PACIFIC HERRING, *Clupea pallasi*, STUDIES AND FISHERY MANAGEMENT IN TOMALES BAY, 1992–93, with Notes on Humboldt Bay and Crescent City Area Landings

by Thomas O. Moore *and* John J. Mello

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PACIFIC HERRING, *Clupea pallasi*, STUDIES AND FISHERY MANAGEMENT IN TOMALES BAY, 1992–93,

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ABSTRACT

The 1992–93 spawning biomass estimate for Pacific herring, *Clupea pallasi,* in Tomales Bay increased for the fourth year in a row to 4,078 tons. This is the highest estimate since the 1986–87 season. The December spawning biomass total of 1,346 tons was the second highest December escapement total since surveys began in 1972–73.

A total of 3.58 million m^2 of eelgrass, *Zostera marina*, was measured in Tomales Bay this season. Eelgrass density increased in the majority of beds.

The commercial catch of 222 tons was taken entirely from Tomales Bay since outer Bodega Bay was closed to herring fishing during the season. Gill net mesh size was increased to 2.125 inches from 2.0 inches this season. Herring aged 4, 5, and 6 comprised 92% by number of the season's herring catch. Mean weight of herring for each age decreased while mean length for all ages combined increased slightly.

Tomales Bay herring samples indicated that older year-classes, missing in commercial catch samples, were present prior to the January start of the commercial fishery. The abundance of 4-yr-old herring was low in samples from variable-mesh and commercial gill nets, indicating less than average recruitment of the 1989 year-class.

In Humboldt Bay the 1992–93 season commercial herring catch totalled 28.6 tons, less than half of the 60-ton quota. Crescent City area herring fishermen nearly caught their 30-ton quota with a total of 28.5 tons landed. No spawning biomass estimate is available for the 1992–93 season for either area.

INTRODUCTION

Since 1973, the California Department of Fish and Game has estimated the annual spawning biomass of Pacific herring, *Clupea pallasi*, in Tomales Bay, as well as the age, length, and sex composition of the herring catch for the area's roe fishery. Biomass estimates are derived from estimates of the number of herring eggs deposited during the spawning season. California bays where herring spawn are relatively small and well suited for intensive spawning-ground surveys.

This report includes the spawning biomass estimate, biological characteristics, and landing statistics for the 1992–93 Pacific herring spawning season in Tomales Bay. Landing statistics are also reported for the Humboldt Bay and Crescent City area roe herring fisheries.

DESCRIPTION OF STUDY AREAS

Tomales Bay

Tomales Bay (Figure 1) lies in Marin County, north of San Francisco. It is 20 km (12.4 mi) long and averages 1.5 km (0.9 mi) wide. The predominant flora in the bay is eelgrass, *Zostera marina*, (Hardwick 1973) which is surveyed annually for its distribution (Figure 1). Herring spawn primarily on eelgrass, but other species of marine flora (e.g. *Gracilaria*, *Phylospadix*, *Ulva*) are utilized to a much lesser extent. Herring may also spawn on substrates other than plants in this bay including bare rocks and pier pilings in the intertidal and subtidal zones.

Humboldt Bay

Humboldt Bay is California's northernmost embayment, 129 km (80 mi) south of the Oregon border. Humboldt Bay has an unusual shape, with the northern and southern ends broadened into shallow mud flats that are interspersed by tidal drainage channels. These mud flats, which are exposed on most minus tides, support vast areas of eelgrass covering an estimated 13 million m^2 (Harding and Butler 1979). The general distribution of eelgrass in north Humboldt Bay has not changed since 1979. Herring utilize both the north and south ends of the bay, but surveys found most spawning to occur in the northern end (Rabin and Barnhart 1986).

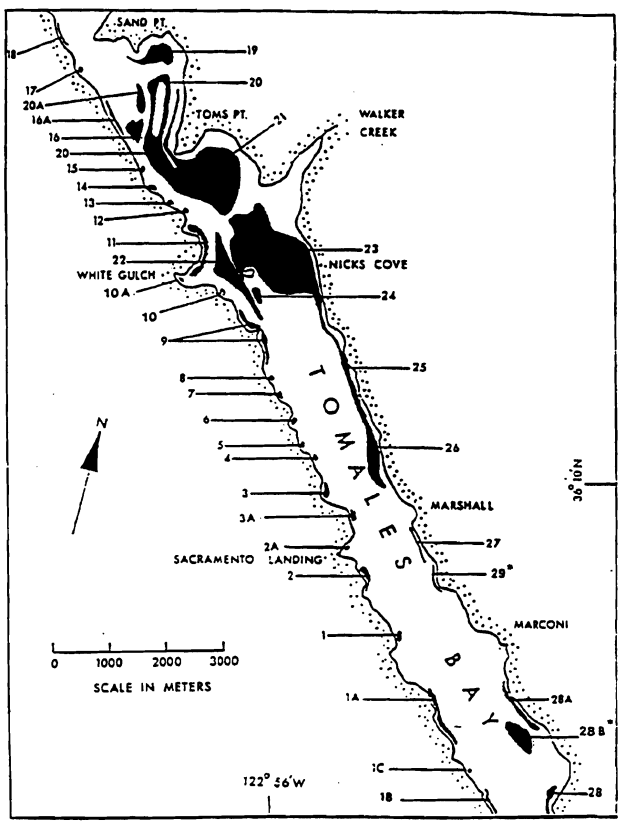

FIGURE 1. Tomales Bay with numbered vegetation beds. All beds are eelgrass except where (*) indicates *Gracilaria* spp.

Crescent City Area

The Crescent City harbor breakwater and all rocky areas and kelp beds to the south near the harbor provide spawning habitat. Elk Creek discharges into the harbor embayment providing a source of fresh water and locally depressing salinities during significant rainfall. Most fishing takes place in the area around the commercial boat marina.

METHODS

Tomales Bay

Spawning-Ground Surveys

Spawning-ground surveys were conducted from 13 November 1992 to 29 March 1993. As in the previous year, sampling frequency was reduced from daily to 3 or 4 days per week due to project budget restrictions. We inspected eelgrass beds (Figure 1) for evidence of spawn from a 5.2 m (17 ft) boat.

Spawn deposition area and density of spawn was determined by dragging a vegetation sampler (rake) through eelgrass beds to collect samples at random locations. The number of samples taken per bed (minimum of four) varied with the size of the bed, and at least 10 g of eelgrass with eggs were collected per sample. When the perimeter of the spawn was found, the location was marked by dropping an anchored float as a reference point. Measuring between floats with an optical range-finder provided linear measurements that were used to calculate spawning area.

Processing of spawn samples was unchanged from previous seasons (Spratt 1981). Herring eggs were removed from the eelgrass blades and counted or estimated by weighing (ca. 750 eggs/g) to the nearest 0.1 g. The eelgrass was then reweighed to the nearest 0.1 g to obtain the number of eggs per unit weight of eelgrass.

The density of eelgrass for beds with 100% bottom cover was estimated using a multiple linear regression between eelgrass blade measurements (length and width) and density (Spratt 1989):

$$Y = a_l(\text{length}) + a_w(\text{width}) + B$$

where:

Y = kg eelgrass per m^2
a_l = slope of regression for blade length
a_w = slope of regression for blade width
B = Y intercept.

During December and January, eelgrass blade length and width measurements were taken from eelgrass samples collected from the project's boat with a vegetation sampler. Between 6 and 15 sets of eelgrass blade lengths and widths were collected from 29 of the 37 eelgrass beds in the bay.

Estimated eelgrass densities were adjusted downward if bottom coverage was less than 100%. Percent cover estimates were determined using paper traces from a Lowrance model LRG 1510 recording fathometer. Percent cover estimates were obtained by examining traces for each bed and determining what percentage of the trace exhibited eelgrass.

We remeasured the surface area of 18 eelgrass beds. The perimeter of smaller beds was determined with a recording fathometer, then marked with anchored floats. An optical rangefinder was used to measure distance between floats, and these measurements were used to calculate area. Larger beds were measured by triangulation using known landmarks, or by plotting bed perimeters on navigation charts and calculating the area directly from the chart.

We also estimated the amount of herring eggs deposited on *Gracilaria* spp. beds and in intertidal areas. In previous years the quantity of spawn was not empirically determined for *Gracilaria* beds. However, substantial spawning took place on *Gracilaria* beds this year and therefore we estimated the quantity of spawn using the same techniques to sample eelgrass beds. We measured the area of spawns using an optical rangefinder and anchored floats. Unfortunately, we did not determine the density of *Gracilaria* prior to spawning events and could not subsequently estimate it since densities may change due to foraging by diving birds (Bayer 1980). As a result we used a value (0.5 kg/m^2) presented in the literature (Hansen et al.1981; Hansen 1983).

Spawning in intertidal areas was estimated by measuring the area of spawn and taking random 100-cm^2 samples from rocks or by removing samples of cobble covered with eggs. In the laboratory, the number of eggs per 100 cm^2 was determined for rock, cobble, and gravel substrates by counting or estimating numbers of eggs. Surface area corrections were made for each substrate type.

Biomass Computation In Tomales Bay, the estimated number of herring eggs spawned was converted to tons of spawning adult fish by incorporating sex ratio estimates for each spawning run. The sex ratio of spawning schools was determined from herring caught in multipanel research gill nets. However, we were not able to obtain the sex ratio of all schools either due to an inability to catch herring or because commercial fishing altered the sex ratios. When sex ratio data were not available, an average sex ratio based on previous seasons' data for similar spawn dates was used. The following formula was used to calculate the conversion factor:

$$\text{Conversion factor} = 1 / (F \times f / p \times K)$$

where:

F = fecundity (males and females combined)
f = percent females in a given spawning run
p = percent females in population (assumed to be 50%)
K = 908,000 (grams/short ton).

A fecundity value of 113 eggs/g of body weight (males and females combined) (Hardwick 1973) was used in calculating 1992–93 biomass estimates.

Confidence Limits Confidence limits for herring spawn escapement estimates in Tomales Bay were calculated from variation in the density of egg deposits (Sokal and Rohlf 1969). Each spawning event usually encompassed several small spawning sites and total spawning escapement was the sum of the estimates for each site. The confidence intervals were calculated for most spawn sites individually. In some cases where a large discrete variation in density of egg deposition occurred within an eelgrass bed, separate estimates of spawning within the bed were calculated.

Catch Sampling

Tomales Bay fishery samples were collected at an off-loading site at Marshall. Up to four samples (one per boat) were routinely taken per day from the commercial gill net catch when herring were available. Each sample, consisting of 20 randomly selected herring, was collected from bins or totes after vessels unloaded.

Tomales Bay samples were processed fresh when time permitted and remaining samples were frozen for later processing. Laboratory procedures have remained unchanged since the fishery began in 1973 (Spratt 1981). A 1.0 kg subsample was randomly selected for processing. Each fish in the subsample was weighed to the nearest 0.1 g, measured in body length (BL) to the nearest millimeter, and sex and maturity were determined. Body length was measured from the tip of the snout to the end of the silver pigmentation on the caudal peduncle. Otoliths were removed for age determination and stored in gelatin capsules. Ages were determined from otoliths by the authors using previously determined criteria (Spratt 1981).

Population Sampling

A variable-mesh monofilament-nylon set gill net was used to collect fish for age and sex composition analysis. The gill net was composed of five 10-ft. panels, each with a different mesh size (1.5, 1.75, 2.0, 2.25, and 2.5-inch mesh).

We determined the sex and maturity of all herring captured, measured their body length to the nearest millimeter, and removed otoliths for age analysis.

Length Corrections

Some herring samples from Tomales Bay were frozen before processing. Reilly and Moore (1982) determined that herring shrink when frozen, and developed correction factors for thawed lengths. Based on these corrections, body length for frozen/thawed fish in four size categories was increased as follows:125–155 mm BL, 4 mm; 156–189 mm, 5 mm; 190–224 mm, 6 mm; 225–250 mm, 7 mm.

RESULTS

Tomales Bay

Spawning-Ground Surveys

Of the 37 previously documented eelgrass beds (Figure 1), 34 were located again in Tomales Bay. Spawning was also found in two *Gracilaria* spp. beds: one south of Reynolds and the other south of Marconi Cove.

Twenty-four of the 34 eelgrass beds were remeasured this season, but the total area for all beds remained about the same as last year (Table 1).

Vegetation Density Estimates The relationship between eelgrass density and blade length and width for the 1992–93 season was:

$$\text{Density (kg/m}^2) = 0.002177(l) + 0.0765(w) - 1.1810,$$
$$r^2 = 0.61.$$

The majority of eelgrass beds increased in density (Table 2). However, over one-half the 1992–93 herring spawning occurred in eelgrass beds that had decreased in density.

Spawning Biomass Five distinct periods of spawning activity, involving 10 separate eelgrass beds, occurred during the 1992–93 season. The first spawning occurred 3 December 1992 at eelgrass beds 1A, 1B, 1C, and 28 (Figure 1 and Table 3). The season's second largest spawn took place on 28 December 1992, again at eelgrass beds 1A,1B, and 1C (Table 3). The December spawning biomass total of 1,346 tons was the second highest for that month since surveys began in 1972–73.

Several small spawns occurred as the fishery proceeded in early January (Table 3). At midmonth, herring spawned again and, although a large school of herring remained in the Bay, no further January spawning was detected.

The largest spawn of the season occurred on 6 February 1993 and covered nine separate eelgrass beds, one *Gracilaria* spp. bed, and an intertidal area near Marconi Cove (Figure 1, Table 3). The season's last spawn occurred on 28 February 1993. The total season's spawn escapement estimate (does not include catch) for Tomales Bay was 3,857 tons (Table 3).

No hydroacoustic surveys were attempted in outer Bodega Bay during the 1992–93 season. Additionally, outer Bodega Bay was closed to herring fishing so the catch was composed entirely of fish from Tomales Bay (Table 4). The 1992–93 spawning biomass estimate of 4,078 tons in Tomales Bay was the highest for the Tomales area in the past five seasons (Table 5).

Confidence Limits The 95% confidence intervals for the 1992–93 season were broad for smaller spawns due to the very light and patchy distribution of spawn (Table 6). However, confidence intervals were narrower (<51% of the estimate) at eight of the larger spawn sites which accounted for over 85% of the spawn escapement.

Catch Sampling

A total of 295 herring from commercial catches was measured and sexed this season. Of that total, 176 herring from 18 samples were collected and processed for age and weight determination.

Age Composition The dominant age groups this season were once again 4 through 6, comprising 92% (84% last year) by number and 91% (85% last year) by weight of the Tomales Bay commercial gill net catch (Table 7). Age groups 4 through 7 comprised over 99% (90% last year) of the catch. The number of 4-yr-old herring, an indicator of recruitment, decreased to 15% (26% last year) of the catch by number (Table 7).

Length Composition The average length of herring in the 1992–93 commercial gill net catch was 194 mm, the same as last season (Table 8). However, the length of 4- through 6-yr-old herring (Table 9) decreased an average of 2 mm from the 1991–92 season (Spratt and Moore 1992). While all fish were shorter at a given age, an increase in numbers of older and larger 5- through 7-yr-old herring coupled with fewer 3- and 4-yr-olds (16%) compared with the 1991–92 season (36%) kept the mean length for all ages combined unchanged (Table 8).

Weight Composition Mean weights-at-age of the three dominant age groups in this season's catch from Tomales Bay ranged from 1 g below the long-term mean for 6-yr-olds to 5 g below the long-term mean for 4-yr-olds (Table 10). The weight-at-age of 7-yr-olds, the only older age group, was also below average. Very low numbers of 3-yr-old herring and a complete lack of 8- and 9-yr-old herring dropped the 13-yr combined unweighted mean to the second lowest value since the 1979–80 season (Table 10).

Sex Ratio Female to male number and weight ratios in the commercial catch were nearly equal, at 1:0.84 and 1:0.88, respectively. The percent of females in the catch was 54% by number and 53% by weight. Catch sex ratios of over 60% female are high, and indicate good roe recovery during the season.

Population Sampling

Spawning occurred in early December but fish did not hold in the Bay prior to spawning and were not sampled. A large school of herring spawned on 28 December 1992, and we were successful in obtaining a sample (Table 11). Another small sample was obtained on 25 January from a different school. Our final variable-mesh gill net sample was obtained after the commercial fishery had been closed from a new school on 22 February.

Sex and Length Composition Mean body length for research gill net-caught herring was 188.1 mm; lengths were greatest in January 1993, and smallest in December 1992 (Table 11). Sex ratios were about even in January 1993, but catches were male-dominated in December and February. Reilly and Moore (1985) found that herring schools in San Francisco Bay were male-dominated in November and December, about even by mid-January, and were female-dominated in February and March. Additionally, body length was greatest in November and December for San Francisco Bay schools and typically decreased throughout the rest of the spawning season.

Age Composition We captured a total of 689 herring , of which 164 herring between 161 mm and 220 mm were used for aging (Table 12). The dominant age class was 5-yr-olds, comprising 26% of the sample by number (Table 13). Age-class three, while not dominant this season, comprised a slightly lower percentage of the total age composition than was observed in the previous two seasons. Older age

classes (8 and 9), which were not present in 1991–92 samples, were present in 1992–93 and comprised less than 3% of the total number of herring aged (Table 13).

Fisheries

Tomales Bay

The season opened with an initial 120-ton quota at sunset on Sunday, 3 January 1993. About 80 tons of herring were landed on 4 January 1993 (Table 14). Roe recovery for landed herring was less than the 10% dealer minimum and fishermen voluntarily stopped fishing to allow the herring to ripen. Fishing resumed on 10 January and approximately 66 tons of herring were landed by 12 January. A total of about 146 tons, 26 tons over quota, was landed and the fishery closed on 11 January (herring recovered from a fishing vessel that sank were landed on 12 January).

Herring landed on 11 and 12 January (Table 14) had comparatively low roe counts for Tomales Bay. Typically, roe counts have averaged over 12% in the preceding eight seasons (Table 15). During the period from 4 January until fishing resumed on 10 January, many tons of unripe herring entered the Bay and joined the school that had been fished. In the past, unripe herring have proved to be uncatchable by fishermen in Tomales Bay.

The regulations for the season allowed for an additional quota of 80 tons of herring (200-ton total quota) if the spawning biomass reached 2,000 tons by 31 January 1993. As the end of January approached, the total spawning biomass was about 1,900 tons. Hydroacoustic surveys showed that a large school was in the Bay and that when it spawned the 2,000-ton threshold would easily be exceeded. In addition, research gill net catches obtained near the end of the month indicated that the roe count would exceed 10%.

The fishery reopened at 0600 hrs on 26 January, for the remaining 54 tons of the 80-ton additional quota. Fishing was slow during the daytime but improved after dark. An announcement was made at 2300 hrs to close the fishery at 0200 hrs on 27 January. About 76 tons, with an average roe count of 15.9%, were landed by 27 January (Table 14). The overall 200-ton quota was exceeded by 22 tons.

Humboldt Bay

The Humboldt Bay roe fishery opened on 2 January 1993 with a 60-ton quota. A delayed crab season opening caused a delay in herring fishing. The first landings were made on 19 January, when approximately 7 tons of herring with an average 10.2% roe count were delivered (Table 16). Fishermen landed herring on 18 days during the season for a total of 28.6 tons. Fishermen felt that if they had begun fishing in early January when a large school of herring was present in Humboldt Bay they might have caught the quota. In each of the previous three seasons fishermen have caught the 60-ton quota (Table 17).

Crescent City Area

The Crescent City area roe fishery opened on 15 January 1993 with a 30-ton quota. The first landings were made on 16 January with over 17 tons of herring landed (Table 18). Four additional days were fished and a season total of 28.5 tons of herring was landed. In only one year out of the previous eight years have fishermen failed to catch the quota (Table 19).

DISCUSSION

Spawning-Ground Surveys

Tomales Bay

Spawing biomass estimates in Tomales Bay have increased in each of the past four seasons, three of which were closed to herring fishing (Table 5). The increase in biomass could be linked to reduced fishing mortality.

Full recovery of the Tomales Bay herring spawning stock will depend on rebuilding the population through successful reproduction and/or recruiting herring to Tomales Bay that may or may not have previously spawned there. The reduced spawning biomass in Tomales Bay from the 1986–87 to 1991–92 spawning seasons was most likely due to reduced freshwater inflow because of the 1987–92 drought. Rainfall in the Tomales Bay watershed during winter of 1992–93 was approximately 38 inches and was near normal.

Examination of spawn events in relation to rainfall and high tides (tides greater than +5.0 ft), revealed that for five of the eight recorded spawns, rainfall greater than 0.1 inch (significant rainfall) had fallen at the time of the spawn (Figure 2). High tide was a factor along with significant rainfall in two of the five rainfall-related spawns and seemed to be the primary factor in two additional spawns. The apparent correlation of spawning events with high tide and rainfall was also documented in San Francisco Bay

(Reilly and Moore 1985), although heavy rainfall and periods of greatly reduced salinities (<12 ppt) seemed to inhibit spawning in San Francisco Bay (Reilly and Moore 1983). In central to upper Tomales Bay there were short periods of time (< 5 days) when a lens of fresh water, up to 15 ft in depth, overlayed more saline Bay waters. Hydroacoustic surveys in Tomales Bay showed that herring did not venture into this layer and remained in the more outer portion of the Bay that did not exhibit this stratification.

The periods of greatly reduced salinities seemed to do little in delaying spawning and in fact seemed to initiate spawning this season, but the effect on Tomales Bay herring egg survival and hatching success remains unknown. Alderdice and Velsen (1971) found that Canadian herring eggs and sperm can tolerate salinities in the range of 8–28 ppt. A number of spawns (Figure 2) were followed by periods of significant rainfall during the 10 to 12-day hatching period for herring eggs in Tomales Bay.

The major source of freshwater input to Tomales Bay is Lagunitas Creek at the upper end of the Bay. Since the low-rainfall years of 1987–92, spawning has shifted to eelgrass beds at the upper end of the Bay (Figure 3) which became less saline with runoff in the upper Bay watershed. The 1992–93 season was the first season since 1985–86 in which Nicasio Dam overflowed into Lagunitas Creek. The return to a more normal winter weather pattern may explain the increase in spawning biomass and the shift in spawning to more centrally-located eelgrass beds (Figure 3).

This season's December spawning biomass total (1,346 tons) was the second highest since surveys began in the 1973–74 season (Table 20). The highest December spawning total was 2,004 tons for the 1976–77 season. Both of these events followed a drought and occurred during an El Niño.

Another seemingly El Niño-related event is the dramatic increase in biomass during the 1992–93, 1982–83, and 1976–77 seasons (Figure 4). Each of these increases occurred in an El Niño year. The magnitude of recovery of the Tomales Bay herring stock (4,078 tons) could be related to this apparent effect. The 1992–93 biomass total is less than the 20-yr average biomass of 4,835 tons but is higher than the 11-yr (post 1982–83 El Niño) average of 2,793 tons (Table 20).

Equally dramatic has been the decrease in Tomales Bay biomass following these "El Niño increases" (Figure 4 and Table 20). Confusing the issue further is the fact that the current El Niño has lingered. Typically, the conditions that define an El Niño, oceanic warming and lack of upwelling, decrease in intensity after a year or two. How three years of El Niño conditions will affect the Tomales Bay biomass is uncertain at this time.

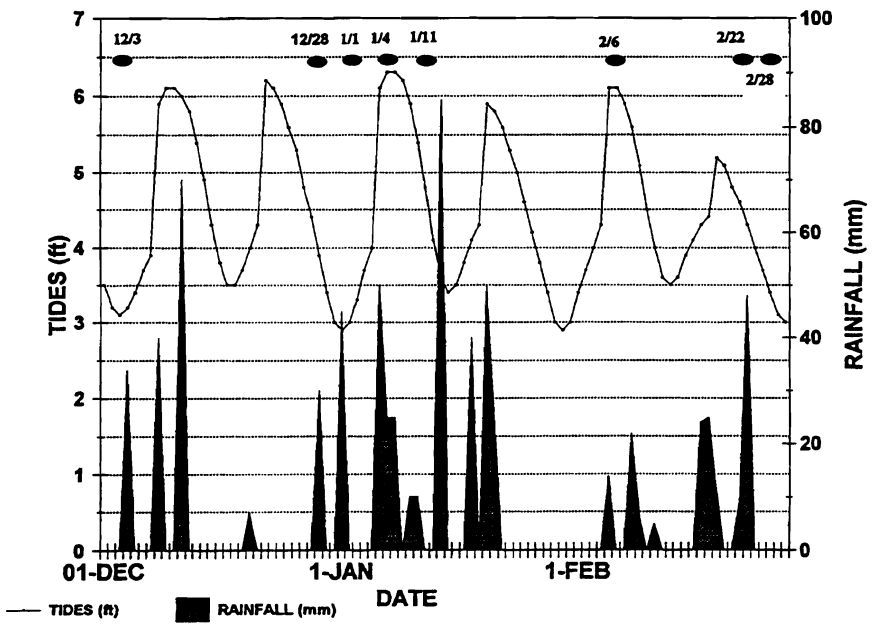

FIGURE 2. High tides, rainfall, and Pacific herring spawning events in Tomales Bay, 1992–93.

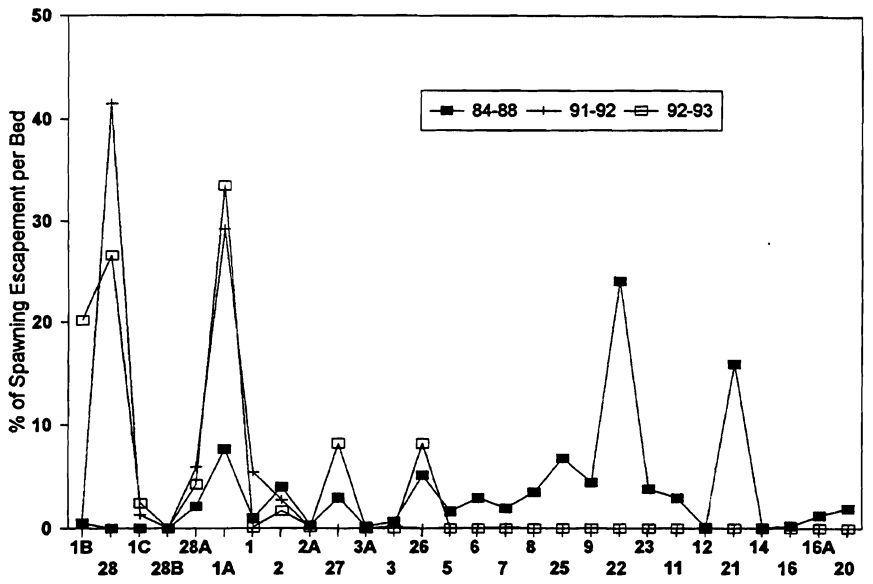

FIGURE 3. Average spawn escapement per eelgrass bed in Tomales Bay expressed as percent of season total.

Fishery

Tomales Bay

Three significant changes were made to the regulations concerning herring fishing for the 1992–93 season in Tomales Bay. The first of these changes increased the mesh size to 2.125 inches from 2.0 inches. The second change limited each permittee to fishing just one shackle of net (65 fm) instead of two. The last change allowed two permits to be fished simultaneously from one vessel.

The increase in mesh size brought Tomales Bay gill net mesh size up to the same size as that used in the San Francisco Bay herring fishery. Previously only 2.0-inch mesh had been used in the Tomales and outer Bodega Bay herring fisheries. The effect of this change would be to increase the take of larger, older herring in the commercial fishery. The use of smaller diameter (stretchier) monofilament in recent years has allowed fishermen to use smaller-sized (i.e. illegal) mesh due to enforcement problems.

Crowding of boats and gear has been a long-standing problem on Tomales Bay. The last attempt at addressing this problem was in 1983, when Tomales Bay permittees were given the chance to move permanently to the San Francisco Bay herring fishery. Currently, the total number of Tomales Bay permittees is 40. Reducing the number of nets per permit and allowing two permits per boat made management of the fishery with small quotas easier, since the pace of fishing was slowed down. The response by fishermen has been overwhelmingly positive, since damage to nets and lost fishing time has been greatly minimized. Average pounds per trip was also the highest in the last nine seasons (Table 8).

The commercial catch of 222 tons of herring represents an exploitation rate of only 5.5%. Exploitation rates have averaged 13% since the 1973–74 season with only three years above this average (Figure 6). The 120-ton initial quota was based on a below- average exploitation rate of 10% of the previous year's spawning biomass of 1,214 tons. The additional 80-ton quota was made available only after spawning biomass reached 2,000 tons in order to keep the exploitation rate at 10% or less.

Humboldt Bay

The commercial catch of 28.6 tons was only 48% of the 1992–93 season quota of 60 tons and less than the 20-year average catch for Humboldt Bay (39.3 tons) (Table 10). The 60-ton quota for Humboldt Bay represents a 20% exploitation rate if the spawning biomass is approximately 300 tons. The long-term average catch would approximate a 13.1% exploitation rate.

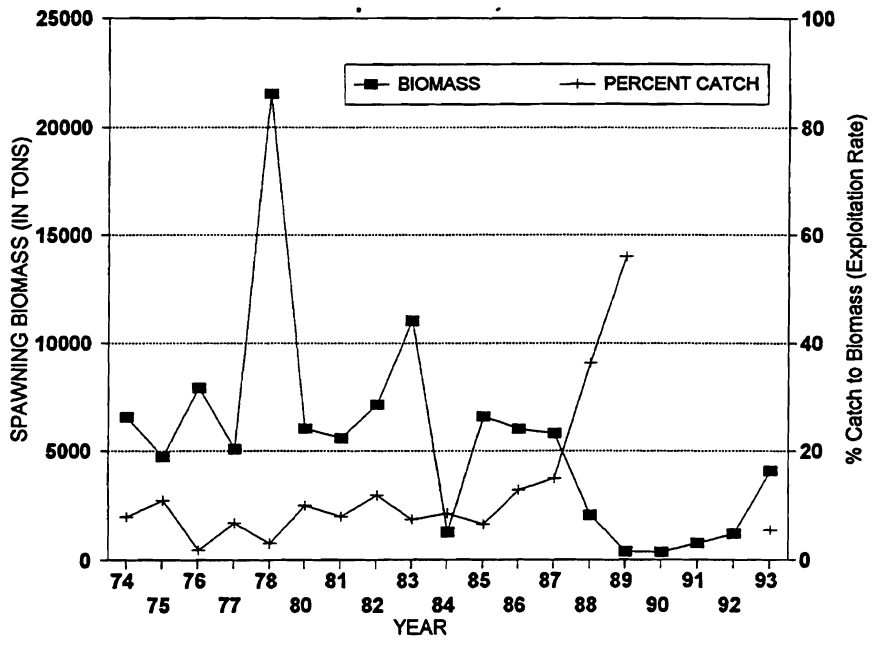

FIGURE 4. Pacific herring spawning biomass and exploitation rates, Tomales Bay, 1974–93.

Crescent City

The commercial catch of 28.5 tons was 95% of the season quota for the Crescent City area and was greater than the 20-year average for this area (23.7 tons) (Table 12). Spawns in the Crescent City harbor were sampled in the 1977 and 1978 seasons, with conservative spawn-escapement estimates of 139.4 tons and 127.2 tons, respectively (Patrick Collier, pers. comm.). A 30-ton quota, representing an approximate 20% exploitation rate, was set using the 133-ton average of the Crescent City harbor spawn escapement estimates.

Catch Sampling

Spawning biomass in Tomales Bay declined to a historic low of 167 tons in the 1988–89 season (Spratt 1989). Since then, it has increased to 3,857 tons in the 1992–93 season. During this time, Tomales Bay was closed to herring fishing from 1989–90 through the 1991–92 season, and catch data were obtained from the outer Bodega Bay herring fishery. However, it is possible that herring caught in outer Bodega Bay may be from a separate stock and that catch data from the previous four seasons may not be representative of Tomales Bay herring. However, no comparative commercial fishery data were available from Tomales Bay to evaluate this possibility.

In the previous two seasons an increase in the number of 4-yr-old herring was seen in the outer Bodega Bay commercial catch. However, the 1989 year-class of 4-yr-olds was weakly represented in the 1992–93 Tomales Bay commercial catch (Table 13). Offsetting the low abundance of 4-yr-olds was the strong 1988 year-class (5-yr-olds). The percentage of 7-yr-olds in the catch, which represented a fairly strong year-class two years earlier, was similar to the previous season.

Population Sampling

A different picture of the Tomales Bay herring spawning population is seen when the variable-mesh gill net catch is examined. A more balanced population structure is found in samples from a wider time range (December through March) (Table 19). The age composition of these samples suggests good recruitment throughout the drought years, except for the 1989 year-class of 4-yr-old herring.

The age composition of variable-mesh gill net samples for the 1991–92 season (Table 19) shows a reduced contribution by 6- and 7-yr-olds, with 8- and 9-yr-olds missing. However, this was based on a small sample from one mid-season school. This suggests the need to sample herring from schools throughout the entire spawning season when trying to assess the age structure of the Tomales Bay herring spawning population.

A relatively low percentage of 2-yr-old herring were caught again this season. While this could be due to poor recruitment, the high percentage of 3-yr-old herring in the sample may indicate that in some years recruitment is not complete until age three. It is possible that 2-yr-olds were underrepresented in samples, since younger herring are more prevalent later in the spawning season. We did, however, sample a late-season school.

CONCLUSIONS

Tomales Bay

The Tomales Bay herring spawning biomass estimate rebounded to predrought levels during the 1992–93 season. The estimate was above the 10-yr average but was still lower than the 20-yr average of 4,800 tons. The 1992–93 season marked the fourth consecutive year of increasing spawning biomass since the low in 1988–89.

The mechanism responsible for the increase in spawning escapement is unknown. Good recruitment could be responsible for some of the increase since population sampling indicates that recently only the 1989 year-class was weakly represented. However, the biomass of age 5 and older herring exceeds the entire previous season's biomass. Movement of herring from other spawning areas to Tomales Bay would explain a large portion of the increase in spawning biomass in 1992–93.

The Department has proposed a herring quota increase from 120 tons to 300 tons for the 1993–94 season. The quota was set conservatively at less than 10% of the estimated 1992–93 spawning biomass in Tomales Bay. The low harvest level (7.4%) was selected for three reasons. First, while the stock appears to have recovered, more than one spawning season of near long-term average biomass levels is needed to demonstrate full recovery. Second, while the 1992–93 spawning season saw higher than normal rainfall and highly reduced Bay salinities, there is no guarantee that these optimal conditions for herring spawning will persist next season. Third, Tomales Bay biomass has historically peaked in El Niño years and has declined considerably in the season following El Niño.

Provisions for 100-ton incremental catch quota increases are also proposed but only if Tomales Bay spawning biomass demonstrates continued recovery and reaches 3,000 tons prior to February 15, 1994.

Humboldt Bay

Humboldt Bay herring spawning biomass averaged over 300 tons in the 1990–91 and 1991–92 seasons and appears large enough to support the existing 60-ton quota. The 1992–93 season's reduced catch resulted from a late start of fishing rather than reduced abundance of herring.

Crescent City

The Crescent City area herring biomass appears sufficient to support the existing 30-ton quota.

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TABLE 1. Tomales Bay eelgrass bed measurements, 1992-93 season.

Bed No.	Area m^2	Season Last Surveyed	Bed No.	Area m^2	Season Last Surveyed
1	6,577	1992-93	12	1,343	1992-93
1A	41,498	1992-93	13	165	1992-93
1B	17,979	1992-93	14	1,420	1992-93
1C	1,372	1992-93	15	0	1989-90
2	8,949	1992-93	16	4,500	1990-91
2A	557	1992-93	16A	7,800	1989-90
3	973	1992-93	17	2,000	1989-90
3A	0	1992-93	18	0	1989-90
4	0	1992-93	19	38,000	1989-90
5	4,514	1992-93	20	135,500	1989-90
6	9,363	1992-93	20A	33,400	1989-90
7	6,838	1992-93	21	1,488,000	1990-91
8	3,595	1992-93	22	140,000	1990-91
9 North	8,626	1992-93	23	1,209,000	1990-91
9 South	14,409	1992-93	24	49,967	1992-93
10	2,287	1992-93	25	83,269	1992-93
10A	0	1992-93	26	110,208	1992-93
11 North	20,746	1992-93	27	23,556	1992-93
11 Middle	3,246	1992-93	28	73,603	1992-93
11 South	2,128	1992-93	28A	22,977	1992-93
TOTAL AREA = 3,578,365 m^2					

Table 2. Eelgrass density estimates (kg/m²) for most of Tomales Bay eelgrass beds, calculated from multiple regression.

BED NO.	DENSITY OF BED				% CHANGE
	1989-90	1990-91	1991-92	1992-93	91-92 vs.92-93
1	1.67	0.88	1.39	1.17	-19
1A	1.44	1.99	1.85	1.62	-14
1B	2.03	2.10	1.94	1.52	-28
1C	1.41	1.61	1.24	1.51	18
2	1.61	1.46	1.63	1.46	-12
2A	No data	No data	No data	1.25	*
3	1.23	1.11	0.93	1.21	23
3A	No data	0.77	No data	Not present	*
4	0.93	1.22	No data	Not present	*
5	1.24	0.69	0.34	1.42	76
6	1.04	1.08	0.60	0.84	29
7	1.24	1.13	1.17	0.82	-43
8	1.33	No data	0.48	0.94	49
9 North	1.46	0.83	0.72	1.02	29
9 South	1.18	0.83	0.92	0.58	-59
10	2.06	1.45	1.09	0.76	-43
10A	No data	0.94	1.19	Not present	-100
11	1.19	1.07	0.95	0.71	-34
12	1.16	No data	1.03	1.01	-2
13	No data	No data	No data	0.52	*
14	0.68	No data	0.47	0.53	11
15	No data	No data	0.44	Not sampled	*
16	1.76	1.09	No data	1.92	*
16A	2.03	No data	0.83	2.07	60
17	1.59	1.17	2.16	Not sampled	*
18	0.00	No data	No data	Not sampled	*
19	1.79	No data	No data	Not sampled	
20A	0.86	0.43	No data	Not sampled	*
21	2.78	0.96	1.18	1.84	36
22	1.98	1.99	2.08	1.58	-32
23	1.75	0.98	1.35	1.53	12
24	1.28	1.83	1.86	2.01	7
25	1.55	No data	0.14	0.59	76
26	1.47	0.63	0.30	0.96	69
27	1.11	2.07	0.72	1.81	60
28	1.35	1.91	1.09	1.54	29
28A	1.83	2.08	1.17	1.51	23
30	No data	No data	No data	1.05	*
AVERAGE PERCENT CHANGE:					+8

TABLE 3. Tomales Bay herring spawn data, 1992-93 season.

Date	Location	Area	Eggs/m^2	Millions of eggs	Conversion Factor X 10^{-8}	Tons
03 Dec 92	1A	41,498	160,700	6,620	1.21	80.69
03 Dec 92	1B	17,277	157,066	2,710	1.21	32.84
03 Dec 92	1C	1,372	104,969	143	1.21	1.74
03 Dec 92	28A	3,840	20,634	79	1.21	0.96
28 Dec 92	1A	41,498	1,392,478	57,800	1.21	699.20
28 Dec 92	1B	17,277	2,230,309	38,500	1.21	466.25
28 Dec 92	1C	1,372	1,768,261	2,406	1.21	29.36
28 Dec 92	1	6,170	474,487	2,930	1.21	35.42
04 Jan 93	2	8,849	336,169	3,010	0.966	29.06
04 Jan 93	2A	557	933,629	520	0.966	5.02
11 Jan 93	26-South	4,211	17,303	73	0.966	0.70
11 Jan 93	26-North	15,919	13,574	216	0.966	2.09
11 Jan 93	27	23,556	1,132,022	26,700	0.966	257.59
11 Jan 93	*	5,040	375,012	1,890	0.966	18.26
11 Jan 93	**	11,903	282,448	3,362	0.966	32.48
06 Feb 93	1A	41,498	1,276,652	53,000	0.966	511.77
06 Feb 93	1B	17,277	1,671,953	29,000	0.966	279.04
06 Feb 93	1C	1,372	4,795,795	6,580	0.966	63.56
06 Feb 93	1	6,170	44,400	274	0.966	2.65
06 Feb 93	2-High	3,691	877,321	3,240	0.966	31.28
06 Feb 93	2-Low	4,633	429,670	664	0.966	6.41
06 Feb 93	26-North	5,418	22,935	124	0.966	1.20
06 Feb 93	26-South	4,211	70,598	297	0.966	2.87
06 Feb 93	27	23,556	191,123	4,502	0.966	43.49
06 Feb 93	28	59,534	1,600,061	95,300	0.966	989.30
06 Feb 93	28A-High	9,947	1,647,989	16,400	0.966	158.35
06 Feb 93	28A-Low	11,748	62,313	732	0.966	7.07
06 Feb 93	***	1,730	470,156	813	0.966	7.86
06 Feb 93	****	7,880	547,532	4,315	0.966	41.68
22 Feb 93	1A	41,498	789	33	0.966	0.32
28 Feb 93	26	14,939	2,504	37	0.966	17.16
28 Feb 93	27	23,556	75,394	1,776	0.966	0.36
28 Feb 93	*****	100	350,000	35	0.966	0.34
	TOTAL	479,097		364,081		3,856.37

* Intertidal spawn at intermittent locations between Reynolds and Marshall.
** Spawn on Gracilaria bed south of Reynolds.
*** Intertidal spawn south of Marconi Cove.
**** Spawn on Gracilaria bed south of Marconi Cove.
***** Intertidal spawn at Marshall Boat Works.

TABLE 4. Tomales/Bodega Bay Area Herring Biomass Estimates.*

Season	Biomass Estimates		Catch (tons)	Total Tons
	Tomales Bay	Bodega Bay		
1988-89	167	NO SURVEY	213**	380
1989-90	345	350	95**	790
1990-91	779	NO SURVEY	86**	874
1991-92	1,214	NO SURVEY	24**	1,238
1992-93	3,856	NO SURVEY	222***	4,078

* Biomass estimates are from spawning ground surveys in Tomales Bay and hydroacoustic surveys in Bodega Bay.
** Herring catch is from Bodega Bay.
*** Herring catch is from Tomales Bay.

TABLE 5. Pacific herring biomass estimates in Tomales Bay, 1973-74 through 1992-93 seasons.

Season	Spawn Escapement (tons)	Catch (tons)	Spawning biomass (tons)
1973-74	6,041	521	6,562
1974-75	4,210	518	4,728
1975-76	7,769	144	7,913
1976-77	4,739	344	5,083
1977-78	21,513	646	22,163
1978-79	--	448	--
1979-80	5,420	603	6,023
1980-81	5,128	448	5,576
1981-82	6,298	851	7,149
1982-83	10,218	822	11,040
1983-84	1,170	110	1,280
1984-85	6,156	430	6,586
1985-86	435	771	6,000*
1986-87	4,931	867	5,798
1987-88	1,311	750	2,061
1988-89	167	213	380
1989-90	345	--	345
1990-91	779	--	779
1991-92	1,214	--	1,214
1992-93	3,856	222	4,078

* Biomass estimated by cohort analysis; for all other years, biomass was estimated from spawning-ground surveys.

TABLE 6. Confidence limits for Tomales Bay herring spawn estimates, 1992-93 season.

Spawn Date	Location	Std. Error (eggs/m^2)	D.F. n - 1	Estimated Tons	95% Conf. Int.
03 Dec 92	1A	72,357	15	81	36
03 Dec 92	1B	235,829	4	33	51
03 Dec 92	1C	303,181	1	2	5
03 Dec 92	28A	15,015	3	1	1
28 Dec 92	1A	405,165	20	699	202
28 Dec 92	1B	960,036	12	466	209
28 Dec 92	1C	1,202,908	3	29	20
28 Dec 92	1	301,669	4	35	20
04 Jan 93	2	107,952	11	29	9
04 Jan 93	2A	1,805,567	3	5	10
11 Jan 93	26-South	18,078	6	1	2
11 Jan 93	26-North	25,357	4	2	1
11 Jan 93	27	479,437	11	257	129
11 Jan 93	*	163,086	6	18	8
11 Jan 93	**	280,494	3	33	32
06 Feb 93	1A	514,370	15	512	206
06 Feb 93	1B	771,494	15	279	129
06 Feb 93	1C	14,810,595	2	64	196
06 Feb 93	1	55,180	3	3	3
06 Feb 93	2-High	830,313	3	31	30
06 Feb 93	2-Low density	793,430	2	7	36
06 Feb 93	26-North	64,018	2	1	3
06 Feb 93	26-South	79,873	3	3	3
06 Feb 93	27	308,572	5	44	70
06 Feb 93	28	784,564	14	989	451
06 Feb 93	28A-High density	1,002,367	7	158	96
06 Feb 93	28A-Low density	84,750	3	7	10
06 Feb 93	Intertidal28A	266,716	3	8	5
06 Feb 93	*Gracilaria*28A	936,532	3	42	71
22 Feb 93	1A	2,253	5	0.35	0.9
22 Feb 93	26	4,436	5	0.36	0.64
22 Feb 93	27	159,080	7	17	36
22 Feb 93	Reynolds Pier	--	--	Trace	--
TOTAL				3,857	

TABLE 7. Age and weight composition of the Tomales/Bodega Bay gill net catch, 1982-83 through 1992-93 seasons.

	Age (years)							
Season	2	3	4	5	6	7	8	9
1982-83								
% by number	-	-	4	24	34	24	11	3
% by weight	-	-	3	21	33	25	13	5
1983-84								
% by number	-	-	13	36	35	11	2	3
% by weight	-	-	10	34	36	13	3	4
1984-85								
% by number	1	6	13	27	33	15	4	1
% by weight	1	5	11	25	35	17	5	1
1985-86								
% by number	-	14	25	27	18	10	5	1
% by weight	-	11	23	27	20	12	6	1
1986-87								
% by number	-	4	20	38	27	6	3	2
% by weight	-	3	17	37	29	7	4	3
1987-88								
% by number	-	<1	11	31	34	18	4	<2
% by weight	-	<1	9	28	34	21	5	2
1988-89 *								
% by number	-	4	22	33	28	9	3	1
% by weight	-	3	18	30	31	12	4	2
1989-90 *								
% by number	-	2	9	18	37	26	8	-
% by weight	-	2	7	16	36	31	10	-
1990-91 *								
% by number	-	4	21	32	26	12	4	1
% by weight	-	3	17	29	28	15	6	2
1991-92								
% by number	-	10	26	37	21	6	-	-
% by weight	-	8	23	38	24	7	-	-
1992-93								
% by number	-	1	15	47	30	7	-	-
% by weight	-	<1	13	47	31	8	-	-

* The Tomales Bay fishery was closed three seasons and the samples were collected from the outer Bodega Bay catch.

TABLE 8. Mean length of herring from Tomales/Bodega Bay roe fisheries, 1972-73 through 1992-93.

YEAR	MEAN LENGTH (mm BL)	SIZE RANGE	YEAR	MEAN LENGTH (mm BL)	SIZE RANGE
1972-73	186	150-234	1983-84	199	174-242
1973-74	190	146-248	1984-85	202	164-232
1974-75	189	142-236	1985-86	198	166-226
1975-76	184	150-230	1986-87	197	174-236
1976-77	169	140-216	1987-88	201	170-234
1977-78	217	194-248	1988-89	197	170-236
1978-79	*	*	1989-90	204	172-222
1979-80	214	196-236	1990-91	197	174-232
1980-81	208	172-234	1991-92	194	168-214
1981-82	211	176-236	1992-93**	196	166-226
1982-83	208	184-236			

* No field work this season. ** Tomales Bay fishery only, outer Bodega Bay closed.

TABLE 9. Length frequency of the 1992-93 Tomales Bay commercial gill net catch of Pacific herring.

Body Length (mm)	Age 2	3	4	5	6	7	8	9
220								
218								
216						1		
214					1	4		
212				1	2			
210				1		2		
208				3	5	1		
206					4	1		
204				3	11	1		
202				2	2	2		
200				6	1			
198				5	9			
196			1	11	3			
194			1	9	5			
192			2	6	2			
190			1	10	3			
188			4	8	2			
186			3	7	2			
184			7	6				
182			2	3				
180			4	2				
178			1					
176			1					
174		1						
172								
170								
168		1						
n		2	27	83	52	12		
Mean		171.0	185.7	193.5	200.4	210.1		
s.d.		5.7	4.8	7.1	6.9	5.0		

TABLE 10. Mean weight (g) at age of Tomales/Bodega Bay herring in the commercial gill net catch by area and season.

Season	Age 2	3	4	5	6	7	8	9	Unwted. mean*
1979-80	-	-	130	135	137	145	188	-	147
1980-81	-	92	113	131	141	153	161	177	138
1981-82	-	83	116	121	147	158	160	172	137
1982-83	-	-	100	120	132	150	169	172	141
1983-84	-	-	91	106	114	131	141	150	122
1984-85	76	102	109	117	135	151	161	172	128
1985-86	73	94	106	121	137	150	148	162	124
1986-87	-	89	98	113	127	150	165	186	133
1987-88	-	78	94	110	125	146	162	166	126
1988-89	-	88	101	114	134	147	171	192	128
1989-90**	-	88	101	120	133	154	173	-	128
1990-91**	-	85	99	110	129	152	177	191	135
1991-92**	-	87	103	122	135	147	-	-	118
1992-93***	-	83	99	117	130	143	-	-	122
Unwted. mean	74	88	104	118	133	148	165	174	130

* Calculated for ages 4 through 8; they comprise 95% of the samples.
** Catch from outer Bodega Bay only, Tomales Bay closed.
*** Catch from Tomales Bay only, outer Bodega Bay closed.

TABLE 11. Pacific herring mean body lengths and sex ratios from variable mesh gill net catches in Tomales Bay, 1992-93 season.

Date	Mean length (BL mm)	Sex ratio (F/M)
12/28/92	187.0	155/377 (71% M)
1/25/93	199.2	19/18 (49% M)
2/22/93	189.7	52/68 (57% M)
Total	188.1	226/463 (67% M)

TABLE 12. Length frequency of Pacific herring from the 1992-93 Tomales Bay variable-mesh gill net catch.

Body Length (mm)	Age 2	3	4	5	6	7	8	9
220					1	1		
218								
216								1
214					2	3	1	
212					2		1	
210					2	4	1	
208				1				
206					4	2		
204					2			
202				1	4	2		
200				3	5	3		
198				6	4			
196				4		1		
194				4	1			
192				2	1			
190			3	5	3			
188		1		4				
186			5	4				
184			2	3				
182			2	2				
180		2	3	2				
178			3	1				
176		5	2					
174		4	3					
172		6						
170		6	1					
168		4						
166	1	8	1					
164	4	4						
162								
160		1						
n	5	41	25	42	31	16	3	1
Mean	165.0	171.1	181.1	191.5	203.0	207.4	212.3	216
s.d.	1.2	5.3	6.4	6.9	7.4	6.7	2.5	-

TABLE 13. Pacific herring age composition from variable-mesh gill net catches in Tomales Bay, 1990-91 through 1992-93 seasons.

Season	Age (yrs) 2	3	4	5	6	7	8	9
1990-91 % by number	10	32	19	17	17	4	<1	<1
1991-92 % by number	3	31	37	20	6	3	-	-
1992-93 % by number	3	25	15	26	19	10	2	<1

TABLE 14. Daily landings of Tomales Bay gill net fleet, 1992-93 season.

Date	Pounds	Tons	Trips	Lbs/Trip	Roe count
04 Jan 93	159,959	79.98	22	7,271	9.7
11 Jan 93	124,346	62.17	21	5,921	7.2
12 Jan 93	7,546	3.77	1	7,546	6.2
26 Jan 93	4,553	2.28	3	1,518	15.6
27 Jan 93	148,208	74.10	19	7,800	16.0
Total	444,612	222.31	66	6,737	11.1

TABLE 15. Annual landings by the Tomales/Bodega Bay gill net fleet.

Year	Pounds	Tons	Trips	Lbs/Trip	Roe count
84-85	844,472	422.24	215	3,928	12.8
85-86	1,542,676	771.34	512	3,013	12.5
86-87	1,732,428	866.21	429	4,038	12.5
87-88	1,499,402	749.52	484	3,097	12.4
88-89	426,163	213.08	291	1,465	12.7
89-90	190,409	95.23	61	42	13.5
90-91	173,103	86.55	72	2,404	13.7
91-92	47,125	23.56	30	1,571	14.6
92-93*	444,312	222.31	66	6,737	11.1

* Catch from Tomales Bay, outer Bodega Bay closed to fishing.

TABLE 16. Daily landings of Pacific herring by the Humboldt Bay gill net fleet, 1992-93 season.

Date	Pounds	Tons	Trips	Lbs/Trip	Roe Count
19 Jan 93	14,369	7.18	4	3,592	10.2
21 Jan 93	4,264	2.13	4	1,066	
24 Jan 93	116	0.06	1	116	
25 Jan 93	298	0.15	1	298	14.0
28 Jan 93	1,316	0.66	1	1,316	
29 Jan 93	1,630	0.82	1	1,630	
30 Jan 93	2,814	1.41	1	2,814	11.0
31 Jan 93	4,114	2.06	3	1,371	
01 Feb 93	925	0.46	2	463	
02 Feb 93	909	0.45	2	454	
03 Feb 93	319	0.16	1	319	
04 Feb 93	1,855	0.93	2	927	
05 Feb 93	5,611	2.81	2	2,806	
06 Feb 93	13,266	6.63	3	4,422	
07 Feb 93	4,553	2.28	3	1,518	
11 Feb 93	122	0.06	1	122	
14 Feb 93	240	0.12	1	240	
23 Feb 93	470	0.24	1	470	
Total	57,191	28.6	42	1,362	

*Roe count was not obtained on most landing dates.

TABLE 17. Humboldt Bay commercial gill net landings, 1974 to 1993.

Season	Pounds	Tons
1974	4,478	2.2
1975	2,000	1.0
1976	23,134	11.6
1977	42,949	21.5
1978	23,417	11.7
1979	98,831	49.4
1980	98,981	49.5
1981	85,920	43.0
1982	103,280	51.6
1983	18,980	9.5
1984	110,384	55.2
1985	118,734	59.4
1986	119,884	59.9
1987	143,202	71.6
1988	62,480	31.2
1989	87,143	43.6
1990	121,873	60.9
1991	126,769	63.4
1992	123,735	61.9
1993	57,191	28.6
Total	1,573,365	786.7
Average	78,663.8	39.3

TABLE 18. Daily landings of Pacific herring by the Crescent City gill net fleet, 1992-93 season (roe count not obtained).

Date	Pounds	Tons	Trips	Lbs/Trip
16 Jan 93	35,507	17.54	10	3,551
17 Jan 93	2,185	1.09	1	2,185
23 Jan 93	340	0.17	1	340
02 Feb 93	17,398	8.70	5	3,480
06 Feb 93	1,492	0.75	1	1,492
Total	56,922	28.46	18	3,162

TABLE 19. Crescent City commercial gill net landings of Pacific herring, 1974 to 1993.

Season	Pounds	Tons
1973	24,155	12.1
1974	119,043	59.5
1975	25,514	12.8
1976	2,100	1.1
1977	0	0
1978	25,516	12.8
1979	24,772	12.4
1980	52,228	26.1
1981	18,566	9.3
1982	7,772	3.9
1983	50,481	25.2
1984	37,206	18.6
1985	70,979	35.5
1986	70,606	35.3
1987	0	0.0
1988	99,254	49.6
1989	60,357	30.0
1990	66,411	33.2
1991	72,002	36.0
1992	64,601	32.3
1993	56,922	28.5
Total	948,485	474.2
Average	45,166	22.6

TABLE 20. Pacific herring spawn escapement (tons) and percent of total spawn escapement in Tomales Bay, 1973 to 1993.

Season	Dec	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-28	Mar	Total
73-74	551	0	2,186	3,052	250	2	6,041
	9%	0%	36%	51%	4%	1%	
74-75	421	357	2,361	769	168	134	4,211
	10%	9%	56%	18%	4%	3%	
75-76	452	4,557	717	1,929	Trace	117	7,769
	6%	59%	9%	25%	0%	2%	
76-77	2,004	2,031	245	212	41	204	4,739
	42%	43%	5%	4%	1%	4%	
77-78	1,072	2,711	17,243	405	88	0	21,517
	5%	13%	80%	2%	1%	0%	
78-79	NO	FIELD	WORK	THIS	SEASON		
79-80	659	1,164	3,497	100	0	0	5,420
	12%	22%	64%	2%	0%	0%	
80-81	192	1,803	2,300	Trace	20	0	5,135
	4%	35%	45%	0%	1%	0%	
81-82	216	1,161	4,528	39	354	0	6,298
	3%	18%	72%	1%	6%	0%	
82-83	159	1,756	2,807	1,777	3,310	553	10,362
	2%	17%	27%	17%	32%	5%	
83-84	51	308	771	40	0	0	1,170
	4%	26%	66%	3%	0%	0%	
84-85	120	190	5,411	590	45	0	6,156
	2%	3%	88%	10%	1%	0%	
85-86	0	5	195	41	193	0	435
	0%	1%	45%	9%	44%	0%	
86-87	0	130	1,350	1,170	2,281	0	4,931
		3%	27%	24%	46%		
87-88	160	195	956	0	0	0	1,311
	12%	15%	73%	0%	0%	0%	
88-89	2	18	146	0	0	0	167
	1%	12%	87%	0%	0%	0%	
89-90	0	0	345	0	0	0	345
			100%				

TABLE 20 (continued). Pacific herring spawn escapement (tons) and percent of total spawn escapement in Tomales Bay, 1973 to 1993.

Season	Dec	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-28	Mar	Total
90-91	0	54	671	0	50	3	779
	0%	7%	86%	0%	6%	1%	
91-92	150	0	890	163	8	2	1,214
	12%	0%	74%	13%	1%	0%	
92-93	1,346	345	0	2,140	18	0	3,857
	35%	9%	0%	55%	1%	0%	
Ave. 73-93	398	883	2,454	654	359	53	4,835
Ave. %	8.5%	15.4%	54.8%	12.5%	7.9%	0.9%	
Cum. %	8.5%	23.9%	78.7%	91.2%	99.1%	100%	
Ave. 82-93	181	273	1,231	538	537	51	2,793
Ave. %	6.5%	9.8%	44.1%	19.3%	19.2%	1.8%	
Cum. %	6.5%	16.3%	60.4%	79.7%	98.9%	100%	