	TREAT-MENT	TANK	TL	FL	BL	SL
5.43	21	1	0	1	4	71	67	57	56
5.49	21	1	0	1	4	71	68	57	56
5.25	21	1	1	1	4	73		69	
5.11	21	1	1	1	4	72		68	
5.85	21	1	1	1	4	75		60	
5.57	24	1	1	1	4	72		59	
5.46	24	1	1	1	4	72		59	
5.89	24	1	1	1	4	74		61	
5.99	24	1	1	1	4	75		62	
5.88	24	1	1	1	4	74		60	
0.86	24	1	0					45	44
1.44	26	1	0	1	3	53		42	41
1.49	26	1	0	1	3	53		41	40
1.43	26	1	0	1	3	55		44	43
1.55	26	1	0	1	3	52		41	40
1.63	26	1	0	1	3	55		43	42
1.66	26	1	0	1	3	54		41	40
1.63	26	1	0	1	3	56		42	41
1.47	26	1	0	1	3	52		41	40
1.44	26	1	0	1	3	55		45	44
1.37	26	1	0	1	3	50		40	39
1.57	26	1	0	1	3	57		43	42
1.74	26	1	0	1	3	53		40	39
6.04	27	1	0	1	4	74	71	60	59
6.15	27	1	1	1	4	75		61	60
6.50	34	1	0	1	4	71	68	58	57
5.74	37	1	1	1	8	75		61	
5.84	37	1	0	1	8	72	68	57	56
5.96	37	1	0	1	8	72	69	59	58
6.27	37	1	0	1	8	73	70	58	57
5.19	37	1	0	1	8	68	64	54	53
5.11	37	1	0	1	8	70	67	57	56
6.77	37	1	0	1	8	74	70	59	58
6.04	37	1	0	1	8	72	68	57	56
6.46	37	1	0	1	8	74	71	60	58
6.20	38	1	0	1	8	72	69	58	57
5.52	38	1	0	1	8	70	67	56	55

Table 37. continued.

WWT	DAY	BORN	LIVE	TREAT-MENT	TANK	TL	FL	BL	SL
6.67	38	1	0	1	8	73	70	58	57
6.59	38	1	0	1	8	72	69	58	57
6.74	38	1	0	1	8	74	71	60	59
5.41	38	1	0	1	8	71	67	57	56
6.80	38	1	0	1	8	72	69	58	57
5.65	39	1	0	1	8	74	71	60	58
5.19	39	1	0	1	8	70	66	57	56
5.77	39	1	0	1	8	73	69	59	58
5.50	39	1	0	1	8	71	68	57	56
5.73	39	1	0	1	8	73	70	58	57
5.77	39	1	0	1	8	71	68	58	57
6.31	39	1	0	1	8	70	66	57	56
6.22	40	1	1	1	8	76		61	60
5.28	40	1	0	1	8	72	68	57	56
6.04	40	1	0	1	8	75	72	61	60
6.18	41	1	1	0	8	76	74	62	61
7.56	41	1	1	0	6	80		66	
7.82	41	1	1	0	6	80		66	
8.34	41	1	1	0	6	84		68	
7.80	41	1	1	0	6	82		67	
8.07	41	1	1	0	6	82		67	
7.69	41	1	1	0	6	81		67	
7.88	41	1	1	0	6	82		67	
8.43	41	1	1	0	6	84		68	
7.46	41	1	1	0	6	81		66	
6.35	42	1	0	1	8	75	72	61	59
5.05	43	1	0	1	8	72	69	59	58
	44	1			8			62	61
5.07	44	1	0	1	7	70	68	55	54
5.23	44	1	1	1	7	72	69	57	56
2.09	47	1	0	1	7	60	57	47	46
6.22	48	0	0	1	7	72		58	57
4.58	48	0	0	1	7	70	67	56	55
4.43	48	0	0	1	7	69	66	56	55
5.88	48	0	0	1	7			67	65
5.55	48	0	0	1	7			66	65
5.64	48	0	0	1	7			61	60
5.34	48	0	0	1	7			58	57
4.61	48	0	0	1	7			58	57
8.72	51	1	1	0	6			70	68
8.12	51	1	1	0	6			67	65
7.42	51	1	1	0	6			67	65
9.26	51	1	1	0	6			71	69
8.22	51	1	1	0	6			66	65
8.81	51	1	0	0	6	80	77	66	64
9.86	51	1	0	0	6	83	79	69	67
8.45	51	1	0	0	6	83	80	70	68

Table 37. continued.

WWT	DAY	BORN	LIVE	TREAT-MENT	TANK	TL	FL	BL	SL
8.39	51	1	0	0	6	82	78	69	67
7.23	51	1	0	0	6	78	75	65	64
9.15	51	1	0	0	6	84	80	69	68
7.04	57	1	1	0	5	80		66	64
7.42	57	1	1	0	5	83		68	66
6.90	57	1	1	0	5	79		65	64
6.60	57	1	1	0	5	80		65	64
6.64	57	1	1	0	5	78		64	63
6.99	57	1	1	0	5	80		65	64
6.09	57	1	1	0	5	76		62	61
6.82	57	1	1	0	5			65	64
5.91	56	1	0	0	5	75		61	59
1.22	56	1	0	0	5			47	46
7.19	66	1	1	0	5	81		67	65
7.37	66	1	1	0	5	81		67	65
6.81	68	1	1	0	5	79		65	64
7.51	68	1	1	0	5	81		66	64
7.85	68	1	1	0	5	81		67	65
7.88	68	1	1	0	5	81		67	65
7.76	68	1	1	0	5	80		66	64
8.04	68	1	1	0	5	82		68	66
8.77	68	1	0	0	6			68	
6.06	68	0	0	0	6			64	
7.66	68	0	0	0	6			71	
6.94	68	0	0	0	6			66	
6.84	68	0	0	0	6			69	
7.30	68	0	0	0	6			67	
7.99	68	0	0	0	6			67	
7.85	72	0	1	0	5			66	
8.58	72	0	1	0	5			68	
1.10	72	0	0	0	2				42
1.32	72	0	0	0	2				42
1.33	72	0	0	0	2				41
1.19	72	0	0	0	2				42
1.34	72	0	0	0	2				42
1.13	72	0	0	0	2				40

Table 38. Neonate *Amphistichus rhodoterus* data from the 1991 late-gestation experiment. Parent identification number (N), body length (BL), wet weight (Wt), condition (K), and temperature (TEMP). Live embryos had vitality = 1, and dead embryos vitality = 0.

N	BL	Wt	K	VITALITY	TANK	TEMP
91100	45	1.52	16.68	1	1	12
91100	42	1.72	23.22	1	1	12
91100	43	1.83	23.02	1	1	12
91100	44	1.84	21.60	1	1	12
91100	41	1.53	22.20	1	1	12
91100	41	1.46	21.18	1	1	12
91100	42	1.61	21.73	1	1	12
91100	45	1.77	19.42	1	1	12
91100	43	1.83	23.02	1	1	12
91100	43	1.67	21.00	1	1	12
91100	42	1.54	20.79	1	1	12
91100	43	1.70	21.38	1	1	12
91100	42	1.68	22.68	1	1	12
91100	43	1.72	21.63	1	1	12
91100	43	1.30	16.35	1	1	12
91101	44	1.74	20.43	1	1	12
91101	45	1.83	20.08	1	1	12
91101	42	1.54	20.79	1	1	12
91101	44	1.88	22.07	1	1	12
91101	46	2.05	21.06	1	1	12
91101	44	1.64	19.25	1	1	12
91101	43	1.62	20.38	1	1	12
91101	43	1.82	22.89	1	1	12
91101	45	1.76	19.31	1	1	12
91101	44	1.74	20.43	1	1	12
91101	43	1.58	19.87	1	1	12
91101	43	1.78	22.39	1	1	12
91101	45	1.81	19.86	1	1	12
91101	45	1.75	19.20	1	1	12
91101	44	1.80	21.13	1	1	12
91101	43	1.74	21.88	1	1	12
91101	39	0.24	4.05	0	1	12
91102	37	1.12	22.11	1	2	12
91102	38	0.93	16.95	1	2	12
91102	36	0.82	17.58	1	2	12
91102	37	8.95	17.69	1	2	12
91102	38	0.99	18.04	1	2	12
91102	37	0.86	16.98	0	2	12
91102	37	0.92	18.16	0	2	12
91102	34	0.78	19.85	0	2	12
91102	32	0.72	21.97	0	2	12
91103	43	1.54	19.37	1	2	12
91103	43	1.65	20.75	1	2	12

Table 38. continued.

N	BL	Wt	K	VITALITY	TANK	TEMP
91103	42	1.61	21.73	1	2	12
91103	44	1.69	19.84	1	2	12
91103	42	0.16	2.11	1	2	12
91103	42	1.57	21.19	1	2	12
91103	42	1.50	20.25	1	2	12
91103	44	1.59	18.67	1	2	12
91110	41	1.42	20.60	1	8	12
91110	42	1.61	21.73	1	8	12
91110	45	1.64	18.00	1	8	12
91110	41	1.24	17.99	1	8	12
91110	42	1.55	20.92	1	8	12
91110	41	1.46	21.18	1	8	12
91110	43	1.51	18.99	1	8	12
91110	41	1.34	19.44	1	8	12
91110	43	1.48	18.61	1	8	12
91110	42	1.38	18.63	1	8	12
91110	42	1.59	21.46	1	8	12
91110	40	1.38	21.56	1	8	12
91110	40	1.46	22.81	0	8	12
91110	41	1.47	21.33	0	8	12
91110	41	1.40	20.31	0	8	12
91110	40	1.39	21.72	0	8	12
91110	39	1.39	23.43	0	8	12
91110	40	1.09	17.03	0	8	12
91110	41	1.49	21.62	0	8	12
91104	52	2.94	20.91	1	3	15
91104	52	3.12	22.19	1	3	15
91104	52	3.00	21.34	1	3	15
91104	52	3.26	23.19	1	3	15
91104	51	2.76	20.81	1	3	15
91104	52	2.92	20.77	1	3	15
91104	52	3.01	21.41	1	3	15
91104	53	3.06	20.55	1	3	15
91104	52	2.89	20.55	1	3	15
91104	51	2.84	21.41	1	3	15
91104	52	2.99	21.26	1	3	15
91104	52	3.22	22.90	1	3	15
91104	50	2.70	21.60	1	3	15
91104	51	3.07	23.14	1	3	15
91104	52	3.14	22.33	1	3	15
91104	53	3.25	21.83	1	3	15
91104	50	2.77	22.16	1	3	15
91104	51	2.97	22.39	1	3	15
91104	52	3.12	22.19	1	3	15
91105	56	4.07	23.18	1	3	15
91105	55	3.92	23.56	1	3	15
91105	54	4.26	27.05	1	3	15
91105	55	3.52	21.16	1	3	15
91105	56	4.03	22.95	1	3	15

Table 38. continued.

N	BL	Wt	K	VITALITY	TANK	TEMP
91105	56	4.22	24.03	1	3	15
91105	52	3.43	24.39	1	3	15
91105	55	3.86	23.20	1	3	15
91105	56	3.93	22.38	1	3	15
91105	54	3.75	23.81	1	3	15
91105	56	3.82	21.75	1	3	15
91105	53	3.52	23.64	1	3	15
91105	56	3.83	21.81	1	3	15
91105	52	3.31	23.54	1	3	15
91105	55	3.65	21.94	1	3	15
91105	52	3.56	25.32	1	3	15
91105	56	3.98	22.66	1	3	15
91105	57	3.94	21.28	1	3	15
91105	56	3.71	21.13	1	3	15
91105	55	3.71	22.30	1	3	15
91105	52	3.44	24.47	1	3	15
91105	53	3.72	24.99	1	3	15
91105	55	3.92	23.56	1	3	15
91105	54	3.33	21.15	1	3	15
91105	57	3.99	21.55	1	3	15
91105	58	3.85	19.73	1	3	15
91105	53	3.68	24.72	1	3	15
91105	54	3.56	22.61	1	3	15
91105	53	3.38	22.70	1	3	15
91105	54	3.71	23.56	1	3	15
91105	54	3.78	24.01	1	3	15
91105	53	3.73	25.05	1	3	15
91105	54	3.61	22.93	1	3	15
91105	56	3.60	20.50	1	3	15
91105	56	3.78	21.52	1	3	15
91105	58	4.22	21.63	1	3	15
91105	57	3.93	21.22	1	3	15
91105	56	3.96	22.55	1	3	15
91105	57	3.71	20.03	1	3	15
91106	45	2.22	24.36	1	4	15
91106	49	2.44	20.74	1	4	15
91106	48	2.48	22.42	1	4	15
91106	49	2.51	21.33	1	4	15
91106	48	2.50	22.61	1	4	15
91106	48	2.32	20.98	1	4	15
91106	49	2.60	22.10	1	4	15
91106	49	2.35	19.97	1	4	15
91106	47	2.25	21.67	1	4	15
91106	47	2.24	21.58	1	4	15
91106	47	2.35	22.63	1	4	15
91106	49	2.36	20.06	1	4	15
91106	47	2.51	24.18	0	4	15
91106	46	2.07	21.27	1	4	15
91106	42	1.75	23.62	0	4	15

Table 38. continued.

N	BL	Wt	K	VITALITY	TANK	TEMP
91106	40	1.46	22.81	0	4	15
91106	42	1.29	17.41	0	4	15
91106	42	1.33	17.95	0	4	15
91106	42	1.52	20.52	0	4	15
91106	44	1.56	18.31	0	4	15
91106	43	1.48	18.61	0	4	15
91106	43	1.20	15.09	0	4	15
91106	38	0.96	17.50	0	4	15
91106	49	2.91	24.73	1	4	15
91107	49	2.58	21.93	1	4	15
91107	50	2.77	22.16	1	4	15
91107	48	2.29	20.71	1	4	15
91107	50	2.83	22.64	1	4	15
91107	50	2.82	22.56	1	4	15
91107	48	2.63	23.78	1	4	15
91107	50	2.85	22.80	1	4	15
91107	44	1.99	23.36	1	4	15
91107	59	2.49	12.12	1	4	15
91107	52	3.34	23.75	1	4	15
91107	47	2.17	20.90	1	4	15
91107	46	2.09	21.47	1	4	15
91107	51	3.10	23.37	1	4	15
91107	44	1.97	23.13	1	4	15
91107	49	3.21	27.28	1	4	15
91107	41	1.25	18.14	1	4	15
91109	43	1.49	18.74	0	5	15
91109	40	0.98	15.31	0	5	15
91109	43	1.62	20.38	0	5	15
91109	45	1.60	17.56	0	5	15
91109	43	1.54	19.37	0	5	15
91109	47	1.76	16.95	0	5	15
91109	46	1.70	17.47	0	5	15
91109	44	1.63	19.14	0	5	15
91109	41	1.08	15.67	0	5	15
91109	39	1.06	17.87	0	5	15
91109	41	0.93	13.49	0	5	15
91109	42	1.38	18.63	0	5	15
91109	43	1.46	18.36	0	5	15
91109	43	1.66	20.88	0	5	15
91109	44	1.56	18.31	0	5	15
91109	43	1.64	20.63	0	5	15

Table 39. Temperature during mid-gestation experiment. Treatments were: 1 is ambient water, 2 is heated mixed with ambient water, and 3 is heated water only.

DAY	TEMP	TANK	TREATMENT	DAY	TEMP	TANK	TREATMENT
1	16.3	3	3	2	16.8	3	3
3	18.5	3	3	4	18.6	3	3
5	18.8	3	3	6	17.0	3	3
8	18.7	3	3	10	18.8	3	3
11	18.7	3	3	13	18.8	3	3
14	17.1	3	3	15	18.0	3	3
18	18.5	3	3	19	18.5	3	3
20	18.0	3	3	21	18.4	3	3
23	19.8	3	3	25	20.2	3	3
27	20.4	3	3	29	19.8	3	3
31	20.6	3	3	34	20.3	3	3
36	20.4	3	3	39	18.3	3	3
1	16.2	5	3	2	16.7	5	3
3	18.3	5	3	4	18.6	5	3
5	18.7	5	3	6	16.9	5	3
8	18.7	5	3	10	18.7	5	3
11	18.6	5	3	13	18.5	5	3
14	17.9	5	3	15	17.8	5	3
18	18.3	5	3	19	18.5	5	3
20	17.9	5	3	21	18.3	5	3
23	20.1	5	3	25	21.2	5	3
27	21.2	5	3	29	19.9	5	3
31	22.2	5	3	34	20.5	5	3
36	22.0	5	3	39	19.4	5	3
1	12.7	2	1	2	12.9	2	1
3	14.8	2	1	4	14.0	2	1
5	15.1	2	1	6	14.0	2	1
8	16.0	2	1	10	14.8	2	1
11	13.8	2	1	13	14.5	2	1
14	13.5	2	1	15	15.0	2	1
18	15.5	2	1	19	13.1	2	1
20	14.5	2	1	21	13.5	2	1
23	13.4	2	1	25	15.1	2	1
27	15.7	2	1	29	15.5	2	1
31	16.5	2	1	34	14.6	2	1
36	11.8	2	1	39	13.0	2	1
1	12.9	1	2	2	14.0	1	2
3	15.3	1	2	4	15.3	1	2
5	16.5	1	2	6	16.0	1	2
8	17.7	1	2	10	17.1	1	2
11	18.0	1	2	13	16.7	1	2
14	15.5	1	2	15	15.8	1	2
18	16.4	1	2	19	13.4	1	2
20	15.0	1	2	21	15.0	1	2
23	16.3	1	2	25	17.9	1	2
27	17.9	1	2	29	18.5	1	2

Table 39. continued.

DAY	TEMP	TANK	TREATMENT	DAY	TEMP	TANK	TREATMENT
31	18.9	1	2	34	18.5	1	2
36	17.3	1	2	39	18.2	1	2
1	12.9	4	2	2	15.5	4	2
3	16.0	4	2	4	16.7	4	2
5	17.5	4	2	6	16.5	4	2
8	18.0	4	2	10	16.3	4	2
11	16.3	4	2	13	19.3	4	2
14	15.5	4	2	15	15.3	4	2
18	16.4	4	2	19	14.5	4	2
20	15.9	4	2	21	15.7	4	2
23	16.3	4	2	25	19.4	4	2
27	20.0	4	2	29	18.0	4	2
31	19.1	4	2	34	20.5	4	2
36	18.3	4	2	39	19.0	4	2

Table 40. Temperature records from 1991 late-gestation experiment.

DAY	TEMPERATURE	TANK	DAY	TEMPERATURE	TANK
15	14.0	1	16	14.5	1
17	14.0	1	18	14.0	1
19	12.0	1	20	15.0	1
21	14.6	1	26	14.8	1
27	14.8	1	28	14.9	1
32	15.0	1	33	15.0	1
34	15.0	1	35	14.6	1
36	15.6	1	39	16.8	1
40	17.3	1	41	16.0	1
42	16.1	1	43	16.0	1
44	16.2	1	47	16.3	1
48	16.2	1	49	16.2	1
50	16.0	1	15	10.0	0
16	9.5	0	17	9.4	0
18	9.6	0	19	9.6	0
20	10.7	0	21	12.3	0
26	12.5	0	27	12.5	0
28	11.7	0	32	12.1	0
33	11.5	0	34	11.0	0
35	11.2	0	36	11.3	0
39	11.0	0	40	10.9	0
41	11.3	0	42	13.3	0
43	13.8	0	44	14.7	0
47	14.7	0	48	14.4	0
49	14.5	0	50	14.0	0

Table 41. Regression statistics for conversion of neonate *Amphistichus rhodoterus* total, fork, and standard lengths to body length. Fish body length was measured from the most anterior point on the fish to the end of scales on the tail and was used to decrease the handling time of live neonates. Lengths listed on the preceding three pages were used for the regression analysis. All slopes, intercepts, and regression models were significant at the p=0.025 level.

Length	Slope	Intercept	R-squared
Standard	1.05	- 1.69	99.5
Fork	0.91	- 7.81	98.6
Total	0.70	-12.28	82.7

Table 42. Live, normal developing *Amphistichus rhodoterus* embryo measurements from 1989 mid-gestation experiment. Parent identification number (N), body length (BL), wet weight (Wt), and Condition (K) are column headings.

N	BL	Wt	K	N	BL	Wt	K
89018	38	0.88	1.604	89018	34	0.81	2.061
89018	34	0.78	1.985	89018	36	0.88	1.886
89018	37	0.88	1.737	89018	39	0.95	1.602
89018	40	0.83	1.297	89018	37	0.87	1.718
89018	35	0.85	1.983	89018	38	1.08	1.968
89018	36	0.94	2.015	89018	37	1.08	2.132
89018	38	0.87	1.586	89019	24	0.22	1.591
89020	28	0.40	1.822	89020	30	0.62	2.296
89020	30	0.61	2.259	89020	30	0.59	2.185
89020	30	0.68	2.519	89020	27	0.40	2.032
89020	24	0.29	2.098	89021		0.42	
89021		0.62		89021		0.32	
89021		0.54		89022	31	0.58	1.947
89022	28	0.41	1.868	89022		0.36	
89022		0.24		89022	29	0.65	2.665
89023	31	0.81	2.719	89023	26	0.38	2.162
89024	31	0.65	2.182	89024	31	0.63	2.115
89024	31	0.66	2.215	89024	32	0.67	2.045
89024	31	0.57	1.913	89024	31	0.69	2.316
89024	31	0.60	2.014	89024	30	0.64	2.370
89024	32	0.67	2.045	89024	31	0.63	2.115
89024	31	0.72	2.417	89024	31	0.67	2.249
89024	31	0.72	2.417	89024	30	0.65	2.407
89024	30	0.63	2.333	89024	31	0.69	2.316
89024	31	0.70	2.350	89025	35	0.83	1.936
89025	38	0.86	1.567	89025	35	0.77	1.796
89025	36	0.86	1.843	89025	33	0.69	1.920
89025	35	0.91	2.122	89025	34	0.77	1.959
89025	36	0.82	1.758	89025	32	0.79	2.411
89025	35	0.82	1.913	89025	34	0.79	2.010
89025	35	0.88	2.052	89025	32	0.74	2.258
89025	33	0.82	2.282	89026	29	0.52	2.132
89026	30	0.54	2.000	89026	28	0.50	2.278
89026	32	0.59	1.801	89026	32	0.57	1.740
89026	30	0.56	2.074	89026	30	0.53	1.963
89026	31	0.60	2.014	89026	30	0.62	2.296
89026	31	0.56	1.880	89026	31	0.60	2.014
89026	30	0.59	2.185	89026	30	0.62	2.296
89027	25	0.30	1.920	89027	26	0.28	1.593
89027	23	0.31	2.548	89027	26	0.46	2.617
89028	25	0.27	1.728	89028	23	0.23	1.890
89028	24	0.24	1.736	89028	29	0.40	1.640
89028	25	0.30	1.920	89029	30	0.53	1.963
89029	31	0.62	2.081	89029	32	0.61	1.862
89029	31	0.73	2.450	89029	31	0.66	2.215
89031	24	0.30	2.170	89031	24	0.38	2.749
89031	26	0.37	2.105	89031	27	0.49	2.489

APPENDIX C

HORSEFALL BEACH SURF CATCH PER HOUR AND TIME OF SAMPLING

Table 43. Catch per hour, start times, and period of the day when sampling of the Horsefall Beach surf fishery occurred during 1987. Time period abbreviations are N noon (midday), M morning, E evening, and A afternoon. Species caught included *Amphistichus rhodoterus*, *Hyperprosopon ellipticum*, and *Leptocottus armatus*.

Date	Angler	Start Time	Time Period	*A. rhodoterus*	*H. ellipticum*	*L. armatus*
7-26	1	0614	M			1.88
8-6	1	1045	N	3.20	0.80	0.40
8-7	1	0857	M	1.13		1.13
8-8	2	0800	M		1.00	
8-8	3	0800	M	0.41		0.41
8-8	1	0800	M	2.45		0.41
8-10	1	1952	E	5.71		
8-11	1	1135	N	4.62		
8-11	1	1900	E	3.50		4.66
8-12	1	1107	N	2.43		
8-14	1	1049	N			1.18
8-15	1	1159	N			
8-22	1	0759	M	0.41		1.23
8-23	1	0730	M			0.49
8-31	1	1209	N	2.61	12.0	
9-1	1	1322	A	7.11	4.89	0.44
9-1	4	1404	A	6.25	0.63	1.86
9-2	1	1647	A	9.46		
9-5	1	1649	A	2.37	0.79	
9-5	5	1649	A	3.16		
9-9	1	0956	M	1.00		1.00

APPENDIX D

HORSEFALL BEACH SURF FISHERY MINUTE BY MINUTE CATCH SAMPLES WITH NOTES ON THE PRESENCE OF HARBOR SEALS IN FISHING AREA

Table 44. Minute by minute hook-and-line sampling results using two baited hooks from 1987 Horsefall Beach surf fishery, with notes on the presence of harbor seals. Species caught include redtail surfperch, silver surfperch, staghorn sculpin, shiner perch, and Dungeness crab. Times categories are start and stop of angling, and the time when the catch occurred. Locations include Horsefall Beach (HFB), the industrial waste "blood pool", and a Federal Aeronautic Administration (FAA) building on the seawall south of HFB.

		TIME			MINUTES							
DATE	LOCATION	START	CATCH	STOP	PER FISH	ELA-PSED	ANG-LER	RED-TAIL	SIL-VER	STAG-HORN	SHI-NER	CRAB
7/26/87	FAA BUILD.	0614	0620		6	6	1			1		
7/26/87	FAA BUILD.	0620	0640		20	26	1			1		
7/26/87	FAA BUILD.	0640	0653		13	39	1			1		
7/26/87	FAA BUILD.	0653	0707		14	53	1					1
7/26/87	FAA BUILD.	0707	0714		7	60	1			1		
7/26/87	FAA BUILD.	0714	0800		46	106	1			1		
7/26/87	FAA BUILD.	0800	0946		106	212	1			1		
7/26/87	FAA BUILD.	0946	1057		71	283	1			1		
7/26/87	FAA BUILD.	1057		1105		291	1					
8/6/87	HFB	1045		1102		17	1					
8/6/87	HFB	1153	1204		11	28	1	1				
8/6/87	HFB	1204	1222		18	46	1					1
8/6/87	HFB	1222	1224		2	48	1		1			
8/6/87	HFB	1224	1239	1239	15	63	1	1				
8/6/87	HFB	1304	1325		21	84	1	1				

Table 44. continued.

DATE	LOCATION	TIME			MINUTES							
		START	CATCH	STOP	PER FISH	ELAPSED	ANGLER	REDTAIL	SILVER	STAGHORN	SHINER	CRAB
8/6/87	HFB	1325	1330		5	89	1	1	1			
8/6/87	HFB	1330	1340	1340	10	99	1	1				
8/6/87	HFB	1355	1412		17	116	1	1		1		
8/6/87	HFB	1412	1418		6	122	1	1				
8/6/87	HFB	1418	1430		12	134	1	1				
8/6/87	HFB	1430		1446		150	1					
8/7/87	HFB	0857	0857		1	1	1			1		
8/7/87	HFB	0857	0907		10	11	1			1		
8/7/87	HFB	0907	0959		52	62	1	1				
8/7/87	HFB	0959	1103		64	126	1	1				
8/7/87	HFB	1103		1142		165	1					
8/8/87	HFB	0800	0806		6	6	2				1	
8/8/87	HFB	0806	0824		18	24	2				1	
8/8/87	HFB	0824	0842		18	42	2		1			
8/8/87	HFB	0842		0900		60	2					
8/8/87	HFB	0800	0816		16	16	3	1				
8/8/87	HFB	0816	0837		21	37	3			1		
8/8/87	HFB	0837		0900		60	3					
8/8/87	HFB	0910		1037		147	3					
8/8/87	HFB	0800	0821		21	21	1	1				
8/8/87	HFB	0821	0822		1	22	1	1				
8/8/87	HFB	0822	0828		6	28	1			1		
8/8/87	HFB	0828	0834		6	34	1	1				
8/8/87	HFB	0834		0900		60	1					
8/8/87	HFB	0910	0956		46	106	1	2				
8/8/87	HFB	0956	1017		21	127	1	1				
8/8/87	HFB	1017		1037		147	1					

Table 44. continued.

DATE	LOCATION	TIME START	TIME CATCH	TIME STOP	MINUTES PER FISH	MINUTES ELAPSED	ANGLER	REDTAIL	SILVER	STAGHORN	SHINER	CRAB
8/10/87	B. POOL	1952	2006		14	14	1	1				
8/10/87	B. POOL	2006	2016		10	24	1	1				
8/10/87	B. POOL	2016	2022		6	30	1	1				
8/10/87	B. POOL	2022	2041		19	49	1	1				
8/10/87	B. POOL	2041	2055	2055	14	63	1	2				
8/11/87	B. POOL	1135	1145		10	10	1	1				
8/11/87	B. POOL	1145	1154		9	19	1	1				
8/11/87	B. POOL	1154	1206	1206	12	31	1	1				
8/11/87	B. POOL	1222		1230		39	1					
8/11/87	B. POOL	1900	1908		8	8	1			2		
8/11/87	B. POOL	1908	1916		8	16	1	1				
8/11/87	B. POOL	1916	1927		11	27	1					1
8/11/87	B. POOL	1927	1934		7	34	1	1				
8/11/87	B. POOL	1934	1939		5	39	1			1		
8/11/87	B. POOL	1939	1942		3	42	1			1		
8/11/87	B. POOL	1942	1954		12	54	1			1		
8/11/87	B. POOL	1954	1958		4	58	1	1				
8/11/87	B. POOL	1958	2000		2	60	1	1				
8/11/87	B. POOL	2000	2007		7	67	1	1				
8/11/87	B. POOL	2007	2014		7	74	1	1				
8/11/87	B. POOL	2014	2031		17	91	1			1		
8/11/87	B. POOL	2031	2036		5	96	1			1		
8/11/87	B. POOL	2036	2043	2043	7	103	1			1		

Table 44. continued.

DATE	LOCATION	TIME START	TIME CATCH	TIME STOP	MINUTES PER FISH	MINUTES ELAPSED	ANGLER	REDTAIL	SILVER	STAGHORN	SHINER	CRAB
8/12/87	HFB	1107	1110		3	3	1	1				
8/12/87	HFB	1110	1114		4	7	1	1				
8/12/87	HFB	1114	1120		6	13	1	1				
8/12/87	HFB	1120		1205		58	1	11:24 HARBOR SEAL IN AREA				
8/12/87	HFB	1224		1240		74	1					
8/14/87	B. POOL	1049	1059		10	10	1			1		
8/14/87	B. POOL	1059		1125	26	36	1					
8/14/87	B. POOL	1204		1210	6	42	1					
8/14/87	B. POOL	1241		1250	9	51	1					
8/15/87	HFB	1159	1206		7	7	1					1
8/15/87	HFB	1206		1359		120	1					1
8/22/87	HFB	0759	0807		8	8	1			1		
8/22/87	HFB	0807		0824	17	25	1					
8/22/87	HFB	0845	0848	0915	3	28	1			1		
8/22/87	HFB	0934	1000		26	81	1	1				
8/22/87	HFB	1000	1105	1105	5	146	1			1		
8/23/87	HFB	0703	0818		15	15	1			1		
8/23/87	HFB							7:25 HARBOR SEAL IN AREA				
8/23/87	HFB	0818		0905	47	122	1					

Table 44. continued.

DATE	LOCATION	TIME START	TIME CATCH	TIME STOP	MINUTES PER FISH	MINUTES ELA-PSED	ANG-LER	RED-TAIL	SIL-VER	STAG-HORN	SHI-NER	CRAB
8/31/87	HFB	1209	1210		1	1	1		2			
8/31/87	HFB	1210	1225		15	16	1		1			
8/31/87	HFB	1225	1228		3	19	1		2			
8/31/87	HFB	1228	1233		5	24	1		2			
8/31/87	HFB	1233	1238		5	29	1	1				
8/31/87	HFB	1238	1242		4	33	1		1			
8/31/87	HFB	1242	1249		7	40	1		1			
8/31/87	HFB	1249	1255		6	46	1		2			
8/31/87	HFB	1255	1258		3	49	1		1			
8/31/87	HFB	1258	1301		3	52	1		1			
8/31/87	HFB	1301	1304		3	55	1	1				
8/31/87	HFB	1304	1312		8	63	1		1			
8/31/87	HFB	1312	1316	1316	4	67	1	1				
8/31/87	HFB	1342	1344		2	69	1	1	1			
8/31/87	HFB	1344	1350		6	75	1		2			
8/31/87	HFB	1350	1355		5	80	1		1			
8/31/87	HFB	1355	1400		5	85	1		1			
8/31/87	HFB	1400	1405		5	90	1	1				
8/31/87	HFB	1405	1409		4	94	1		1			
8/31/87	HFB	1409	1421		12	106	1		1			
8/31/87	HFB	1421	1430	1430	9	115	1		2			

Table 44. continued.

DATE	LOCATION	TIME START	TIME CATCH	TIME STOP	MINUTES PER FISH	MINUTES ELAPSED	ANGLER	REDTAIL	SILVER	STAGHORN	SHINER	CRAB
9/1/87	HFB	1322	1323		1	1	1		1			
9/1/87	HFB	1323	1327		4	5	1			1		
9/1/87	HFB	1327	1331		4	9	1	1	1			
9/1/87	HFB	1331	1335		4	13	1	1				
9/1/87	HFB	1335	1340		5	18	1		1			
9/1/87	HFB	1340	1347		7	25	1	1				
9/1/87	HFB	1347	1352		5	30	1	1				
9/1/87	HFB	1352	1356	1356	4	34	1	1				
9/1/87	HFB	1408	1411		3	37	1	1				
9/1/87	HFB	1411	1413		2	39	1		1			
9/1/87	HFB	1413	1419		6	45	1	1	1			
9/1/87	HFB	1419	1429		10	55	1		1			
9/1/87	HFB	1429	1433		4	59	1	1				
9/1/87	HFB	1433	1439		6	65	1	1				
9/1/87	HFB	1439	1446		7	72	1	1				
9/1/87	HFB	1446	1451		5	77	1	1				
9/1/87	HFB	1451	1458		7	84	1		1			
9/1/87	HFB	1458	1509		11	95	1	1				
9/1/87	HFB	1509	1513		4	99	1		1			
9/1/87	HFB	1513	1517		4	103	1		1			
9/1/87	HFB	1517	1522		5	108	1	1				
9/1/87	HFB	1522	1527		5	113	1	1				
9/1/87	HFB	1527	1531		4	117	1	1				
9/1/87	HFB	1531	1539		8	125	1	1				
9/1/87	HFB	1539	1543		4	129	1		1			
9/1/87	HFB	1543	1549	1549	6	135	1		1			

Table 44. continued.

DATE	LOCATION	TIME START	TIME CATCH	TIME STOP	MINUTES PER FISH	MINUTES ELAPSED	ANGLER	REDTAIL	SILVER	STAGHORN	SHINER	CRAB
9/1/87	HFB	1404	1405		1	1	4	1		1		
9/1/87	HFB	1405	1417		12	13	4	1				
9/1/87	HFB	1417	1426		9	22	4	1				
9/1/87	HFB	1426	1430		4	26	4		1			
9/1/87	HFB	1430	1435		5	31	4	1				
9/1/87	HFB	1435	1438		3	34	4	1				
9/1/87	HFB	1438	1443		5	39	4	1				
9/1/87	HFB	1443	1456		13	52	4			1		
9/1/87	HFB							14:56 HARBOR SEAL IN AREA				
9/1/87	HFB	1456	1459		3	55	4	1				
9/1/87	HFB	1459	1504		5	60	4	1				
9/1/87	HFB	1504	1510		6	66	4	1				
9/1/87	HFB	1510	1516		6	72	4	1				
9/1/87	HFB	1516	1522		6	78	4			1		
9/1/87	HFB	1522		1540		96	4					
9/2/87	HFB	1647	1650		3	3	1	1				
9/2/87	HFB	1650	1655		5	8	1	1				
9/2/87	HFB	1655	1658		3	11	1	1				
9/2/87	HFB	1658	1710		12	23	1	2				
9/2/87	HFB	1710	1723	1723	13	36	1	2				
9/2/87	HFB		1741				1	17:41 HARBOR SEAL IN AREA				
9/2/87	HFB	1729	1744		15	51	1	1				
9/2/87	HFB	1744	1749	1749	5	56	1	1				

Table 44. continued.

DATE	LOCATION	TIME START	TIME CATCH	TIME STOP	MINUTES PER FISH	MINUTES ELAPSED	ANGLER	REDTAIL	SILVER	STAGHORN	SHINER	CRAB
9/5/87	HFB	1649	1701		12	12	1	1				
9/5/87	HFB	1701	1734		33	45	1		1			
9/5/87	HFB	1734	1746		12	57	1	1				
9/5/87	HFB	1746	1750		4	61	1	1				
9/5/87	HFB	1750		1805		76	1					
9/5/87	HFB	1649	1703		14	14	5	1				
9/5/87	HFB	1703	1705		2	16	5	1				
9/5/87	HFB	1705	1744		39	55	5	1				
9/5/87	HFB	1744	1749		5	60	5	1				
9/5/87	HFB	1749		1805		76	5					
9/9/87	HFB	0956	1019		23	23	1			1		
9/9/87	HFB							10:19 HARBOR SEAL IN AREA				
9/9/87	HFB	1019	1037		18	41	1	1				
9/9/87	HFB	1037		1056		60	1					

Table 45. Identification of anglers sampling at Horsefall Beach during 1987.

ANGLER	NAME	ADDRESS
1	Karl Brookins	Dept. Fish and Wildlife, Oregon State University
2	Teri Sharpe	Corvallis, Oregon. Contact through Angler 3.
3	Cameron Sharpe	Dept. Fish and Wildlife Oregon State University
4	unknown	
5	Rick Ericson	North Bend, Oregon. Contact through Angler 1.

APPENDIX E

DATA USED IN CORRELATIONS WITH ENVIRONMENTAL VARIABLES

Table 46. Commercial catch (pounds) and valve (dollars) of *Amphistichus rhodoterus* from Oregon (Lukas and Carter 1985, 1993).

YEAR	LBS	DOLLARS
1974	6769	
1975	0	
1976	39	
1977	0	
1978	288	48
1979	2487	279
1980	121	121
1981	167	93
1982	342	80
1983	2421	1286
1984	4920	2311
1985	3314	1963
1986	4369	2177
1987	2539	1748
1988	5551	3105
1989	3710	2810
1990	4953	3540
1991	2201	1748

Table 47. Commercial catch (pounds) of *Amphistichus rhodoterus* from California (Gloria Hawks, California Department of Fish and Game, Long Beach, California).

	Region		
Year	Crescent City	Eureka	Combined
1979	36426	28269	64695
1980	19023	16055	35078
1981	34985	14742	49727
1982	68255	11794	80049
1983	44329	7837	52166
1984	5117	13450	18567
1985	26748	7484	34232
1986	13931	13120	27051

Table 48. Estimated number of fishing trips targeting *Amphistichus rhodoterus*. Calculated from the Marine Recreational Fishery Statistics Survey estimated trips and percent of trips angling for *A. rhodoterus* (USDC 1984a, 1984b, 1985, 1986, 1987).

YEAR	WA	OR	NCA
1979	46987	9631	20036
1980	31477	10464	65020
1981	10534	12874	65382
1982	45684	14891	83945
1983	7472	15123	79147
1984	22500	18386	63578
1985	29517	19967	33875
1986	0	12768	23435

Table 49. Estimated number of fishing trips targeting surfperch (Embiotocidae). Calculated from the Marine Recreational Fishery Statistics Survey estimated trips and percent of trips angling for surfperch (USDC 1984a, 1984b, 1985, 1986, 1987).

YEAR	WA	OR	CA
1979	30924	31144	165346
1980	139048	141612	424939
1981	171171	202926	354682
1982	139447	178967	269088
1983	137695	191948	277315
1984	108750	137564	243715
1985	99519	190638	200723
1986	58099	156384	282317

Table 50. Average monthly sea surface temperature measured during high tide at Trinidad Beach, California (Scripps 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1986, 1994b, 1994c, 1994d).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1977	11.39	11.67	10.26	9.26	10.78	10.19
1978	12.27	11.70	13.03	12.63	10.68	11.51
1979	9.63	9.68	10.62	11.08	10.25	10.23
1980	11.21	11.54	11.62	10.19	10.26	11.25
1981	12.77	12.09	11.31	10.00	9.90	10.85
1982	10.03	10.78	11.22	11.59	10.74	12.22
1983	11.98	12.45	13.19	11.93	12.34	11.97
1984	11.37	11.04	11.38	10.44	11.14	10.42
1985	10.98	10.76	9.57	11.30	11.15	12.84
1986	11.45	11.54	12.46	10.73	10.71	13.43

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1977	11.14	13.35	12.11	11.63	10.47	11.32
1978	10.96	10.99	10.84	11.36	9.50	8.89
1979	12.26	12.24	14.19	12.36	12.90	11.29
1980	12.39	11.50	12.25	11.32	11.36	11.32
1981		11.00	11.13	13.37	13.49	12.48
1982	12.37	11.10	12.20	13.18	13.07	12.49
1983		14.56	14.02	14.19	14.19	12.85
1984	12.06	13.93	12.58	12.98	12.08	11.08
1985	13.55	13.48	12.88	11.62	9.63	10.01
1986	11.35	12.82	13.25	12.61	12.34	12.10

Table 51. Average monthly sea surface temperature measured during high tide at Charleston, Oregon (Scripps 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1986, 1994b, 1994c, 1994d).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1977	9.76	10.86	10.11	10.12	11.48	11.90
1978	11.39	11.32	11.70	11.10	10.80	12.80
1979	8.61	9.03	10.21	11.10		11.27
1980	10.56	10.64	11.12	11.03	12.26	12.98
1981	11.93	11.58	11.80	11.56	11.59	13.41
1982	9.86	9.61	9.90	10.33	11.34	11.12
1983	11.23	11.62	12.70	12.11	12.51	11.89
1984	10.73	10.42	11.11	10.97	12.17	11.09
1985	10.00	9.43	8.83	9.82	11.11	11.76
1986	10.05	10.74	11.67	10.41	11.64	12.43

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1977	11.38	12.75	12.98	11.25	11.19	10.69
1978	11.94	12.08	14.26	11.64	9.46	8.76
1979	13.55	14.08	14.84	12.59	12.67	11.60
1980	12.64	11.19	11.76	11.93	12.18	11.32
1981	11.54	13.32	13.38	12.53	12.25	11.48
1982	12.88	12.36	12.47	12.44	12.48	11.81
1983	14.70		12.69	11.99	13.15	11.59
1984	11.46	12.57	12.58	12.72	11.56	10.50
1985	10.71	11.90	12.14	10.76	9.92	9.06
1986	11.70	10.62	11.31	10.81	11.22	10.73

Table 52. Average monthly sea surface temperature measured during high tide at Neah Bay, Washington (Scripps 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1986, 1994b, 1994c, 1994d).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1977	7.65	8.36	8.38	8.94	10.80	11.58
1978	7.80	8.46	8.95	9.95	10.62	12.39
1979	5.69	6.38	8.19	9.03	10.66	10.87
1980	10.56	10.64	11.12	11.03	12.26	12.98
1981	9.10	8.68	9.81	9.83	10.74	12.20
1982	7.31	7.57	8.20	9.13	10.35	10.77
1983	8.82		10.53	11.03	11.93	12.15
1984	7.76	8.11	9.21	10.41	11.30	11.84
1985	7.07	7.39	7.78	9.47	10.96	11.60
1986	7.57	7.87	10.09	9.45	10.86	11.92

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1977	10.79	11.91	11.94	10.59	9.13	6.17
1978	11.42	11.65	13.58	10.92	7.69	7.33
1979	12.00	11.14	13.58	11.39	10.38	9.39
1980	12.64	11.19	11.76	11.93	12.18	11.32
1981	11.59	11.81	11.53	11.69	11.07	9.02
1982	11.89	11.05	11.47	11.86	9.56	8.95
1983	12.84	12.63	12.07	10.31	11.92	7.56
1984	12.20	12.28	12.49	11.06	9.56	7.66
1985	12.48	12.26	12.10	10.34	7.62	6.60
1986	11.86	12.72	11.43	10.90	9.55	

Table 53. United States west coast upwelling index at 42°N. Data supplied by Peter Lawson, Oregon Department of Fish and Wildlife, Newport (see Bakun 1973).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1977	-21	-57	44	27	36	203
1978	-170	-68	0	10	111	87
1979	-30	-69	3	13	100	153
1980	-7	-124	22	6	122	83
1981	-179	-39	-1	44	66	78
1982	-7	-31	-2	3	189	66
1983	-212	-256	-129	8	56	77
1984	-17	-85	-9	18	21	101
1985	-32	9	5	21	32	89
1986	-269	-72	-19	47	14	35

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1917	192	79	32	4	-18	-110
1978	192	73	8	33	4	3
1979	62	46	8	-4	-88	-146
1980	152	179	29	-3	-46	-116
1981	201	78	15	-1	-69	-105
1982	97	51	37	-22	-49	-97
1983	68	45	62	0	-142	-22
1984	181	63	31	-4	-117	-4
1985	80	63	21	1	1	-80
1986	118	77	11	-6	-1	-101

Table 54. United States west coast upwelling index at 45°N. Data supplied by Peter Lawson, Oregon Department of Fish and Wildlife, Newport (see Bakun 1973).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1977	-40	-109	8	1	9	71
1978	-145	-88	-1	-1	28	34
1979	-67	-103	0	6	34	86
1980	-19	-155	1	-7	52	32
1981	-206	-68	-14	0	12	8
1982	-31	-72	-5	-2	79	59
1983	-202	-216	-95	3	35	19
1984	-29	-131	-33	-8	-2	37
1985	-63	-2	-5	5	15	52
1986	-301	-55	-36	13	1	25

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1977	73	41	7	-7	-67	-100
1978	92	13	-5	5	-4	-4
1979	30	31	0	-8	-127	-157
1980	103	96	9	-19	-121	-113
1981	107	40	-1	-5	-103	-106
1982	51	38	12	-40	-52	-98
1983	14	36	25	-1	-168	-52
1984	121	37	3	-21	-138	-14
1985	83	46	12	-9	-3	-112
1986	66	84	10	-7	-16	-149

Table 55. United states west coast upwelling index at 48°N. Data supplied by Peter Lawson, Oregon Department of Fish and Wildlife, Newport (see Bakun 1973).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1977	-45	-99	11	-2	9	39
1978	-129	-111	-4	-3	17	28
1979	-73	-82	-2	10	24	83
1980	-68	-218	3	-15	41	32
1981	-251	-76	-16	-1	8	5
1982	-24	-73	-1	0	59	74
1983	-165	-197	-63	5	45	24
1984	-42	-143	-29	-14	-1	33
1985	-107	-20	-9	7	20	49
1986	-327	-69	-52	6	2	26

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1977	42	24	2	-30	-65	-63
1978	58	3	-16	0	-16	-10
1979	25	35	-2	-16	-187	-140
1980	63	68	5	-39	-145	-113
1981	80	24	-6	-10	-123	-102
1982	36	38	7	-44	-56	-96
1983	18	26	12	-3	-127	-126
1984	72	27	0	-21	-121	-28
1985	79	39	12	-21	-19	-155
1986	57	84	9	-17	-25	-194

Table 56. Monthly mean significant wave height (m) off the Columbia River (Earle and Eckard 1988).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1979						
1980	2.33	2.68	2.67	2.88	2.00	1.36
1981	2.84	2.71	2.61	2.31	1.69	
1982	3.02	2.54	3.13			
1983	3.39	3.54	2.81	1.92	1.08	1.75
1984	2.46	3.12	2.48	2.64	2.01	1.43
1985	1.86	2.56	2.99	2.10	1.52	1.56
1986	3.37	1.69	1.64	1.97	1.51	1.35

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1979					2.14	3.13
1980	1.38	1.44	1.60	2.20	3.04	2.60
1981	1.31	1.26	1.76	2.06	2.93	3.33
1982			1.67	2.32	2.30	3.20
1983	1.43	1.29	1.52	1.83	3.75	2.39
1984	1.19	1.08	1.54	2.58	3.26	2.68
1985	1.18	1.57	1.58	2.40		1.75
1986	1.47	1.23	1.47	1.92	2.77	2.64

Table 57. Monthly mean significant wave period (s) off the Columbia River (Earle and Eckard 1988).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1980	10.55	12.44	12.01	12.15	10.80	8.25
1981	12.78	11.79	12.05	9.86	9.10	
1982	10.70	11.07	10.54			
1983	12.53	13.18	12.01	10.24	9.30	10.12
1984	10.99	12.05	11.73	10.80	9.68	8.76
1985	12.08	11.28	12.88	10.81	9.81	9.15
1986	11.71	11.47	9.76	10.93	9.97	8.94

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1980	7.59	8.10	8.84	11.46	11.47	10.41
1981	7.60	8.78	9.38	9.87	11.55	11.36
1982			9.68	10.51	10.51	11.89
1983	8.11	7.82	8.92	10.80	11.64	10.99
1984	7.80	8.66	10.10	10.71	12.15	11.39
1985	8.69	8.87	9.73	11.29		13.50
1986	8.56	8.86	8.91	11.42	11.73	11.58

Table 58. Monthly mean significant wave height (m) off Humboldt Bay, California (Earle and Eckard 1988).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1979						
1980				3.37	2.44	1.77
1981	3.51	2.39	3.24	2.43	1.83	1.89
1982	3.49	2.36	2.95	2.69	2.17	1.64
1983	3.39	3.97	3.24			2.06
1984	2.25	3.32	2.91	2.90	2.08	1.97
1985	2.46	2.82	3.36	2.14	1.73	2.25
1986	3.20	3.37	2.79	2.83	2.23	1.87

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1979						
1980	2.04	2.38	1.61	2.75	2.90	2.40
1981	2.02	1.61	1.91	2.24	3.17	
1982	1.83	1.29	1.85	2.42	2.51	3.32
1983	1.50	1.56	2.09	1.78	3.79	2.85
1984	2.30	1.19				2.32
1985	1.65	1.76	1.99	2.44	2.40	2.52
1986	2.15	1.80	1.88	2.35	2.78	

Table 59. Monthly mean significant wave period (s) off Humboldt Bay, California (Earle and Eckard 1988).

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1979						
1980				11.94	10.74	8.14
1981	13.16	12.43	12.77	10.95	9.07	8.71
1982	12.56	10.77	11.92	10.18	8.19	8.15
1983	13.05	14.21	12.63			9.86
1984	11.45	12.97	12.56	11.80	10.03	9.03
1985	13.84	10.59	13.02	10.63	9.88	9.79
1986	12.95	14.10	11.75	11.29	10.04	9.92

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1979						
1980	8.71	8.27	8.68	12.13	12.27	10.83
1981	8.33	9.05	9.44	9.98	11.80	
1982	8.93	7.77	9.10	10.46	11.37	12.36
1983	8.00	8.14	8.92	10.83	12.47	11.64
1984	8.43	9.12				10.80
1985	9.77	9.40	9.69	11.27	10.90	13.96
1986	8.72	9.54	8.57	12.08	13.28	

APPENDIX F

SCALE MEASUREMENTS, SURVIVAL AT AGE, AND SIZE OF AGE CLASSES AT HORSEFALL BEACH

Table 60. Size (mm) and state of scale formation for *Amphistichus rhodoterus* embryos used in determining size at iniation of scale formation. A size of 20 mm was used because most fish larger than this had scales formed.

Standard Length	Parent	Scales Present	Standard Length	Parent	Scales Present
39	1	yes	32	6	yes
31	1	yes	31	6	yes
28	2	no	32	6	yes
30	2	no	26	7	yes
29	2	no	32	7	yes
37	3	yes	22	7	yes
38	3	yes	19	7	no
38	3	yes	23	8	starting
37	3	yes	28	8	yes
30	4	yes	29	8	yes
32	4	yes	25	8	yes
27	4	yes	24	8	yes
28	5	yes	29	9	yes
22	5	yes	25	9	yes
26	5	yes	23	9	yes
25	5	yes			

Table 61. Scale size of *Amphistichus rhodoterus* at formation of first annuli.

Scale	ocular units	mm
1	3	0.084
2	2	0.056
3	3	0.084
4	3	0.084
5	3	0.084
6	2	0.056
7	4	0.112

Table 62. Relative numbers of *Amphistichus rhodoterus* in different age groups for Horsefall Beach, Oregon 1979 to 1985. Age 2 and 3+ information was collected by the Marine Recreational Fishery Statistics Survey, and Age 0 are estimates of offspring production for each year.

	Age 0	Age 2	Age 3+
1979	477	169	138
1980	396	35	149
1981	456	129	141
1982	74	24	42
1983	204	53	81
1984	374	61	156
1985	212	47	82

Table 63. Percent of organisms surviving to given ages with different mortality rates.

MORTALITY	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9
0.4	60.	36.	22.	13.	8.	5.	3.
0.41	59.	35.	21.	12.	7.	4.	2.
0.42	58.	34.	20.	11.	7.	4.	2.
0.43	57.	32.	19.	11.	6.	3.	2.
0.44	56.	31.	18.	10.	6.	3.	2.
0.45	55.	30.	17.	9.	5.	3.	2.
0.46	54.	29.	16.	9.	5.	2.	1.
0.47	53.	28.	15.	8.	4.	2.	1.
0.48	52.	27.	14.	7.	4.	2.	1.
0.49	51.	26.	13.	7.	3.	2.	1.
0.5	50.	25.	13.	6.	3.	2.	1.
0.51	49.	24.	12.	6.	3.	1.	1.
0.52	48.	23.	11.	5.	3.	1.	1.
0.53	47.	22.	10.	5.	2.	1.	1.
0.54	46.	21.	10.	4.	2.	1.	0.
0.55	45.	20.	9.	4.	2.	1.	0.
0.56	44.	19.	9.	4.	2.	1.	0.
0.57	43.	18.	8.	3.	1.	1.	0.
0.58	42.	18.	7.	3.	1.	1.	0.
0.59	41.	17.	7.	3.	1.	0.	0.
0.6	40.	16.	6.	3.	1.	0.	0.
0.61	39.	15.	6.	2.	1.	0.	0.
0.62	38.	14.	5.	2.	1.	0.	0.
0.63	37.	14.	5.	2.	1.	0.	0.
0.64	36.	13.	5.	2.	1.	0.	0.
0.65	35.	12.	4.	2.	1.	0.	0.
0.66	34.	12.	4.	1.	0.	0.	0.
0.67	33.	11.	4.	1.	0.	0.	0.
0.68	32.	10.	3.	1.	0.	0.	0.
0.69	31.	10.	3.	1.	0.	0.	0.
0.7	30.	9.	3.	1.	0.	0.	0.
0.71	29.	8.	2.	1.	0.	0.	0.
0.72	28.	8.	2.	1.	0.	0.	0.
0.73	27.	7.	2.	1.	0.	0.	0.
0.74	26.	7.	2.	0.	0.	0.	0.
0.75	25.	6.	2.	0.	0.	0.	0.
0.76	24.	6.	1.	0.	0.	0.	0.
0.77	23.	5.	1.	0.	0.	0.	0.
0.78	22.	5.	1.	0.	0.	0.	0.
0.79	21.	4.	1.	0.	0.	0.	0.
0.8	20.	4.	1.	0.	0.	0.	0.
0.81	19.	4.	1.	0.	0.	0.	0.
0.82	18.	3.	1.	0.	0.	0.	0.
0.83	17.	3.	0.	0.	0.	0.	0.
0.84	16.	3.	0.	0.	0.	0.	0.
0.85	15.	2.	0.	0.	0.	0.	0.

APPENDIX G

LENGTH, MATURITY, OFFSPRING PRODUCTION, AND NUMBER OF REDTAIL SURFPERCH FROM PREVIOUS STUDIES

Table 64. Redtail surfperch back calculated total length (mm), percent maturity, and numbers sampled at age from Oregon (Bennett and Wydoski 1977) and Northern California (Ngoile 1978). Size at maturity is also given. Northern California lengths were converted to total lengths using relationship of Bennett and Wydoski (1977).

Females

Oregon				Northern California			
Age	N	Total Length	Percent Mature	Age	N	Total Length	Percent Mature
1	44	103	0	1	29	106	0
2	92	160	0	2	52	159	0
3	117	211	17	3	100	209	22
4	88	254	88	4	112	258	94
5	46	284	97	5	60	303	98
6	34	312	100	6	31	339	100
7	21	334	100	7	12	367	100
8	5	357	100	8	2	384	100
9				9	1	402	100
Size at Maturity >240mm				Size at Maturity >254mm			

Males

Oregon				Northern California			
Age	N	Total Length	Percent Mature	Age	N	Total Length	Percent Mature
1	29	104	0	1	22	108	0
2	69	161	70	2	44	160	58
3	99	208	100	3	32	203	100
4	54	240	100	4	29	237	95
5	30	264	100	5	17	262	100
6	27	280	100	6	16	286	100
7	14	293	100	7	4	305	100
8	4	310	100	8	3	313	100
9	1		100	9	1	326	100
Size at Maturity >200mm				Size at Maturity not given			

Table 65. Relative contribution of different ages to estimated offspring production of redtail surfperch populations sampled by Bennett and Wydoski (1977) and Ngoile (1978). Length is the average of length at age n and n+1. Offspring production was calculated as (length X gravidity at length X number sampled X percent mature) (see Table 64).

Oregon
Bennett and Wydoski (1977)

Age	Size	Offspring Production	Percent of Offspring Produced
3	232.5	22	0.84
4	269.0	659	25.02
5	298.0	642	24.37
6	323.0	662	25.13
7	345.5	505	19.17
8	369.0	144	5.47
SUM		2634	

California
Ngoile (1978)

Age	Size	Offspring Production	Percent of Offspring Produced
3	233.5	29	0.82
4	280.5	1141	32.15
5	321.0	1121	31.59
6	353.0	792	22.32
7	375.5	362	10.20
8	393.0	67	1.89
9	410.0	37	1.04
SUM		3549	

PLEASE NOTE

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this material. It is, however, available for consulation
at the author's graduate school library.

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