In situ Ecosystem Effects of Trace Contaminants in the San Francisco Bay Estuary: The Necessary Link to Establishing Water Quality Standards

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Conversion Table

Multiply | **By** | **To Obtain**

Multiply	By	To Obtain
meter (m)	3.28	foot
micron (μm)	3.94×10^{-5}	inch
milligram (mg)	2.20×10^{-6}	pound
gram (g)	2.20×10^{-3}	pound
liter (L)	1.06	quart
cubic meter/sec	35.3147	cubic feet/sec

Temperature is given in degrees Celsius (°C) and can be converted to degrees Fahrenheit (°F) using the following equation:

$$°F = 1.8\ (°C) + 32$$

Abstract

Reproduction and condition of *Potamocorbula amurensis* were compared with cadmium concentration in the tissues of individual *P. amurensis* from five stations in northern San Francisco Bay to determine if either parameter could be used to assess ecosystem effects of trace metal contaminants. There is a gradient in cadmium content (µg/animal) and concentration (µg/g dry tissue) in tissues of clams which follows the freshwater gradient, with the freshest stations having the highest levels of cadmium contamination. Condition decreases with increasing cadmium content; animals from Honker Bay and Chipps Island have the highest cadmium content and lowest condition and those from San Pablo Bay have the lowest cadmium levels and highest condition. Synchrony in spawning was similarly related to cadmium content; animals with the highest cadmium concentration have asynchronous spawning. Asynchrony is potentially deleterious to organisms which depend on external fertilization, and thus may indicate that the reproductive success of other organisms in Suisun and San Pablo Bays may be harmed. The number of reproductive cycles, timing of reproduction, speed with which animals regain weight after spawning, and amount of weight gained during spawning, are most strongly related to food availability.

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Introduction

The ecosystem effects of trace contaminants are the subject of ongoing discussions within San Francisco Bay regulatory agencies. Water-quality standards for all trace contaminants will be established within the next few years, and will be based on the ecological effects of each of the metals. Water-quality standards are established after preliminary standards are published, reviewed by the public, modified, and then subjected to further review. These regulatory processes will take several years to complete and the decisions will be aided by data describing the ecological effects of these contaminants. Trace-metal concentrations in San Francisco Bay are presently being assessed by analyzing the water column and the sediment, by doing bioassay tests on specific organisms, and by studying tissue burdens in some species. Although the ultimate goal of these studies is to determine what level of contamination results in harmful effects to the ecosystem, none of these approaches directly measures the effect of contaminants on the ecosystem. The major reason that direct measures of ecosystem effects have not been made is that the complexity of ecological processes can hide correlations between organism, population, or community changes and trace element concentrations.

Some of this complexity is reflected in the way in which contaminants can affect animals and the communities in which they live. Chemical-biological interactions at the molecular level within an organism can influence developmental stages resulting in reproductive abnormalities, toxicity and adaptation due to changes in metabolic processes, and cellular damage due to effects on mitotic processes. At the organism level, contaminant stress can be seen with changes in physiology, behavior, reproductive success, larval success, and rates of parasitism and disease. At the more complex population level, changes in mortality, recruitment, biomass, production, and the structure of age and size classes are all possible effects of contaminants. At the community level, contaminant exposure may result in changes in species diversity, species composition, secondary production, and biomass. However, environmental stress, *eg.* osmotic and thermal extremes, can also cause many of the same effects. Thus, if ecosystem effects of contaminants are to be measured, it is necessary to examine selected parameters in a manner in which environmental and contaminant stresses can be separated.

This report is the first step in looking at ecosystem effects of trace elements. Two life history parameters, reproductive periodicity and condition (change in tissue weight for a specific size of animal) of one species, *Potamocorbula amurensis*, are examined within a reach of San Francisco Bay that has a known trace metal concentration gradient (Brown and Luoma 1995). The contaminants within this gradient appear to originate with the freshwater inflow, *i.e.* the contaminant gradient opposes the salinity gradient. The presence of a salinity gradient within the study area supports the importance of addressing the effects of environmental and trace metal stresses separately, and in combination with each other. This approach is possible for the following reasons: 1) Infaunal communities along the contaminant gradient are dominated (>95% of biomass) by a single species, *P. amurensis*, which reduces the complexity of the ecosystem such that species interactions and community "effects"are minimized (Nichols et al., 1990). 2) *P. amurensis* lives in a broader salinity range than the salinity range of the study area. Thus, although animals may react to salinity variations, lethal osmotic stress is unlikely. 3) The coincident collection of environmental data (*e.g.* salinity, temperature, chlorophyll *a* concentration) allows us to analyze "natural" environmental stresses as well as stresses due to the contaminants. 4) The trace metal and ecological data were collected at the same times and locations. 5) The study includes a large range of environmental stress; the study period encompasses a time when temporal variability, and therefore environmental stresses, were small due to the drought (1991, 1992, and 1994) and a period of normal freshwater inflow (1993), when larger environmental stresses are expected. 6) Our studies of *P. amurensis* since its introduction in 1988 have provided a good database of population and community characteristics throughout the bay.

Background on *Potamocorbula amurensis*

Potamocorbula amurensis (family Corbulidae) is a native of China, Japan, and Korea, and was introduced, most likely by an inoculation with ballast water, into San Francisco Bay in late 1986 (Carlton et al., 1990). Since its introduction, *P. amurensis* spread rapidly and became, by 1990, the dominant bivalve (based on biomass) in much of the bay (J. Thompson, unpublished data). *P. amurensis* is capable of living in all bathymetric and sedimentary habitats in the bay, including those exposed to large seasonal changes in salinity, temperature, and sediment composition. These characteristics, in conjunction with the clams' fast growth rate (J. Thompson, unpublished data), early age at reproductive readiness (Parchaso, 1993), and voracious feeding rates (Cole et al., 1992) suggest that *P. amurensis* is an opportunistic or r-selected species. Therefore *P. amurensis* might be expected to be very tolerant of environmental stress and exhibit various reactions to stress;*i.e.* stress which negatively affects one part of the life history of the organism, such as reproduction, may not affect other, equally vital functions, such as growth.

Brown and Luoma (1995) concluded that "*Potamocorbula amurensis* is an effective biosentinel for studying processes controlling trace contamination and bioavailability in San Francisco Bay because it is found throughout the bay, has an unusually wide salinity tolerance and is sensitive in indicating environmental differences in trace metal uptake." (Brown and Luoma, 1995). Thus it is expected that observed changes in some life history parameter of *P. amurensis* that correlates with contaminant concentrations in its tissue may also be related to similar contaminant concentrations in the environment.

The goal of this study is to begin assessing the response of an *in situ* population to a contaminant and to the concomitant environmental stresses. This report contains a description of the environmental conditions observed during the study and an overview of the condition data and the concentration and content data for one contaminant, cadmium. This metal is used as a surrogate for other freshwater derived contaminants. Neither the contaminant or condition data will be described in detail here as these can be found in Brown and Luoma, 1995. The reproductive cycle of animals along this contaminant gradient will be described in detail at each station and will be examined relative to environmental conditions and condition indices.

Environmental Setting

Stations were chosen along the salinity gradient in northern San Francisco Bay to be representative of the benthic communities based on a survey of 200 stations in 1988 (Thompson unpublished data). The four channel stations (fig. 1, table 1), stations 4.1, 6.1, 8.1, and 12.5, are near U.S. Geological Survey (USGS) hydrologic monitoring stations 4, 6, 8, and 12 (Conomos et al., 1985); the three upstream stations are also near the California Department of Water Resources (DWR) monitoring stations D10, D8, and D6. The Chipps Island station (4.1) is the most upstream station and has a sandy to muddy sand substrate. The Honker Bay station (433), the only non-channel station, is located near the Chipps Island station, has a mud or peaty mud substrate, and may receive freshwater from up-river of station 4.1 through Spoonbill Creek (fig. 1). The Suisun Bay station (6.1) has a muddy sand substrate and may have been intermittently disturbed by a sand dredge. Station 8.1 is at the eastern end of the Carquinez Strait, a narrow high current velocity section of the bay, and has a heterogenous bottom with pockets of hard clay, sand, and mud. The San Pablo Bay station (12.5) is on the channel edge adjacent to a the broad expanse of intertidal areas in San Pablo Bay (fig. 1)., and has a muddy substrate. It is most likely that, of the channel stations, this station would most freely exchange water with the shallow reaches.

The study period, January 1991 through December 1994, included three drought years and one normal run-off year. Following a major flood in 1986, northern California began a six year drought which ended in 1993 (fig. 2). The rainfall and snowpack, both of which result in freshwater inflow into San Francisco Bay, were again low enough in 1994 for that year to be considered a drought year. Surface water electrical conductivity and temperature near Mallard Island and Martinez (fig. 1) show how this change in the hydrograph during our study period affected these parameters in the vicinity of our four upstream stations (figs. 3 and 4).

Until 1986 the northern estuary had a late summer to early fall phytoplankton bloom (fig. 5). The cessation of this annual phytoplankton bloom since 1986 coincided with the introduction of *Potamocorbula amurensis* and it is believed that the lack of a phytoplankton bloom is due to over grazing by this filter feeder (Alpine and Cloern 1992). Therefore the major sources of food for *P. amurensis*, a filter feeder, are a combination of riverborne detritus and river derived phytoplankton in addition to locally grown phytoplankton, which never reaches high biomass levels. Each of these sources has a different seasonal and interannual pattern (fig. 6). The riverborne detritus is richest in non-refractory carbon at the beginning, not the peak, of the freshwater run-off during each year (Hager and Schemel 1996) and was, no doubt, quite high in early 1993 when the drought ended. River chlorophyll *a* peaks in late spring and summer, but its transport into the bay is dependent on the amount and timing of freshwater runoff, so its quantity and seasonality vary between years. Growth rates of locally derived phytoplankton are dependent on light availability (Cloern 1987) and in this part of the estuary the growth rates usually peak in summer and fall.

Summary of Contaminant and Condition Data

Both cadmium content (µg in a 15mm animal, fig. 7) and concentration (µg/g dry tissue, fig. 8) show a down-bay gradient with highest values seen in Honker Bay animals and the lowest values seen in San Pablo Bay animals (Brown and Luoma, written commun., 1996). Annual mean cadmium content was highest in 1993 in animals from the three upstream stations, showed little annual variation in Carquinez Strait animals, and was lowest in 1993 in San Pablo Bay animals (fig. 9). Condition for *P. amurensis* was generally higher at the down bay stations than at the freshest stations (fig. 10). Annual mean condition (fig. 11) was highest in animals from the seaward stations, San Pablo Bay and Carquinez Straits, and lowest in animals from Honker Bay.

Methods

Collection Methods

To determine the reproductive pattern and gonadal development of *P. amurensis*, monthly samples were collected from the four channel stations and one shallow station for a period of 47 months, from January 1991 to December 1994. Animals representative of the size range present at each site were collected on the United States Geological Survey (USGS) research vessel Polaris with a Van Veen grab (0.05 m^2) and rinsed through a 0.5 mm sieve, and preserved in 10 percent buffered formalin.

Fifteen clams were examined for reproductive condition during 1991 for each sampling date and station and 10 clams were examined for each sampling date and station for the remaining years. There were several periods at all stations when no clams were found (table 2) and some periods when the sample size was reduced due to tissue damage during histological preparation.

Reproductive Tissue Preparation

Clam tissue was prepared and thin-sectioned by Bay Histology (San Rafael, California). The visceral mass of each clam was removed, stored in 70 percent ethyl alcohol, and then prepared using standard histological techniques: tissues were dehydrated in a graded series of alcohol, cleared in toluene (twice for one hour each), and infiltrated in a saturated solution of toluene and Paraplast for one hour, and two changes of melted Tissuemat for one hour each. Samples were then embedded in Paraplast in a vacuum chamber. The embedded samples were thin sectioned (10 μm) using a microtome and then stained with Harris' hematoxylin and eosin. The stained thin sections were examined with a light microscope. Each specimen was characterized by size (length), sex, developmental stage and condition of the gonads thus allowing each specimen to be placed in one of five qualitative classes of gonadal development.

Categories of Gonadal Development (Adapted from Rosenblum 1981)

Female Gonads:

Inactive Phase. Sex may be difficult or impossible to determine. Small ovocytes occur at the periphery of alveoli. A round nucleus in the ovocyte, encircled by an irregularly shaped cytoplasm, contains a conspicuous nucleolus. Follicle cells completely imbed the ovocytes and may fill the lumina of alveoli.

Active Phase. Definite qualitative and quantitative changes in the gonads occur. Enlarging ovocytes grow between follicle cells towards the centers of alveoli. The ovocytes may be sub-conical, hemispherical, or cylindrical in shape, are rounded at the apices, and have broad cytoplasmic bases attaching them to the walls of the alveolus.

Ripe Phase. Ovocytes appear as round cells in the lumina of the alveoli as if free of attachment to the basal membrane, but attachment is via a slender stalk. The nuclei of the largest ovocytes contain amphinucleoli, each consisting of an almost transparent nucleolus and a small opaque nucleolus membrane in cross section. The large ovocytes that fill the lumina are generally more numerous than the less-developed ovocytes.

Partially Spawned Phase. Gonadal tissues contain a few ripe ovocytes. Small ovocytes are imbedded in follicle cells at the periphery of an empty alveolus. Many alveoli are devoid of ripe ovocytes.

Spent Phase. Very few ripe ovocytes are present. Numerous spherical droplets of lipoids and other products of cytolysis are characteristic. The spent phase progresses into the inactive phase.

Male gonads:

Inactive Phase. During the inactive phase, male tissues contain products of atypical spermatogenesis. Tissues appear active although this activity will not result in viable sperm. Pycnoitic cells (cells with moribund and shrunken nuclei) and multinucleated cells appear in the follicles. Follicle cells fill the alveoli, surround the aberrant cells and the few spermatogonia and primary spermatocytes at the periphery of the alveoli.

Active Phase. Proliferating primary spermatocytes exist at the basal membrane or the alveoli. These are small and uniformly sized cells which are similar to the earliest ovocytes. They can be seen growing between follicle cells, extending towards the centers of the alveoli. Early stages of meiosis occur at the periphery of the alveoli, while spermatids occur at the alveolar centers where they later form a distinct mass. The follicle cells eventually disappear.

Ripe Phase. Masses of spermatozoa arranged in more or less radial columns exist in rounded alveoli with tails oriented toward the center.

Partially Spawned Phase. Relatively few spermatozoa can be seen. Follicle cells start to refill alveoli. Some pycnoitic cells occur.

Spent Phase. Spent male tissues contain no or few spermatozoa in the central alveolar area. Numerous follicle cells with multinucleated cells and pycnoitic cells from atypical spermatogenetic activities surround small groups of spermatozoa. Tissues lack cells in the active phase of spermatogenesis.

Environmental Data

Freshwater inflow is estimated using the Delta Outflow Index as calculated by DWR. Chlorophyll *a* concentration is based on DWR data at stations D9 (near station 433), D10 (near station 4.1), D8 (near station 6.1), D6 (near station 8.1) (DWR database 1991-1994) and based on USGS data at station 12 (Caffrey and others, 1994, Edmonds and others, 1995, Wienke and others, 1992, 1993) and DWR data at station D41 for station 12.5 . The temperature and electrical conductivity data for surface water at Mallard Island and Martinez (figs. 3 and 4, DWR database 1991-1994) were used for comparison with reproduction data at the three upstream stations and at the Carquinez Strait station respectively. Temperature and salinity data, collected by DWR (station D41, DWR database 1991-1994) was used for comparison to the San Pablo Bay reproduction data. Irradiance data, shown for the first three years of the study, are a combination of insolation data at Redwood City which are collected by the USGS and air pollution data collected for the city of San Jose, California.

Results

Reproductive data are displayed as cumulative percentages of ripe, spawning, and spent animals; the non-tinted parts of the graphs are a combination of active and inactive animals (see appendix 1 for the complete reproduction data). As this presentation can be difficult to interpret, two of these stages, ripe and spawning, are displayed as cumulative and simple percentages in a hypothetical population with four different spawning cycles (figs. 12a and 12b). As synchrony in spawning within populations is an important factor in this report, this hypothetical population is shown with increasing asynchrony from the first to the fourth cycle (fig. 12c). The first cycle is totally synchronous (i.e. all organisms in the population spawn at one time) which results in a ripe/spawn ratio of zero. The second through fourth cycles have an increasing percentage of the population occurring concurrently in the ripe and spawning stages. We have considered the second cycle, when a few animals spawn early and late relative to the rest of the population, to be synchronous. Animals in the third and fourth cycles are considered to be asynchronous with some percentage of the population concurrently in a ripe and spawned stage over several months.

San Pablo Bay - Station 12.5

San Pablo Bay animals appeared to have two distinct reproductive periods, one in spring and one in fall. Animals were in a nearly continuous state of ripe, spawning or spent from January 1992 through September of 1993 (fig. 13, app. 1). The highest percentages of inactive animals were seen in fall 1993 and 1994. Spawning was synchronous in spring of 1993 and 1994 and strongly asynchronous in the preceding years and in fall of 1994.

Carquinez Strait- Station 8.1

Animals in Carquinez Strait had one reproductive cycle each year. Spawning was distinctly synchronous in 1992 through 1994, and possibly asynchronous in 1991. There were also longer periods of inactivity at this station (fig. 14, app. 1) than was seen at other stations.

Suisun Bay - Station 6.1

Suisun Bay animals had two reproductive cycles per year in most of the years, with the second cycle being much smaller than the first cycle during most years. Gametes entered the late stage of development in late fall or early winter and were released in spring (fig. 15, app. 1). Spawning was asynchronous in 1991 through 1993 and synchronous in 1994 (fig. 15).

Chips Island- Station 4.1

Animals at Chips Island had distinct periods of inactivity in fall of each year followed by a single reproductive period which began in late fall and continued into spring (fig. 16, app. 1). There is indication of a second reproductive cycle beginning in summer of 1991 but our inability to collect animals in several of the summer and fall months makes it difficult to confirm this. Spawning was not synchronous during any of the years although there were periods when the population was entirely spent and inactive, or spawning and spent (for example 1994).

Honker Bay - Station 433

Animals at the Honker Bay site were reproductively active throughout the year and had the lowest percentage of animals in an inactive stage of all of the stations. This resulted in a large percentage of the population being in a ripe, spawned, or spent stage most of the time (fig. 17, app. 1). This phenomenon was particularly evident in 1993 and 1994 (fig. 17) when no animals were found in an inactive phase or an active phase from January 1993 through February 1994 and August through December 1994 (note that no animals were found in March through July 1994). This was apparently due to animals cycling from the spent phase through the active and into the ripe phases within the time between samples (usually 4 weeks). There were two reproductive periods in Honker Bay animals in each year with gametes being released in late winter/early spring and again in late summer/early fall. Spawning was not synchronous for this population as there were several contiguous months when a sizeable portion of the population was coincidentally in the ripe, spawned, and spent stages.

Discussion

Reproductive Cycle and Environmental Factors

Environmental conditions are compared wiyh reproductive activity in the following sections. The percentage of animals at the beginning of gametogenesis (active stage) and the percent of those spawning (that is when there is a sharp drop in the number of ripe animals) were chosen for discussion as both reproductive stages are usually triggered by some environmental cue in organisms with external fertilization. The use of environmental cues insures that these animals release their gametes in synchrony, thereby increasing the chance of successful fertilization. The environmental factors considered in our interpretation of the reproduction data are volume of freshwater inflow, electrical conductivity or salinity, water temperature, water column chlorophyll *a* concentration, and irradiance. Freshwater inflow is examined as it is an important carrier of food from allochthonous carbon sources and is a possible stressor if the animals are affected by changes in salinity and temperature. As noted earlier, the earliest run-off, not the peak run-off, of the rainy season carries the highest percentage of particulate organic carbon (Hager and Schemel 1996), and thus it is the first signs of freshwater inflow that may be important as a carrier of the allochthonous carbon. Chlorophyll *a* concentration is discussed because it is a measure of phytoplankton biomass. However, chlorophyll *a* does not distinguish between viable and non-viable phytoplankton cells, and therefore, although an increase in chlorophyll *a* concentration does indicate an available food source, it does not necessarily indicate a growing phytoplankton population. In this study , there was at least one instance (summer 1993) when the phytoplankton that composed the chlorophyll *a* concentration peak in Suisun Bay were predominately *Melosira lirata* (Caffrey et al. 1994), a freshwater species that was washed out from the San Joaquin River and unlikely to be viable in the estuary. Due to the overgrazing of the phytoplankton populations that was discussed earlier, biomass levels (chlorophyll *a*) cannot be used as a measure of phytoplankton growth rate. The only measure we have of the food supplied by increased phytoplankton growth is irradiance (shown by Cloern and others (1985) to generally correspond to growth rate) which is therefore used as a measure of the availability of autochthonous food sources.

San Pablo Bay - Station 12.5 : The onset of gametogenesis in spring in San Pablo Bay animals appeared to coincide with the first increase in freshwater inflow (fig. 18a). Animals became ripe in fall coincident with peak irradiance (figs. 20a and 20b). Spawning usually followed peaks in chlorophyll *a* concentration (figure 19b) or freshwater inflow (figure 18b). Reproductive activity showed no direct relationship to salinity or temperature at this station with animals developing gametes and spawning throughout the salinity and temperature ranges (figs. 21a, 21b, 22a, and 22b).

Carquinez Strait- Station 8.1: Gametogenesis in Carquinez Strait animals began during initial increases in freshwater inflow except in 1992 (fig. 23a) and animals became ripe during peak freshwater flows (fig. 23b). Spawning occurred with large increases in chlorophyll a concentration in 1992 and 1993 and with small increases in chlorophyll concentration and irradiance in 1991 and 1994 (figs. 24b and 25b). Thus environmental factors which increase phytoplankton growth rates may have been important as a spawning cue in 1991 and 1994 despite low phytoplankton biomass levels.

Carquinez Strait animals became active during the highest electrical conductivities (EC) of each year (fig. 26a) and spawned with or immediately after the low EC of each year (fig. 26b) although the absolute values of these parameters were not the same during each year. The relationship between reproductive periodicity and temperature was unclear, with gametogenesis beginning with temperatures ranging from 14-22° C (fig. 27a) and animals spawning from 8-15° C(fig. 27b).

Suisun Bay - Station 6.1: Gametogenesis in Suisun Bay animals began with the first freshwater inflow in all years (figs. 28a). Animals in 1993 began to develop new gametes immediately after the winter spawn (figs. 15, 28a, 28b) coinciding with a period of extended freshwater inflow. Animals became ripe during the peak freshwater inflow (fig. 28b) or, in the case of the second reproductive period in 1993, coincident with a dramatic increase in chlorophyll a concentration (fig. 29b) and irradiance (figure 30b). Animals in all years spawned within two months of peaks in freshwater inflow but no distinct cue at the time of spawning was evident in 1991 and 1994. Animals did spawn coincident with, or following increases in chlorophyll a concentration in 1992 and 1993 (fig. 29b).

Suisun Bay animals were similar to those elsewhere with no specific range of EC or temperature being necessary for gamete development or spawning (figs. 31a and 32a).

Chipps Island- Station 4.1: As elsewhere, the reproductive periodicity of animals at Chipps Island corresponds most closely to peaks in freshwater inflow (fig. 33) with some secondary influence by increases in chlorophyll *a* concentration (fig. 34). Animals began gametogenesis with the first increase in freshwater (fig. 33a), and became ripe coincident with, or preceding the peak freshwater runoff (fig. 33b). Spawning occurred either during the maximum freshwater inflow (1991 and 1992, fig. 33b) or with peaks in chlorophyll a concentration (1993 and 1994, fig. 34b). Spawning preceded the peak in irradiance during all years (fig. 35b).

The initiation of gametogenesis and spawning were not sensitive to EC (fig. 36a) or temperature (fig. 37a).

Honker Bay - Station 433: The three environmental factors most important in determining the time when Honker Bay animals became active, became ripe, and spawned were freshwater inflow, chlorophyll *a* concentration, and irradiance (figs. 38, 39, and 40). As active stage animals were not successfully sampled at this station (fig. 38a), only ripe and spawned animals will be discussed. The maximum percentage of ripe animals in the spring reproductive period coincided with the peak freshwater inflow (1991 and 1992), or followed the increased freshwater inflow at the beginning of the rainy season (1993 and 1994, fig. 38b). During the fall reproductive period, the maximum number of ripe animals followed the peak irradiance values in 1991-1993 (fig. 40) and coincided with a small increase in freshwater inflow in 1994 (fig. 38b). The environmental cue for spawning was difficult to define for both the spring and fall reproductive cycles.

Both gametogenesis and spawning were initiated over a broad range of EC values (0-14000 μSeimens/cm, fig. 41) and temperatures (fig. 42).

Summary: Despite some differences, there were large similarities in the reproductive cycles of *P amurensis* at the locations examined (fig. 43). The timing of the reproductive cycles of *P. amurensis* in northern San Francisco Bay was most coincident with food availability at all of the stations in the study. Gametogenesis started with the first increase in freshwater each year which is coincident with increases in allochthonous food sources. Spawning was less consistent between stations but occurred with, or following increases in phytoplankton biomass, peaks in freshwater inflow, or irradiance at most stations which is indicative of peak growth in the autochthonous food sources.

Neither water temperature nor salinity could be seen to consistently influence the timing of the reproductive cycle. Although reproductive cycles seemed to be inversely correlated to the temperature cycle during some periods, this correlation was most likely due to the cross correlation of temperature and freshwater inflow. We conclude that temperature or change in temperature is not an important reproductive cue because the absolute value of temperature or change in temperature during the reproductive events varied so much between years, stations, and the two seasonal reproduction cycles.

Reproductive cycles were distinctly seasonal except in Honker Bay and San Pablo Bay animals, which exhibited near continuous reproduction with no apparent inactive stages during most years. These animals also showed a lower percentage of inactive stage animals in the years in which reproductive activity wasn't continuous than did the populations at the other locations.

Condition and Reproduction

The condition index is calculated for animals of one shell length (15 mm) and should reflect weight losses and gains due to reproductive activity in addition to somatic tissue (all non-reproductive tissue) losses and gains. However, because condition is determined from a pooled sample of many animals, it may contain animals in various reproductive stages at the stations where animals have asynchronous spawning. Therefore, changes in condition that coincide with reproductive activity, weight gain during gametogenesis, and weight loss during the spawning and spent stages, will be discussed for synchronous spawning populations only. At these stations, the speed with which animal weight rebounds following spawning, and the amount of weight gained during gamete development, is dependent on the balance between energy intake (that is food consumption) and metabolic requirements. Stressors, such as contaminants can affect the supply side of this balance by inhibiting feeding rates and can influence the demand side by increasing metabolic rate. Thus when there is little weight gain during late gametogenesis for synchronously spawning populations, it is assumed that the animal is metabolizing somatic tissue (for example glycogen and lipid stores as well as structural tissue) in order to develop the reproductive tissue. Similarly, when there is little weight loss following spawning in synchronously spawning populations, it can be assumed that there was sufficient food relative to the animals metabolic needs to replace the loss in weight due to the released gametes with new reproductive tissue or new somatic tissue. Finally, if condition is stable for populations which spawn asynchronously, this pattern for condition may confirm that spawning in this population is asynchronous.

San Pablo Bay - Station 12.5: Condition was not consistently related to reproduction (fig. 44) in San Pablo Bay animals. Although there were periods of weight gain coincident with animals becoming ripe in spring of 1993 (fig. 44b) there were many of times when the expected weight losses and gains did not occur, e.g. the loss in weight in early 1992 and 1994 that was coincident with animals becoming ripe (fig. 44b). As noted earlier, this population asynchronously spawned except in early 1993 and possibly in 1994 (fig. 13), and therefore the lack of correspondence between reproductive activity and condition was not unexpected.

Carquinez Strait- Station 8.1: Carquinez Strait animals spawned synchronously and condition and reproductive stage were related in most years (fig. 45). Animals in 1994 had the highest condition values and the largest post-spawning rebounds. In 1992, there was relatively little change in condition during the reproductive cycle. This population was synchronously spawning in 1992 (fig. 14) so this low and relatively stable condition may mean that these animals were scavenging somatic tissue to produce reproductive tissue, but were able to quickly regain weight after spawning.

Suisun Bay - Station 6.1: Condition corresponded to reproductive stage in early 1991 in San Pablo Bay animals, but there was less correspondence after that date (fig. 46). We have few data points in 1993 and 1994 but the few points available indicate that maximum condition was seen in 1994, which was the only year when animals were synchronously spawning at this location.

Chipps Island- Station 4.1: Condition in Chipps Island animals was, on average, higher in 1993 and 1994 than in previous years (fig. 11) and varied greatly between seasons in all years of the study (figs. 47a and 47b). Changes in condition did not always correspond to changes in the reproductive state of the animals which is expected in a population which asynchronously spawned in all years of the study.

Honker Bay - Station 433: Condition values were stable from 1991 through early 1993, due at least in part to the strong asynchrony in spawning at this station, and much more seasonally varying and larger in late 1993 and early 1994 (fig. 48). The data for late 1993 and early 1994 show a good correspondence between condition and reproduction with animals gaining substantial weight during reproductive development and losing weight at spawning (fig. 48). The post-spawning condition in 1993 was similar to the average condition seen in 1991 and 1992.

Summary: Condition was inversely related to the cadmium content of animals; San Pablo Bay animals had the highest condition and those in Honker Bay had the lowest condition. Within this condition gradient, animal condition was usually related to reproductive stage with animals decreasing condition at spawning and increasing condition with developing gametes in those populations that spawned synchronously. The strongest relationships between reproductive state and condition and the largest post-spawning condition rebound were seen in 1993 and 1994 when the food supply was greatest.

Condition either varied very little (for example Honker Bay animals in 1991-1992) or without a relationship to reproductive cycles at stations with asynchronously spawning animals. The increase in condition during some years at these stations may have been due to an increase in condition during one or all of the reproductive stages or due to an increase in somatic tissue weight. One of these periods, 1993, coincided with an increase in food, and thus both reproductive and somatic tissue may have benefitted by the extra food available.

Reproductive Cycle and Cadmium Concentration

Spawning was asynchronous in animals from Honker Bay and Chipps Island in all years and in Suisun Bay in animals in 1991 through 1993 (figs. 49d, 49e, and 49f). Cadmium concentration and content had a downstream gradient which was consistent with this pattern of spawning synchrony: cadmium content was highest at the two landward sites and highest in 1991-1993 in Suisun Bay (fig. 9). Cadmium content may be best used for this analysis because content is not affected by condition if it is assumed that the reproductive products assimilate little trace metal relative to somatic tissue. Because concentration values are normalized by condition, and reproductive stage does affect condition, both condition and concentration values may shown smaller seasonal fluctuations in asynchronous populations. The consistent pattern between cadmium content and spawning asynchrony may indicate that there is some threshold of cadmium above which animals are either unable to interpret spawning cues or unable to control spawning. This hypothesis is consistent with the findings of Kluytmans et al. (1988) who found that cadmium had a stimulating effect on the spawning of *Mytilus edulis* in laboratory experiments.

The asynchronous spawning of animals in the spring of 1993 and 1994 in San Pablo Bay occurred when cadmium levels were well below the threshold level suggested by data at the upstream stations (figs. 8 and 9). Therefore, some over factor, possibly seasonal peaks in cadmium concentration which were not examined in this study or increased concentrations of selenium which is known to be elevated in these areas (Luoma, unpublished data), may be affecting the spawning synchrony of these animals during some years. It is not possible to determine what caused this change in reproductive pattern based on our present data collection, but ongoing work on cadmium and selenium tissue burdens in this area of the bay by S.N. Luoma may help.

Conclusions

I. The number of reproductive cycles in *P. amurensis* during each year and the time spent in inactive and early gametogenic stages is a function of food availability.

II. Asynchrony in spawning occurred at the three locations with the highest cadmium content.

III. Change in condition may be a function of food, spawning synchrony, and cadmium concentration:

- Condition decreases with increasing cadmium content (figs. 9 and 10).
- Condition changes very little or erratically in populations with asynchronous spawning.

IV. Studies on reproductive cycles in *P. amurensis* in northern San Francisco Bay show promise in determining ecosystem effects of trace metals. Although *P. amurensis* is not an important economic species in the bay, the asynchronous spawning of these animals is a cause of concern. The long term effects of a confused spawning cue on a less opportunistic species might be devastating. This *in situ* measure of the effect of a contaminant on an organism is the first that has been reported in San Francisco Bay.

V. Studies of this kind require multiple years of data in order to interpret the many environmental factors.

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Tables 1 and 2.

Table 1. Collection Stations. Latitude, Longitude and depth (meters) at mean lower low water.

Station number	Station Name	Lattitude	Longitude	Depth (m)
12.5	San Pablo Bay	38 02.43' N	122 18.85' W	6.7
8.1	Carquinez Strait	38 01.90' N	122 08.40' W	14.9
6.1	Suisun Bay	38 03.70' N	122 02.20 'W	9.8
4.1	Chipps Island	38 03.30' N	121.56.70' W	8.8
433	Honker Bay	38 04.23' N	121 56.03' W	2.5

Table 2. Collection dates by station when no clams were available for examination.

8.1 Carquinez Strait	6.1 Suisun Bay	4.1 Chipps Island	12.5 San Pablo Bay	433 Honker Bay
Dec-92	Jul-92	Jun-91	Jun-92	Dec-91
	Feb-94	Jul-91	Dec-92	Jan-92
	Jul-94	Sep-92	Feb-94	Feb-93
		Sep-93	Jun-94	May-93
			Nov-94	Aug-93
			Dec-94	Mar-94
				Apr-94
				May-94
				Jun-94
				Jul-94

Figures 1 through 49.

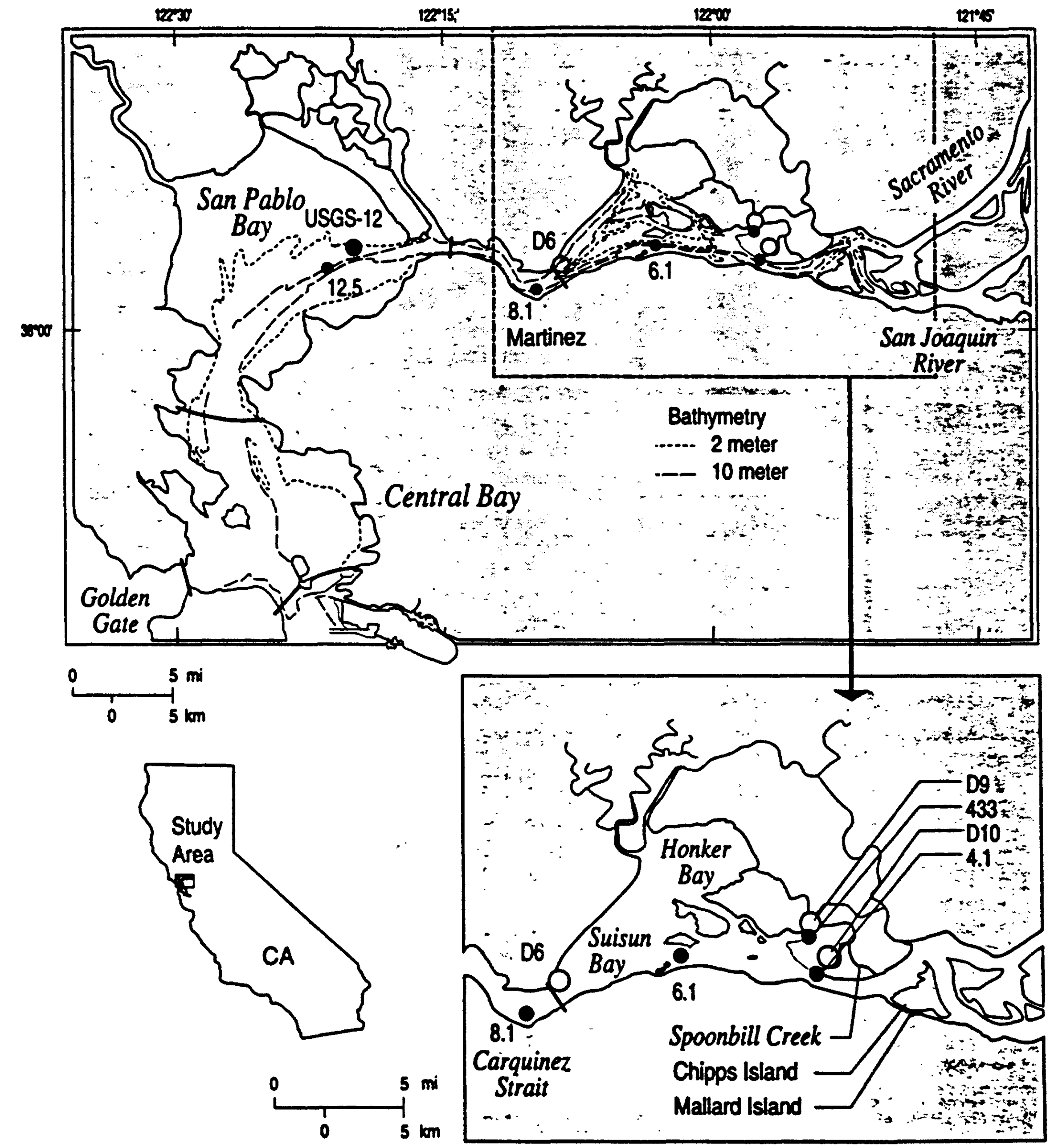

Figure 1. Map of study area including U.S.G.S. and D.W.R. (D6, D9, and D10) stations.

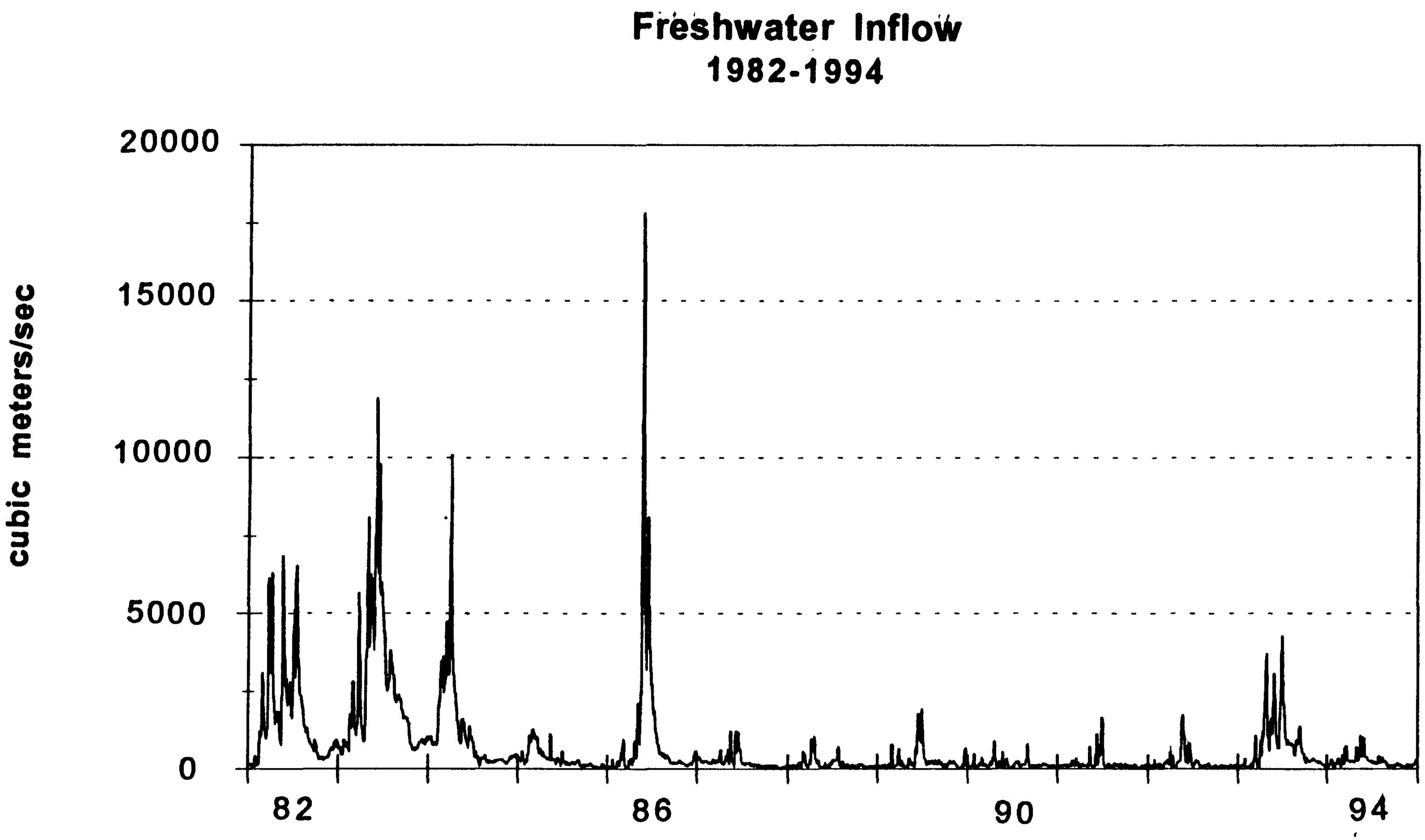

Figure 2. Daily freshwater Inflow into northern San Francisco Bay for water years 1982-1994 (October through September). Data is calculated by California Department of Water Resources as net delat outflow.

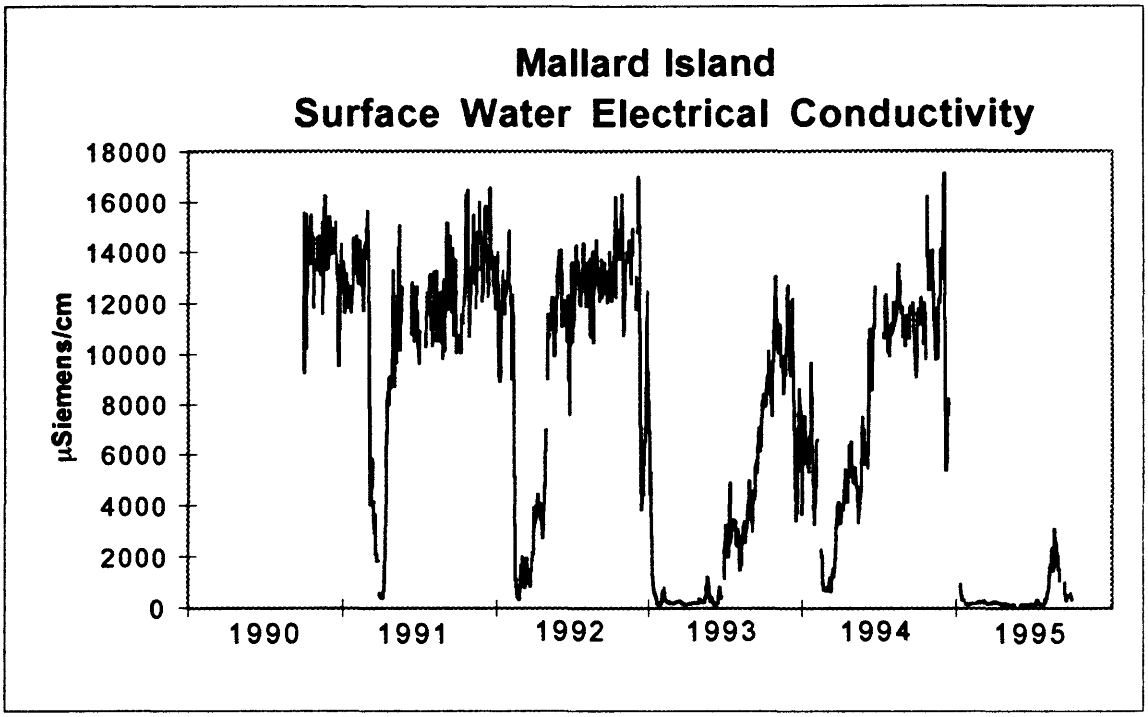

Figure 3a. Surface water electrical conductivity at California Department of Water Resources Mallard Island monitoring station.

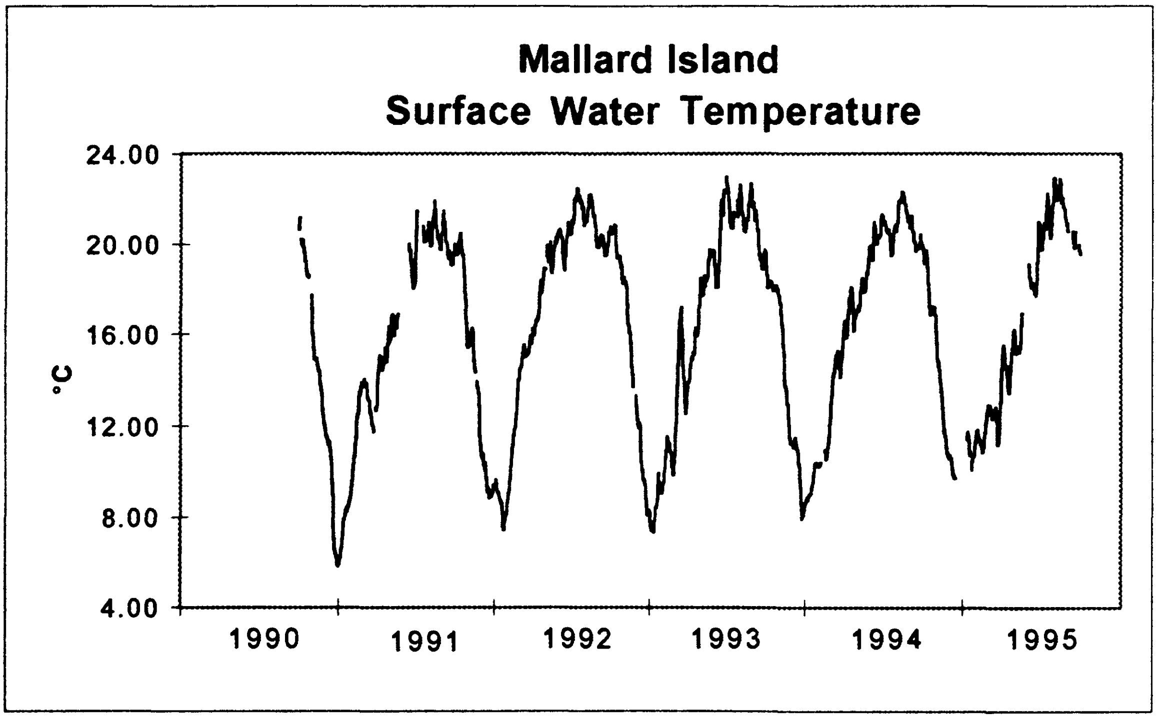

Figure 3b. Surface water temperature at California Department of Water Resources Mallard Island monitoring station.

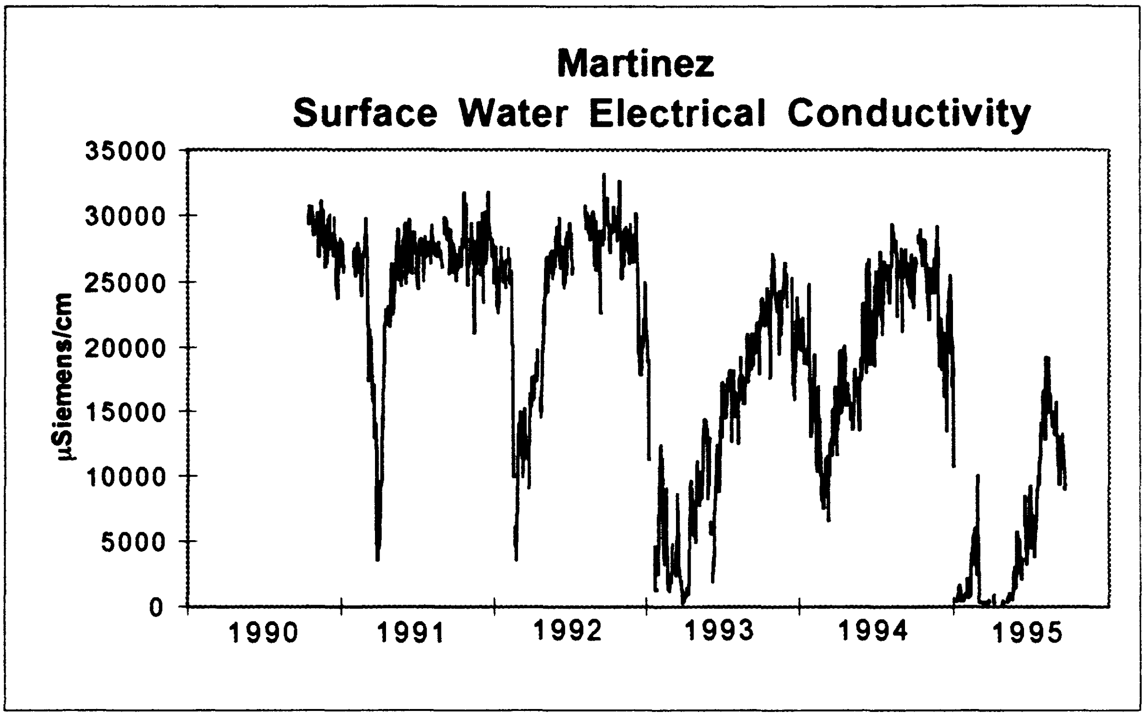

Figure 4a. Surface water electrical conductivity at California Department of Water Resources Martinez monitoring station.

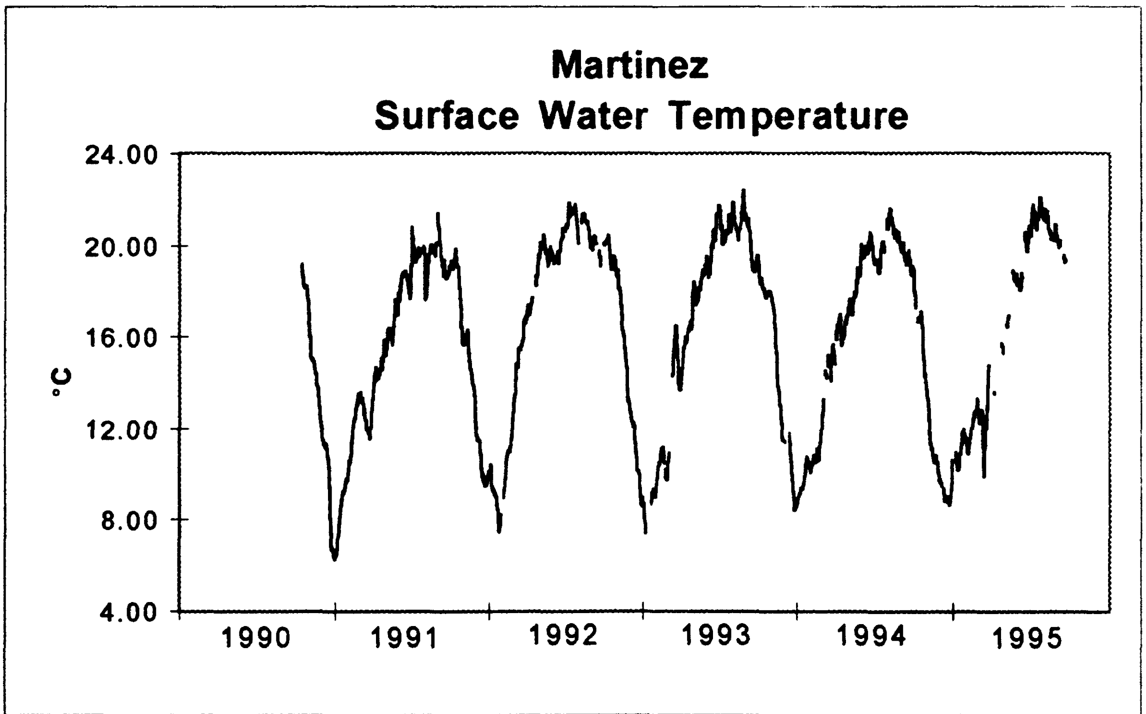

Figure 4b. Surface water temperature at California Department of Water Resources Martinez monitoring station.

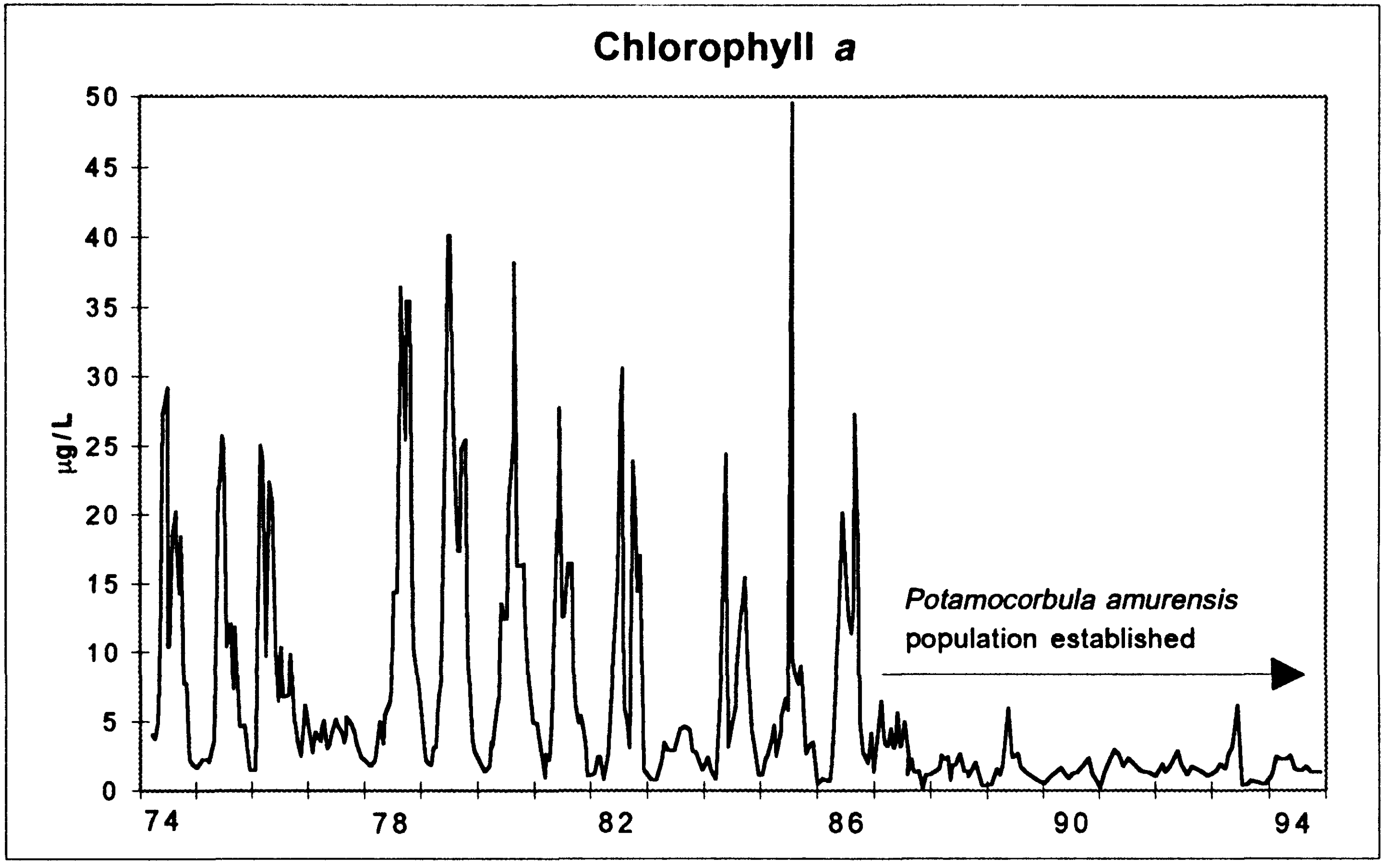

Figure 5. Monthly or semi-monthly measures of chlorophyll a in Suisun Bay. Data from California Department of Water Resources Station D8 (1974-1987) and U.S. Geological Survey station 5 (1988-1994). Figure adapted from Alpine and Cloern, 1992.

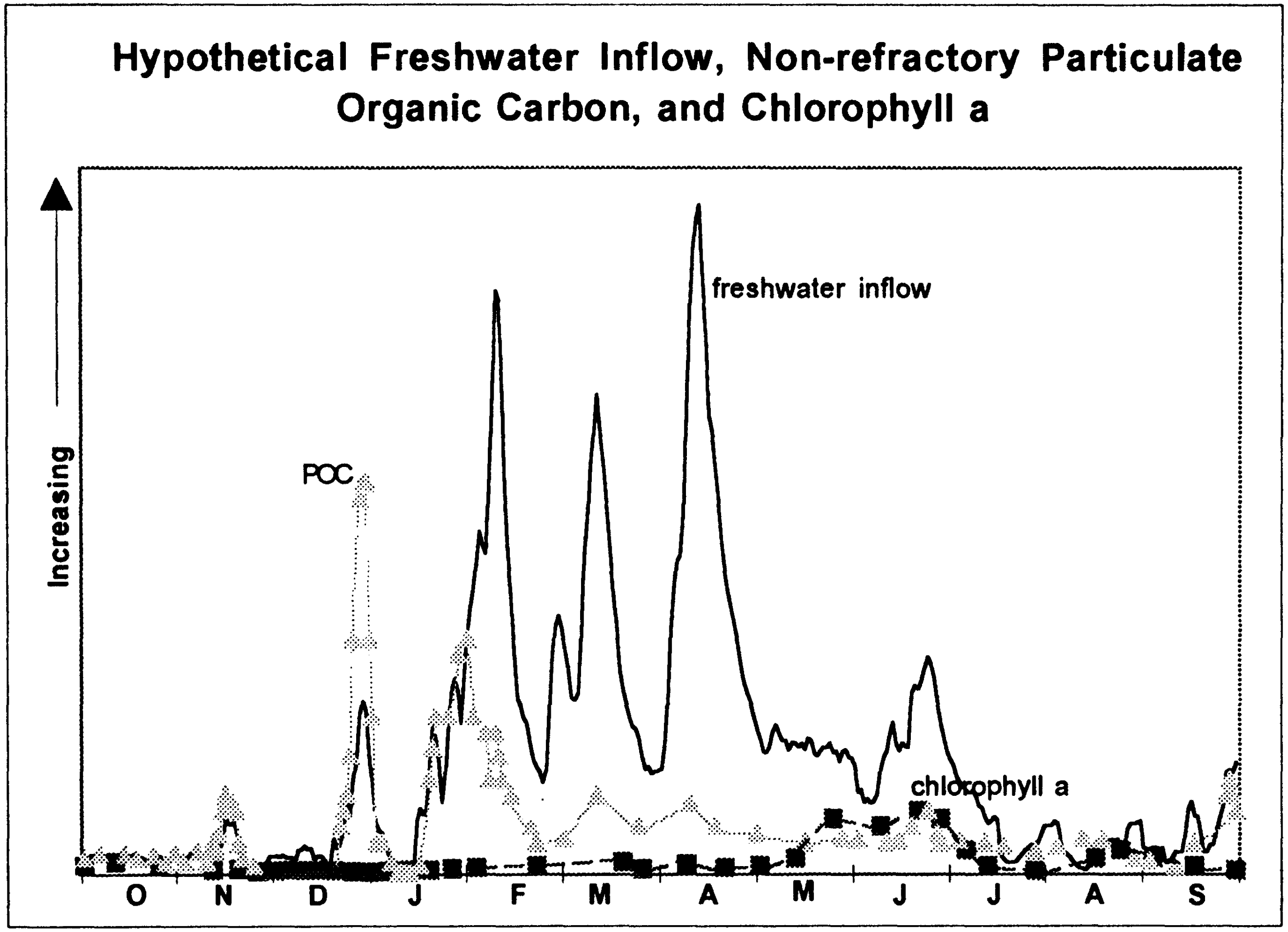

Figure 6. Hypothetical annual (water year) pattern of freshwater inflow, non-refractory particulate organic carbon and chlorophyll a based on Hager and Schemel (1996) and U.S.G.S. historical data (unpublished). Relative magnitudes within the year for each parameter are valid but relative magnitudes between particulate organic carbon and chlorophyll a vary between years and should not be used as relative or absolute values.

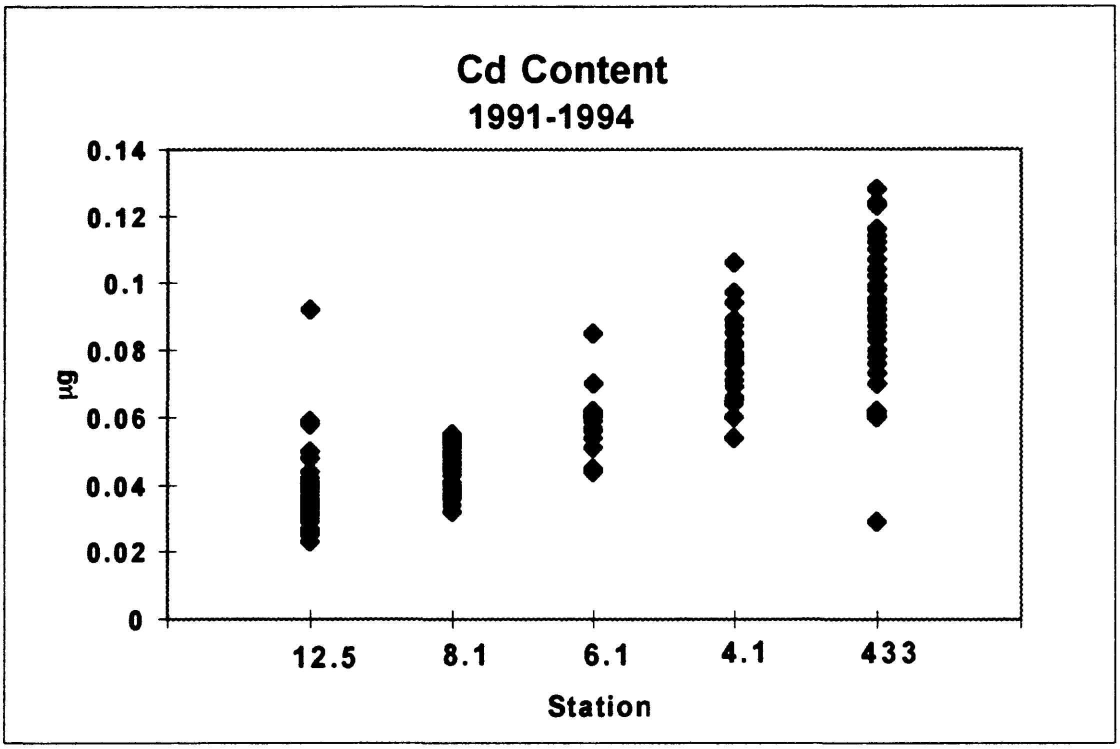

Figure 7. Cadmium content at all stations (1991-1994).

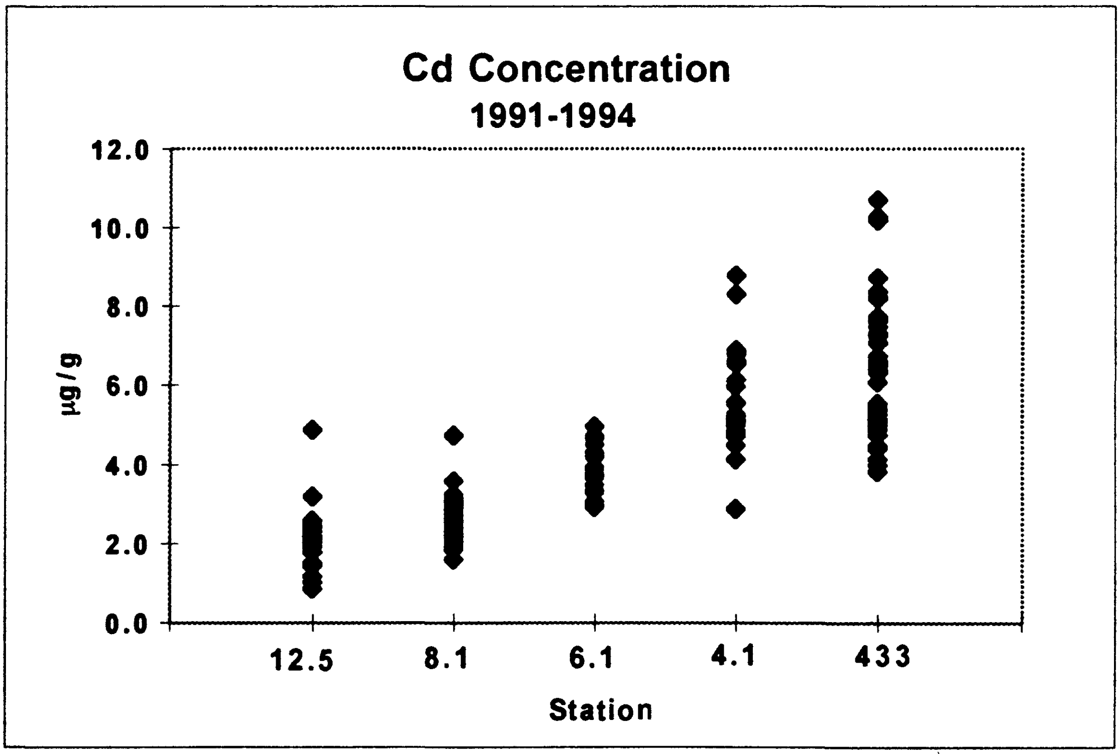

Figure 8. Cadmium concentration at all stations (1991-1994).

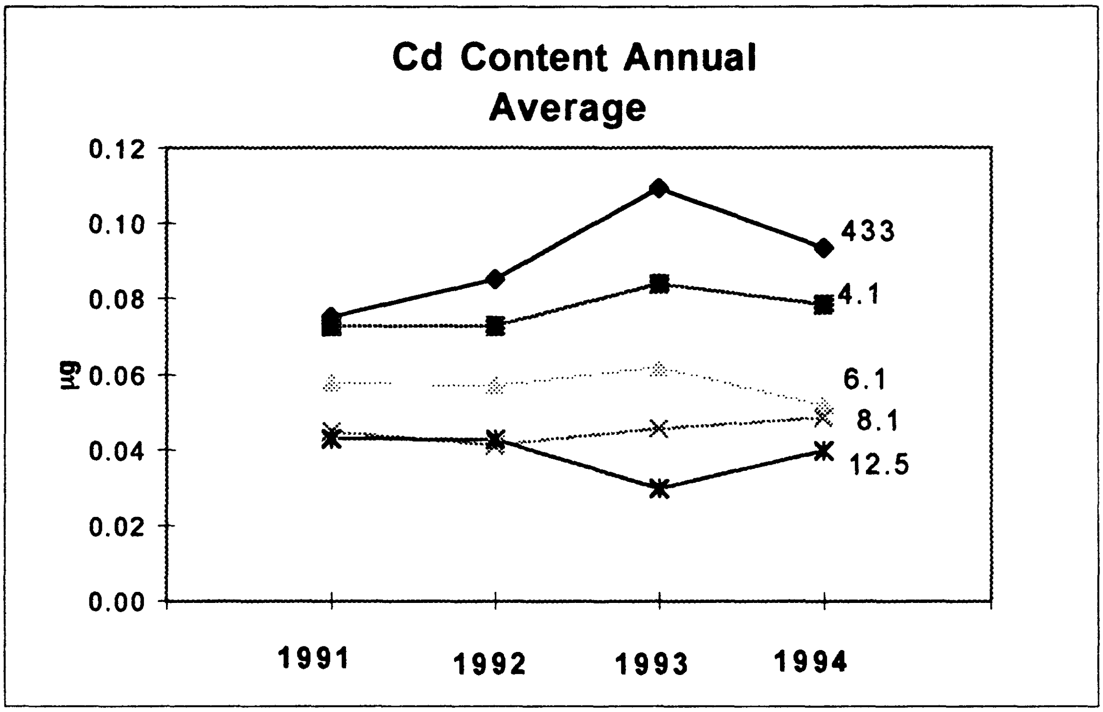

Figure 9. Yearly average cadmium content at all stations.

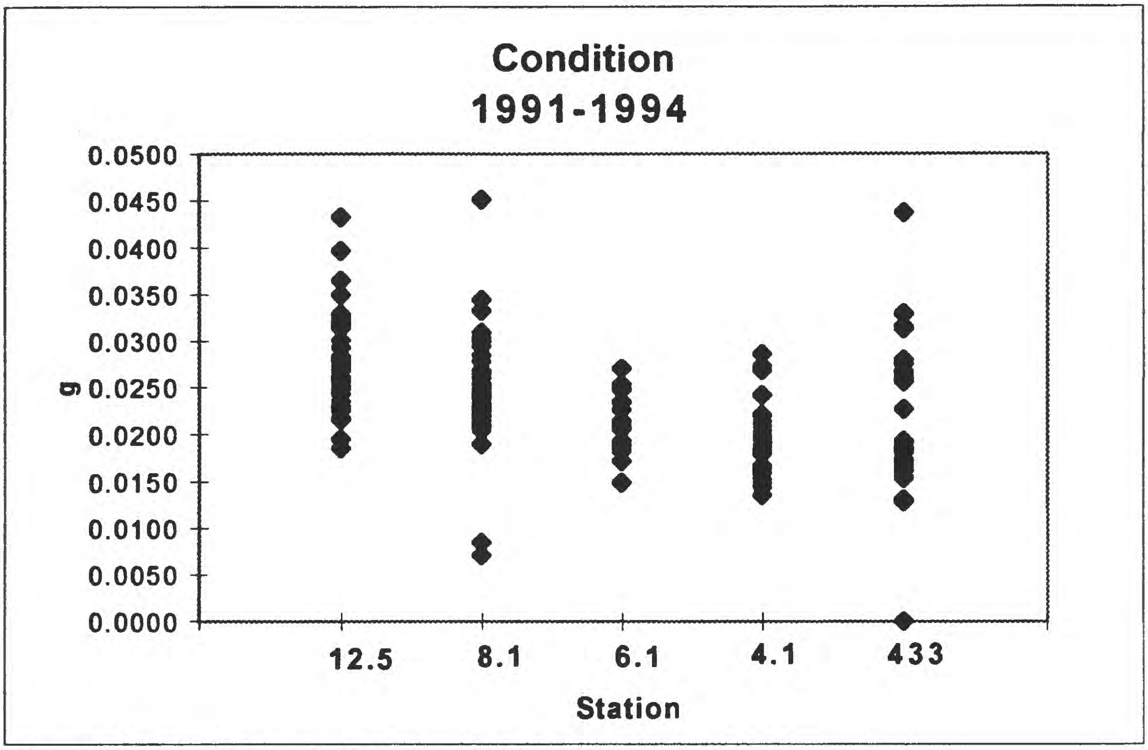

Figure 10. Condition at all stations (1991-1994).

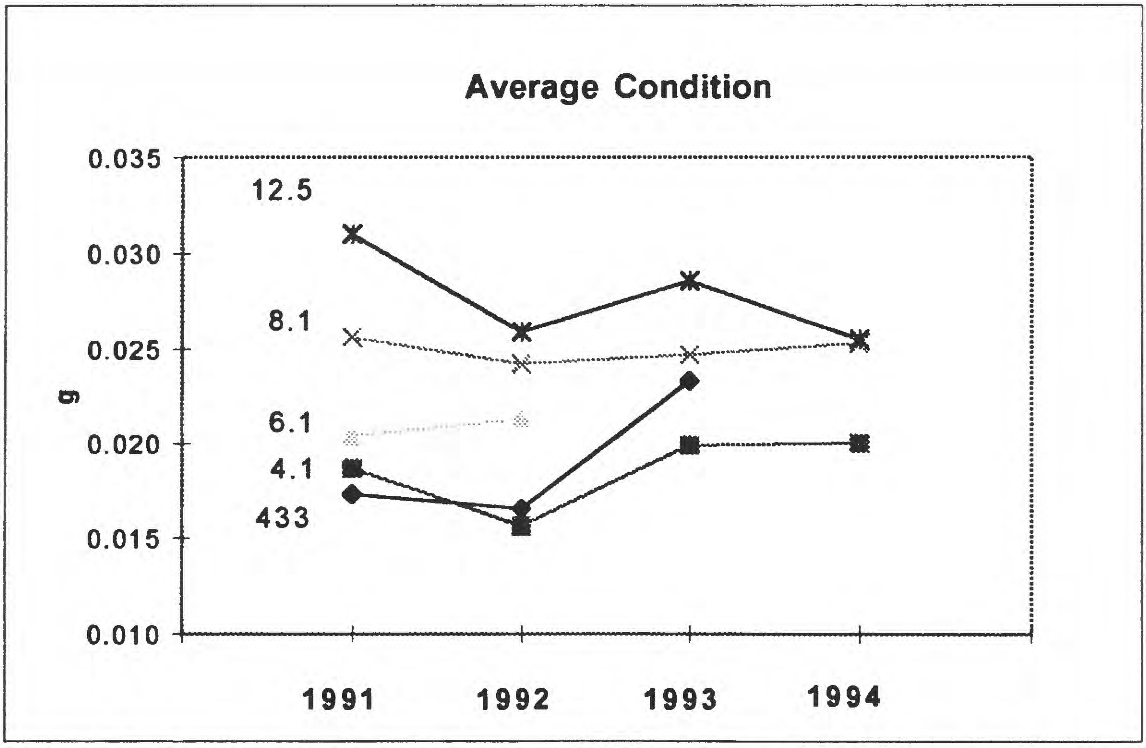

Figure 11. Average condition at all stations for 1991 through 1994. Averages not shown for 1993 and 1994 at station 6.1 and 1994 at station 433 due to incomplete data sets.

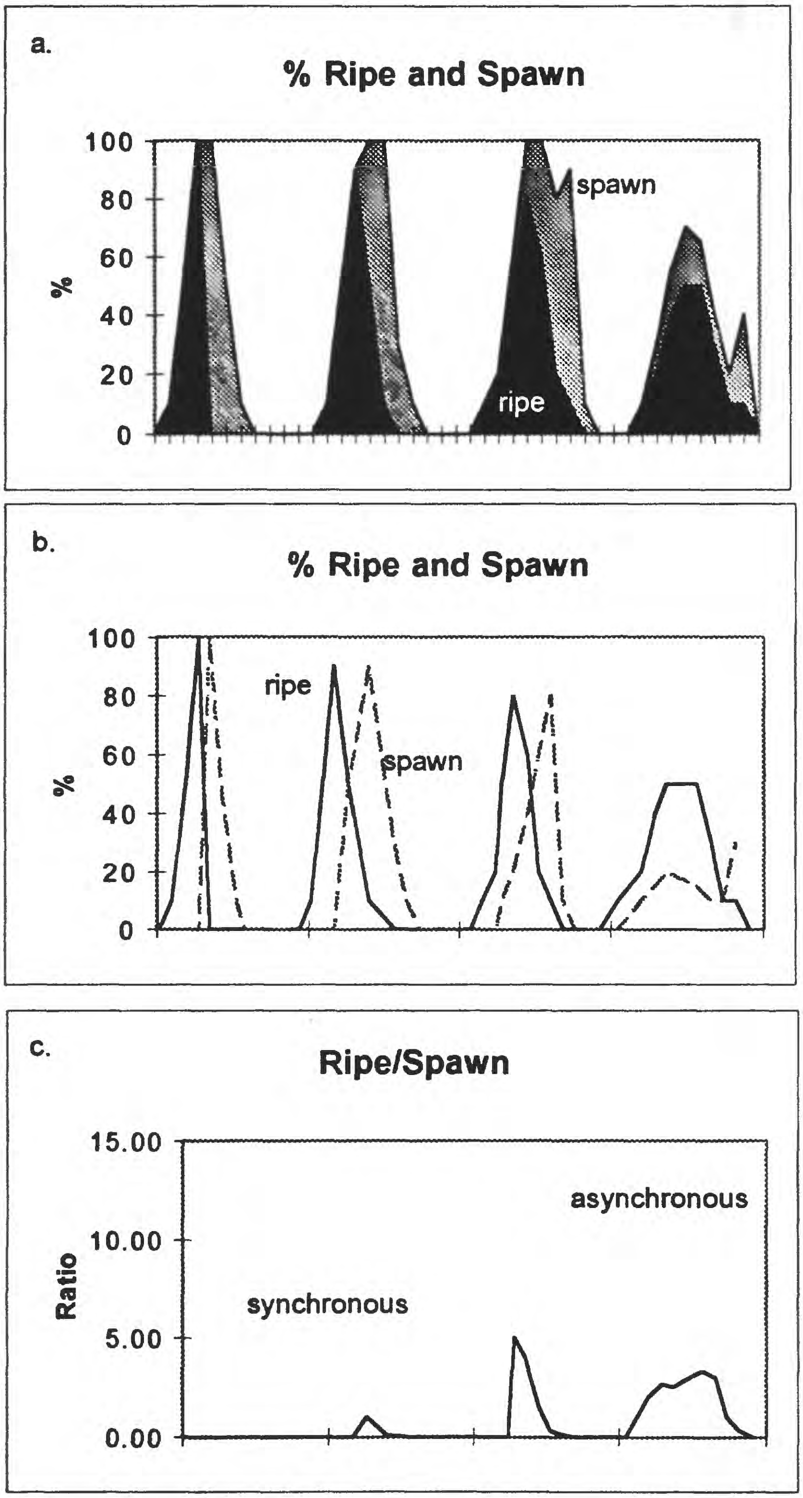

Figure 12. Hypothetical population showing a) cumulative percentages of ripe and spawning animals, b) percent ripe and spawning, and c) ratio of ripe/spawning animals showing synchrony in spawning.

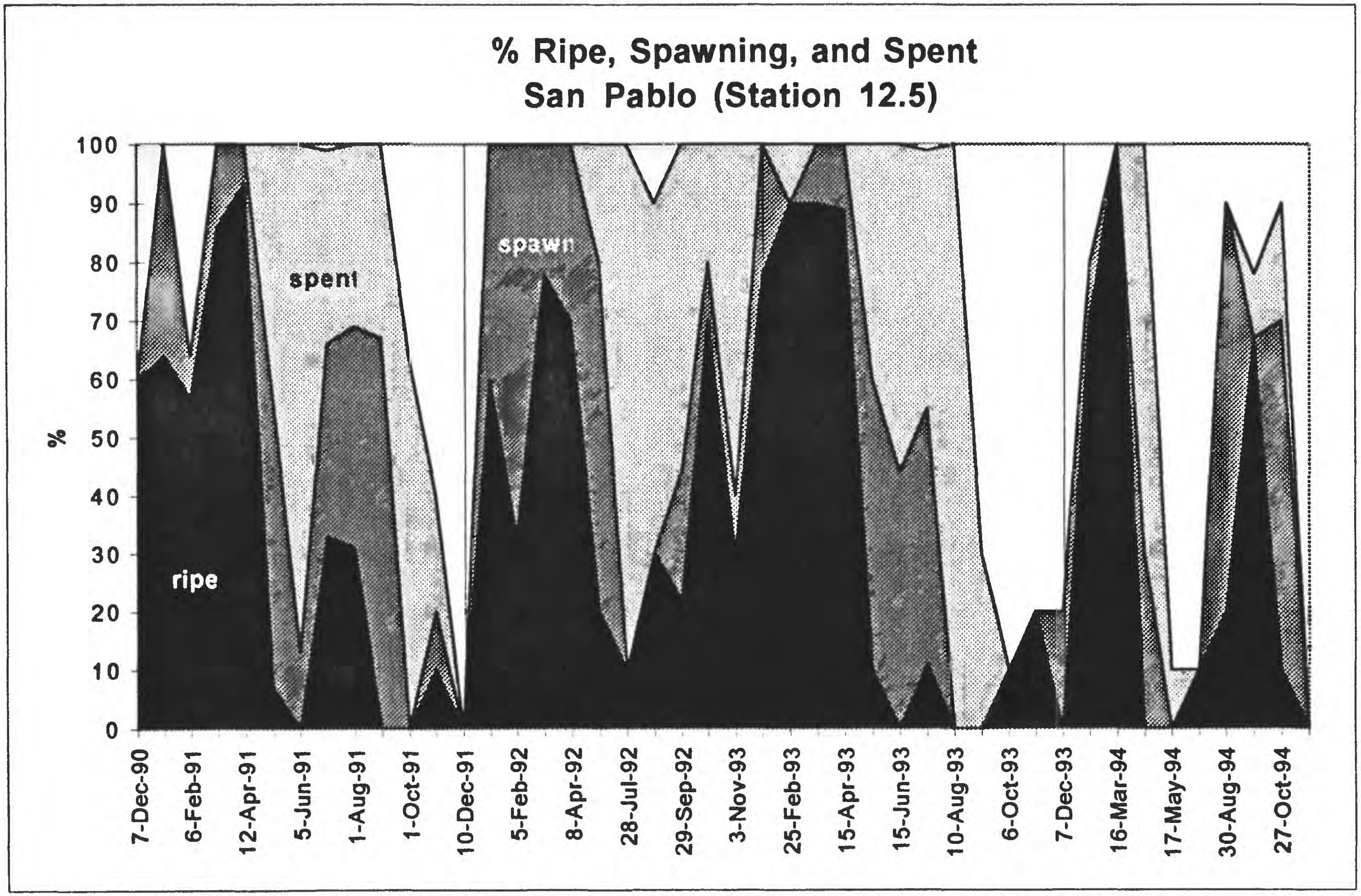

Figure 13. Cumulative percent of animals in ripe, spawning and spent reproductive stage at station 12.5.

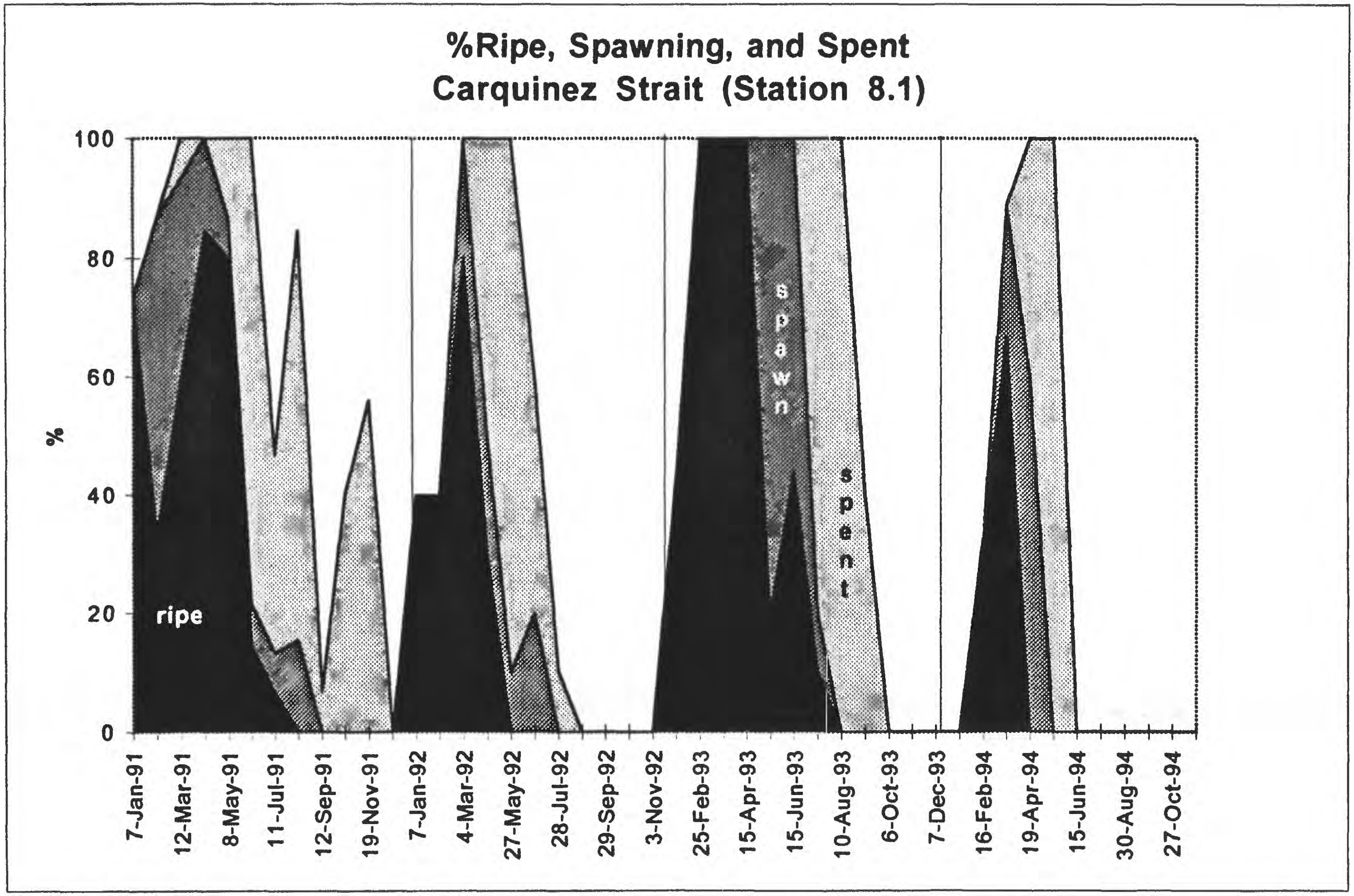

Figure 14. Cumulative percent of animals in ripe, spawning and spent reproductive stage at station 8.1.

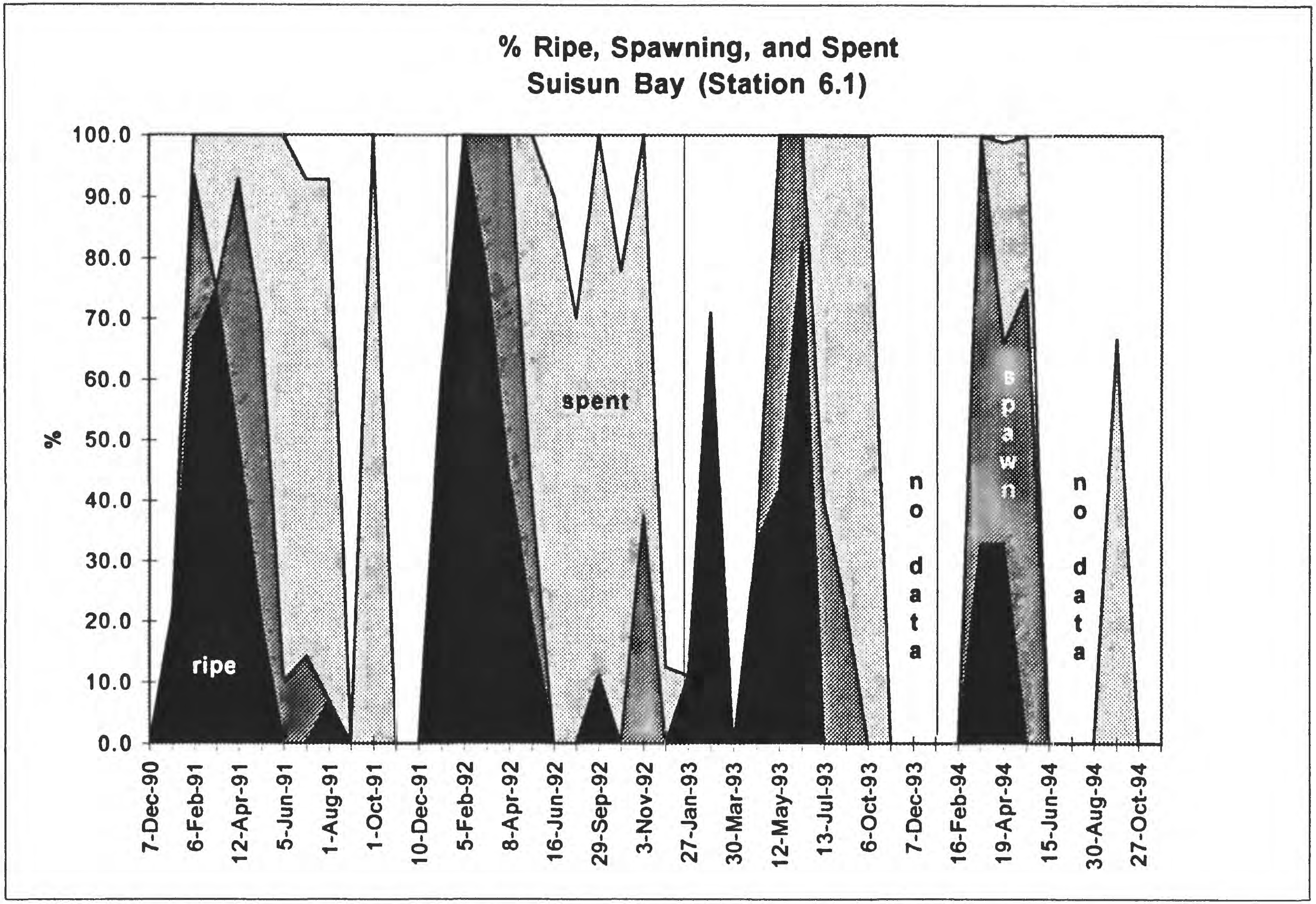

Figure 15. Cumulative percent of animals in ripe, spawning and spent reproductive stage at station 6.1.

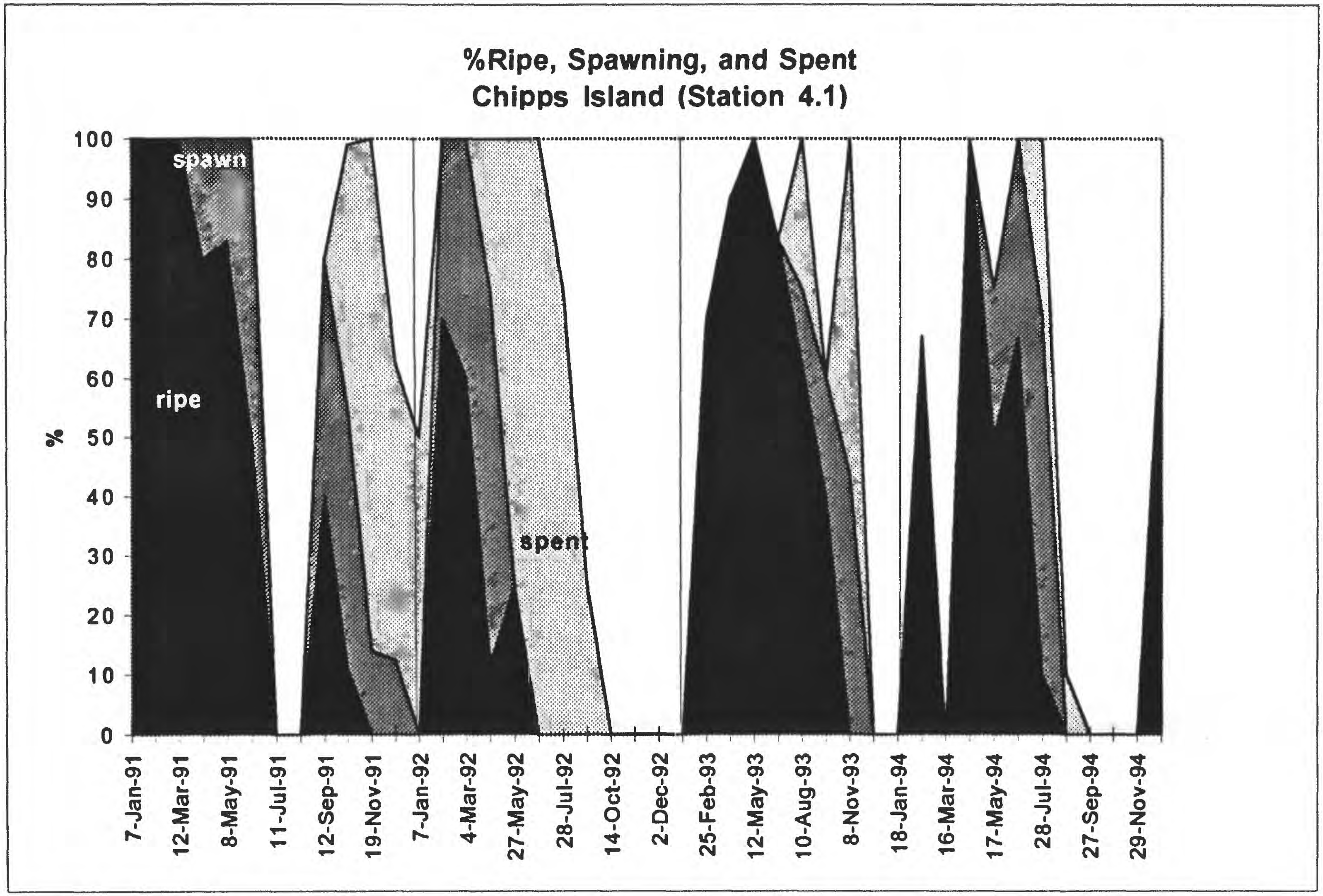

Figure 16. Cumulative percent of animals in ripe, spawning, and spent reproductive stage at station 4.1.

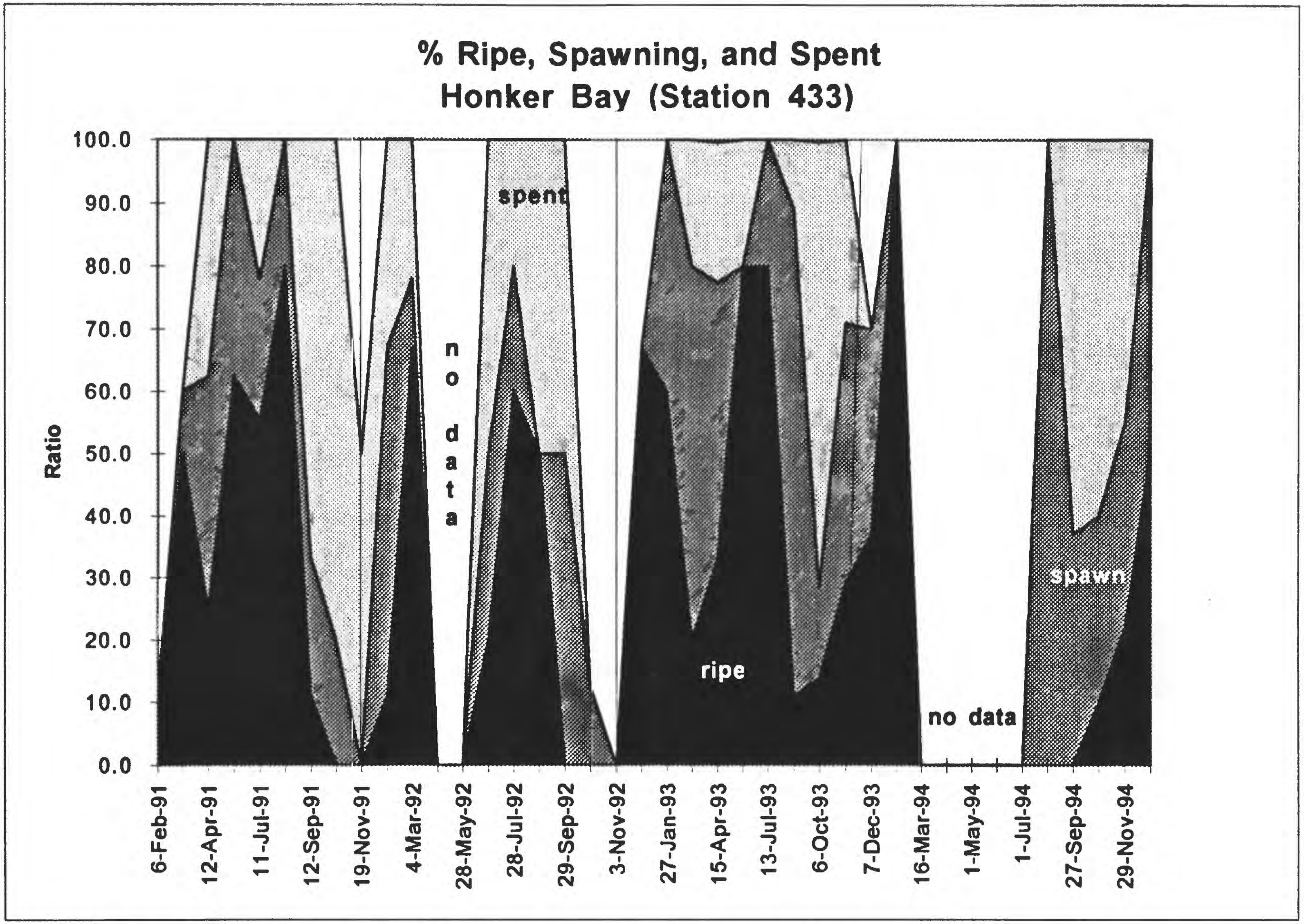

Figure 17 Cumulative percent of animals in ripe, spawning and spent reproductive stage at station 433.

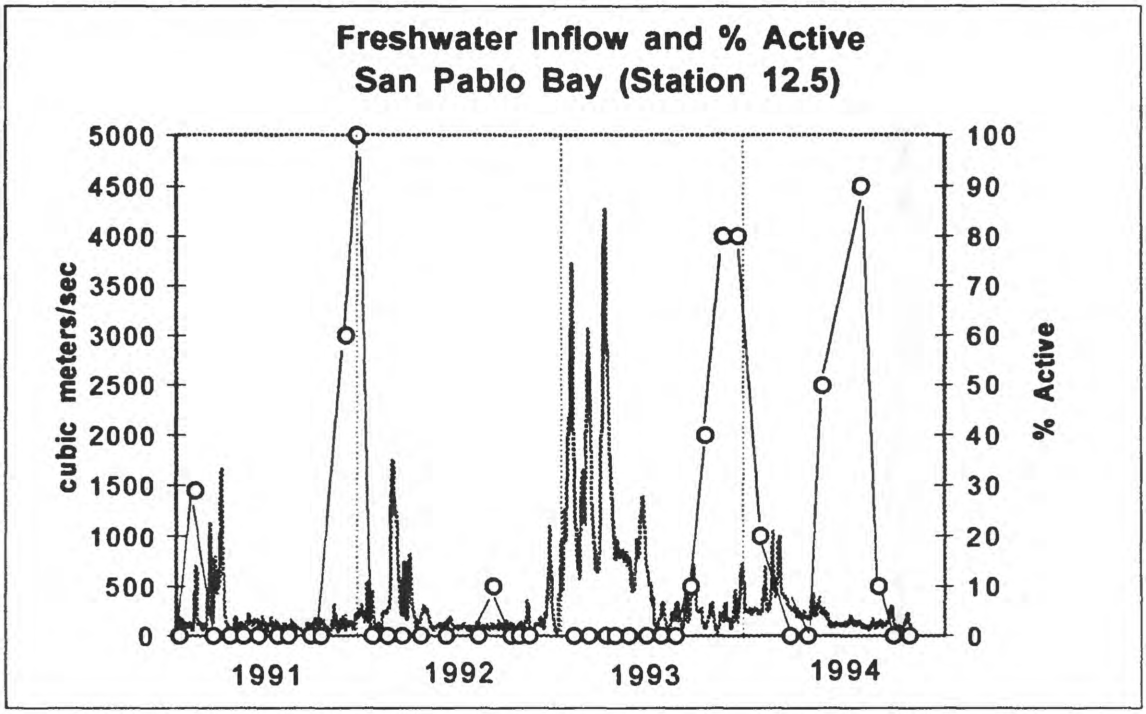

Figure 18a. Freshwater inflow and % of animals in active reproductive stage (°) at station 12.5.

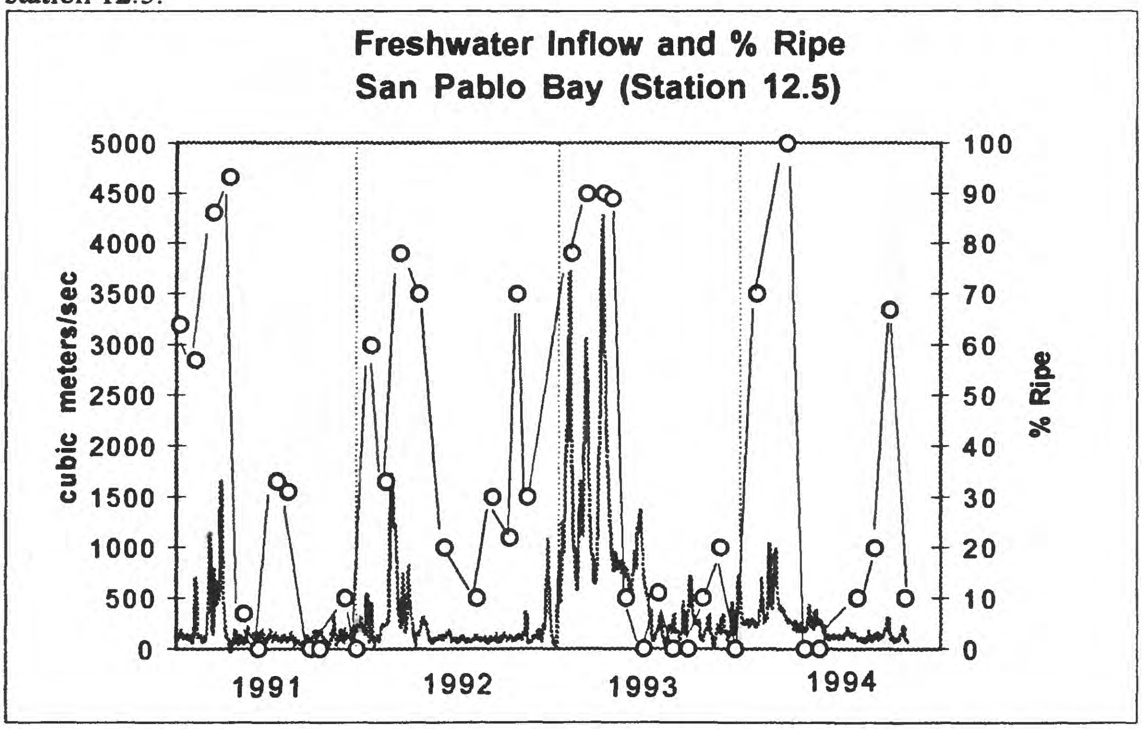

Figure 18b. Freshwater inflow and % of animals in ripe reproductive stage (°) at station 12.5.

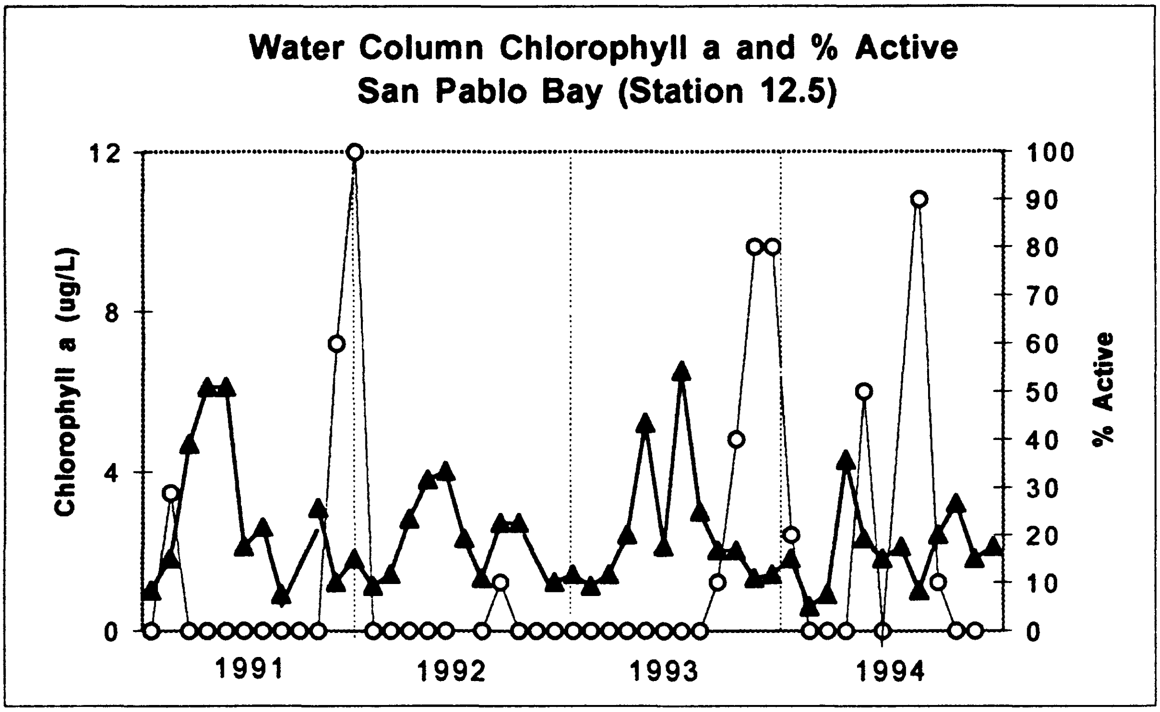

Figure 19a. Water column chlorophyll *a* (▲) and % of animals in active reproductive stage (°) at station 12.5.

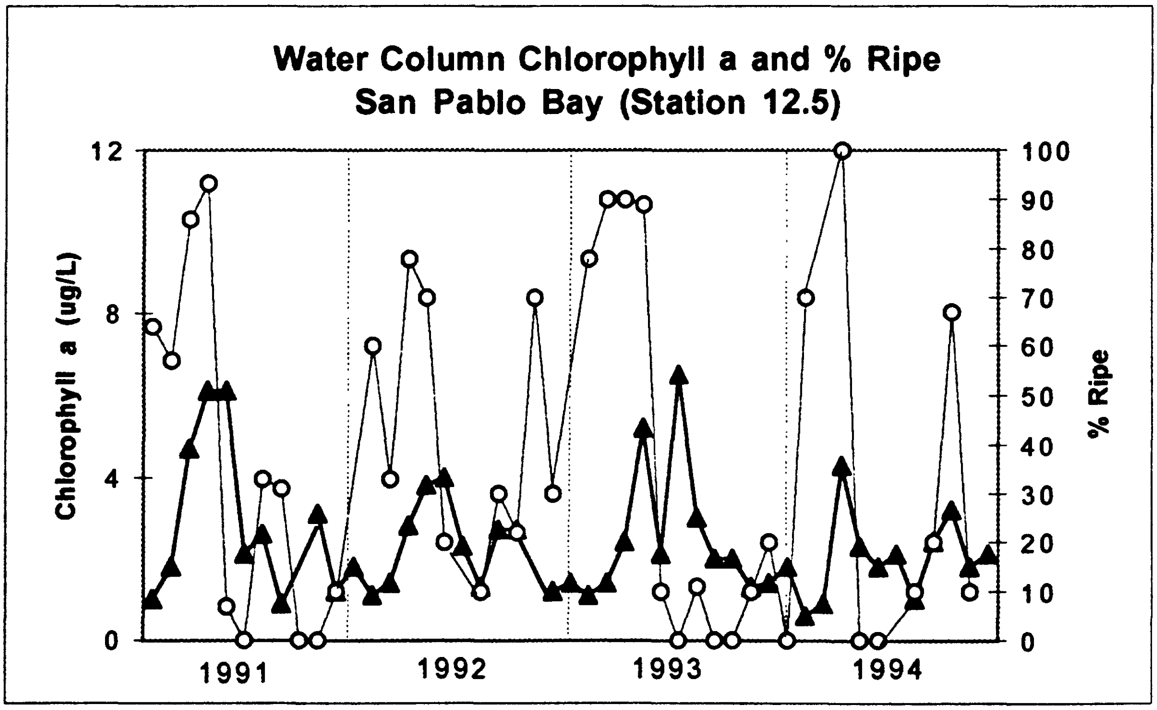

Figure 19b. Water column chlorophyll *a* (▲) and % of animals in active reproductive stage (°) at station 12.5.

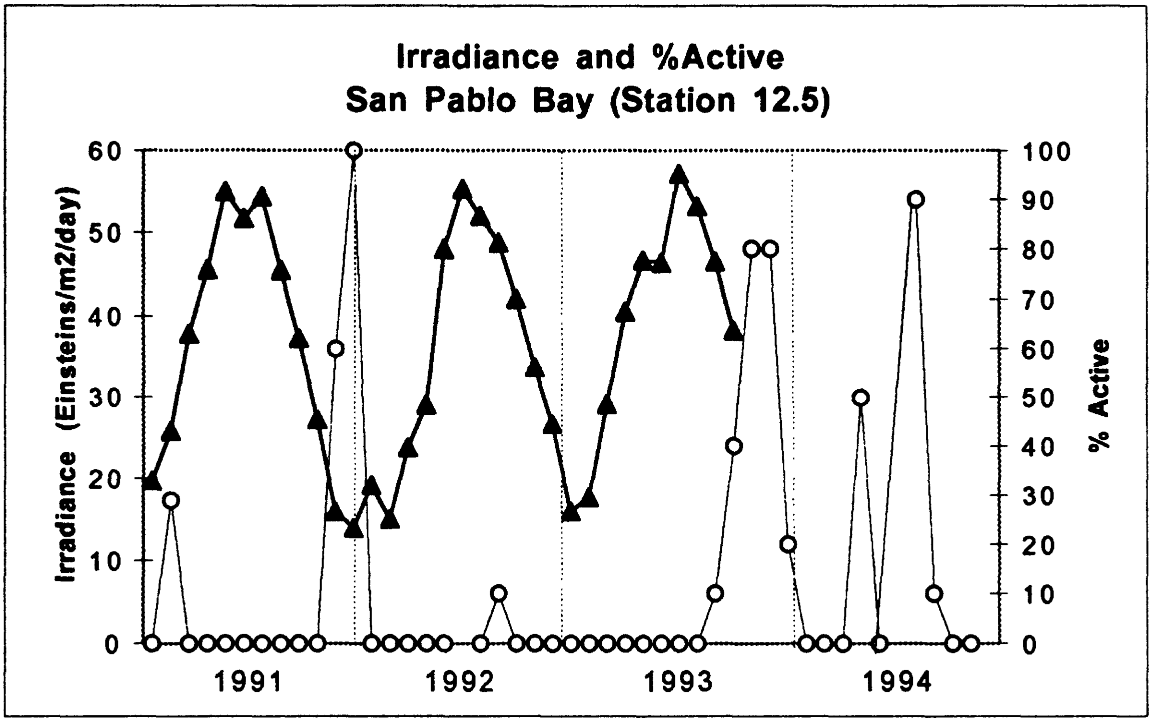

Figure 20a. Irradiance (▲) and % of animals in active reproductive stage (°) at station 12.5.

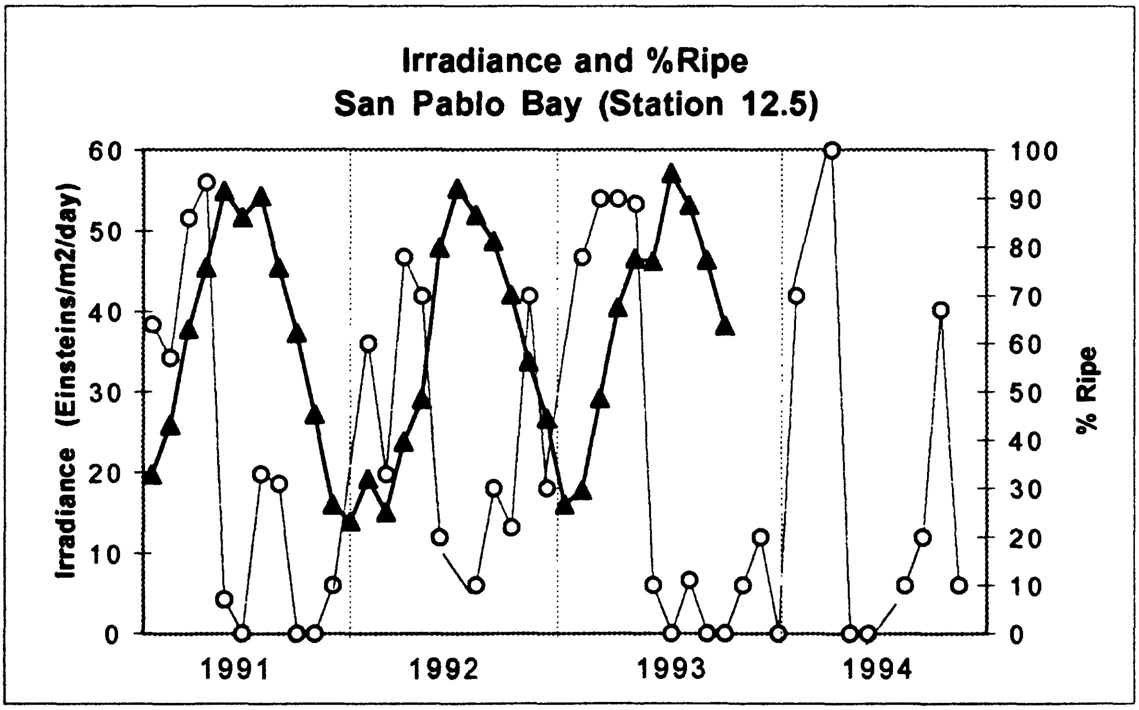

Figure 20b. Irradiance (▲) and % of animals in ripe reproductive stage (°) at station 12.5.

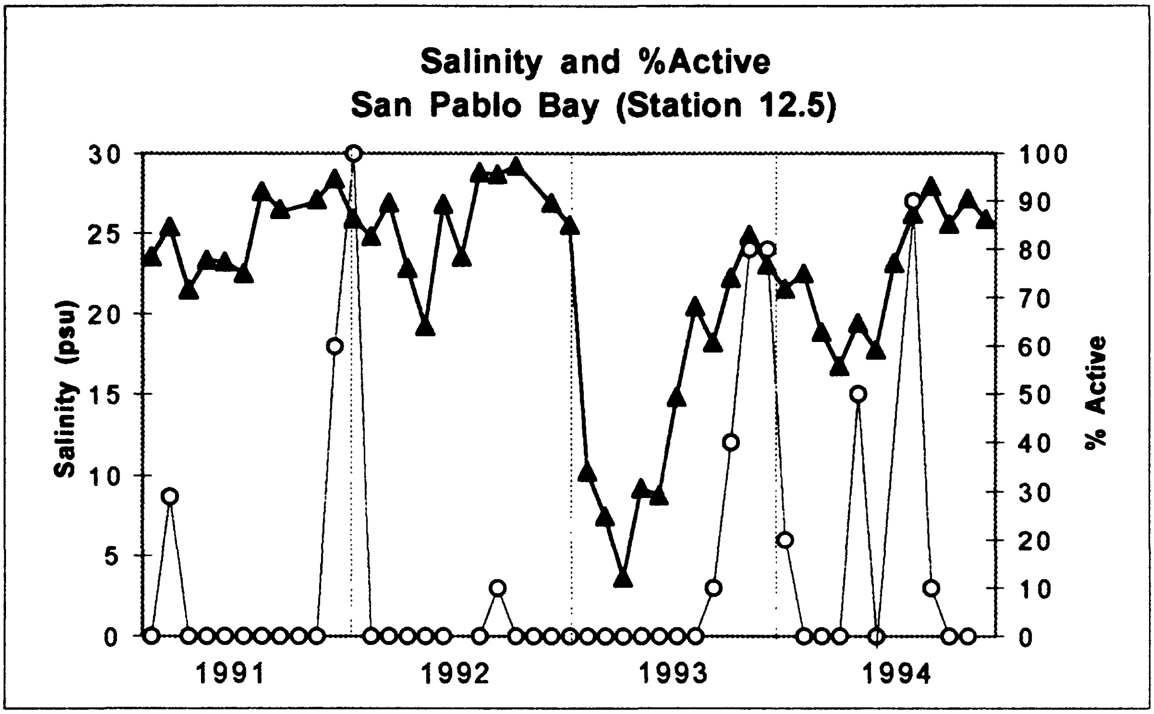

Figure 21a. Salinity (▲) and % of animals in active reproductive stage (°) at station 12.5.

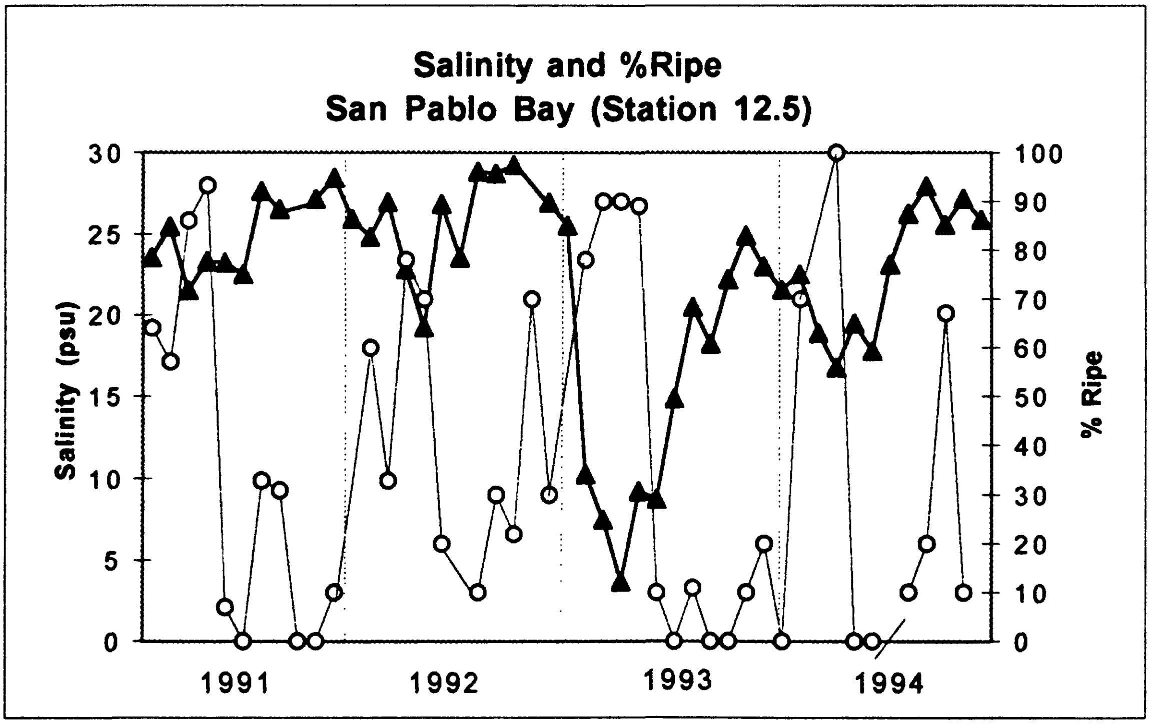

Figure 21b. Salinity (▲) and % of animals in ripe reproductive stage (°) at station 12.5.

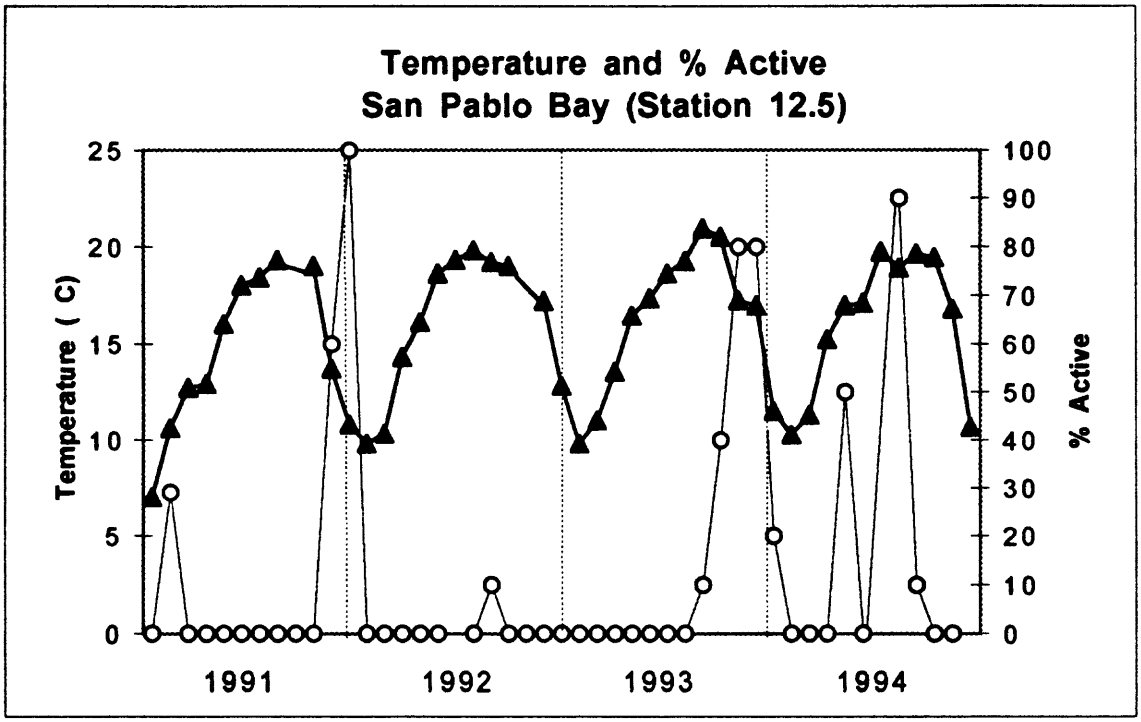

Figure 22a. Temperature (▲) and % of animals in active reproductive stage (○) at station 12.5.

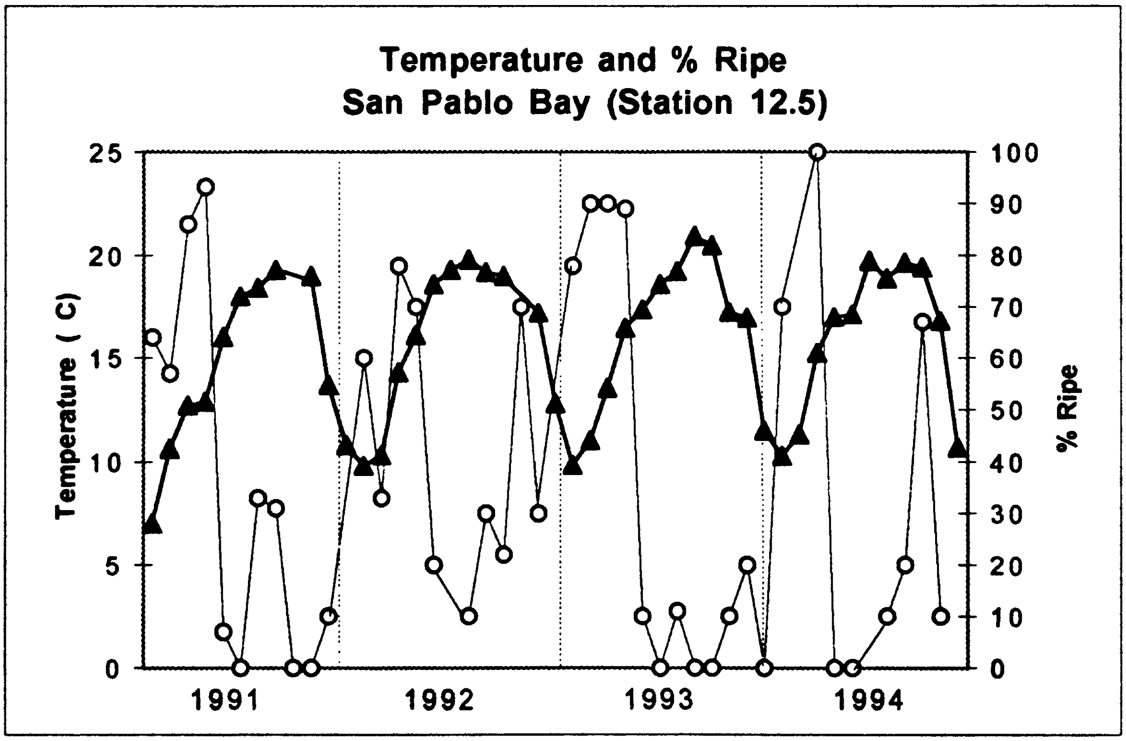

Figure 22b. Temperature (▲) and % of animals in ripe reproductive stage (○) at station 12.5.

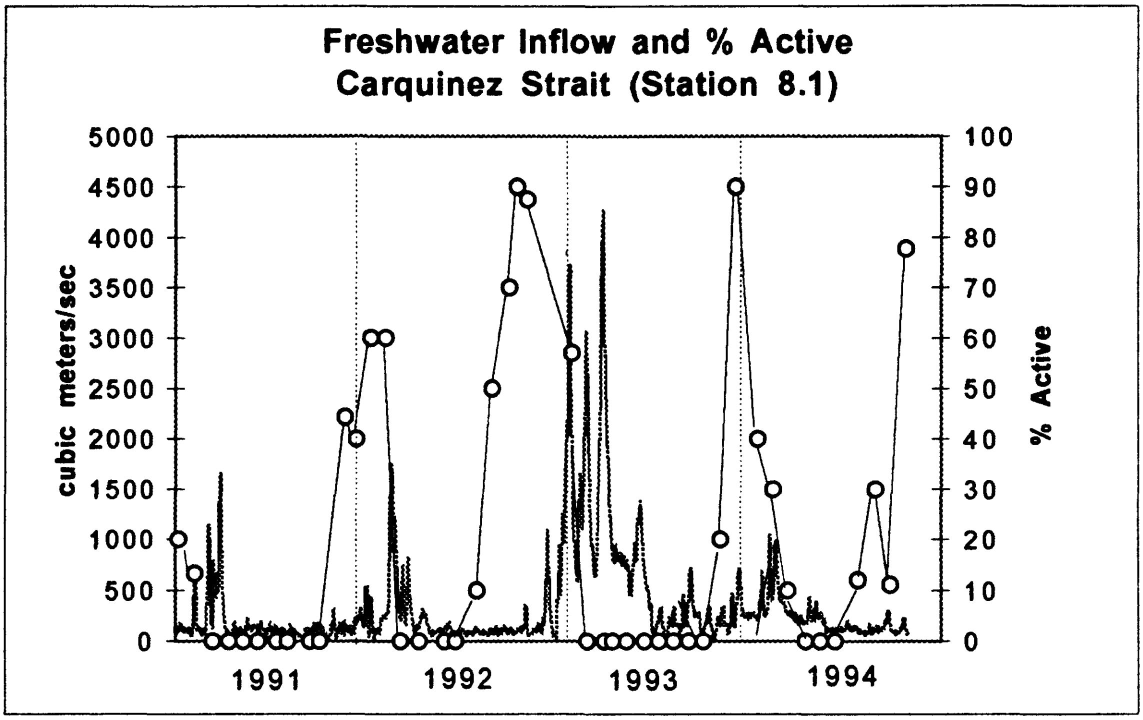

Figure 23a. Freshwater inflow and % of animals in active reproductive stage (°) at station 8.1.

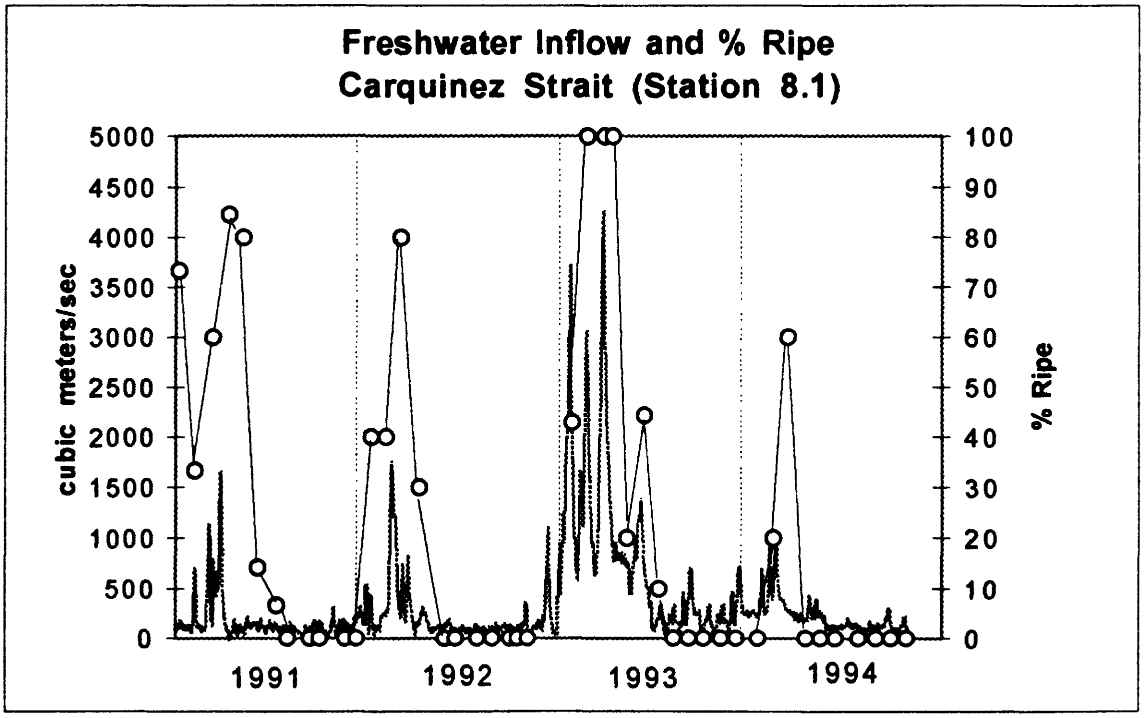

Figure 23b. Freshwater inflow and % of animals in ripe reproductive stage (°) at station 8.1.

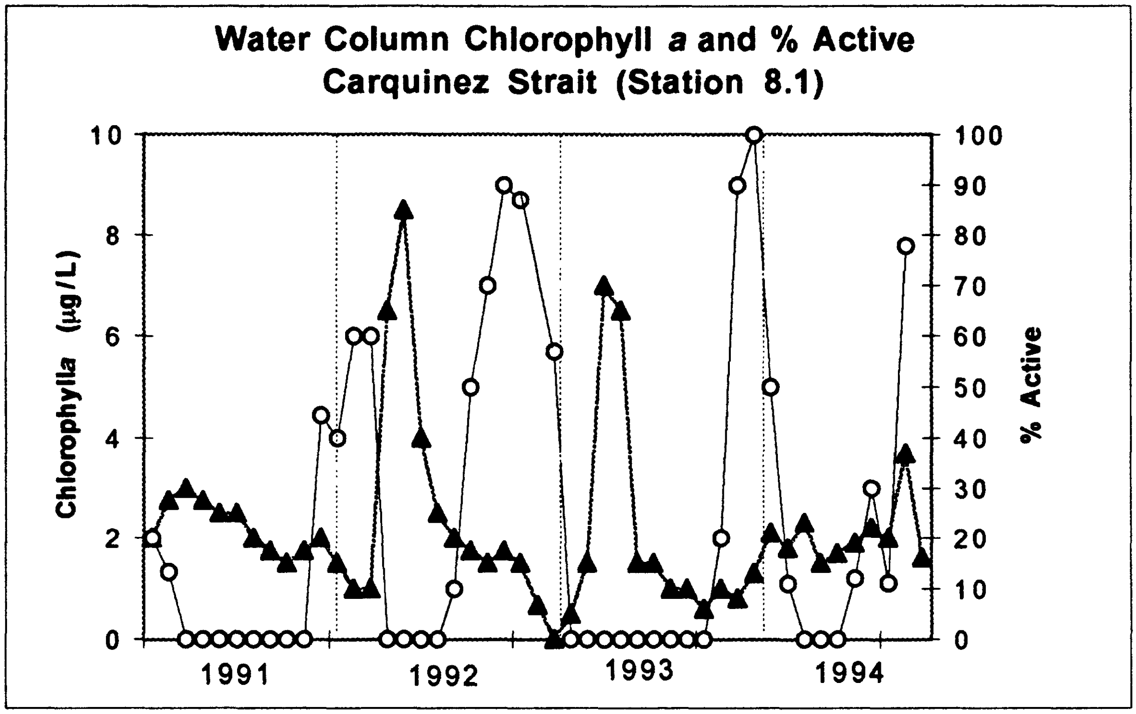

Figure 24a Water column chlorophyll *a* (▲) and % of animals in active reproductive stage (°) at station 8.1.

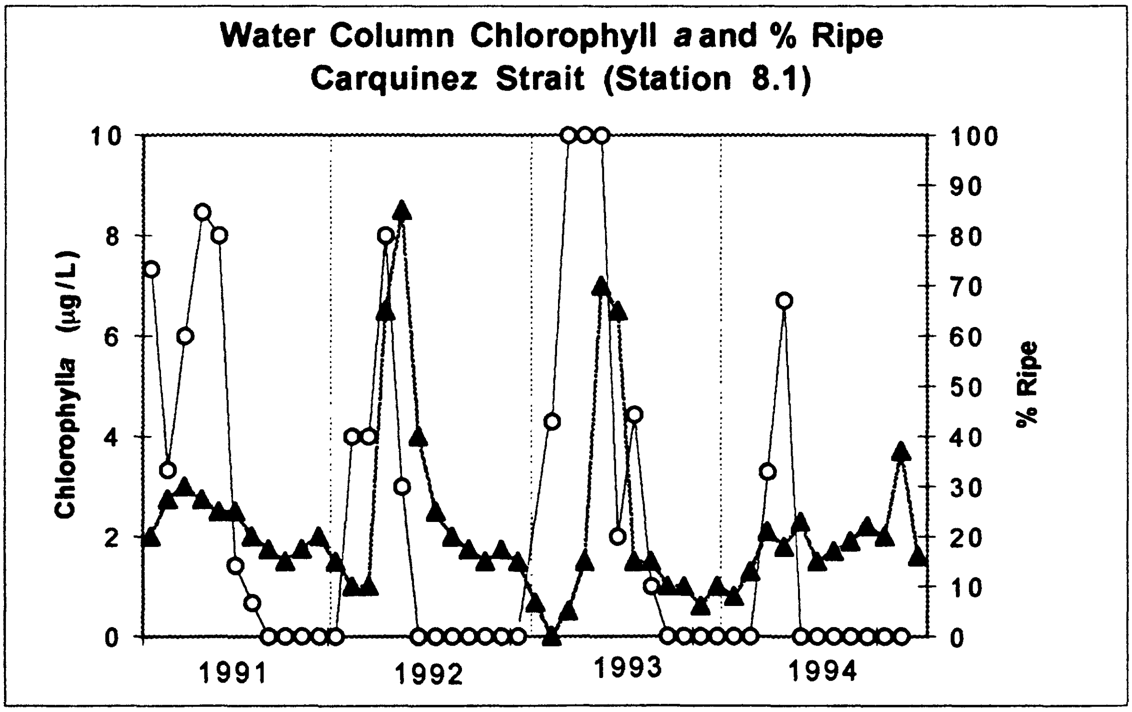

Figure 24b. Water column chlorophyll *a* (▲) and % of animals in ripe reproductive stage (°) at station 8.1.

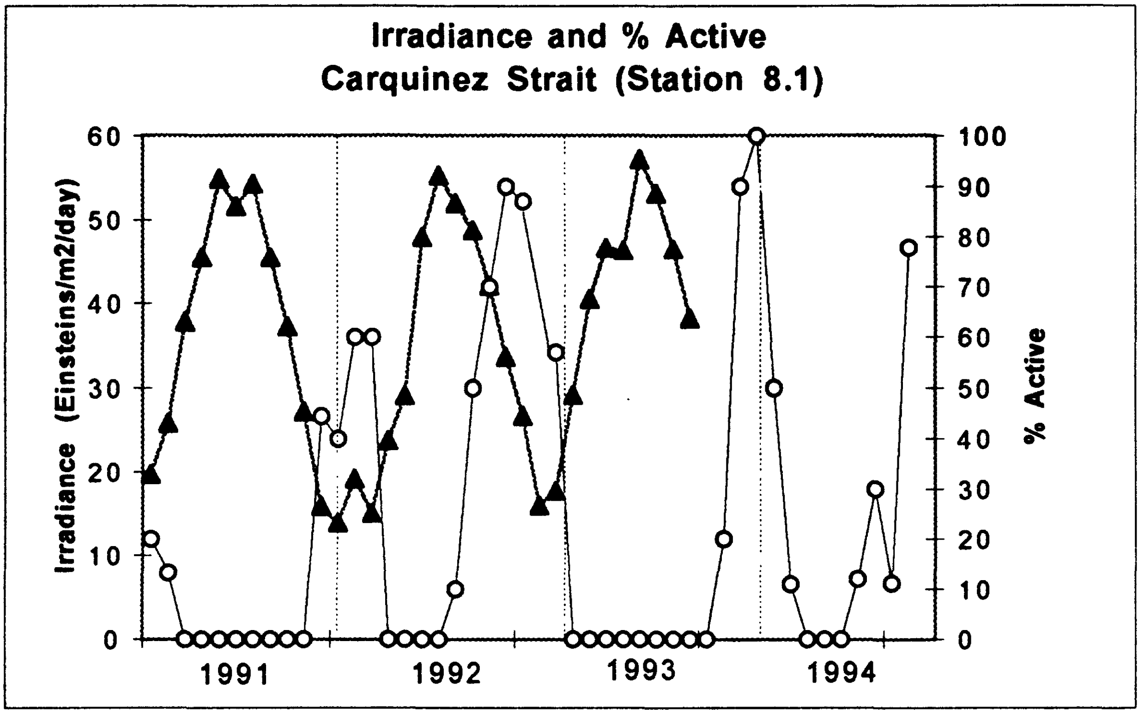

Figure 25a. Irradiance (▲) and % of animals in active reproductive stage (○) at station 8.1.

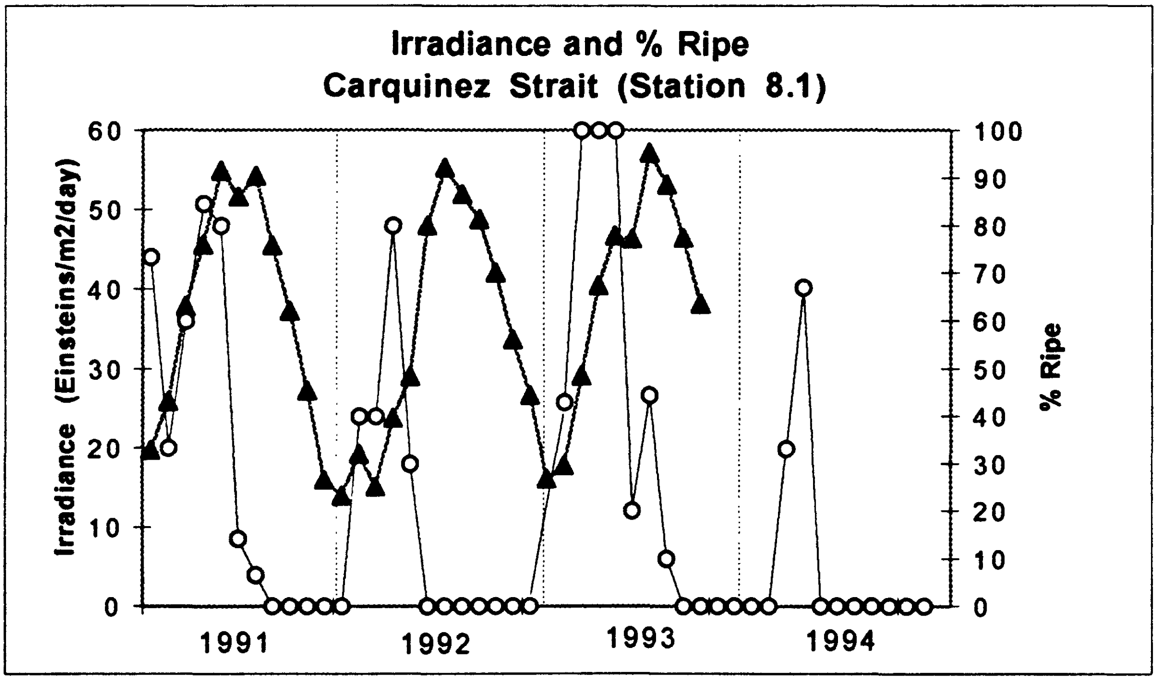

Figure 25b. Irradiance (▲) and % of animals in ripe reproductive stage (○) at station 8.1.

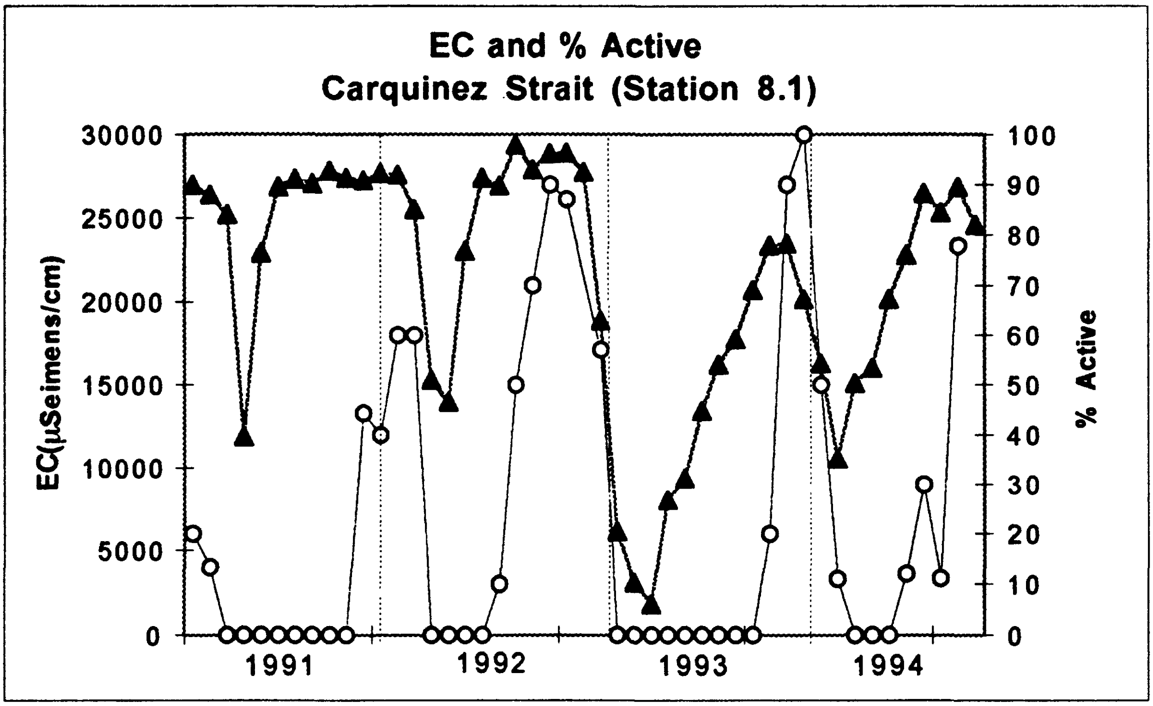

Figure 26a. EC (▲) and % of animals in active reproductive stage (°) at station 8.1.

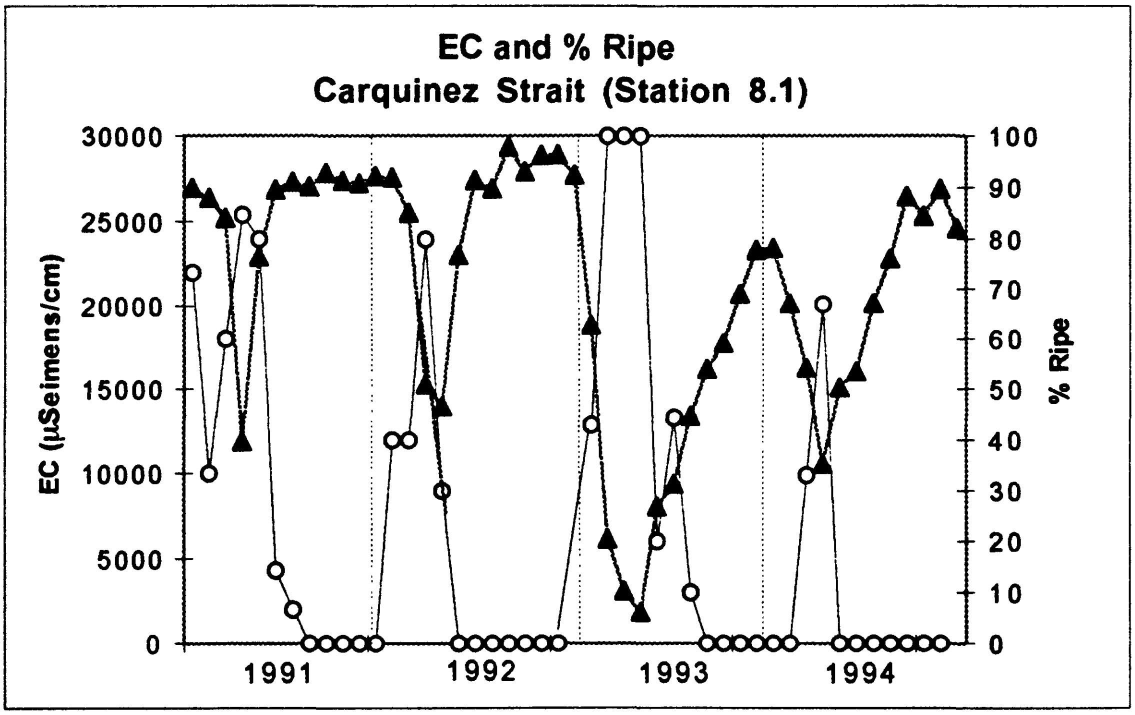

Figure 26b. EC (▲) and % of animals in ripe reproductive stage (°) at station 8.1.

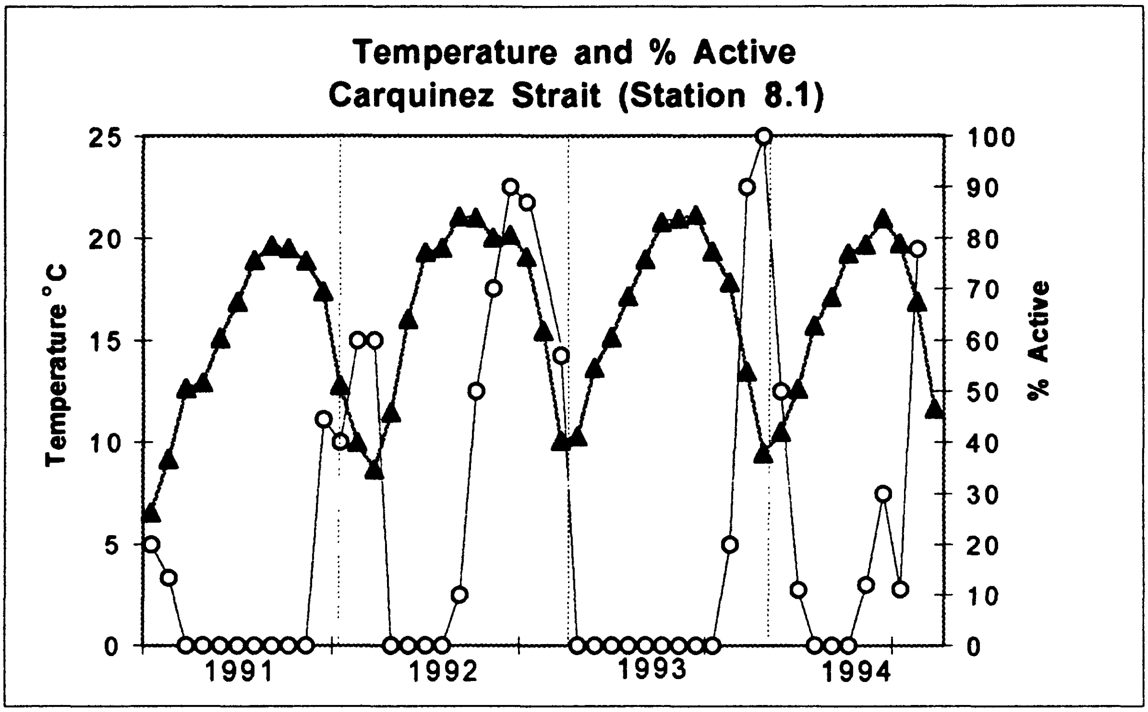

Figure 27a. Temperature (▲) and % of animals in active reproductive stage (°) at station 8.1.

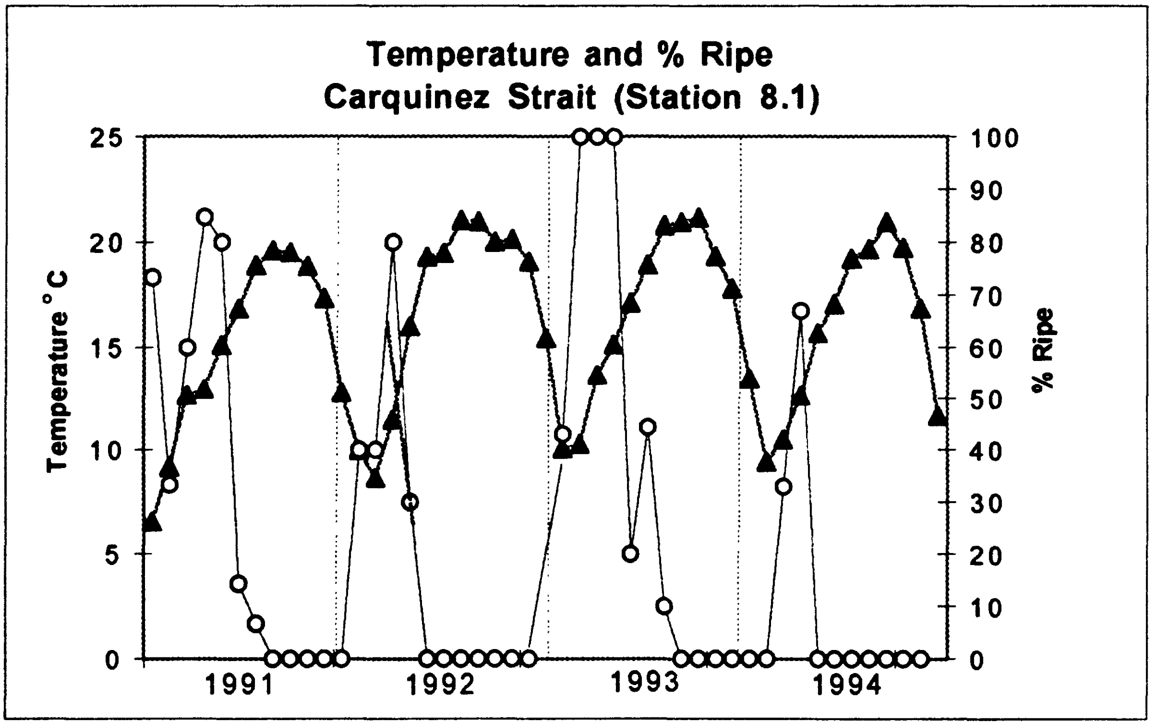

Figure 27b. Temperature (▲) and % of animals in ripe reproductive stage (°) at station 8.1.

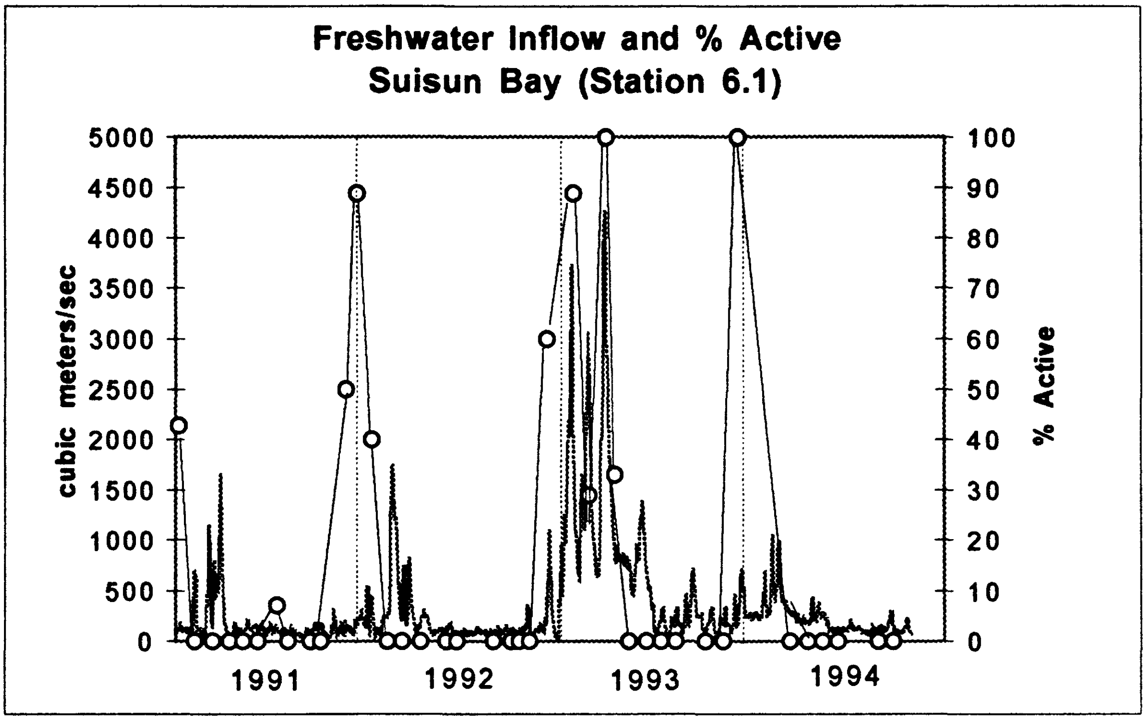

Figure 28a. Freshwater inflow and % of animals in active reproductive stage (°) at station 6.1.

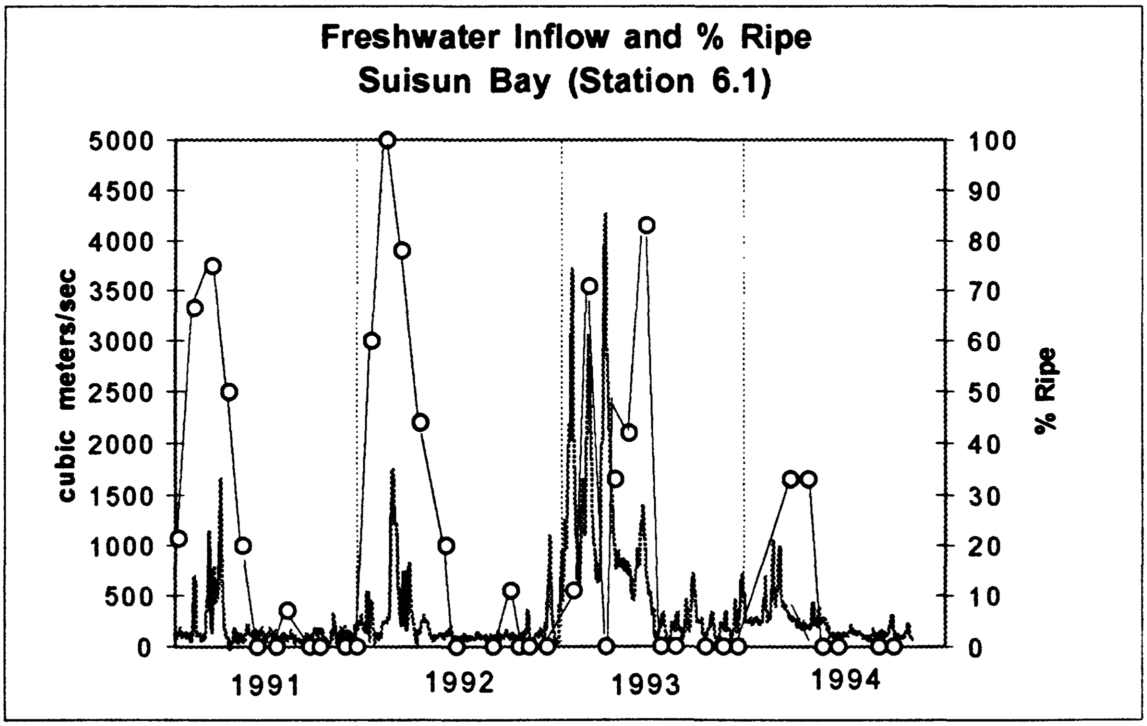

Figure 28b. Freshwater inflow and % of animals in ripe reproductive stage (°) at station 6.1.

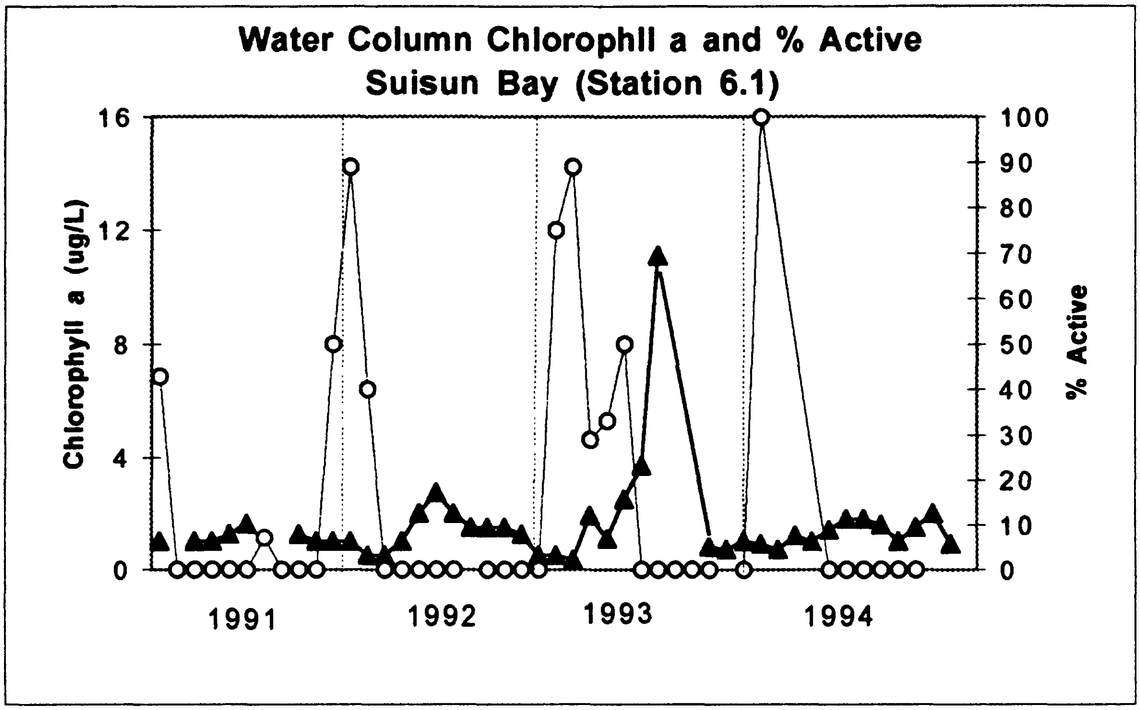

Figure 29a. Water column chlorophyll *a* (▲) and % of animals in active reproductive stage (°) at station 6.1.

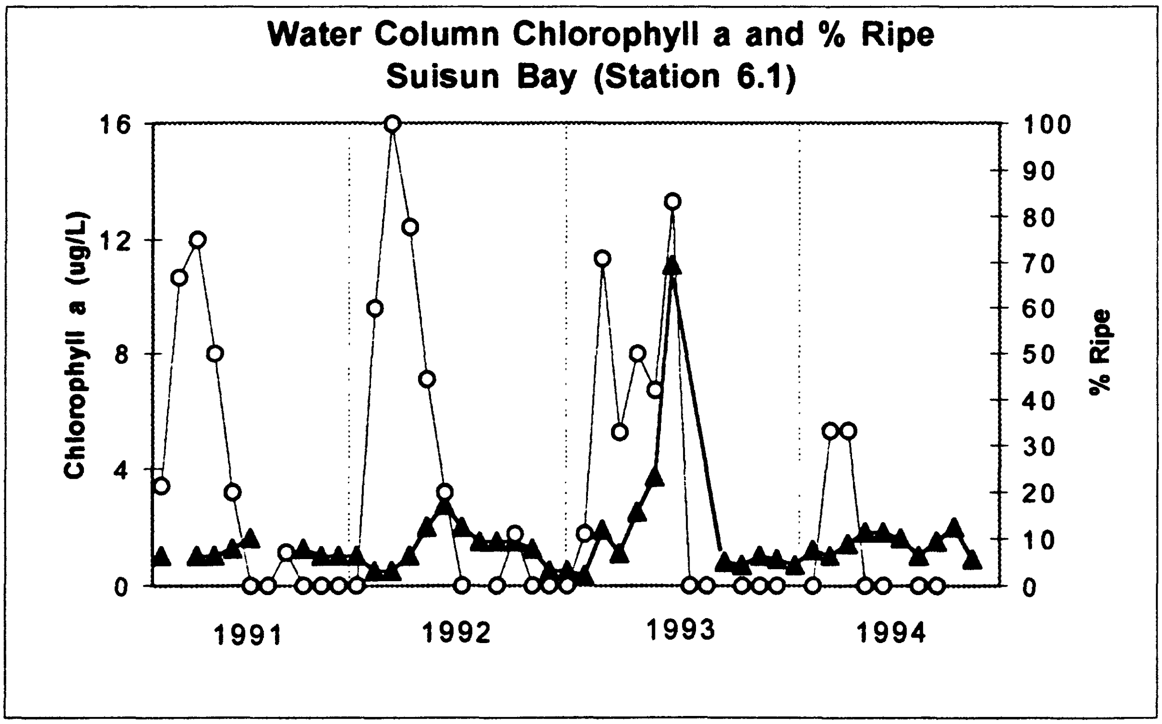

Figure 29b. Water column chlorophyll *a* (▲) and % of animals in ripe reproductive stage (°) at station 6.1.

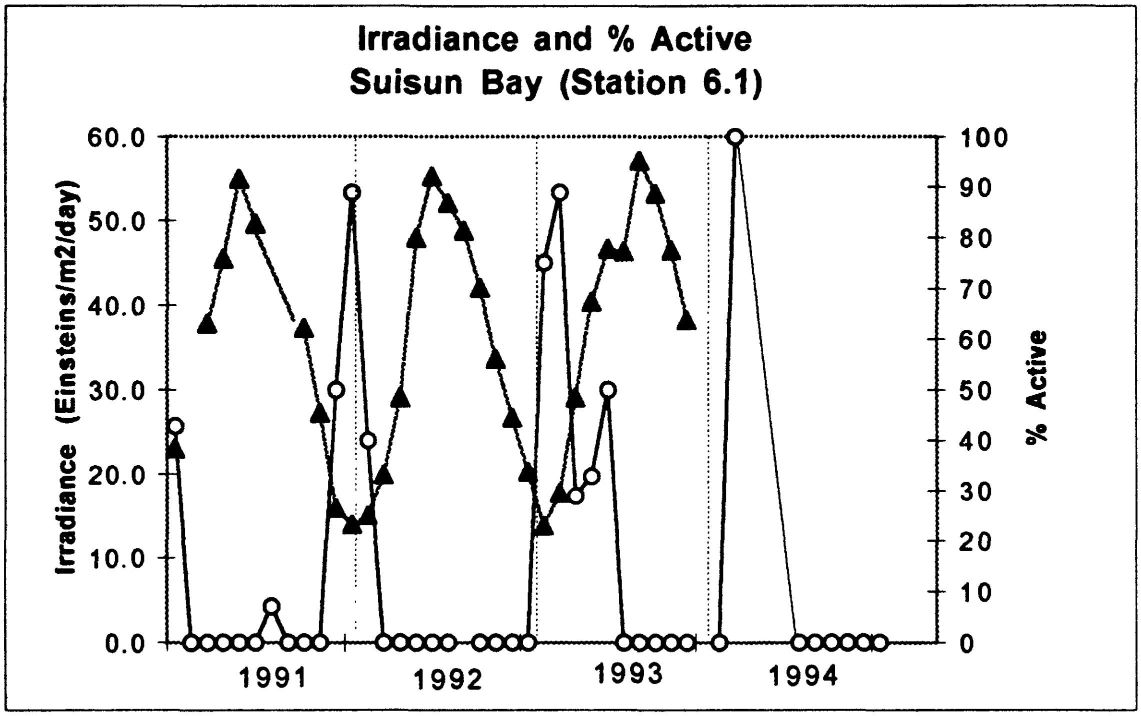

Figure 30a. Irradiance (▲) and % of animals in active reproductive stage (°) at station 6.1.

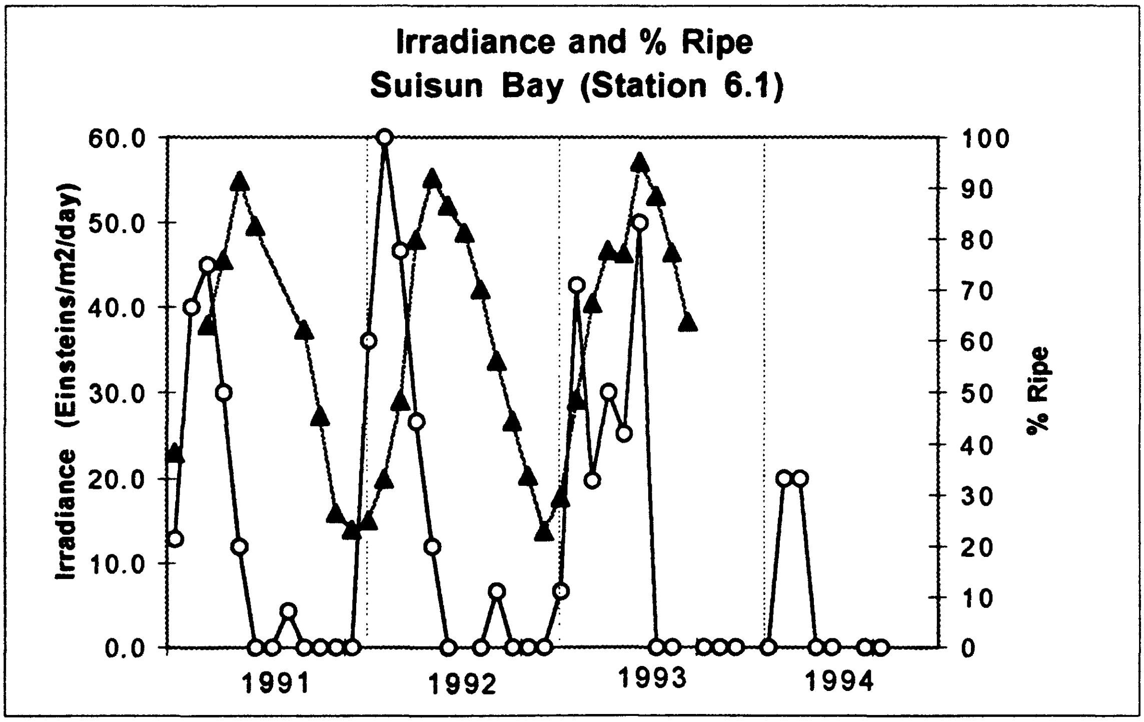

Figure 30b. Irradiance (▲) and % of animals in ripe reproductive stage (°) at station 6.1

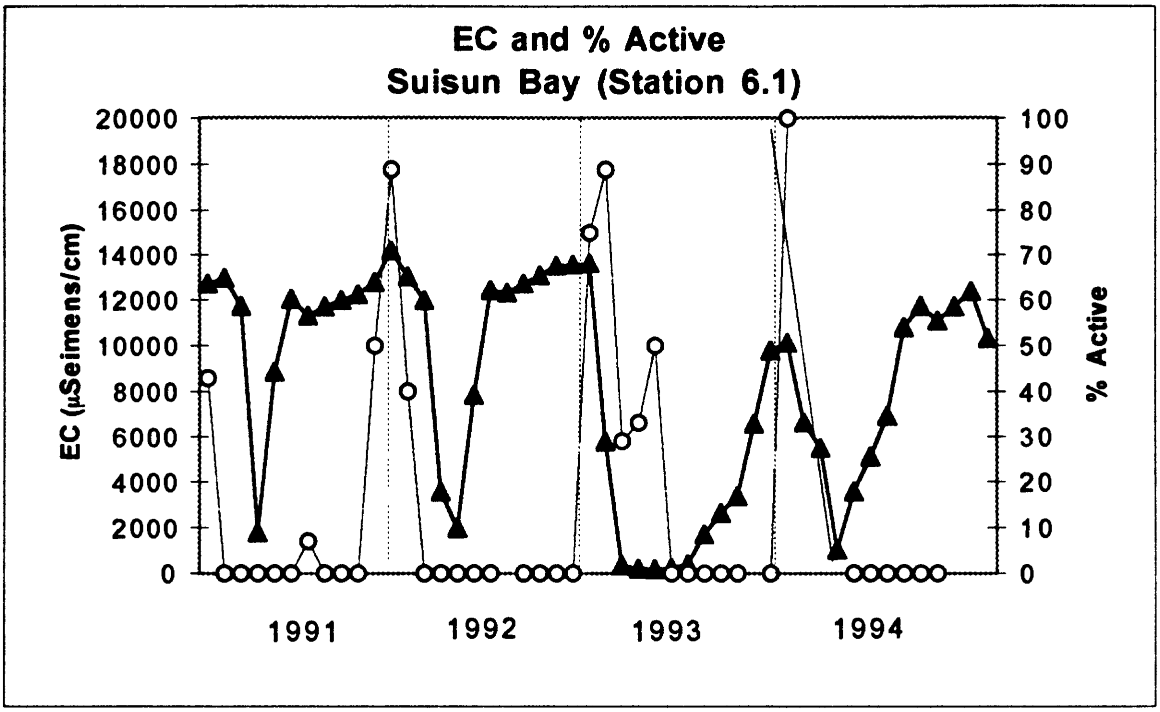

Figure 31a. EC (▲) and % of animals in active reproductive stage (○) at station 6.1.

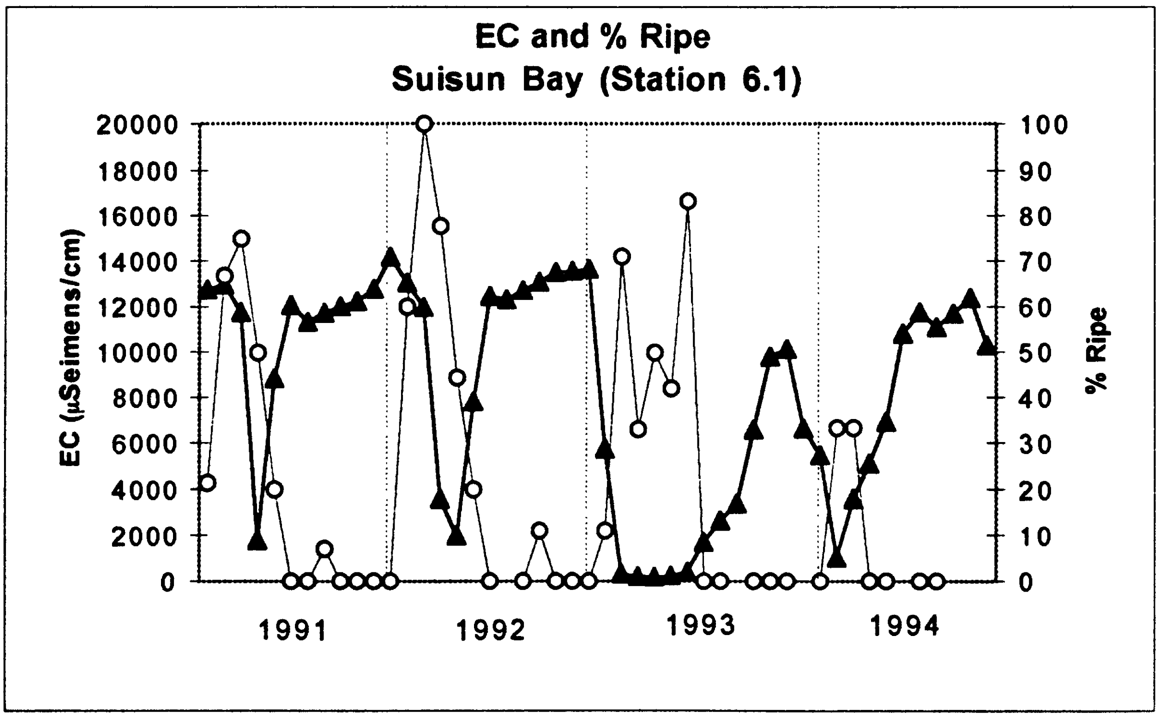

Figure 31b. EC (▲) and % of animals in ripe reproductive stage (○) at station 6.1.

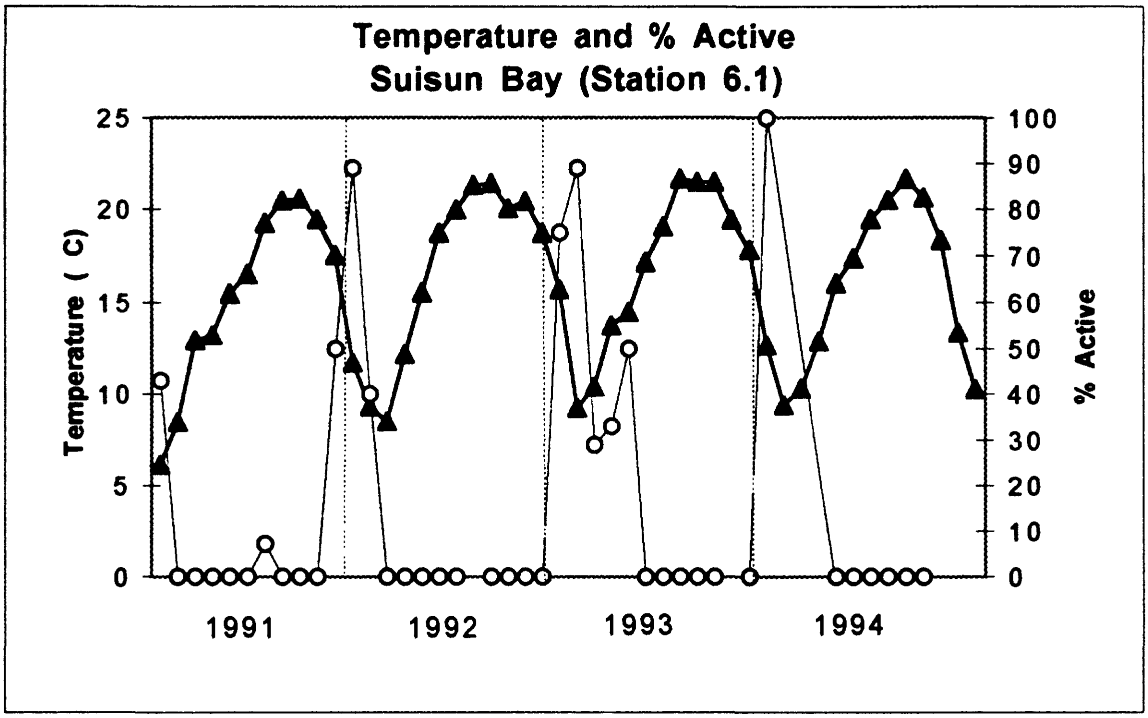

Figure 32a. Temperature (▲) and % of animals in active reproductive stage (°) at station 6.1.

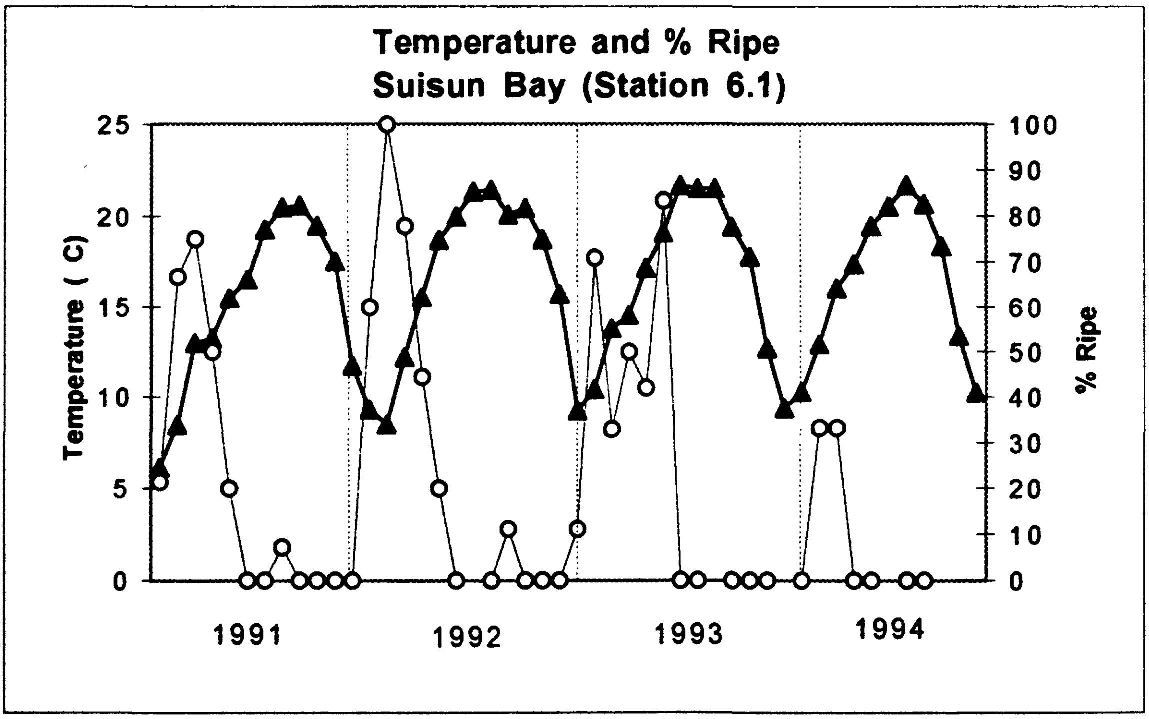

Figure 32b. Temperature (▲) and % of animals in ripe reproductive stage (°) at station 6.1.

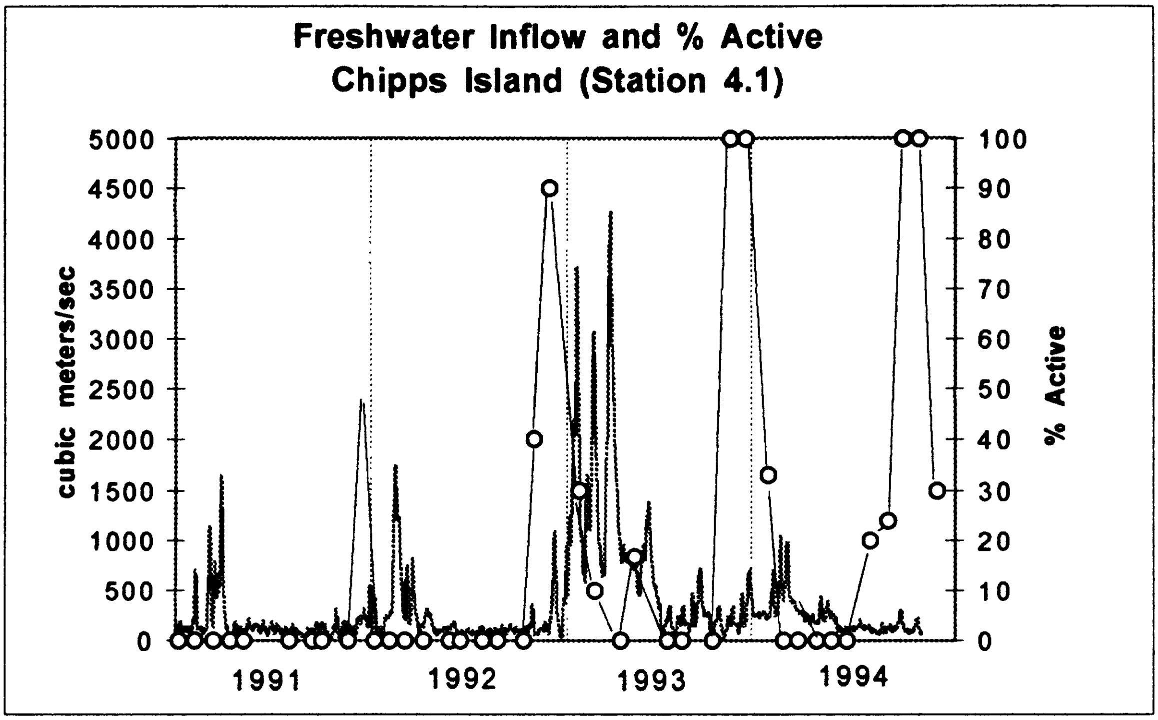

Figure 33a. Freshwater inflow and % of animals in active reproductive stage (°) at station 4.1.

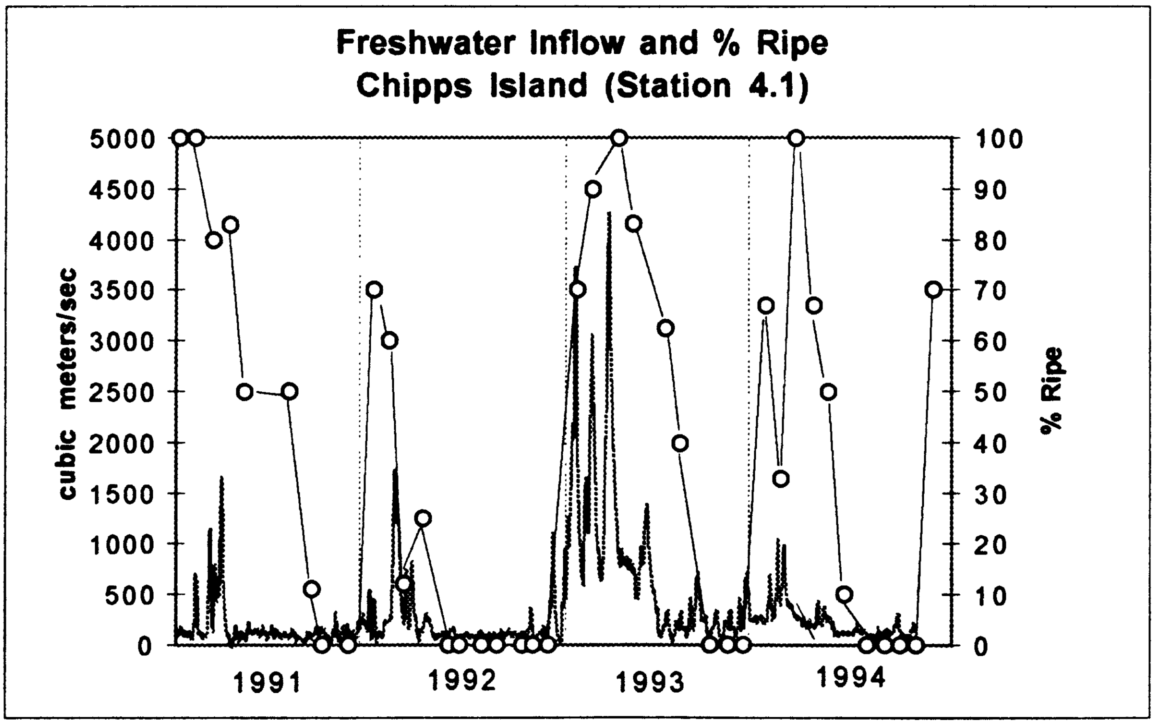

Figure 33b. Freshwater inflow and % of animals in ripe reproductive stage (°) at station 4.1.

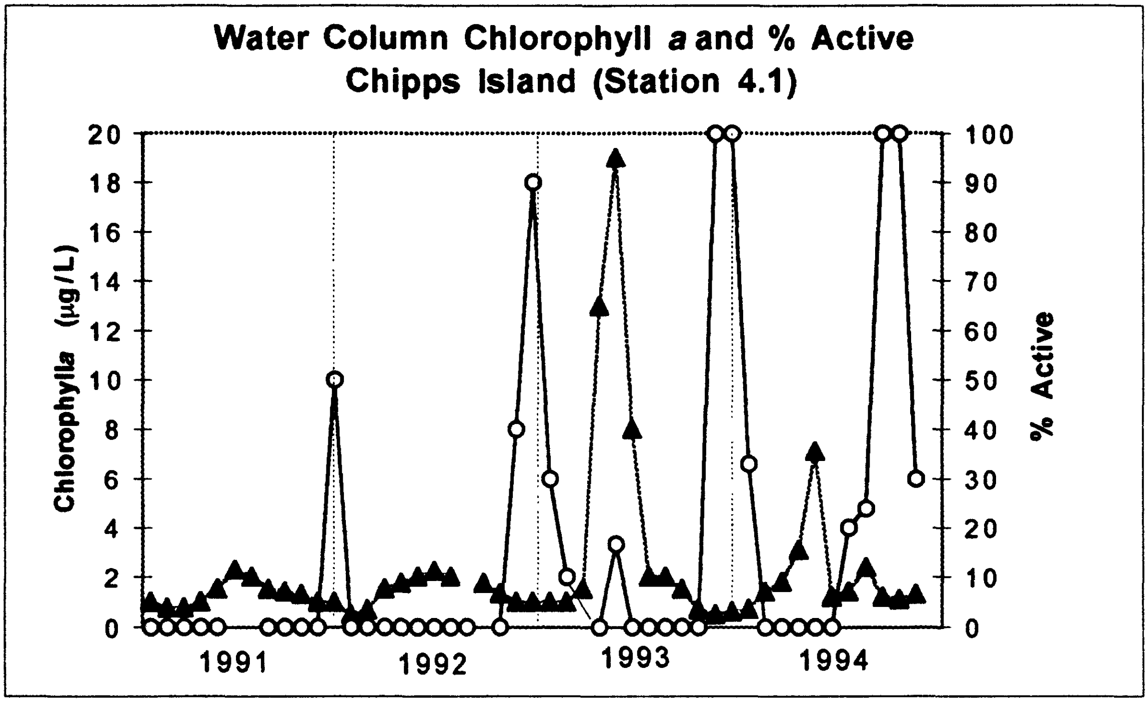

Figure 34a. Water column chlorophyll *a* (▲) and % of animals in active reproductive stage (○) at station 4.1.

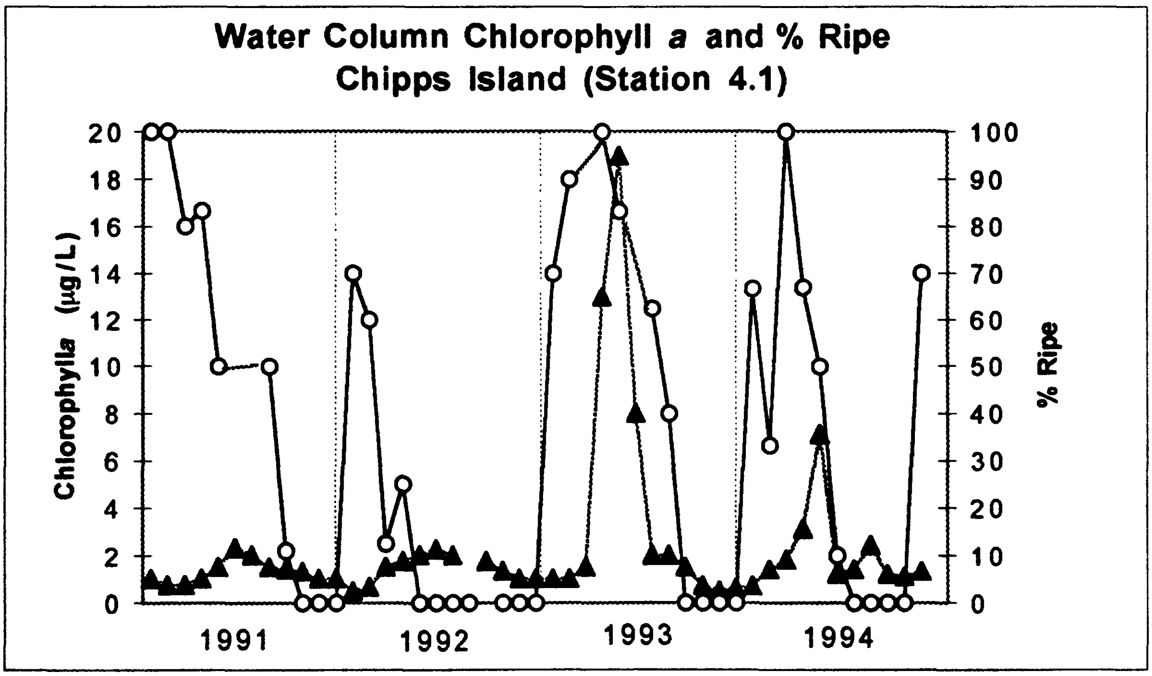

Figure 34b. Water column chlorophyll *a* (▲) and % of animals in ripe reproductive stage (○) at station 4.1.

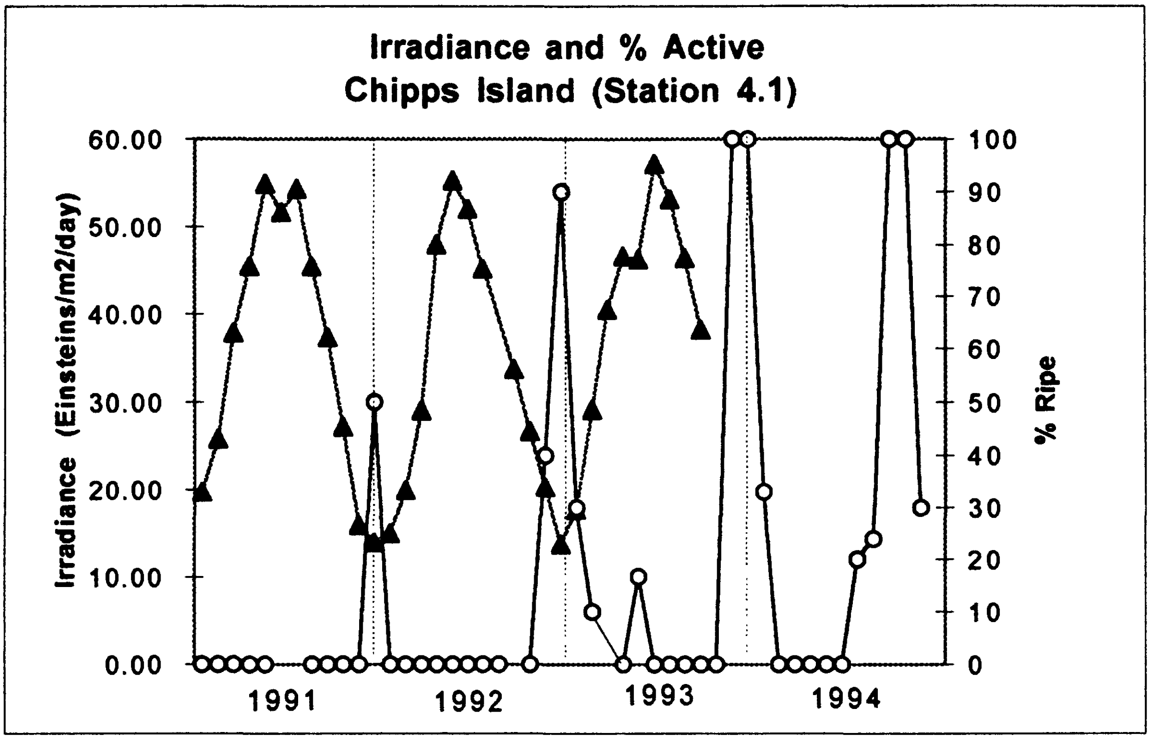

Figure 35a. Irradiance (▲) and % of animals in active reproductive stage (○) at station 4.1.

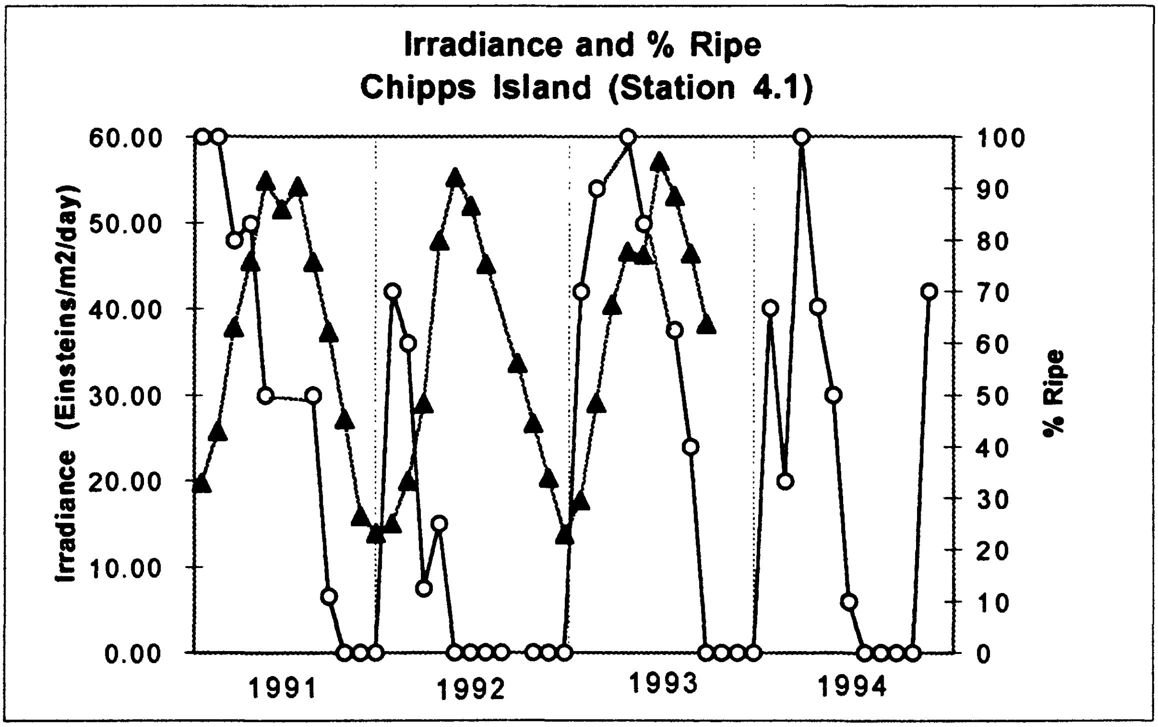

Figure 35b. Irradiance (▲) and % of animals in ripe reproductive stage (○) at station 4.1.

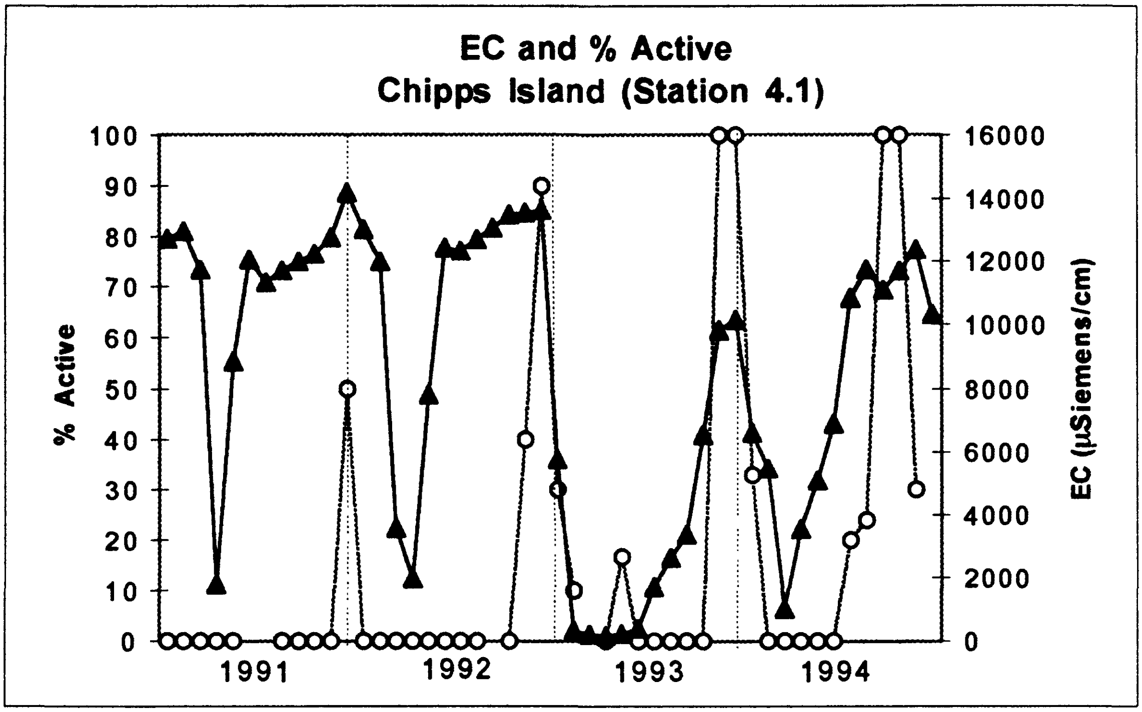

Figure 36a. EC (▲) and % of animals in active reproductive stage (○) at station 4.1.

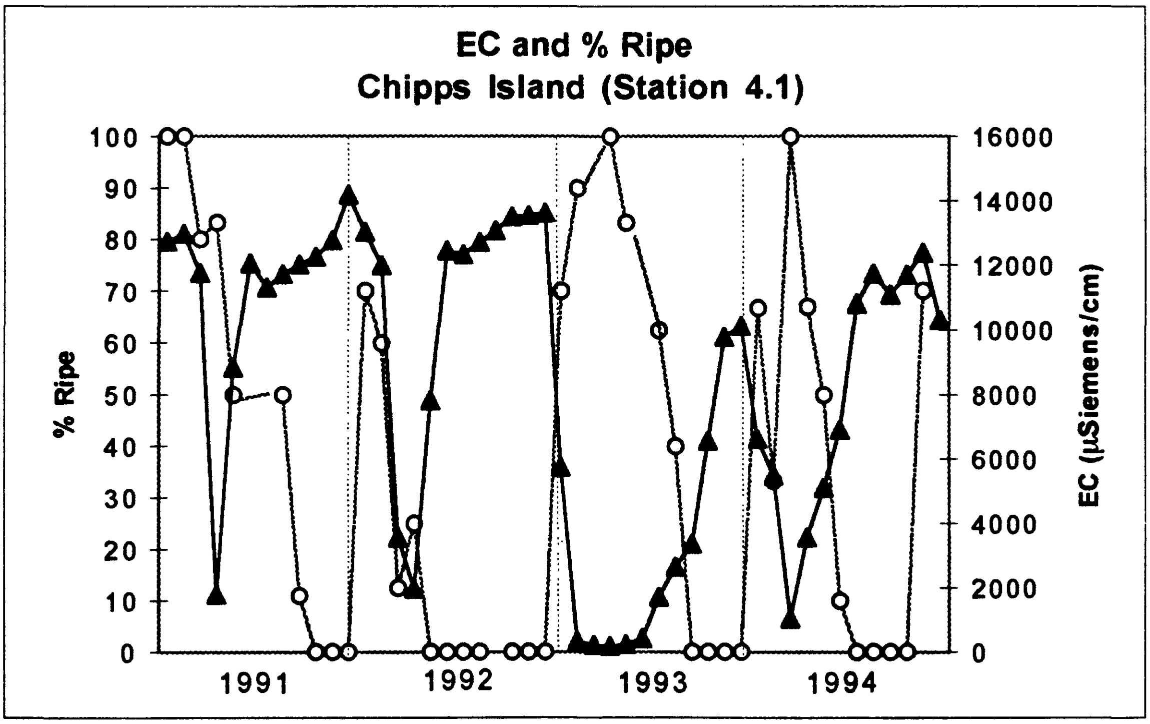

Figure 36b. EC (▲) and % of animals in ripe reproductive stage (○) at station 4.1.

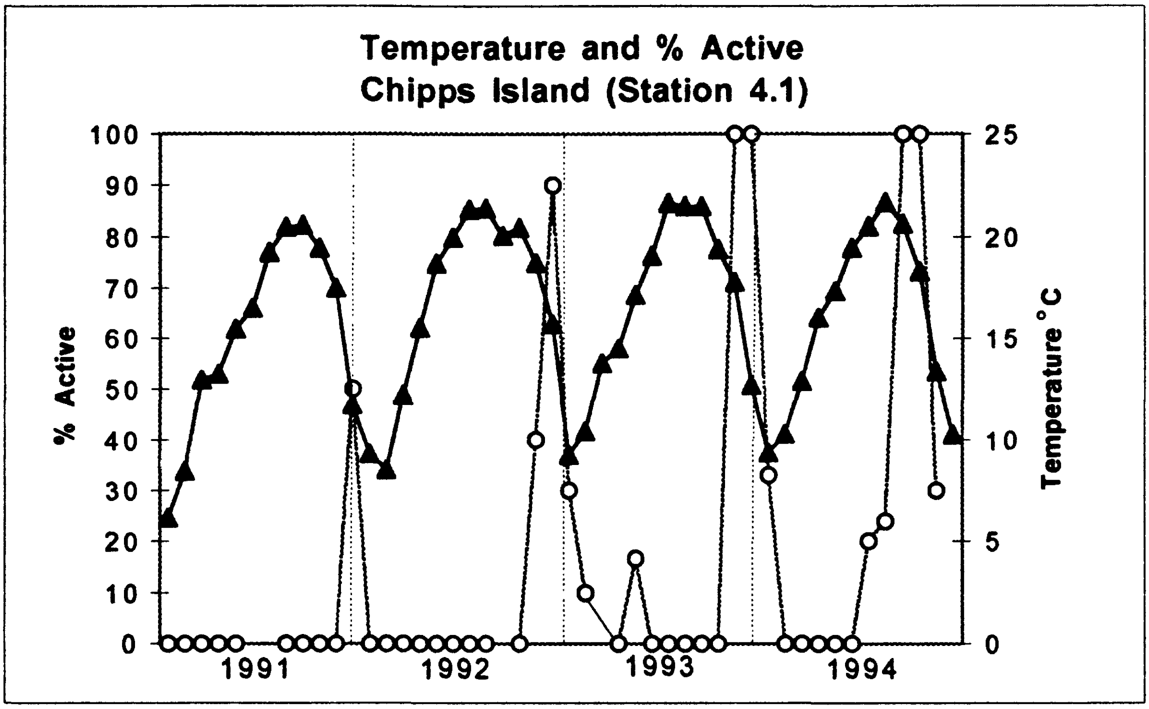

Figure 37b. Temperature (▲) and % of animals in active reproductive stage (°) at station 4.1.

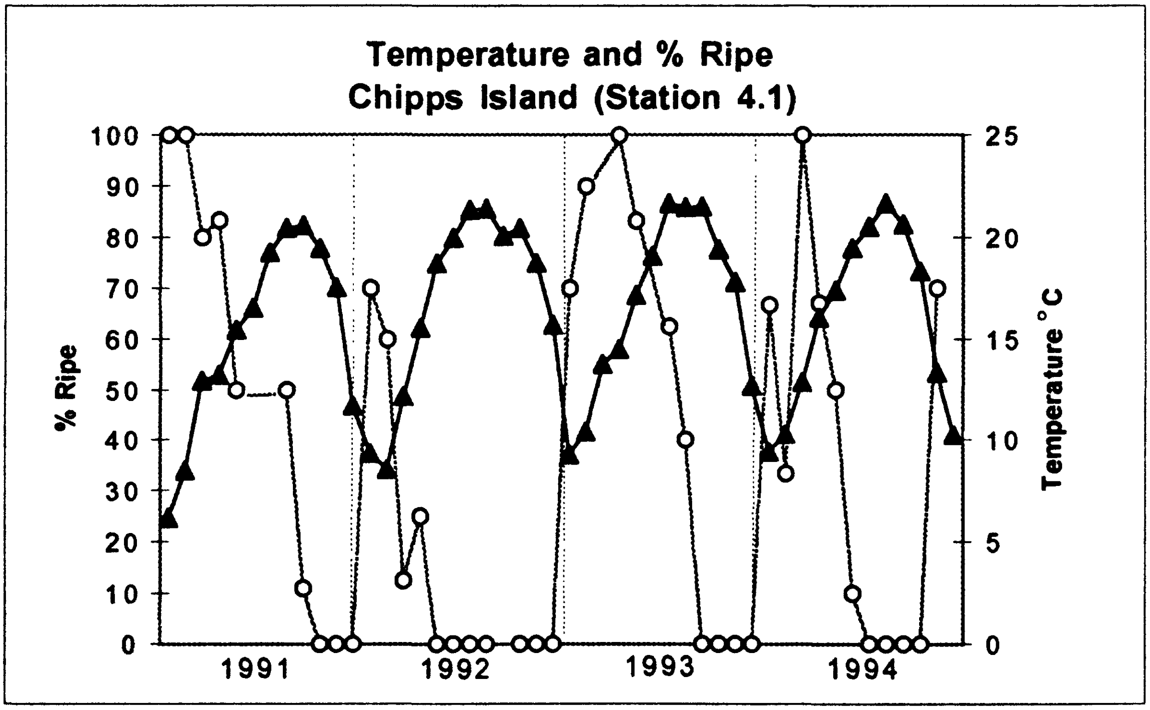

Figure 37b. Temperature (▲) and % of animals in ripe reproductive stage (°) at station 4.1.

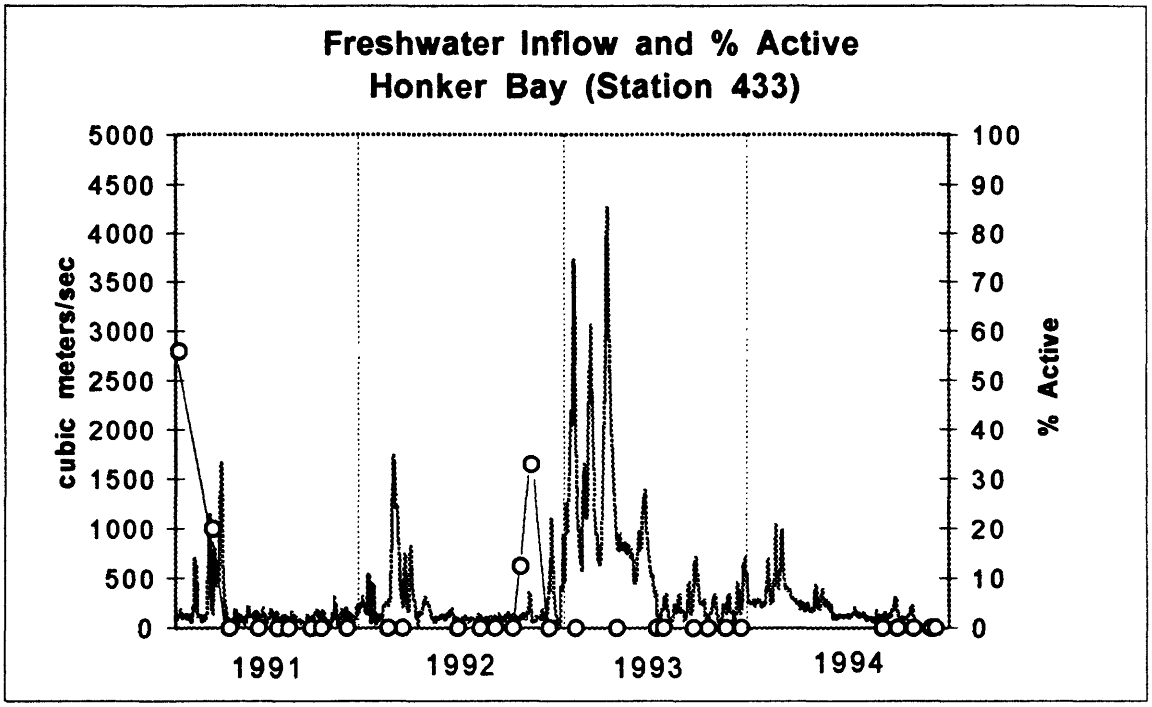

Figure38a. Freshwater inflow and % of animals in active reproductive stage (°) at station 433.

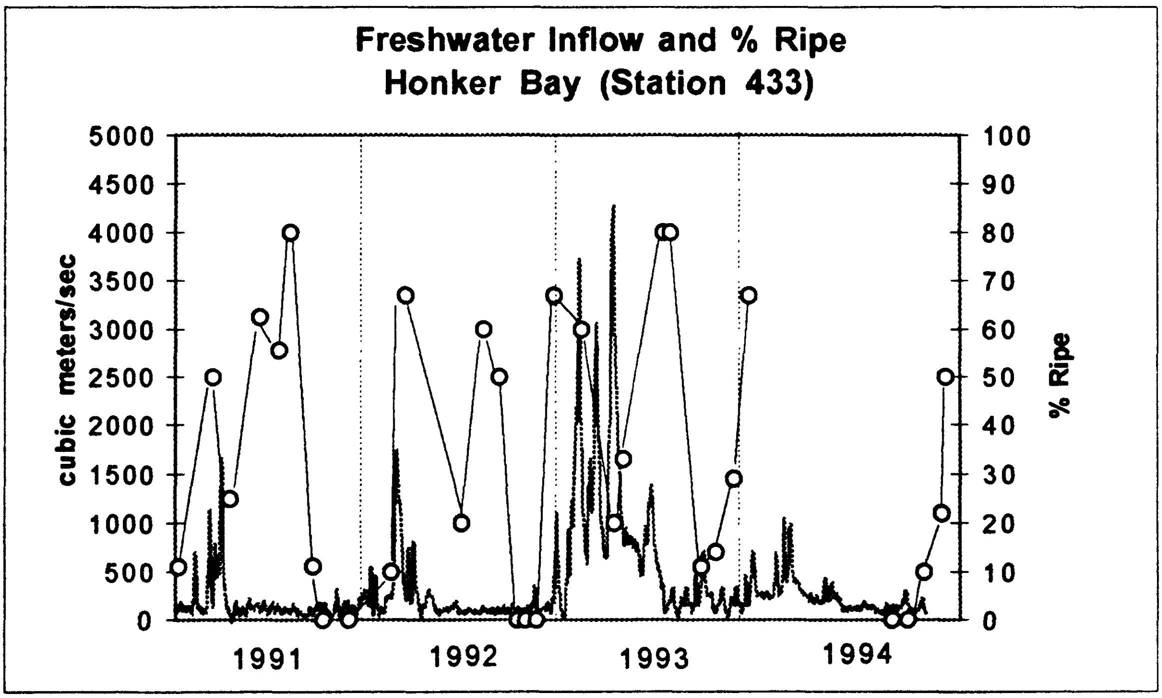

Figure 38b. Freshwater inflow and % of animals in ripe reproductive stage (°) at station 433.

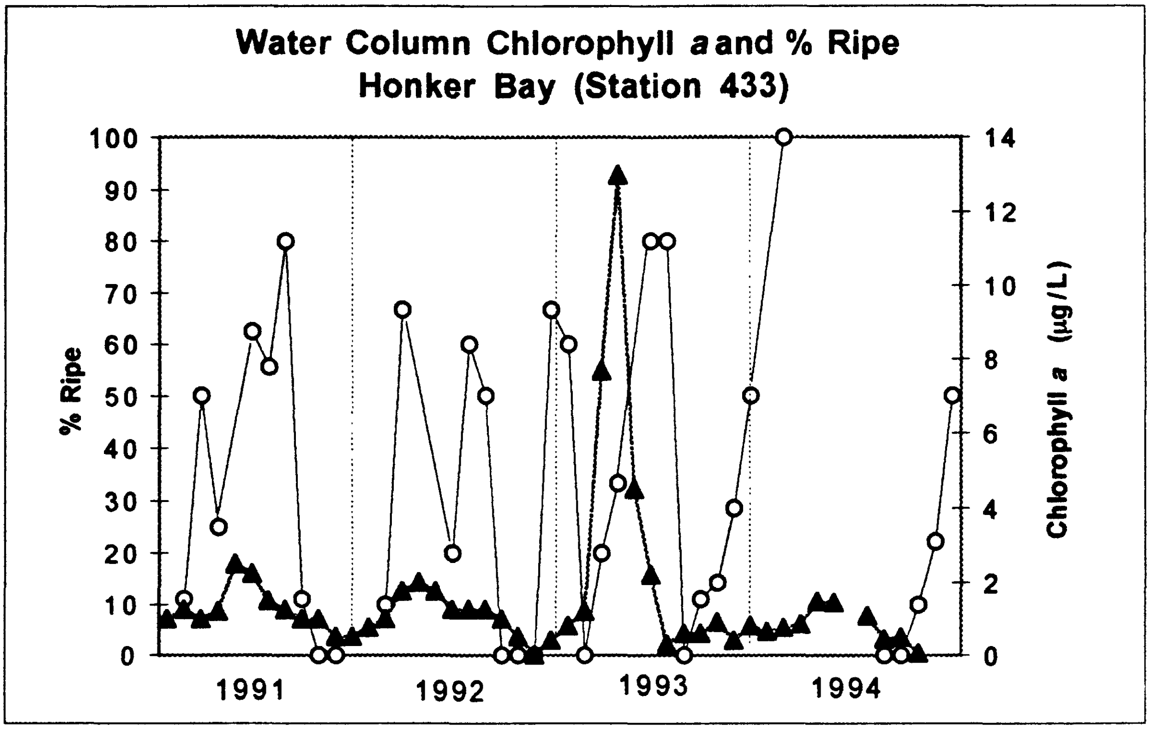

Figure 39. Water column chlorophyll *a* (▲) and % of animals in ripe reproductive stage (○) at station 433.

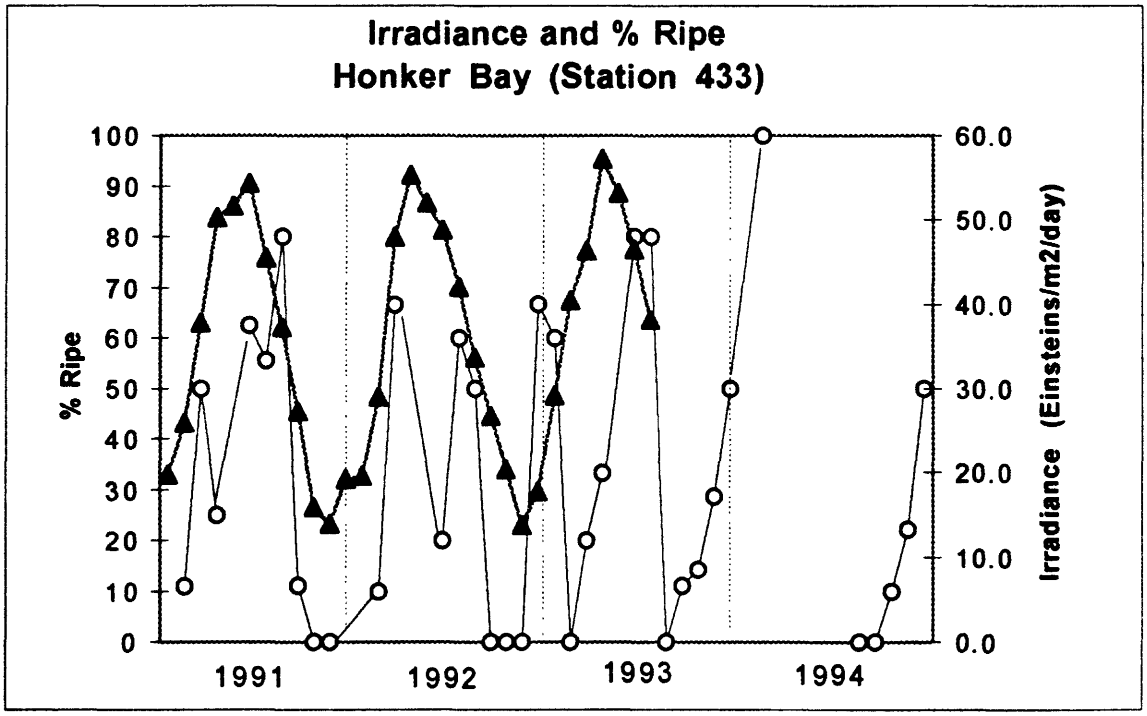

Figure 40. Irradiance (▲) and % of animals in ripe reproductive stage (○) at station 433.

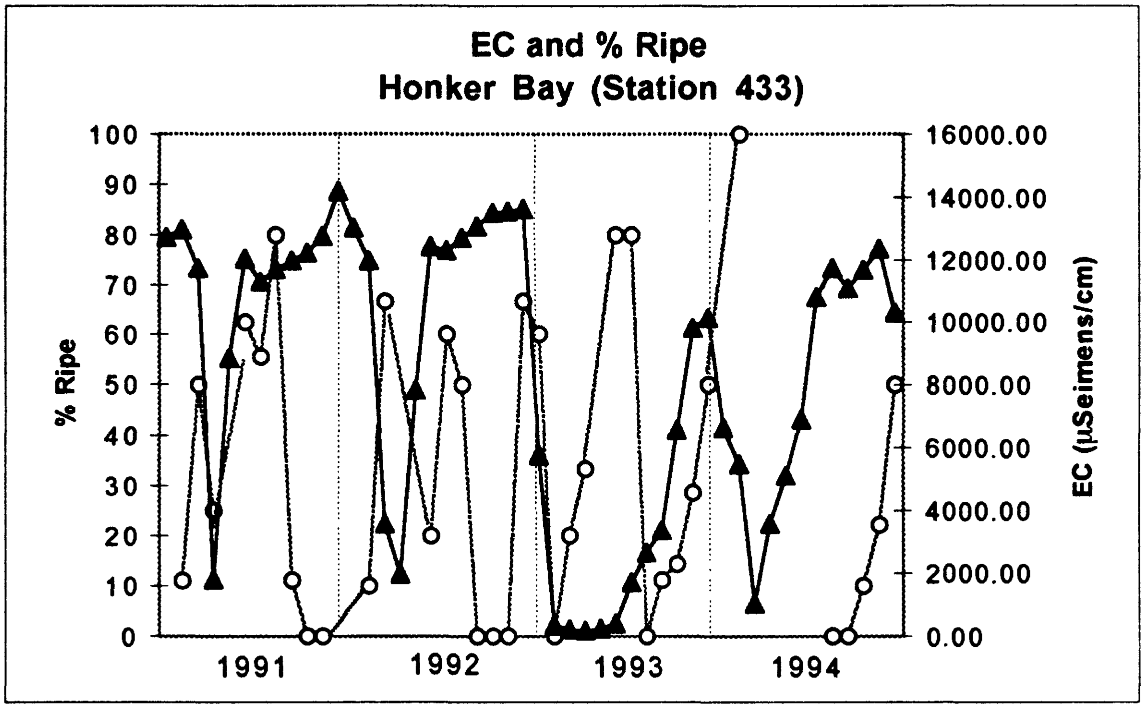

Figure 41. EC (▲) and % of animals in ripe reproductive stage (°) at station 433.

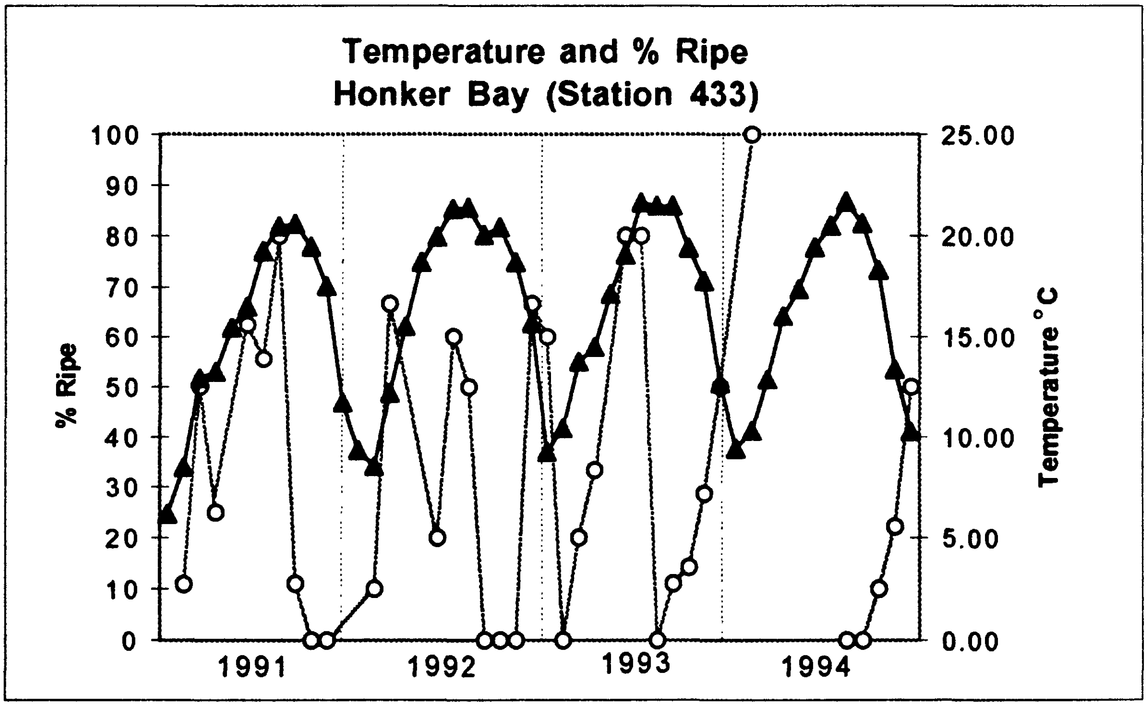

Figure 42. Temperature (▲) and % of animals in ripe reproductive stage (°) at station 433.

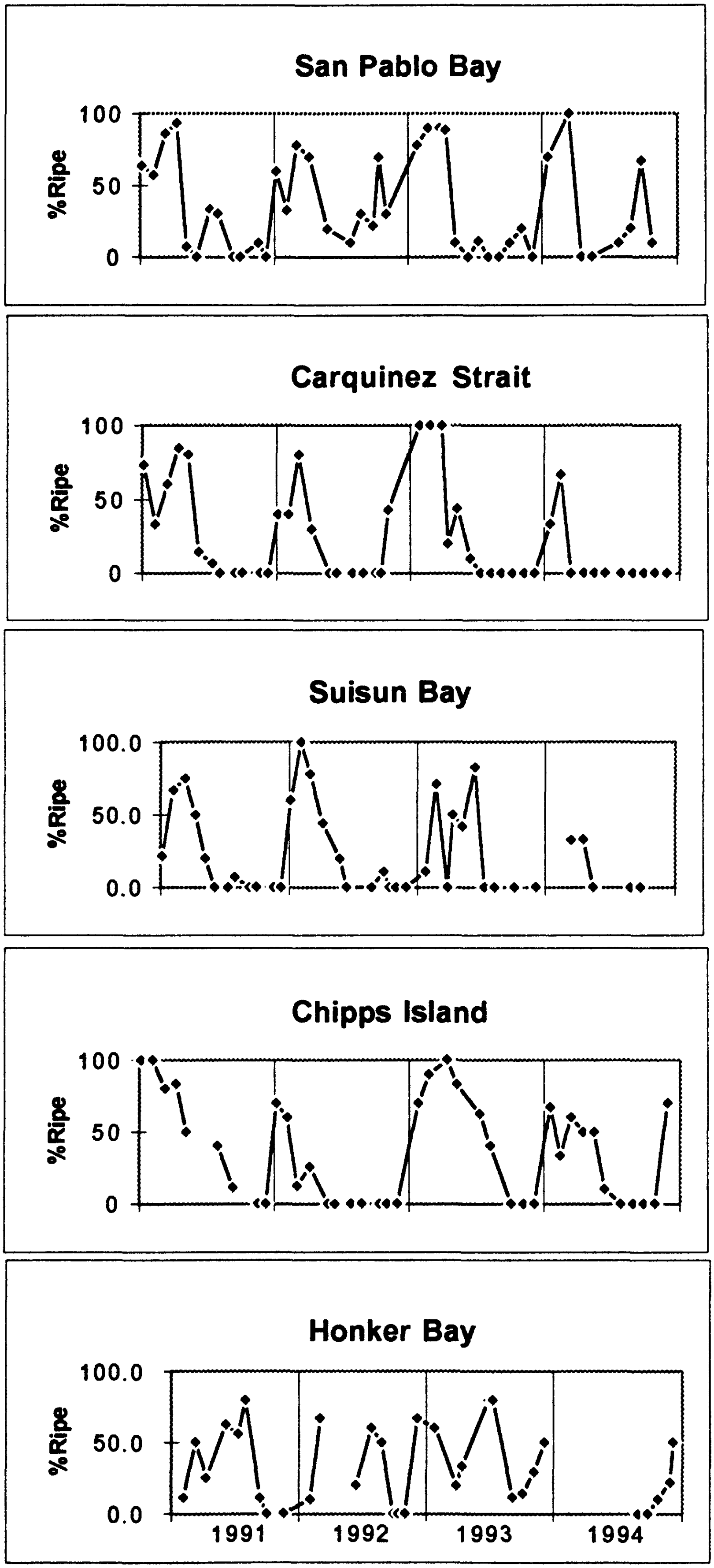

Figure 43. Percent of ripe animals at all stations.

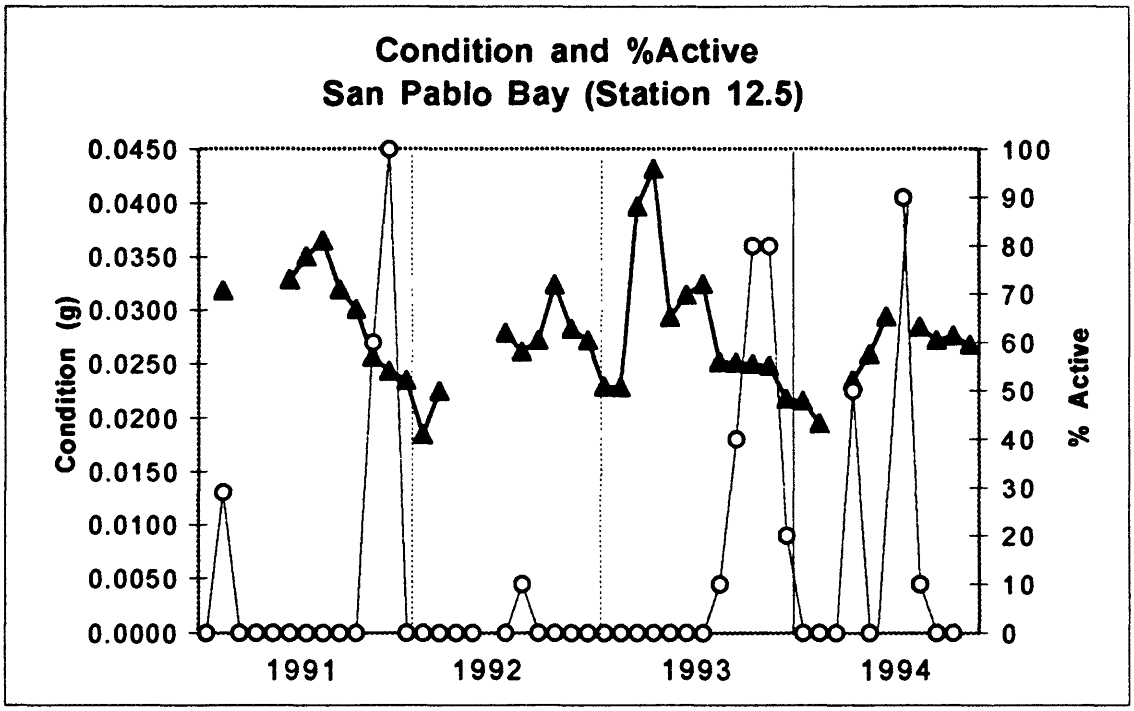

Figure 44a. Condition index for 15mm long animal (▲) and % of animals in active reproductive stage (°) at station 12.5.

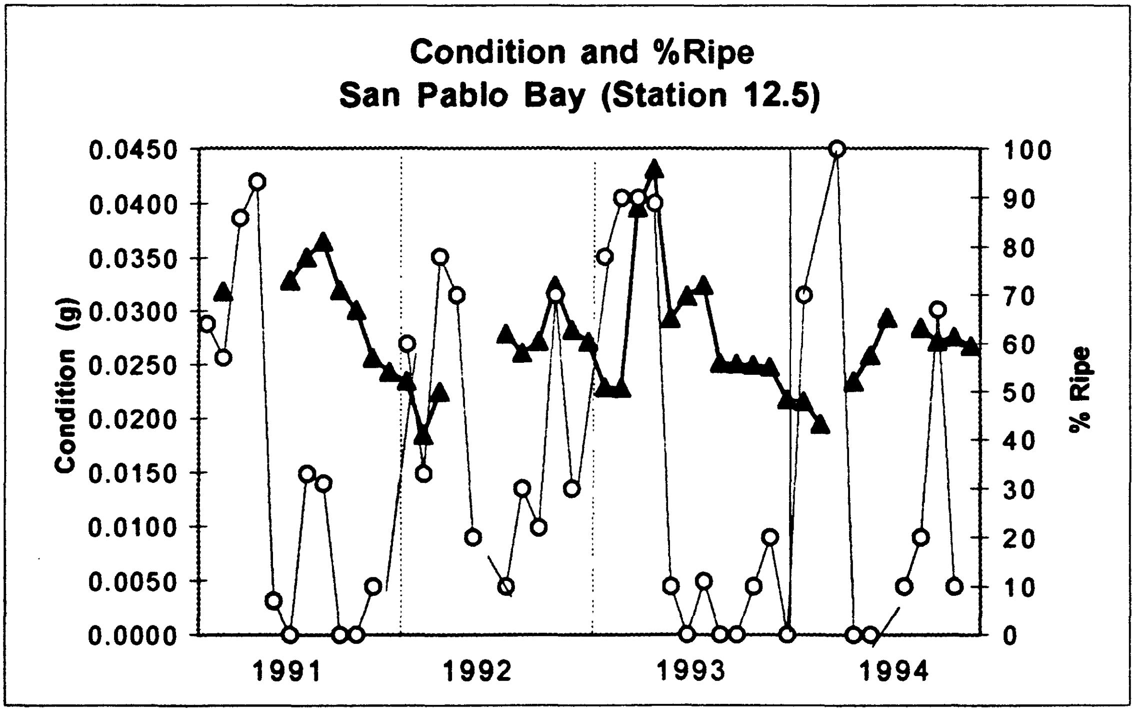

Figure 44b. Condition index for 15mm long animal (▲) and % of animals in ripe reproductive stage (°) at station 12.5.

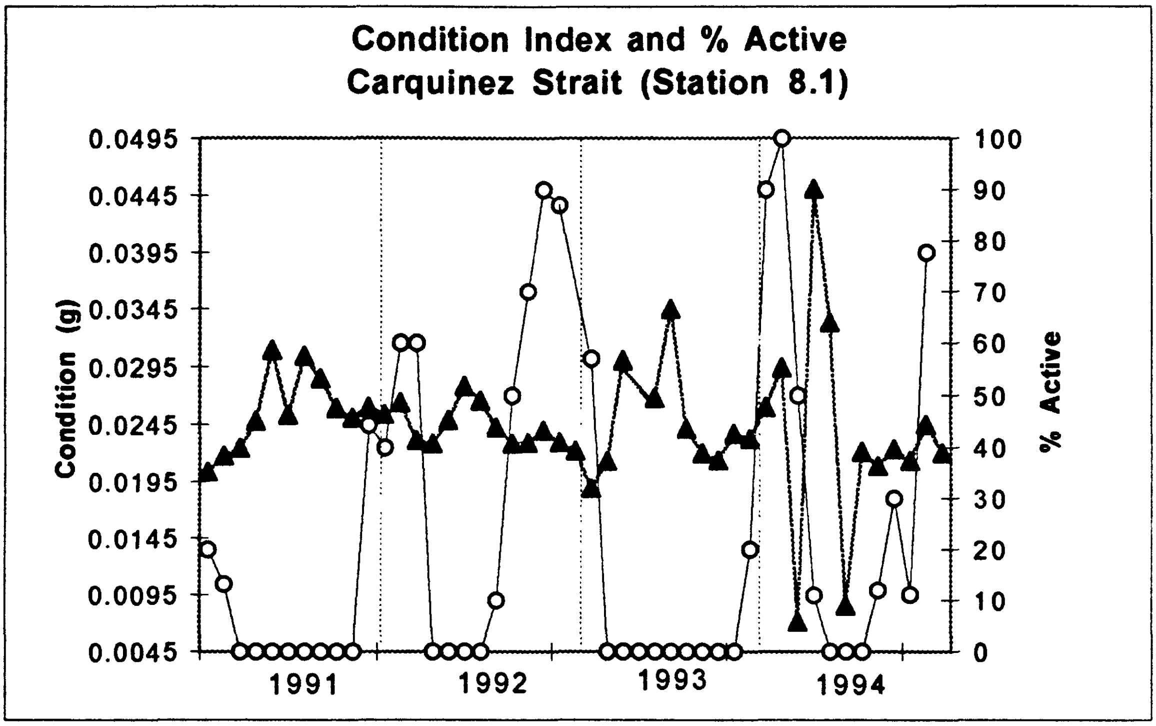

Figure 45a. Condition index for 15mm long animal (▲) and % of animals in active reproductive stage (°) at station 8.1.

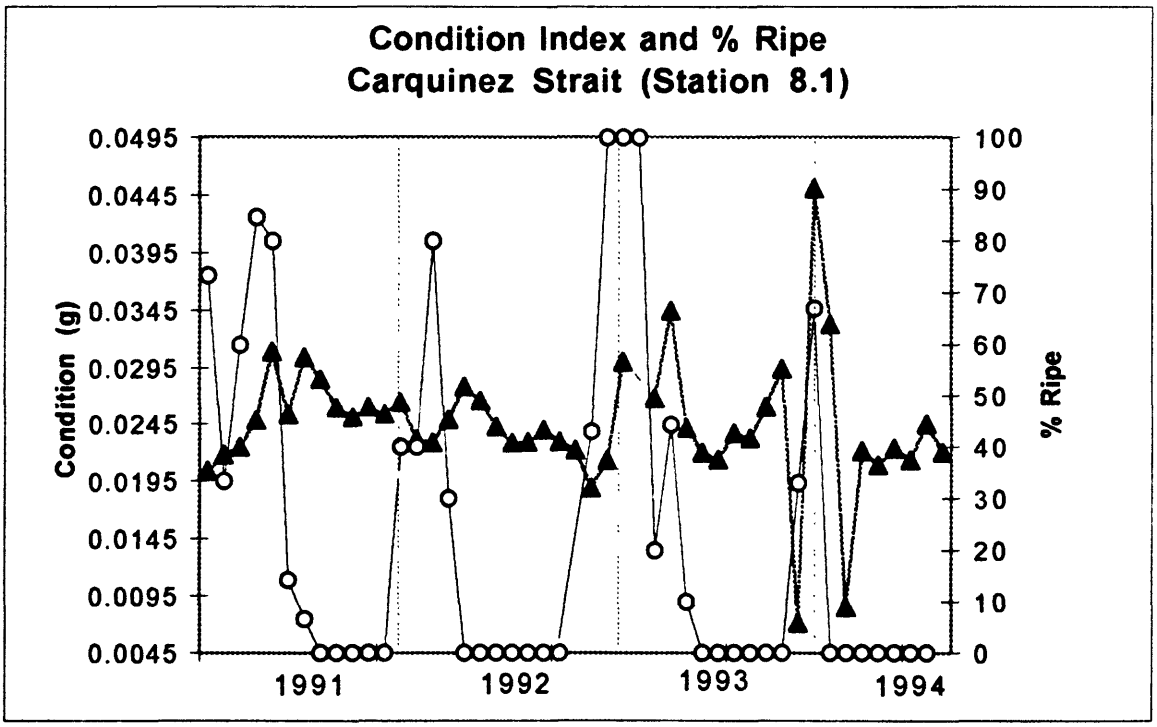

Figure 45b. Condition index for 15mm long animal (▲) and % of animals in ripe reproductive stage (°) at station 8.1.

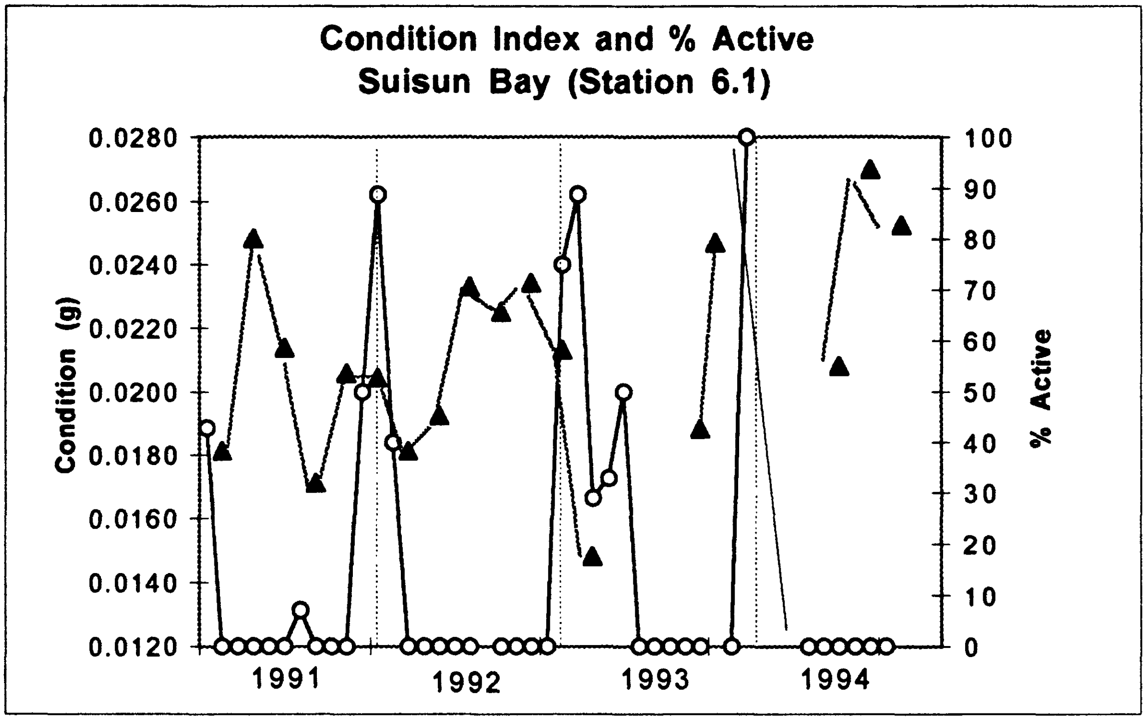

Figure 46a. Condition index for 15mm long animal (▲) and % of animals in active reproductive stage (°) at station 6.1.

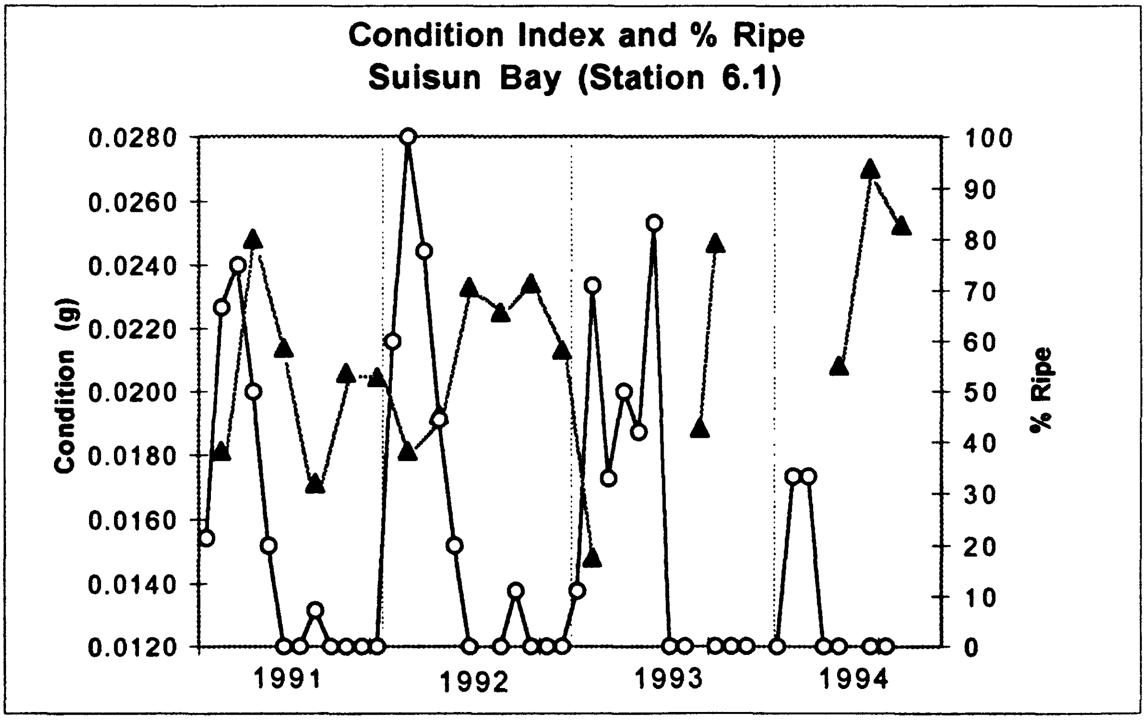

Figure 46b. Condition index for 15mm long animal (▲) and % of animals in ripe reproductive stage (°) at station 6.1.

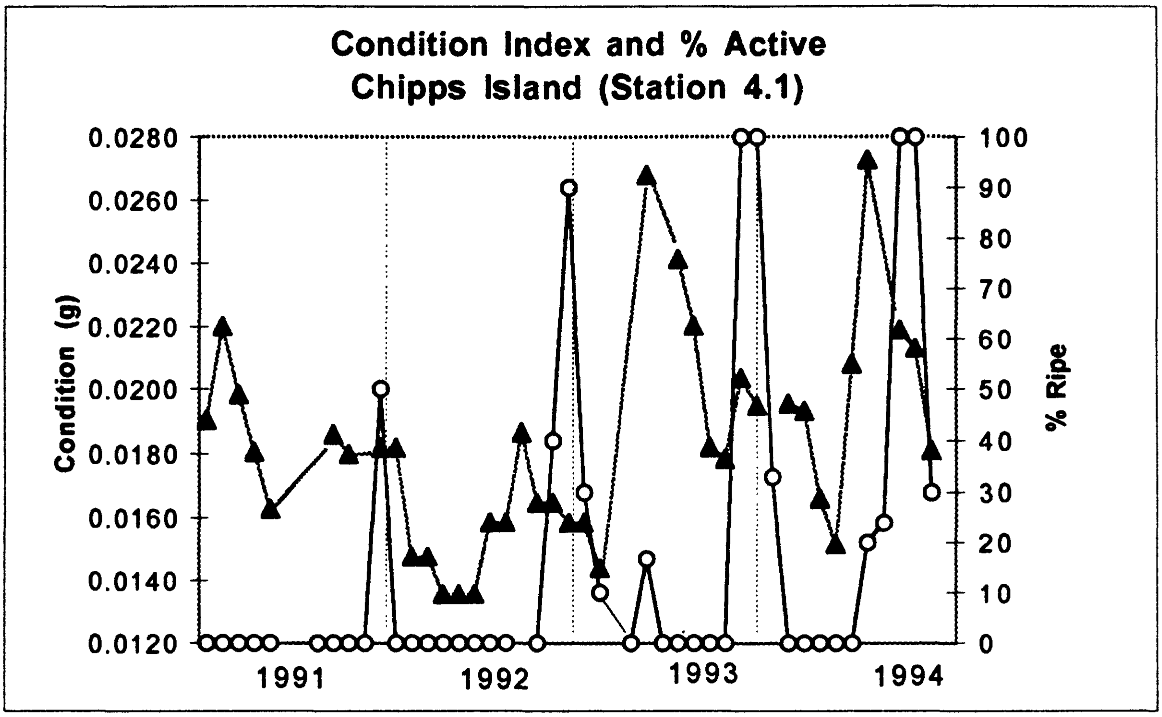

Figure 47a. Condition index for 15mm long animal (▲) and % of animals in active reproductive stage (○) at station 4.1.

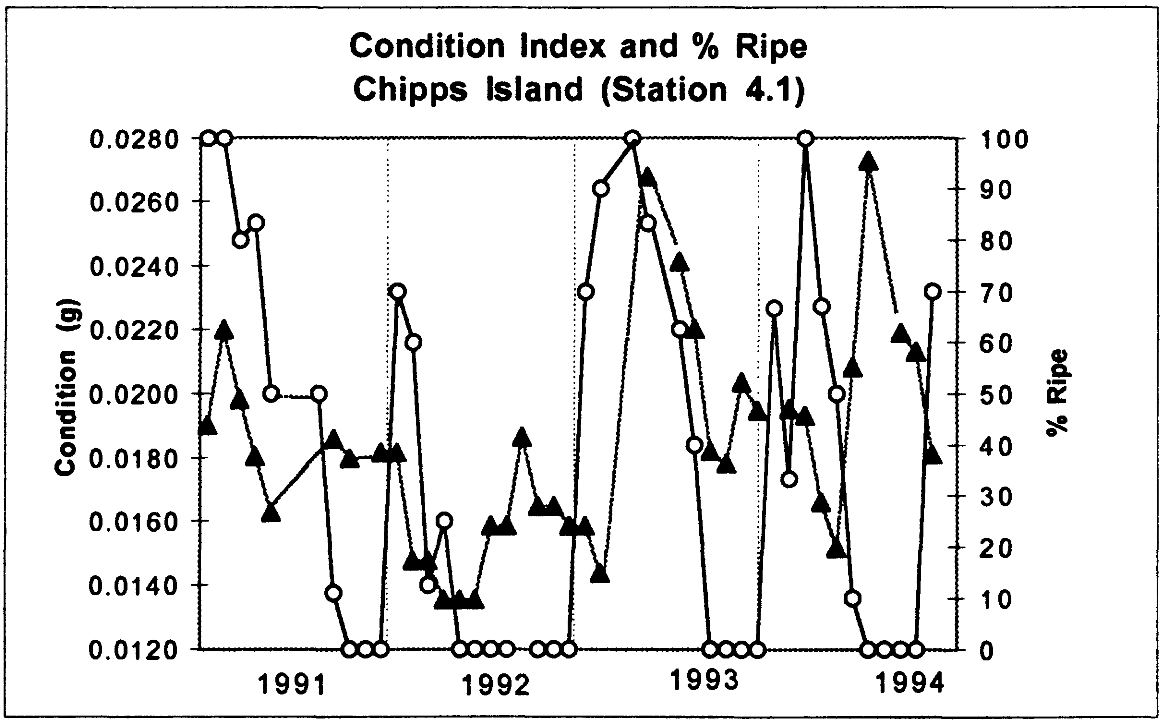

Figure 47b. Condition index for 15mm long animal (▲) and % of animals in ripe reproductive stage (○) at station 4.1.

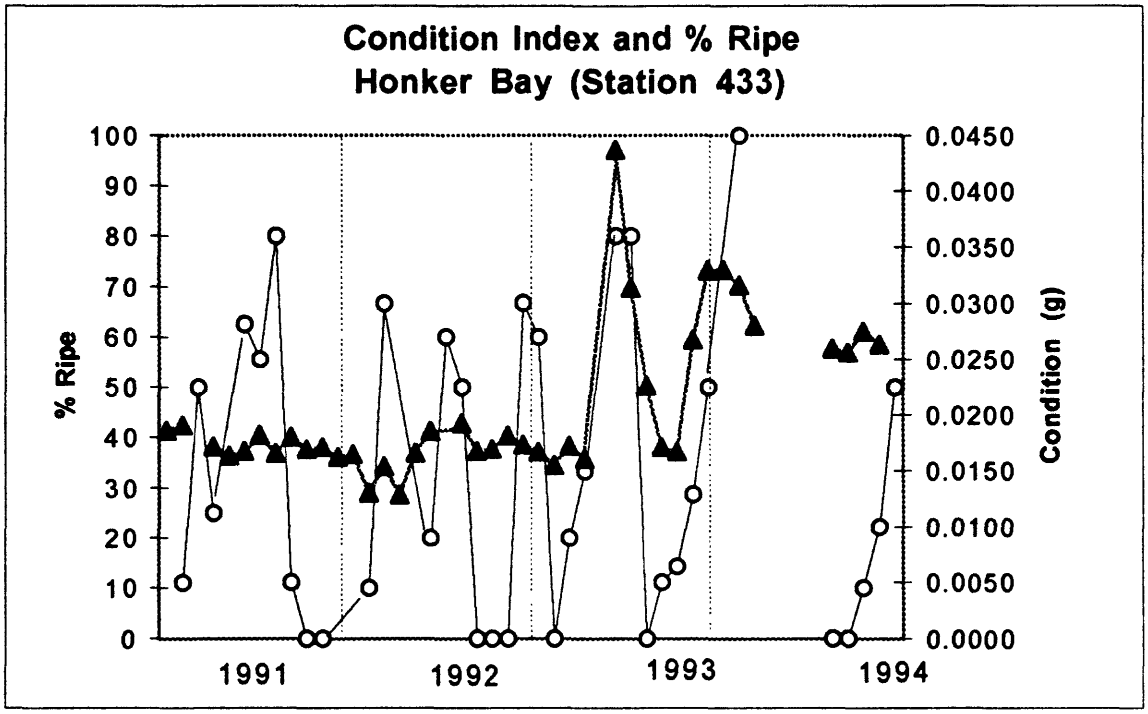

Figure 48. Condition index for 15mm long animal (▲) and % of animals in ripe reproductive stage (○) at station 433.

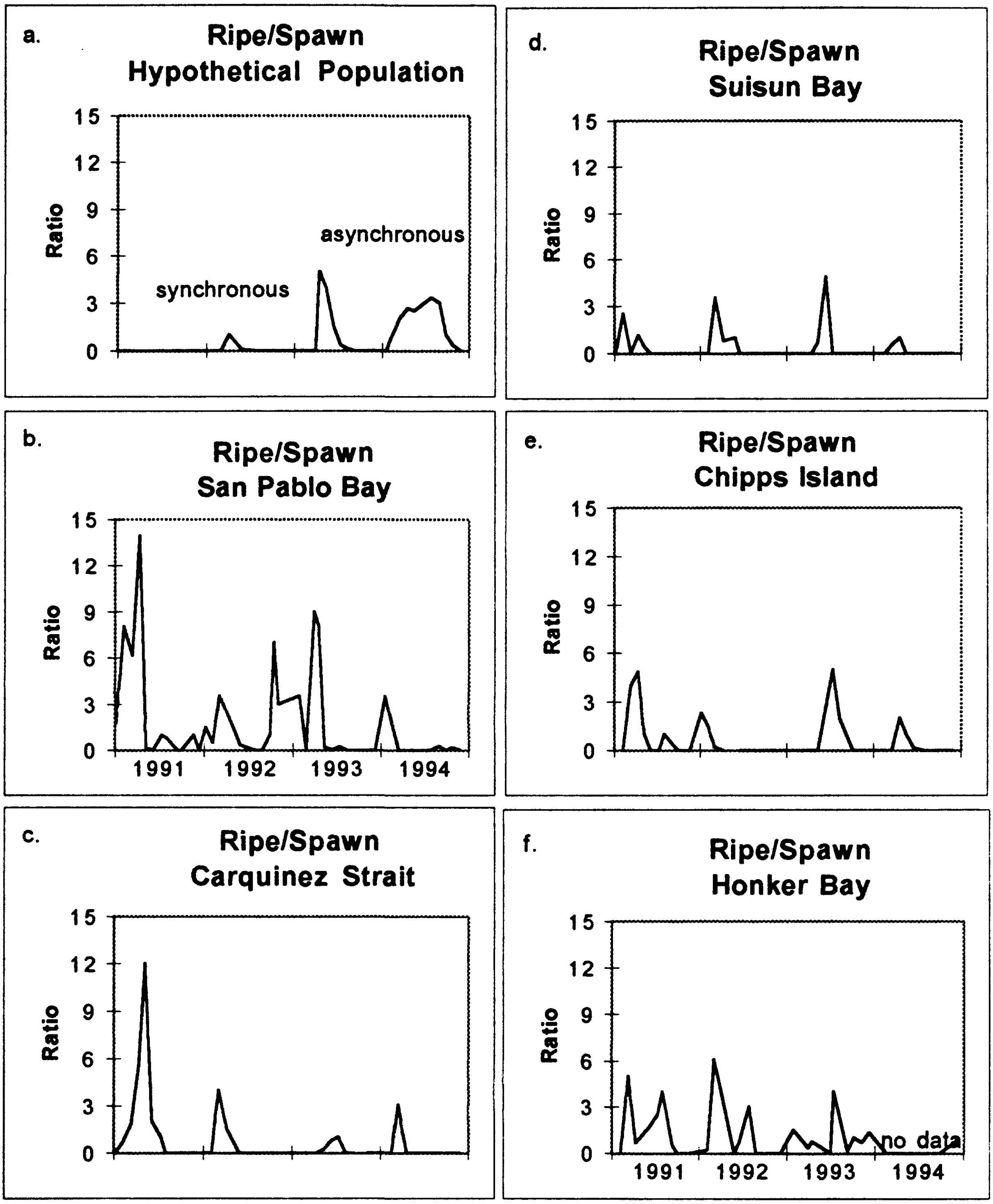

Figure 49. Synchrony of spawning in hypothetical population and populations in this study.

Appendix I.

Station 8.1 Carquinez Strait

Date	Length	Sex	Stage
7-Jan-91	6.8	1	2
	11.5	1	3
	11.0	2	3
	10.5	2	3
	11.8	2	2
	11.5	2	3
	16.8	1	2
	15.1	1	3
	15.5	2	3
	14.2	2	3
	12.0	1	3
	12.8	1	3
	9.9	2	3
	6.8	0	1
	15.6	2	3
7-Feb-91	12.5	2	4
	8.3	1	3
	13.1	1	3
	14.6	2	4
	15.8	1	4
	13.7	1	4
	6.5	1	4
	9.5	1	4
	16.1	2	2
	17.0	1	3
	19.8	1	4
	11.2	1	3
	5.5	1	4
	16.0	1	2
	12.4	1	3
13-Mar-91	16.1	1	3
	15.8	1	3
	17.0	2	3
	14.6	2	3
	13.5	1	3
	10.8	2	3
	14.0	1	3
	8.5	2	4
	10.8	2	4
	9.0	1	4
	16.0	2	5
	12.8	2	3
	16.8	2	4
	12.9	1	4
	14.8	1	3
12-Apr-91	9.5	2	3
	11.2	2	3
	8.9	1	3
	8.5	1	4
	11.8	1	3
	11.2	1	3
	9.8	2	3
	13.4	2	3
	11.9	2	3
	13.2	1	3
	13.9	1	3
	12.8	1	3
	14.7	2	4
8-May-91	9.3	2	3
	10.1	1	3
	13.8	2	5
	14.9	2	4
	13.5	2	3
	8.4	2	3
	14.5	1	3
	13.1	2	3
	11.9	1	3
	15.1	1	3
	12.9	1	3
	12.9	1	3
	13.5	1	3
	7.3	1	5
	15.1	1	3
5-Jun-91	17.1	2	3
	11.1	2	5
	16.5	2	4
	8.2	2	5
	11.8	1	5
	16.0	1	5
	9.8	1	5
	14.5	2	5
	16.8	2	5
	9.9	1	5
	13.2	1	5
	14.5	2	5
	9.1	1	3
	10.5	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 8.1 Carquinez Strait

Date	Length	Sex	Stage
11-Jul-91	7.3	0	1
	7.2	0	1
	8.5	0	1
	7.3	0	1
	6.2	0	1
	11.7	0	1
	12.1	0	1
	11.7	0	5
	11.9	0	1
	12.1	1	5
	14.2	1	5
	14.5	0	5
	15.1	1	5
	16.2	2	4
	15.8	1	3
2-Aug-91	17.2	0	5
	16.2	1	4
	8.2	0	5
	11.1	2	5
	11.1	2	5
	16.0	2	5
	17.1	1	4
	17.9	0	5
	17.4	2	5
	10.9	0	5
	10.1	0	1
	10.8	0	1
	11.9	1	5
12-Sep-91	11.3	0	1
	11.1	0	1
	14.3	0	1
	11.4	0	1
	12.1	0	1
	17.8	2	5
	6.6	0	1
	9.7	0	1
	7.3	0	1
	7.3	0	1
	19.6	0	1
	14.9	0	1
	15.1	0	1
	14.1	0	1
	7.1	0	1

Date	Length	Sex	Stage
1-Oct-91	10.2	0	1
	11.2	0	1
	13.1	1	5
	14.0	2	5
	14.1	0	1
	11.6	0	1
	15.9	2	5
	11.4	0	1
	12.8	0	1
	17.1	0	1
	16.1	0	1
	16.9	1	5
	18.5	0	1
	16.9	0	5
	16.8	1	5
19-Nov-91	14.4	1	0
	15.6	1	2
	10.0	2	5
	11.7	1	5
	11.4	0	5
	9.1	1	2
	15.6	1	2
	10.7	1	2
	10.8	2	5
	17.7	2	1
10-Dec-91	18.9	2	1
	14.4	2	1
	12.6	2	2
	11.2	1	2
	9.4	0	1
	7.8	0	1
	7.5	2	2
	6.5	1	1
	13.3	2	2
7-Jan-92	17.4	2	3
	16.4	1	3
	15.2	1	3
	13.5	2	3
	12.2	2	3
	12.0	2	3
	11.6	1	2
	10.1	1	2
	9.7	2	2
	9.4	1	2

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 8.1 Carquinez Strait

Date	Length	Sex	Stage	Date	Length	Sex	Stage
5-Feb-92	14.7	1	2	16-Jun-92	19.2	1	5
	14.6	2	3		17.7	2	5
	14.5	1	3		16.7	1	4
	13.4	1	3		15.3	1	5
	12.6	2	2		13.0	1	4
	11.7	1	2		12.7	1	5
	10.2	1	2		10.3	0	1
	10.1	1	3		10.0	1	1
	8.3	2	2		6.9	0	1
	8.0	1	2		6.5	0	1
4-Mar-92	18.4	2	4	28-Jul-92	21.4	0	1
	16.0	1	3		19.4	0	1
	15.2	2	4		18.5	1	1
	14.3	1	3		16.1	2	5
	12.7	2	3		12.7	0	1
	12.4	2	3		12.3	2	1
	12.2	1	3		12.0	2	2
	12.1	1	3		10.0	0	1
	11.5	1	3		10.0	0	1
	10.2	1	3		9.6	0	1
8-Apr-92	16.5	1	3	22-Aug-92	19.2	1	2
	15.6	2	3		17.4	2	2
	15.3	1	4		16.1	0	1
	14.5	1	5		14.1	1	1
	14.2	1	5		13.8	2	2
	11.2	1	5		12.5	1	2
	10.9	2	3		11.1	1	2
	10.1	2	4		9.9	0	1
	8.4	1	5		6.7	0	1
	8.1	1	5		5.1	0	1
28-May-92	20.6	2	5	29-Sep-92	18.7	1	2
	16.2	2	5		18.1	1	2
	14.2	2	5		17.0	2	2
	13.9	1	4		14.2	2	2
	11.2	1	5		14.1	2	1
	9.9	1	5		12.4	2	2
	9.2	0	5		12.0	2	2
	9.1	0	5		7.0	0	1
	8.2	0	5		6.8	0	1
	16.4	1	5		5.5	1	2

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 8.1 Carquinez Strait

Date	Length	Sex	Stage
14-Oct-92	20.3	2	2
	19.3	1	2
	18.6	2	2
	16.8	1	2
	15.1	1	2
	14.8	2	2
	13.8	2	2
	13.7	0	1
	13.0	2	2
	12.0	1	2
2-Nov-92	17.0	2	2
	16.6	1	2
	14.6	1	2
	14.1	2	2
	11.7	0	1
	11.6	1	2
	8.8	1	2
	7.3	0	0
	6.7	1	2
	4.6	0	0
27-Jan-93	10.5	2	2
	10.6	2	2
	5.2	0	0
	5.5	1	3
	16.0	0	0
	12.7	2	3
	9.0	1	3
	7.7	0	0
	14.7	2	2
	8.9	2	2
25-Feb-93	8.8	2	3
	10.0	1	3
	13.0	1	3
	8.3	1	3
	8.2	2	3
	7.5	2	3
	18.7	1	3
	9.2	2	3

Date	Length	Sex	Stage
30-Mar-93	9.8	1	3
	6.3	1	3
	7.5	0	0
	7.0	1	3
	9.4	1	3
	10.2	1	3
	10.2	1	3
	5.1	1	3
	6.1	0	0
	9.5	1	3
15-Apr-93	8.5	2	3
	11.4	1	3
	10.4	2	3
	8.9	2	3
	10.5	2	3
	10.9	2	3
	10.5	2	3
	14.2	2	3
	9.4	2	3
	11.3	2	3
12-May-93	8.9	2	4
	17.3	1	3
	12.4	2	4
	6.6	1	4
	9.2	2	4
	8.7	2	4
	16.6	1	3
	8.9	1	4
	14.2	2	4
	12.3	1	4
15-Jun-93	12.1	2	4
	13.7	2	3
	14.6	1	4
	10.7	1	4
	14.0	2	3
	12.9	2	4
	15.5	1	4
	18.7	1	3
	17.3	2	3

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 8.1 Carquinez Strait

Date	Length	Sex	Stage
13-Jul-93	10.8	1	5
	13.1	1	5
	13.4	1	5
	15.3	1	5
	12.6	1	5
	13.5	1	4
	15.3	1	5
	14.6	1	5
	17.2	1	3
	17.7	1	5
10-Aug-93	14.3	0	5
	16.7	2	5
	20.0	1	5
	16.2	0	5
	16.8	0	5
	13.6	2	5
	17.4	0	5
	18.1	0	5
	14.4	1	5
	14.9	1	5
8-Sep-93	14.0	0	1
	14.2	0	1
	14.5	0	1
	12.8	0	1
	12.9	0	1
	16.1	0	1
	14.8	1	5
	20.1	0	5
	17.5	1	5
	18.0	0	5
6-Oct-93	19.8	0	1
	19.6	0	1
	17.5	2	1
	17.0	0	1
	15.6	0	1
	13.6	0	1
	9.2	0	1
	9.3	0	1
	9.1	2	1
	12.3	0	1

Date	Length	Sex	Stage
8-Nov-93	19.2	0	1
	17.7	0	1
	17.1	0	1
	16.7	1	2
	14.3	0	1
	13.7	0	1
	12.9	0	1
	12.8	1	2
	8.3	0	1
	7.3	0	1
7-Dec-93	9.1	0	1
	11.0	1	2
	11.2	2	2
	1.4	1	2
	15.1	1	2
	15.1	1	2
	15.5	1	2
	17.9	2	2
	18.3	1	2
	19.4	2	2
19-Jan-94	3.9	1	2
	4.0	0	0
	5.1	0	0
	6.5	1	2
	15.3	2	2
	11.2	2	2
16-Feb-94	5.3	0	0
	6.8	0	0
	10.7	2	2
	11.1	1	3
	13.4	2	3
	5.0	1	0
	5.9	0	1
	6.1	1	2
	4.8	0	0
	5.0	2	2

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 8.1 Carquinez Strait

Date	Length	Sex	Stage
6-Mar-94	6.0	1	4
	10.0	1	2
	6.0	1	3
	6.0	1	3
	7.0	1	3
	16.1	2	3
	15.6	2	3
	5.2	0	0
	16.7	2	3
	9.8	2	4
19-Apr-94	18.9	2	4
	16.3	2	5
	8.1	1	4
	11.6	1	4
	5.4	0	5
	8.8	0	5
	13.2	1	4
	8.8	1	5
	7.2	2	4
	11.0	1	4
17-May-94	6.0	0	5
	4.2	0	0
	7.2	0	5
	11.0	1	5
	9.1	1	5
	12.9	2	5
	12.8	1	5
	14.5	1	5
	11.3	2	5
	17.4	2	5
15-Jun-94	8.3	0	1
	6.8	0	1
	13.8	0	1
	8.1	0	1
	9.5	1	5
	12.3	2	5
	7.0	0	1
	5.1	0	1
	14.2	0	1

Date	Length	Sex	Stage
28-Jul-94	7.3	0	1
	7.6	0	1
	9.9	0	1
	9.5	0	1
	13.8	2	2
	15.1	0	1
	15.1	0	1
	13.1	0	1
30-Aug-94	15.2	1	2
	8.0	1	1
	11.6	2	2
	10.0	0	1
	6.7	0	1
	1.6	0	1
	11.4	0	1
	18.4	1	1
	8.2	1	1
	17.2	1	2
27-Sep-94	18.2	1	1
	13.5	0	1
	14.9	0	1
	19.9	2	2
	18.4	0	1
	10.1	0	1
	5.9	0	1
	11.4	0	1
	8.5	0	1
26-Oct-94	19.2	2	2
	3.6	0	1
	8.0	0	1
	9.0	2	2
	8.7	2	2
	10.9	2	2
	13.0	1	2
	12.0	1	2
	14.8	1	2

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 6.1 Suisun Bay

Date	Length	Sex	Stage
7-Jan-91	9.0	0	1
	6.5	0	1
	8.0	2	1
	14.1	1	2
	11.5	2	2
	5.2	0	1
	19.1	2	3
	7.0	2	2
	10.6	2	1
	16.0	1	2
	22.7	2	2
	19.7	1	3
	8.6	2	2
	14.5	2	3
7-Feb-91	25.7	1	3
	26.4	1	4
	25.5	2	5
	9.9	2	3
	7.1	2	4
	8.0	2	4
	10.3	2	3
	9.0	2	4
	10.5	1	3
	11.0	1	3
	15.7	2	3
	16.7	1	3
	14.5	1	3
	17.1	1	3
	19.5	1	3
12-Mar-91	17.8	1	3
	12.5	2	3
	17.8	2	3
	16.1	2	3
	16.8	2	3
	17.3	1	3
	17.5	1	3
	19.7	2	3
	17.8	1	5
	20.4	1	5
	19.9	1	5
	18.8	2	3

Date	Length	Sex	Stage
12-Apr-91	19.5	2	5
	18.9	1	3
	9.8	1	3
	6.9	1	4
	10.5	1	4
	12.5	1	3
	8.8	2	4
	16.1	2	3
	10.2	1	3
	5.8	2	4
	9.7	2	4
	7.7	2	4
	14.1	2	3
	14.5	2	3
8-May-91	20.9	1	5
	18.2	2	4
	17.8	1	3
	14.5	1	4
	10.5	1	5
	9.2	1	5
	13.8	1	4
	10.5	1	3
	12.2	1	4
	12.8	1	4
5-Jun-91	19.2	2	4
	19.9	1	5
	11.8	1	5
	14.2	1	5
	12.5	1	5
	11.1	1	5
	12.8	1	5
	14.2	1	5
	9.9	1	5
	17.0	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 6.1 Suisun Bay

Date	Length	Sex	Stage
11-Jul-91	11.2	0	2
	14.1	1	5
	12.2	1	5
	7.2	1	5
	15.0	1	5
	11.0	0	5
	11.1	0	5
	9.5	2	4
	9.8	0	5
	18.9	1	4
	19.8	1	5
	21.0	2	5
	21.9	1	5
	16.8	0	5
2-Aug-91	12.1	0	5
	14.8	2	3
	12.0	0	5
	15.8	0	5
	13.2	0	5
	15.5	0	5
	14.0	0	5
	16.0	2	5
	14.8	0	5
	12.8	0	5
	9.0	0	5
	12.7	0	5
	10.8	0	1
	11.6	0	5
12-Sep-91	10.8	0	1
	9.2	0	1
	12.9	0	1
	6.9	0	1
	6.7	0	1
	8.1	1	1
	8.2	0	1
	8.2	0	1
	11.2	0	1
	10.6	0	1
	18.9	0	1
	17.2	0	1
1-Oct-91	13.9	1	5
	20.2	2	5
	20.1	1	5
	25.2	1	5
	13.1	1	5

Date	Length	Sex	Stage
19-Nov-91	9.9	0	1
	11.3	0	1
	11.9	1	2
	14.1	2	1
	14.5	1	2
	15.1	2	2
	16.0	1	2
	16.3	1	1
	21.4	1	1
	23.3	1	2
10-Dec-91	20.7	2	2
	19.6	1	2
	18.6	2	2
	17.2	2	2
	15.5	2	2
	14.7	2	2
	14.1	1	2
	13.5	1	2
	10.7	0	1
7-Jan-92	20.9	2	3
	18.7	2	3
	15.8	2	3
	15.0	2	2
	13.5	2	3
	12.8	2	3
	12.7	2	2
	8.5	2	2
	7.8	1	2
	13.2	2	3
5-Feb-92	10.1	1	3
	11.9	2	3
	13.8	1	3
	14.2	2	3
	14.9	2	3
	15.1	2	3
	15.3	2	3
	16.8	1	3

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 6.1 Suisun Bay

Date	Length	Sex	Stage
4-Mar-92	21.2	2	3
	20.1	1	3
	15.8	1	3
	15.0	1	3
	14.9	2	3
	12.9	1	3
	12.8	1	3
	12.5	1	4
	9.9	1	4
8-Apr-92	23.0	2	3
	16.1	2	3
	13.6	1	4
	13.2	1	3
	12.1	2	3
	8.9	1	4
	9.0	2	4
	7.5	1	4
	7.1	1	4
28-May-92	19.7	1	4
	19.6	1	3
	16.7	1	5
	17.7	1	5
	15.5	1	4
	15.3	1	5
	12.6	1	3
	10.5	1	5
	8.1	1	5
	7.8	1	5
16-Jun-92	22.8	1	5
	19.0	0	5
	19.0	1	5
	17.8	0	5
	13.4	1	5
	13.1	2	5
	12.4	1	5
	11.1	1	5
	7.9	1	5
	5.9	0	1

Date	Length	Sex	Stage
22-Aug-92	20.1	0	1
	17.8	2	5
	16.2	1	5
	15.7	1	5
	15.1	2	5
	12.8	1	5
	12.5	1	5
	11.5	0	1
	8.6	0	1
	8.4	1	5
29-Sep-92	22.7	1	5
	21.5	1	5
	21.3	0	5
	20.3	2	5
	16.8	1	5
	15.5	1	5
	14.3	2	5
	14.1	1	5
	12.7	1	3
14-Oct-92	20.8	2	5
	17.8	2	5
	16.9	1	5
	11.8	1	5
	11.5	1	5
	10.6	1	5
	9.2	1	5
	7.6	0	1
	7.2	0	1
2-Nov-92	20.4	1	4
	16.8	1	5
	15.5	1	5
	15.5	1	5
	14.7	1	4
	13.8	1	4
	14.1	1	5
	11.8	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 6.1 Suisun Bay

Date	Length	Sex	Stage
2-Dec-92	20.8	1	2
	7.0	0	0
	16.8	1	2
	12.8	2	2
	6.2	0	0
	8.2	1	5
	11.1	2	2
	12.1	1	2
	17.5	1	1
	16.2	2	2
27-Jan-93	12.4	1	2
	10.5	2	2
	12.4	2	2
	121.0	2	2
	12.0	1	2
	8.0	2	2
	15.0	2	2
	10.0	1	2
	16.9	1	3
25-Feb-93	14.2	2	3
	10.1	0	0
	10.5	0	0
	13.5	2	3
	17.3	2	3
	16.7	2	3
	15.4	2	3
	18.2	2	2
	16.7	2	2
30-Mar-93	8.3	1	2
	7.5	1	2
	10.6	2	2
	6.1	1	2
15-Apr-93	5.1	0	0
	5.3	1	2
	17.3	1	3

Date	Length	Sex	Stage
12-May-93	6.9	0	0
	11.4	1	3
	7.3	0	0
	5.8	0	0
	16.1	1	3
	11.2	2	4
	17.0	2	3
	11.5	2	4
	8.5	1	4
	8.5	2	3
15-Jun-93	10.7	2	4
	14.3	1	3
	15.1	2	3
	12.5	1	3
	12.8	1	3
	11.8	1	3
19-Jul-93	7.5	1	5
	9.0	2	5
	16.2	1	5
	15.9	1	4
	6.8	0	0
	12.3	1	4
10-Aug-93	18.3	1	4
	17.2	2	5
	13.8	2	5
	14.0	1	4
	14.1	1	5
	14.6	1	5
	9.7	1	5
	12.8	1	5
	16.3	1	5
8-Sep-93	13.4	1	5
6-Oct-93	21.1	1	5
	22.2	1	5
	23.8	2	5
	19.4	2	5
	16.9	2	5
	10.8	2	5
	20.6	1	5
	14.0	2	5
	17.9	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 6.1 Suisun Bay

Date	Length	Sex	Stage
8-Nov-93	3.8	0	0
	18.5	2	5
7-Dec-93	16.7	2	2
	10.4	2	2
	10.9	1	2
	2.8	0	0
	19.7	1	2
19-Jan-94	17.6	1	3
16-Feb-94	5.1	0	0
6-Mar-94	13.8	2	3
	14.7	1	4
	5.8	1	4
19-Apr-94	13.8	1	4
	14.8	1	5
	20.6	1	3
17-May-94	7.8	0	0
	7.5	1	5
	23.7	1	4
	20.0	1	4
	4.5	1	4
15-Jun-94	4.1	0	0
	21.9	2	4
	4.5	0	0
27-Sep-94	11.1	1	1
	13.5	1	5
	18.1	2	5

Date	Length	Sex	Stage

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 4.1 Chipps Island

Date	Length	Sex	Stage
8-Jan-91	7.7	1	3
	7.8	1	3
	9.4	2	3
	9.9	1	3
	11.1	2	3
	11.4	2	3
	16.9	2	3
	22.7	2	3
	23.0	1	3
	24.1	2	3
6-Feb-91	4.5	1	3
	6.8	1	3
	7.5	1	3
	7.5	1	3
	8.1	1	3
	20.1	1	3
	23.5	2	3
	24.2	1	3
	25.4	2	3
12-Mar-91	6.3	1	4
	7.1	1	4
	9.6	2	3
	12.1	2	3
	19.7	2	3
	15.8	2	3
	20.5	2	3
	21.3	1	3
	23.0	2	3
	25.9	2	3
12-Apr-91	27.3	1	3
	24.1	2	3
	21.6	1	3
	11.0	1	3
	10.6	2	3
	8.8	1	4

Date	Length	Sex	Stage
8-May-91	7.9	1	4
	8.4	1	4
	8.5	1	4
	16.9	1	3
	17.8	1	3
	19.3	2	3
	23.1	2	4
	23.1	2	3
	25.5	1	3
	25.9	2	4
1-Aug-92	6.5	1	3
	8.1	0	0
	9.1	1	4
	12.7	1	3
	13.2	2	4
12-Sep-91	26.0	2	3
	23.4	1	4
	17.0	1	4
	15.8	2	4
	15.1	1	5
	14.2	2	4
	11.2	1	5
	9.1	1	5
	7.1	1	5
1-Oct-91	13.1	1	5
	20.2	2	5
	23.1	2	5
	23.5	1	5
	25.8	1	5
	26.0	2	4
	26.6	1	5
19-Nov-91	4.8	0	1
	5.2	0	1
	5.5	1	5
	6.2	0	0
	6.4	2	5
	9.8	1	5
	11.9	1	4
	14.1	1	5
10-Dec-91	19.2	2	2
	6.5	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 4.1 Chipps Island

Date	Length	Sex	Stage
7-Jan-92	25.1	1	3
	15.1	1	3
	13.9	1	3
	13.5	1	4
	12.0	1	3
	11.7	2	3
	11.5	2	4
	11.0	1	3
	10.9	2	3
	8.5	2	4
5-Feb-92	8.2	2	4
	8.6	2	3
	8.6	2	4
	13.9	1	3
	16.1	2	3
	14.9	2	4
	16.2	2	3
	22.2	1	3
	22.1	1	4
	27.9	1	3
4-Mar-92	13.5	2	5
	12.2	1	4
	10.8	1	3
	16.1	4	5
	8.5	2	4
	24.2	1	4
	17.3	1	4
	25.2	1	4
8-Apr-92	9.4	2	5
	14.6	2	5
	16.0	2	5
	22.5	1	3
28-May-92	17.0	1	5
	13.1	0	5
	7.9	0	0
16-Jun-92	29.3	1	5
	15.9	1	5
	13.4	0	1
	11.2	1	5

Date	Length	Sex	Stage
28-Jul-92	17.7	1	5
	12.4	1	5
	14.8	0	1
	10.7	0	1
	8.8	0	1
	10.5	0	1
	15.9	2	1
	12.5	2	1
22-Aug-92	16.2	1	1
	9.6	1	1
	13.2	0	1
	9.4	0	1
	11.6	2	1
	18.1	0	1
14-Oct-92	9.7	0	1
	11.0	0	1
	11.1	0	1
	12.8	0	1
	16.2	1	1
	16.3	0	1
	15.9	2	1
	17.2	1	1
	19.5	2	1
	20.5	0	1
3-Nov-92	5.7	0	1
	10.4	1	2
	13.7	2	2
	14.3	2	1
	18.0	0	1
2-Dec-92	18.4	1	2
	16.0	1	2
	15.0	2	2
	11.8	1	2
	12.8	2	2
	16.8	2	2
	13.6	1	2
	15.7	1	2
	10.8	2	1
	14.8	2	2

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 4.1 Chipps Island

Date	Length	Sex	Stage
27-Jan-93	10.8	1	3
	16.5	2	3
	11.3	2	3
	12.2	2	2
	17.0	1	2
	13.5	1	2
	8.0	1	3
	11.2	1	3
	10.8	2	3
	12.4	1	3
25-Feb-93	8.9	1	3
	11.5	1	3
	11.9	2	2
	12.0	1	3
	13.6	2	3
	13.7	1	3
	15.2	1	3
	16.2	1	3
	16.7	1	3
	18.5	2	3
30-Mar-93	13.0	1	3
15-Apr-93	6.6	1	3
	11.8	1	3
	12.0	2	3
	12.2	1	3
	12.5	2	3
	12.9	2	3
	13.1	1	3
	14.0	2	3
	17.3	2	3
12-May-93	4.5	2	3
	8.1	1	2
	10.2	2	3
	11.0	1	3
	15.5	1	3
	15.9	2	3
15-Jun-93	11.0	1	5

Date	Length	Sex	Stage
19-Jul-93	19.2	2	3
	17.7	2	3
	17.5	1	3
	16.2	2	3
	14.8	2	3
	7.9	1	5
	6.9	2	5
	6.0	2	4
10-Aug-93	17.1	1	3
	16.7	1	3
	14.9	2	4
	6.2	0	1
	4.4	0	1
6-Oct-93	19.1	1	5
	18.9	1	4
	17.8	1	4
	17.7	1	5
	17.4	1	4
	17.4	1	4
	17.2	2	5
	16.7	2	5
	13.3	1	5
8-Nov-93	19.4	1	2
	18.7	1	2
	18.1	2	2
	18.1	2	2
	16.1	2	2
	15.2	1	2
	14.5	2	2
	13.1	2	2
	11.1	2	2
7-Dec-93	11.1	2	2
	12.2	2	2
	4.5	2	2
19-Jan-94	4.9	1	2
	12.9	2	3
	13.3	2	3
16-Feb-94	5.0	0	0
	4.0	2	3
	4.1	0	0

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 4.1 Chipps Island

Date	Length	Sex	Stage
6-Mar-94	17.8	1	3
	16.9	2	3
	5.1	0	0
	4.5	2	3
	4.2	0	0
19-Apr-94	21.3	2	3
	10.1	2	4
	9.5	2	3
	5.8	0	0
17-May-94	20.2	2	4
	20.1	1	3
	19.5	1	3
	17.3	1	4
	17.0	1	4
	14.2	2	4
	13.0	2	3
	10.9	1	3
15-Jun-94	17.2	2	4
	16.9	2	4
	15.7	2	4
	14.6	2	5
	13.9	1	3
	13.3	1	4
	12.5	1	5
	8.5	1	4
	8.2	1	4
	7.6	1	5
28-Jul-94	6.0	2	1
	6.2	2	1
	6.3	2	1
	6.4	1	1
	6.8	1	1
	6.9	1	1
	8.2	0	1
	8.3	2	2
	9.0	2	5
	10.2	2	2

Date	Length	Sex	Stage
30-Aug-94	4.1	0	0
	6.7	0	0
	6.7	0	0
	8.9	0	1
	9.5	0	1
	10.2	0	1
	18.9	1	2
	18.1	2	2
27-Sep-94	20.9	2	2
	20.7	1	2
	20.2	1	2
	16.2	1	2
	12.9	2	2
	12.8	1	2
	11.9	1	2
	10.7	1	2
	9.4	2	2
26-Oct-94	8.5	2	2
	11.1	1	2
	12.3	1	2
	12.9	2	2
	13.0	2	2
	13.5	1	2
	14.8	2	2
	19.8	1	2
	20.2	1	2
	20.3	1	2
29-Nov-94	11.7	1	3
	11.8	1	3
	11.9	2	2
	13.1	1	3
	14.1	2	2
	14.5	1	3
	14.7	1	2
	15.2	2	3
	17.5	2	3
	21.1	1	3

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 433 Honker Bay

Date	Length	Sex	Stage
6-Feb-91	14.7	2	2
	14.2	2	2
	11.1	0	1
	19.2	2	2
	11.8	0	1
	13.1	1	3
	13.6	2	2
	11.7	0	1
	8.9	0	0
	13.9	2	2
11-Mar-91	10.8	1	3
	16.5	2	3
	11.1	1	3
	9.6	2	3
	11.1	2	2
	9.7	2	3
	8.0	2	1
	10.4	2	2
	7.2	1	1
	8.9	2	4
11-Apr-91	8.8	0	0
	8.5	1	5
	10.7	2	5
	8.3	1	5
	10.1	2	3
	10.1	1	3
	9.6	2	4
	14.1	1	4
	10.8	1	4
	10.0	0	0
5-Jun-91	9.2	1	3
	9.1	1	3
	7.9	0	0
	10.9	1	3
	10.2	2	4
	12.1	2	3
	11.9	1	4
	13.6	2	3
	13.7	1	4

Date	Length	Sex	Stage
11-Jul-91	11.2	1	3
	8.2	1	5
	11.1	2	5
	8.5	0	0
	12.7	2	4
	9.4	1	3
	12.0	2	4
	8.8	1	3
	13.5	2	3
	8.1	1	3
1-Aug-91	8.0	1	4
	8.2	2	4
	11.7	2	3
	11.2	1	3
	11.3	2	3
	10.0	2	3
	13.8	2	3
	10.5	1	3
	12.1	2	3
	11.5	2	3
12-Sep-91	7.8	1	5
	8.4	1	5
	13.0	2	4
	9.5	2	5
	10.0	2	5
	8.8	1	5
	8.1	1	5
	12.1	1	4
	12.2	2	3
1-Oct-91	18.8	1	4
	7.8	2	5
	8.0	1	4
	11.2	2	5
	10.8	1	5
	7.8	2	5
	7.0	0	5
	10.0	2	5
	8.1	1	5
	10.0	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 433 Honker Bay

Date	Length	Sex	Stage
19-Nov-91	13.2	2	5
	13.8	2	5
	11.2	1	1
	12.2	0	1
	11.8	1	1
	9.8	1	5
	8.1	1	5
	9.5	2	5
	8.1	0	1
	7.9	0	1
2-Feb-92	7.9	1	5
	8.2	1	4
	14.2	2	3
	13.3	1	5
	7.2	2	4
	7.5	1	4
	8.1	1	5
	8.9	2	4
	8.5	2	4
4-Mar-92	11.9	2	3
	9.0	1	3
	6.9	2	3
	6.6	2	3
	12.5	1	5
	9.3	1	4
	10.6	1	3
	8.1	1	5
	10.0	2	3
27-May-92	9.9	1	3
	8.0	1	3
	4.5	0	0
	7.6	0	0
	5.8	0	0
	5.8	0	0
	8.3	0	0
	6.0	0	0

Date	Length	Sex	Stage
16-Jun-92	10.7	2	4
	9.9	2	4
	7.1	1	3
	12.1	1	4
	8.0	0	5
	10.3	1	5
	6.1	2	5
	6.1	0	5
	12.0	1	5
	18.0	1	3
28-Jul-92	9.1	1	5
	6.9	1	4
	9.1	1	3
	12.2	1	3
	7.5	1	3
	13.7	2	3
	12.8	2	5
	10.1	2	3
	12.5	2	4
	13.7	2	3
25-Aug-92	14.7	1	3
	16.1	0	5
	12.2	1	5
	13.6	1	5
	11.4	2	3
	14.8	2	5
	8.5	2	3
	9.5	2	3
	10.5	1	3
	10.8	1	5
29-Sep-92	8.0	1	4
	9.5	1	5
	6.1	1	5
	8.3	1	5
	12.7	1	5
	12.1	1	4
	8.3	0	0
	15.2	2	4
	13.0	1	4

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 433 Honker Bay

Date	Length	Sex	Stage
14-Oct-92	10.0	2	4
	6.7	0	1
	12.9	0	1
	9.5	0	1
	7.9	1	2
	5.8	0	1
	7.1	0	1
	7.7	0	1
3-Nov-92	9.8	0	1
	8.8	1	2
	8.5	2	2
	11.1	0	1
	8.4	2	1
	13.0	2	2
	12.1	0	1
	14.1	0	1
	10.6	0	1
7-Dec-92	16.8	2	3
	17.4	1	3
	5.2	0	1
	4.0	0	1
	16.1	1	3
	10.3	1	3
27-Jan-93	11.3	1	3
	8.0	2	3
	8.3	1	4
	8.5	2	3
	11.2	2	3
	10.7	1	3
	14.1	1	4
	11.7	1	4
	12.9	1	3
	12.0	1	4
30-Mar-93	8.8	2	5
	13.5	1	3
	8.8	2	4
	8.5	2	4
	8.7	1	4

Date	Length	Sex	Stage
15-Apr-93	9.8	2	4
	9.9	1	4
	7.0	1	5
	9.5	1	3
	7.3	2	4
	7.1	2	4
	14.5	2	3
	7.7	1	5
	8.5	1	3
30-Jun-93	12.1	2	5
	12.1	2	3
	12.9	2	3
	15.6	1	3
	18.8	1	3
13-Jul-93	10.0	1	4
	15.5	1	3
	15.3	1	3
	13.0	1	3
	16.0	1	3
8-Sep-93	14.1	1	4
	13.8	1	4
	14.7	1	4
	10.9	1	3
	9.7	1	4
	14.3	2	4
	15.2	1	5
	16.0	1	4
	16.0	1	4
6-Oct-93	16.1	1	3
	16.3	2	5
	13.5	2	5
	13.4	1	5
	11.8	2	5
	14.0	1	5
	12.1	2	4
8-Nov-93	17.0	2	5
	14.6	2	4
	13.0	1	5
	16.8	1	4
	14.8	1	3
	16.8	2	3
	15.9	2	4

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 433 Honker Bay

Date	Length	Sex	Stage
7-Dec-93	18.5	1	3
	14.4	1	3
	16.3	2	4
	14.8	1	3
	15.8	2	4
	14.5	1	3
	13.1	2	4
	16.2	2	5
19-Jan-94	18.1	1	3
16-Feb-94	15.6	1	3
	16.2	2	3
	16.0	1	3
16-Mar-94	14.5	1	3
	14.8	2	3
30-Aug-94	5.0	1	4
	5.5	1	4
	13.9	1	4
27-Sep-94	7.1	1	5
	8.1	2	4
	7.0	2	4
	7.0	1	5
	11.2	2	5
	13.8	1	5
	12.8	1	4
	7.1	2	5
26-Oct-94	8.1	2	5
	9.5	1	5
	7.5	2	4
	7.8	1	5
	7.2	2	4
	10.0	1	5
	8.8	2	4
	0.8	2	5
	11.2	2	5
	9.1	1	3

Date	Length	Sex	Stage
29-Nov-94	22.5	2	5
	13.4	2	4
	11.1	1	5
	9.9	2	3
	9.1	2	4
	7.9	2	3
	8.8	2	4
	8.5	2	5
	6.9	1	5
7-Dec-94	14.5	1	3
	15.9	2	4
	16.3	2	4
	14.8	1	3

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 12.5 San Pablo Bay

Date	Length	Sex	Stage
7-Jan-91	15.5	2	3
	16.1	1	3
	12.8	2	4
	6.3	2	3
	12.5	1	4
	14.8	1	3
	16.8	2	3
	6.2	2	4
	15.2	1	3
	15.0	2	3
	7.2	1	4
	13.1	2	3
	6.8	2	4
	12.9	1	3
7-Feb-91	17.0	2	2
	10.9	2	3
	6.5	2	2
	13.8	2	2
	7.0	0	1
	4.1	1	3
	14.5	1	3
	6.8	1	4
	7.9	1	2
	6.5	1	3
	10.0	1	3
	15.5	2	3
	13.4	2	3
	6.8	1	3
12-Mar-91	15.2	1	3
	11.1	2	3
	7.0	1	3
	9.0	1	3
	9.5	2	3
	10.8	2	3
	12.0	1	3
	12.9	2	4
	8.9	1	3
	13.0	1	4
	6.2	2	3
	8.4	1	3
	13.7	2	3
	17.3	2	3

Date	Length	Sex	Stage
12-Apr-91	8.1	2	3
	7.1	2	3
	6.2	2	3
	12.1	2	3
	11.5	1	3
	6.5	2	3
	8.8	2	3
	9.1	1	3
	7.4	1	3
	12.1	2	3
	7.8	2	3
	8.1	2	4
	12.1	1	3
	13.1	1	3
	10.2	2	3
8-May-91	11.2	1	3
	8.5	1	4
	9.8	2	4
	6.2	1	5
	12.2	2	4
	8.2	2	5
	7.8	2	5
	8.2	2	4
	6.1	2	5
	11.1	1	5
	6.1	2	4
	7.2	1	5
	15.2	1	4
	18.9	1	4
5-Jun-91	9.2	1	5
	10.0	1	5
	11.2	1	5
	10.1	2	4
	9.8	1	5
	5.9	2	5
	12.3	2	5
	9.8	1	4
	10.1	1	5
	11.8	1	5
	10.9	1	5
	17.8	2	5
	7.9	1	5
	11.1	2	5
	9.1	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 12.5 San Pablo Bay

Date	Length	Sex	Stage
11-Jul-91	6.9	1	5
	8.0	0	5
	8.1	2	5
	8.0	1	4
	9.3	2	3
	13.0	2	4
	12.9	1	3
	12.8	2	4
	12.2	2	5
	12.1	1	3
	16.1	2	4
	16.5	1	3
	14.3	1	4
	18.1	2	5
	15.5	1	3
2-Aug-91	10.5	1	5
	13.1	1	4
	7.8	2	5
	10.0	1	5
	14.5	2	4
	13.3	1	4
	9.5	1	5
	11.7	2	4
	12.0	1	3
	13.8	1	3
	11.3	2	3
	14.1	2	4
	14.8	1	3
12-Sep-91	8.0	0	5
	7.9	2	4
	7.0	1	5
	8.9	1	4
	10.0	1	4
	11.5	2	4
	12.0	2	4
	11.9	2	4
	13.7	1	4
	10.1	0	5
	14.0	0	5
	14.4	2	5
	11.5	1	4
	16.3	1	4
	16.6	2	4

Date	Length	Sex	Stage
1-Oct-91	6.0	0	1
	7.1	0	1
	6.8	2	5
	9.1	0	1
	6.2	0	1
	7.1	0	1
	11.4	2	5
	12.1	1	5
	11.8	2	5
	15.4	1	5
	15.6	1	5
	16.5	1	5
	16.5	1	5
	15.0	2	5
19-Nov-91	9.0	2	2
	12.5	1	2
	12.8	2	2
	10.0	1	3
	11.0	1	4
	15.2	1	2
	17.2	2	2
	12.8	1	5
	15.0	2	5
	13.1	2	2
10-Dec-91	16.0	2	2
	15.1	2	2
	9.8	1	2
	9.2	1	2
	15.1	1	2
	12.9	2	2
	11.3	1	2
	11.8	2	2
	15.0	2	2
7-Jan-92	14.8	2	3
	16.9	2	4
	15.7	1	4
	12.1	2	3
	14.0	1	3
	14.7	1	4
	13.0	1	3
	12.9	1	3
	11.5	1	3
	12.1	2	4

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 12.5 San Pablo Bay

Date	Length	Sex	Stage
5-Feb-92	10.8	2	4
	11.9	2	3
	10.0	2	3
	12.3	2	3
	9.8	2	4
	12.6	1	4
	10.1	1	4
	9.7	2	4
	10.1	1	4
4-Mar-92	11.0	2	4
	10.2	1	3
	11.1	2	3
	10.7	2	3
	11.3	1	4
	10.1	1	3
	14.5	1	3
	13.6	2	3
	12.3	1	3
8-Apr-92	12.5	1	4
	9.5	2	3
	10.2	1	4
	8.3	1	3
	8.4	2	3
	7.0	2	3
	9.5	1	3
	8.8	2	4
	9.0	1	3
	8.2	2	3
28-May-92	10.8	2	5
	12.8	1	5
	10.5	2	4
	8.1	1	4
	10.8	2	4
	11.7	1	3
	11.0	1	4
	10.6	2	4
	11.9	2	4
	8.8	1	3

Date	Length	Sex	Stage
28-Jul-92	13.3	2	5
	11.2	2	5
	14.8	1	5
	12.8	2	5
	14.7	1	3
	12.9	2	5
	13.7	2	5
	10.9	1	5
	9.5	1	5
	12.1	1	5
22-Aug-92	10.8	1	3
	13.5	1	5
	11.1	2	2
	14.3	2	5
	14.8	1	3
	14.7	2	5
	9.6	2	5
	15.2	1	3
	10.9	2	5
	11.8	1	5
14-Oct-92	13.2	1	4
	14.5	2	3
	15.8	2	3
	15.5	1	3
	14.9	2	3
	13.0	2	5
	11.0	1	3
	13.4	1	3
	10.5	1	3
	9.0	1	5
22-Sep-92	13.5	1	5
	16.1	2	4
	15.0	2	3
	11.5	2	5
	12.3	2	5
	11.5	2	3
	12.2	2	5
	12.1	2	4
	12.1	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 12.5 San Pablo Bay

Date	Length	Sex	Stage
2-Nov-92	14.9	2	5
	15.5	2	3
	10.5	1	5
	17.4	1	3
	13.2	1	3
	9.1	2	4
	13.5	2	5
	10.2	2	5
	15.5	2	5
	14.8	2	5
27-Jan-93	16.2	2	3
	15.0	1	3
	16.5	2	3
	17.1	2	3
	18.0	1	4
	10.2	2	3
	13.0	1	3
	11.5	2	3
	11.1	1	4
25-Feb-93	13.1	1	3
	12.6	1	3
	16.2	1	3
	17.3	2	3
	13.1	1	3
	12.3	2	5
	9.3	2	3
	9.8	2	3
	11.2	1	3
	10.2	1	3
30-Mar-93	10.1	1	3
	13.7	2	3
	8.2	2	3
	7.5	1	4
	9.0	1	3
	14.1	2	3
	13.9	2	3
	11.7	1	3
	12.7	2	3
	8.1	1	3

Date	Length	Sex	Stage
15-Apr-93	6.9	1	3
	7.5	1	3
	12.7	1	3
	8.2	2	3
	9.1	1	3
	9.6	1	3
	7.3	2	4
	10.0	1	3
	11.3	2	3
12-May-93	13.8	2	4
	11.2	1	5
	11.4	2	4
	14.8	1	3
	9.6	1	5
	14.0	2	4
	15.2	2	4
	12.8	1	4
	14.3	2	5
	10.8	1	5
15-Jun-93	12.1	2	5
	11.9	2	5
	13.8	2	5
	14.7	2	5
	16.1	1	4
	14.8	1	4
	14.1	1	5
	15.8	1	4
	14.0	1	4
23-Jul-93	11.5	1	5
	17.1	1	4
	16.1	1	3
	16.9	1	4
	14.0	1	4
	12.7	1	4
	14.8	2	5
	10.1	1	5
	8.2	2	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 12.5 San Pablo Bay

Date	Length	Sex	Stage
10-Aug-93	9.5	2	5
	11.3	2	5
	10.9	1	5
	19.8	1	5
	15.1	2	5
	12.0	2	5
	13.0	1	5
	11.9	1	5
	12.0	2	5
	10.8	1	5
8-Sep-93	10.7	0	1
	9.2	1	5
	11.8	0	5
	14.5	1	1
	12.6	0	1
	12.9	2	2
	14.8	1	5
	12.2	0	1
	11.3	2	1
	11.3	1	1
5-Oct-93	10.2	2	2
	12.0	2	2
	9.3	2	3
	12.5	1	2
	10.9	1	2
	11.2	2	1
	10.8	0	1
	11.1	0	1
	13.8	0	1
	10.0	1	1
8-Nov-93	13.5	2	2
	16.7	1	2
	10.2	2	3
	10.1	2	2
	9.2	2	2
	12.0	1	3
	13.2	1	2
	10.8	2	2
	14.8	1	2
	12.5	1	2

Date	Length	Sex	Stage
7-Dec-93	10.7	1	2
	8.9	1	1
	15.1	2	2
	13.2	1	2
	10.8	2	2
	10.5	1	2
	14.5	2	4
	10.6	2	2
	10.9	1	4
	11.1	1	2
19-Jan-94	10.6	2	3
	9.0	2	2
	9.1	1	3
	9.4	2	3
	8.0	2	3
	16.5	2	3
	15.8	2	2
	17.0	1	3
	10.2	1	4
	13.1	2	3
17-Mar-94	12.0	1	3
	11.8	1	3
	11.7	2	3
	13.8	2	3
	10.1	1	3
	11.1	2	3
	10.5	1	3
	7.8	1	3
	13.2	1	3
	14.5	2	3
19-Apr-94	13.1	2	4
	7.5	1	5
	12.0	1	5
	7.8	2	5
	8.9	1	5
	9.1	1	5
	9.5	1	5
	8.5	2	4
	9.3	1	4
	8.9	1	5

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)

Station 12.5 San Pablo Bay

Date	Length	Sex	Stage
17-May-94	10.0	0	1
	8.9	1	2
	10.6	0	1
	11.6	1	2
	9.0	0	1
	1.1	2	2
	11.2	1	2
	11.3	0	1
	10.5	2	2
	11.4	1	5
28-Jul-94	11.5	1	2
	11.3	1	2
	11.0	2	2
	13.5	1	2
	12.0	2	2
	10.8	1	2
	12.1	2	3
	13.3	2	2
	12.5	2	2
	13.2	1	2
30-Aug-94	9.0	1	4
	8.8	1	4
	12.0	2	4
	11.3	1	4
	13.1	2	2
	10.2	2	4
	10.5	1	4
	11.7	2	3
	12.5	1	3
	12.2	1	4
27-Sep-94	12.0	2	3
	11.5	2	3
	13.8	2	3
	12.8	1	3
	12.3	0	1
	10.2	2	3
	10.8	1	5
	14.8	1	3
	14.9	0	1

Date	Length	Sex	Stage
26-Oct-94	9.9	2	4
	9.7	1	4
	10.4	1	5
	9.2	2	4
	11.0	1	3
	10.7	2	4
	12.1	1	4
	11.2	0	1
	12.2	1	5
	13.7	1	4

Sex: 1=Male, 2=Female. Stage: 1= Inactive, 2=active, 3=Ripe, 4=Partial Spawn, 5=Spent, 0=Undefined (See Text)