# PACIFIC HERRING POUND SPAWN-ON-KELP FISHERY

# IN PRINCE WILLIAM SOUND, ALASKA, 1990

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## ABSTRACT

A total of 20 groups comprised of 128 permit holders participated in the 1990 pound spawn-on-kelp fishery for Pacific herring, *Clupea harengus pallasi*. The groups were made up of 2 to 15 permit holders. Each permit holder within a group was responsible for different tasks during the pound fishery. Nineteen of the twenty groups harvested spawn-on-kelp product. The nineteen groups harvested an estimated 268,825.5 lbs (134.4 tons) of spawn-on-kelp product which resulted in a final product weight of 208,809.1 lbs (104.4 tons) of spawn-on-kelp product. The weight loss from harvest weight to final product weight varied from 2.0% to 36.5% within the groups and averaged 22.3% overall. Weight loss varied depending upon how the spawn-on-kelp product was processed. Fifteen of the groups had their spawn-on-kelp processed by the same processor and the overall weight loss was 26.7%. Five groups processed their own spawn-on-kelp product and their overall weight loss was 8.9%. One test pound was selected to be sampled from each of 18 groups during the study. The amount of spawn-on-kelp product produced in the test pounds averaged 2.17 tons. The amount of herring utilized in each test pound during the fishery averaged 27.1 tons based on egg deposition surveys and 22.0 tons based on brailing. The ratio of biomass estimates from egg deposition averaged 1.37 times larger than the brailed biomass estimates. The amount of herring used to produce 1.0 ton of spawn-on-kelp product was 13.3 tons using the egg deposition survey estimate and 10.0 tons using the brailed estimate. Fifty one percent of the herring introduced into the pounds were female. The female herring had a mean weight of 133.9 g and mean fecundity of 20,524 eggs. It was estimated that 38.5% of the female herring introduced into the pounds did not deposit all their eggs in the pounds. The herring that did not deposit their eggs retained 19,909 eggs or 97% of their eggs on average. Looking at all the female herring introduced into the pounds, the mean number of eggs retained by each female was 7,667. From this, it was estimated that the female herring had an overall egg retention of 37%. Of the eggs that were deposited in the pounds, 58% were deposited on the kelp and 42% on the net of the pounds. Using the information gathered in 1990, the optimum pound volume would have been 17,576 cubic feet.



**KEY WORDS:** Pacific herring, *Clupea harengus pallasi*, Prince William Sound, Alaska, spawn on kelp, pound fishery, spawn deposition survey, *Macrocystis*.

## INTRODUCTION

Pacific herring, *Clupea harengus pallasi*, spawn along the shoreline in Prince William Sound (PWS), Alaska, from mid April through early May each year (Figure 1). Herring deposit their adhesive spawn primarily on marine algae and sea grasses in the intertidal and upper subtidal zones. Natives living in PWS have traditionally harvested herring spawn on kelp as a food source. However, in the late 1960's, interest developed to harvest spawn on kelp commercially. Spawn on kelp, known as "Komachi Kombu", was highly prized as a traditional food source in Japan. Spawn on kelp was not readily accessible in Japan because of a decline in their herring populations.

Spawn on kelp was first harvested commercially in Prince William Sound beginning in 1969. Spawn on kelp was only harvested in the wild by divers until 1979 when spawn on kelp was also harvested from man-made impoundments or pounds. The pound fishery developed rapidly from 1980 until 1988 harvest increased from 1.3 tons to 124.0 tons (Brady *et al.* 1991). The 1988 harvest exceeded the guideline harvest level of 85 tons by 46%. Even though the pound spawn-on-kelp fishery only accounted for 6.5% of the total herring utilized, the fishery was second only to the purse seine sac roe fishery with respect to value. Because of the over-harvest in 1988 and increasing importance of the pound spawn-on-kelp fishery, a research program was to be started in 1989. However, the research program was not started because all the spring herring fisheries in PWS were closed in 1989 due to oil spill resulting from the grounding of the *T/V Exxon Valdez*. It was not until 1990 that a research program was undertaken to study the pound spawn-on-kelp fishery in PWS.

Specific objectives of the study were to estimate: (1) the amount of herring introduced into the pounds, (2) the amount of spawn deposited by the herring on the kelp in the pounds, (3) the amount of spawn on kelp actually harvested from the pounds, (4) the total weight of the spawn on kelp harvested from the pounds while in the totes, and (5) the final product weight of the spawn on kelp that was harvested and processed from the pounds.

Five commercial fisheries annually harvest herring and spawn on kelp in PWS: (1) purse seine sac roe fishery, (2) gill net sac roe fishery, (3) wild spawn-on-kelp fishery, (4) pound spawn-on-kelp fishery, and (5) fall and winter food-and-bait fishery. Herring in Prince William Sound are managed on a sustained yield basis such that the combined harvest of all five fisheries do not exceed 20% of the total spawning biomass in any given year. A detailed stock assessment program is conducted within Prince William Sound each year to monitor harvest of commercial fisheries, estimate spawning biomass, and establish timing of the spring fisheries in order to maximize roe recovery and spawn-on-kelp product quality.

Entry into the pound spawn-on-kelp fishery is presently limited by the Commercial Fisheries Entry Commission (CFEC). Permit holders must register with the Alaska Department of Fish and Game (ADF&G) by March 1 of each year to obtain an ADF&G permit for operation of their pound. The permit specifies the tonnage of herring and number of *Macrocystis* blades each permit holder is allowed to introduce into and the weight of product that can be harvested from each pound. Operational guidelines stipulated in the permit are as follows: 1) all pounds must be permanently identified with permit holders name and ADF&G permit number; 2) the permit holder must be physically present when introducing kelp and herring into and harvesting spawn on kelp from a pound; 3) pounds must be located east of a line from Porcupine Point to Point Freemantle (Figure 1); 4) herring can be held a maximum of six days within a pound; 5) the pound structure and net must remain in place a minimum of four weeks but must be removed from the water within six weeks from the date of harvest.

The pound spawn-on-kelp fishery generally begins in late March with the construction of the pounds. In early April several individuals go to Southeast

Alaska to harvest *Macrocystis* blades and fly the blades to PWS. This process is generally started after the biomass of herring has begun to build in the northeast area of PWS. Upon the arrival of *Macrocystis*, individual blades are selected, trimmed and hung six to 12 inches apart on a poly-line. These lines are strung throughout the pounds at depths varying from four to ten feet below the water surface. As soon as the seining of herring for introduction into pounds is allowed, herring are caught, transferred from the seine to push pounds, transported to the location of the pounds with kelp, and transferred into the pounds. This process is continued until all pounds are filled or the fishery is closed. Six days after herring have been introduced into a pound, the herring are released and the spawn on kelp is removed from the water, drained, trimmed, and weighed. The product is placed in large plastic totes containing enough salt to produce a 100% brine solution. The totes are taken to the processor where the product is further trimmed, graded, and weighed again. Pound structures, net, and unharvested product must be left in the water for four to six weeks to allow viable eggs to hatch.

## METHODS

The sampling program was designed to sample one single or double pound from each group. Sampling was to be conducted throughout the fishery, from the arrival of *Macrocystis* to the hatch of larvae. Data collected during the fishery included: pound dimensions; net specifications; weight and number of *Macrocystis* blades introduced into pounds; age, weight, length, and sex of pre- and post-spawning adult herring; fecundity of female herring; number of eggs per gram of spawn-on-kelp product; weight of spawn-on-kelp product before and after processing; female egg retention after spawning; brailed weight of herring released from each pound; SCUBA diver estimates of the number of eggs per sample quadrant (0.1 $m^2$ plots on pound net); estimates and counts of number of eggs on calibration panels (the number of eggs on the panels was estimated in the laboratory and used to adjust SCUBA diver estimates); and hatching success of eggs deposited on net and kelp left in the pounds.

The pound sampling program began on 11 April 1990. Sampling crews were based on a chartered vessel anchored in Galena Bay. Two small skiffs with outboard motors were used to transport crews to the test pounds. A test pound summary completion list provided a record of sampling dates of events for each test pound throughout the fishery.

By 1 March 1990, 128 of the 129 CFEC permit holders had registered. Permit holders were required to declare their group affiliation when they registered. A total of 20 groups declared for the 1990 season. However, one of the groups was comprised of only two individuals and was not included.

### *Number and Weights of Kelp*

The arrival of *Macrocystis* began on 11 April from Southeast Alaska and continued until 14 April. Test pounds were selected by the sampling crew when the *Macrocystis* was being distributed into pounds. Of the 19 test pounds selected, 14 were double (one structure with two permit holders) and five were single pounds. For each test pound, the total number of *Macrocystis* blades were counted and 25 were selected randomly and weighed to the nearest 0.01 g. Blade weights were recorded separately for each of the test pounds. Using methodology presented on page 77 in Cochran (1977) and assuming a coefficient of variation (CV) of 25% (Brady 1985), a sample size of 25 insured a 95% confidence interval within ± 10%. During the weighing of the *Macrocystis* blades, test pound length, width, and depth measurements were also collected. As a comparison, all permit holders were required to record the number of blades introduced into their pound.

### *SCUBA Diver Estimation of Eggs on Net*

SCUBA divers conducted 20 egg density estimates per pound in 14 of the 19 test pounds. Five estimates were made on each side of each pound at randomly chosen depths and locations. The SCUBA divers estimated the number of eggs deposited within a hand-held 0.1 $m^2$ quadrant frame. SCUBA diver estimates were calibrated and corrected using calibration panels and laboratory egg counts following methods developed for the herring spawn deposition survey program (Biggs and Funk 1988). Prior to herring being introduced into the test pounds, 45 calibration panels were deployed on randomly selected non-test pounds. Thirty of the panels were deployed on the inside and 15 were deployed outside of the non-test pounds. The panels were hung from the frame of the pounds such that the panels rested against the pound nets. The panels were placed at varying depths and locations throughout the selected pounds. All panels were 0.1 $m^2$ quadrant frames with netting identical to that used in the pounds stretched over the frames. SCUBA divers estimated the number of eggs within each calibration panel. Calibration panels were then retrieved. The netting and eggs within each panels were removed and stored in Gilson's solution. The number of eggs on the net that were removed from each panel were counted in the laboratory. The laboratory egg counts and SCUBA diver estimates from the calibration panels were compared to develop a relationship that was used to calibrate the SCUBA diver estimates.

### *Length, Weight and Sex Information*

A sample of 300 herring were collected from 17 of the 19 test pounds prior to spawning. Length, weight, and sex (LWS) information were collected from each herring sampled. Weights were not collected from the samples for six of the test pounds. For those samples where weights were not collected, weights were determined from a length-weight relationship developed from the standard age, weight, length, and sex (AWLS) data collected in the 1990 pound and purse seine fisheries. These samples were collected in the general vicinity of the pounds in the Northeast portion of Prince William Sound during the same time frame. All LWS sampling was conducted either on the chartered vessel or sent to ADF&G in Cordova and sampled in the laboratory. Length and sex data was collected from 300 herring in one test pound after spawning had started. As a result, length-weight relationship described above was used to correct for loss of weight due to spawning in the pound.

### *Weight and Sex Ratio of Females*

The sex ratio and mean weight of the females in each of the test pounds were estimated from a sample of 300 fish. The sample size of 300 was adequate to provide an estimate of the sex ratio to within 5% of the true value 95% of the time. Assuming a ratio of 50:50 would result in 150 females being weighed for mean weight. Usin~ mean weights of females in 1989, a maximum coefficient of variation (CV) of 30% was assumed. From this, a sample size of 150 should have provided an estimate such that the mean weight of females was within 5% of the true weight 95% of the time (Cochran 1977).

### *Fecundity*

Herring fecundity was estimated from fecundity-weight data collected in the northeast area as part of the spawn deposition survey program. To determine egg retention, 50 females were collected from each test pound at the time of brailing. The eggs retained by a female were collected and stored in Gilson's solution and counted later in the Cordova ADF&G laboratory. Assuming a CV of 35% for egg retention in the females, the sample size was determined to be adequate to estimate egg retention to within 10% of the true value 95% of the time (Cochran 1977).

### *Weight of Eggs on Kelp*

To estimate the number of eggs deposited on kelp, the number of eggs per gram was estimated. To estimate the weight of eggs, five samples of eggs 50.0 grams or larger were removed from kelp trimmings at the time of harvest in each test pound. All samples were weighed to the nearest 0.5 gram, stored in Gilson's fluid, and counted at a later time in the department's laboratory in Cordova.

### *Harvested Product*

The total number and weight of blades harvested from each test pound were recorded. Blades were removed from the pound and placed in a container, and excess sea water was allowed to drain off. The blades were then trimmed and weighed by the individual groups before being placed in totes and salted down. The spawn-on-kelp remained in brine solution for up to six days. The total number and weight of unharvested blades and trimmings were also collected from each test pound.

All totes containing spawn-on-kelp were sealed by department personnel. Total weight of spawn-on-kelp within each tote was collected from each group at the time of sealing. Final product weights were collected from the processors.

### *Fleet Questionnaire*

A fleet questionnaire was distributed to all pound operators at the beginning of the season. Questionnaires were collected on the grounds when possible and forms were also turned into the ADF&G office in Cordova after the season. Requested information on the questionnaire included pound dimensions, date and number of blades introduced, location of pound, estimated biomass and date, where herring were caught, date herring were placed into a pound, date of spawn, amount of harvest by date, tote weight (brined) at sealing, and final processed weight.

### *Brailing of Pounds*

To determine the accuracy of the biomass ($B_i$) estimate of equation 5, the herring introduced into the test pounds were brailed, weighed, and released after the spawn-on-kelp was harvested. Herring were moved into a corner of the pound with a crowding seine 100 feet wide and 60 feet deep. To determine the water weight within each brail, five to ten brail loads were weighed, then held until no water remained and weighed again. The percent water weight was subtracted from the total weight of herring brailed. Biomass estimates were determined for all 18 test pounds, but only 15 of those pounds were brailed.

### *Egg Survival*

To estimate the survival of eggs deposited on net and on the unharvested blades, divers returned to the pounds on 11 May. Three of the five mortality frames placed in pounds prior to spawning were collected. Divers estimated the percent of eggs that eyed, the percent hatched, and the percent dead on 11 of the 19 test pounds. Divers also estimated the survival of eggs which spawned naturally on wild kelp in the general vicinity of the pounds.

## DATA ANALYSIS

### *Estimation of Harvest/Biomass Ratios*

The ratio of the harvest weight (unprocessed) to the final processed weight of the spawn-on-kelp product ($R_{HPi}$) was estimated for each test pound by:

$$R_{HPi} = W_{Hi}/W_{Pi}; \qquad (1)$$

where, $W_{Hi}$ = harvest weight (unprocessed) of spawn-on-kelp product from test pound i; and
$W_{Pi}$ = final processed weight of spawn-on-kelp product from test pound i.

A mean ratio of harvest weight to processed weight of spawn-on-kelp product was estimated for each test pound by:

$$\bar{R}_{HP} = [\sum_{i=1}^{n_{tp}} R_{HPi}]/n_{tp}; \qquad (2)$$

where, $n_{tp}$ = the number of test pounds.

The variance of was estimated by:

$$V[\bar{R}_{HP}] = [\sum_{i=1}^{n_{tp}} (R_{HPi} - \bar{R}_{HP})^2]/(n_{tp} - 1). \qquad (3)$$

The standard deviation of $\bar{R}_{HP}$ ($SD[\bar{R}_{HP}]$) was calculated by taking the square root of $V[R_{HP}]$. From this, the coefficient of variation was estimated by:

$$CV[\bar{R}_{HP}] = SD[\bar{R}_{HP}]/\bar{R}_{HP}. \qquad (4)$$

In addition, the following ratios were estimated using equations 1-4:

$\bar{R}_{TP}$ = mean ratio of the tote weight (brined) to the processed weight of the spawn-on-kelp product;

$\overline{R}_{BrP}$ = mean ratio of the biomass of herring that were brailed in the pounds to the final processed weight of the spawn-on-kelp product;

$\overline{R}_{BP}$ = mean ratio of estimated biomass of herring in the pounds to the processed weight of the spawn-on-kelp product; and

$\overline{R}_{BBR}$ = mean ratio of the estimated biomass of herring in the pounds based on egg deposition estimates to the biomass of herring that were brailed in the pounds.

The mean ratio, variance, standard deviation and coefficient of variation for $R_{TP}$, $R_{BrP}$, $R_{BP}$, and $R_{BRB}$ were estimated by substituting these ratios for the ratio $R_{HP}$ in equations 1-4.

The estimated mean ratios compared the harvest weight, tote weight, weight of herring brailed, and estimated weight of herring to the final processed weight of the spawn-on-kelp product. In addition, the biomass of brailed herring was compared to the estimated biomass of herring in the pounds.

*Estimation of Biomass of Herring in Pounds*

The weight or biomass of herring ($B_i$) responsible for the spawn deposited in each test pound was estimated as:

$$B_i = (E_i\overline{W}_iS_i)/(\overline{F}_i - \overline{ER}_i) \qquad (5)$$

where,

$E_i$ = total number of eggs deposited in test pound i;

$\overline{W}_i$ = mean weight of herring in test pound i (males and females)

$S_i$ = sex ratio or 1/(the proportion of females in test pound i);

$\overline{F}_i$ = fecundity at mean weight of females in test pound i; and

$\overline{ER}_i$ = mean number of eggs retained by females in test pound i.

The biomass estimate was estimated based on 5 parameters. The variance of $B_i$ ($V[B_i]$) was estimated as:

$$V[B_i] = [\overline{W}_iS_i/(\overline{F}_i-\overline{ER}_i)]^2V[E_i] + [E_iS_i/(\overline{F}_i-\overline{ER}_i)]^2V[\overline{W}_i]$$
$$+ [E_i\overline{W}_i/(\overline{F}_i-\overline{ER}_i)]^2V[S_i] + [E_i\overline{W}_iS_i/(\overline{F}_i-\overline{ER}_i)^2]^2V[\overline{F}_i]$$
$$+ [E_i\overline{W}_iS_i/(\overline{F}_i-\overline{ER}_i)^2]^2V[\overline{ER}_i] \qquad (6)$$

The standard deviation of $B_i$ ($SD[B_i]$) was estimated by taking the square root of V[Bi] and the coefficient of variation was estimated by:

$$CV[B_i] = SD[B_i]/B_i. \qquad (7)$$

**Total Number of Eggs Deposited in Pounds**

The total number of eggs deposited in each test pound ($E_i$) was estimated as:

$$E_i = E_{Ki} + E_{Ni}; \qquad (8)$$

where, $E_{Ki}$ = the number of eggs estimated to be deposited on the kelp in test pound i, and

$E_{Ni}$ = the number of eggs estimated to be deposited on the net in test pound i.

The variance of $E_i$ was estimated as:

$$V[E_i] = V[E_{Ki}] + V[E_{Ni}]. \qquad (9)$$

The number of eggs deposited on kelp in test pound i was estimated by:

$$E_{Ki} = W_{eKi}\bar{e}_{Ki} ; \qquad (10)$$

and,

$$W_{eKi} = W_{Hi} + W_{Ri} - W_{Ki}; \qquad (11)$$

where, $W_{Hi}$ = weight of the spawn-on-kelp product in test pound i;

$W_{Ri}$ = weight of the spawn-on-kelp product remaining in test pound i;

$W_{Ki}$ = weight of kelp introduced into test pound i; and

$\bar{e}_{Ki}$ = adjusted mean number of eggs per gram on the spawn-on-kelp product in test pound i.

Both $W_{Hi}$ and $W_{Ri}$ were assumed to be measured without error. Therefore, no variance was associated with $W_{Hi}$ and $W_{Ri}$. For this reason, the variance of $E_{Ki}$ was approximated by using the product of two independent random variables $W_{eKi}$ and $e_{Ki}$ (Goodman 1960) and treating $W_{Hi}$ and $W_{Ri}$ as constants:

$$V[E_{Ki}] = (W_{Hi} + W_{Ri} - W_{Ki})^2 V[\bar{e}_{Ki}] + \bar{e}_{Ki}{}^2 V[W_{Ki}] - V[W_{Ki}]V[\bar{e}_{Ki}]; \qquad (12)$$

The total weight of kelp introduced into a test pound was estimated by:

$$W_{Ki} = N_{Bi}\bar{b}_i; \qquad (13)$$

where, $N_{Bi}$ = the number of blades introduced into test pound i, and

$\bar{b}_i$ = the mean blade weight in test pound i.

The number of blades was assumed to be measured without error. Therefore, the variance of $W_{Ki}$ was:

$$V[W_{Ki}] = N_{Bi}^2 V[\bar{b}_i]. \qquad (14)$$

The mean blade weight in test pound i was estimated by:

$$\bar{b}_i = [\sum_{j=1}^{n_{Bi}} b_{ij}]/n_{Bi}; \qquad (15)$$

where, $b_{ij}$ = the weight (g) of blade j in test pound i, and

$n_{Bi}$ = the number of blades weighed in test pound i.

The variance of $b_i$ was estimated by:

$$V[\bar{b}_i] = [\sum_{j=1}^{n_{Bi}} (b_{ij} - \bar{b}_i)]/(n_{ij} - 1). \qquad (16)$$

The adjusted mean number of eggs per gram deposited on the kelp in each test pound was estimated by:

$$\bar{e}_{Ki} = \bar{R}_{Ki}\bar{e}_{uKi}; \qquad (17)$$

where, $\bar{e}_{uKi}$ = the unadjusted mean number of eggs per gram using the weight of the eggs in the laboratory, and

$R_{Ki}$ = the mean ratio of the weight of the egg samples in the laboratory divided by the weight of the egg samples in the field.

The adjustment accounted for a loss of weight from when the eggs were collected in the field and to when the eggs were weighed and counted in the laboratory.

The variance of $\bar{e}_{Ki}$ was estimated as the variance of the product of two random variables (Goodman 1960):

$$V[\bar{e}_{Ki}] = \bar{R}_{Ki}^2 V[\bar{e}_{uKi}] + \bar{e}_{uKi}^2 V[\bar{R}_{Ki}] - V[\bar{R}_{Ki}]V[\bar{e}_{uKi}]. \qquad (18)$$

Five samples of eggs were collected from each test pound and weighed in the field. After completion of the field sampling, each of the samples were weighed in the laboratory and four subsamples were taken from each sample. The subsamples were weighed and the number of the eggs were counted in each subsample. The estimate of $R_{Ki}$ and it's variance were calculated from each sample as follows:

$$\bar{R}_{Ki} = [\sum_{k=1}^{n_{Ki}} (W_{KLik}/W_{Kik})]/n_{Ki}; \tag{19}$$

with

$$V[\bar{R}_{ki}] = [\sum_{k=1}^{n_{Ki}} (W_{KLik}/W_{Kik}) - \bar{R}_{Ki})^2]/(n_{Ki} - 1); \tag{20}$$

where, $W_{KLik}$ = the laboratory weight of egg sample k in test pound i,

$W_{Kik}$ = the field weight of egg sample k in test pound i, and

$n_{Ki}$ = the number of egg samples collected from kelp in test pound i (usually 5).

The unadjusted mean number of eggs per gram (laboratory weight) deposited on the kelp in test pound i was estimated by:

$$\bar{e}_{UKi} = [\sum_{k=1}^{n_{Kik}} \bar{e}_{UKik}]/n_{Kik}; \tag{21}$$

with the variance estimated as:

$$V[\bar{e}_{UKi}] = [\sum_{k=1}^{n_{Kik}} (\bar{e}_{UKik} - \bar{e}_{UKi})^2/(n_{Kik} - 1)$$

$$+ (\sum_{k=1}^{n_{Ki}} V[\bar{e}_{UKik}])/n_{Ki}; \tag{22}$$

The unadjusted mean number of eggs per gram deposited on the kelp in sample k and test pound i was estimated by:

$$\bar{e}_{UKik} = [\sum_{l=1}^{n_{Kik}} e_{UKikl}]/n_{Kik}; \tag{23}$$

with the variance estimated as:

$$V[\bar{e}_{UKik}] = \sum_{l=1}^{n_{Kik}} (e_{UKikl} - \bar{e}_{UKik})^2/(n_{KLik} - 1); \tag{24}$$

where, $e_{UKikl}$ = the number of eggs per gram (laboratory weight) in subsample l from sample k and test pound i; and

$n_{Kikl}$ = was the number of egg subsamples collected from sample k and test pound i (usually 4).

The total number of eggs deposited on the pound net in test pound i was estimated by:

$$E_{Ni} = A_i \overline{E}_{qi}; \quad (25)$$

where, $A_i$ = the total area ($ft^2$) of net that was used in test pound i; and

$E_{qi}$ = the mean number of eggs per sample quadrate ($0.1\ m^2 = 1.0\ ft^2$) in test pound i.

The variance of $E_{Ni}$ was estimated by:

$$V[E_{Ni}] = A_i^2 V[\overline{E}_{qi}]. \quad (26)$$

The total area of net used in each test pound was calculated as:

$$A_i = 2(L_i D_i + 1/2 W_i D_i); \quad (27)$$

where, $L_i$ = length of test pound i,

$W_i$ = width of test pound i, and

$D_i$ = was the depth of test pound i (in ft).

The total number of possible quadrants was equal to the total area ($ft^2$) of net used in a test pound. A quadrant was equal to $0.1 m^2$ which is approximately 1.0 $ft^2$. The sample quadrants were randomly selected in each test pound. The mean number of eggs per sample quadrant and the variance was estimated as:

$$\overline{E}_{qi} = [\sum_{m=1}^{n_{qi}} E_{qim}]/n_{qi}; \quad (28)$$

with

$$V[\overline{E}_{qi}] = [\sum_{m=1}^{n_{qi}} (E_{qim} - \overline{E}_{qi})^2]/(n_{qi} - 1)$$

$$+ \sum_{m=1}^{n_{qi}} E_{qim}/n_{qi}; \quad (29)$$

where, $E_{qim}$ = adjusted diver-estimated egg count from the diver calibration model (equation 31) for quadrant m and test pound i; and

$n_{qi}$ = number of quadrants sampled in test pound i;

Diver estimates of egg numbers were used to estimate the total number of eggs on the net of the test pounds. However, to account for biases due to divers and egg density, a set of quadrant panels covered with pound net were randomly placed in the test pounds prior to the introduction of herring into the pounds. Divers estimated the number of eggs deposited on each quadrant net panel after the herring had spawned and been released. The net on the panels with eggs attached were then cut out and stored in Gilsons solution. The number of eggs on each net panel were later enumerated in the laboratory. The laboratory-enumerated egg counts were used to adjust the diver estimates in each of the test pounds using the following model:

$$E_{Lqim} = e^{\alpha} E_{Uqim}^{\beta_{qm}} e^{\epsilon} ; \qquad (30)$$

where, $E_{Lqim}$ = laboratory-enumerated egg count in quadrant m;

$E_{Uqim}$ = unadjusted diver estimate in quadrant m;

$\alpha$ = a constant;

$\beta_{qm}$ = a parameter that controlled the functional form of the relationship between the diver estimate and laboratory-enumerated egg count for all test pounds; and

$\epsilon$ = a normally distributed random variable with mean 0 and variance $\sigma^2$.

A multiplicative-effect model was used because relative estimation errors were expected to change with egg density. A logarithmic transformation was used to estimate the parameters of the model. The log transform model took the form:

$$\log_e(E_{Lqim}) = \alpha + \beta_{qm}\log_e(E_{Uqim}) + \epsilon. \qquad (31)$$

In logarithmic form, the model comprised a linear regression problem. The parameter estimates from the linear regression were used to adjust the diver estimates in equation 27. However translation of the predicted values from the logarithmic model to the original scale required a correction for bias. The expected bias was $\exp(1/2\sigma^2)$ if the true variance of $E_{Lqim}$ and $\sigma^2$ were known. Laurent (1963) gave an exact expression for the bias correction that incorporated additional terms when $\sigma^2$ was estimated from a sample. However, for diver calibration data in the spawn deposition survey in Prince William Sound, the biases in estimating $\sigma^2$ from a sample were less than 5% (Biggs and Funk 1988). Because of this, the estimates were adjusted as follows:

$$E_{qim} = e^{\alpha} E_{Uqim}^{\beta_{qm}} e^{1/2MSE} ; \qquad (32)$$

where, MSE = the mean square error from the linear regression.

The variance of the individual $E_{qim}$ was estimated by:

$$V[E_{qim}] = (e^{(2E_{qim} + MSE)})(e^{MSE} - 1). \qquad (33)$$

**Mean Weight of Female Herring in Pounds**

A random sample of approximately 300 herring was collected from each test pound to collect length, weight, and sex information. Mean weight was estimated for the herring sampled in each test pound as:

$$\bar{W}_i = (\sum_{f=1}^{n_i} W_{if})/n_i; \qquad (34)$$

with the variance of $\bar{W}_i$ estimated by:

$$V[\bar{W}_i] = [\sum_{f=1}^{n_i} (W_{if} - \bar{W}_i)^2]/(n_i - 1). \qquad (35)$$

The mean weight of female herring ($\bar{W}_{Fi}$) was also estimated for each test pound and was used to estimate the fecundity of female herring in each test pound.

**Sex Ratio of Herring in Pounds**

A sex ratio was estimated from the LWS sample collected from each test pound as the number of herring in the LWS sample to the number of females. The equivalent of this based upon the binomial distribution was applied and the sex ratio for test pound i ($S_i$) was estimated by:

$$S_i = 1/p_i; \qquad (36)$$

where, $p_i$ = the proportion of female herring in the LWS sample from test pound i.

The variance of $S_i$ was simply:

$$V[S_i] = S_i^2(S_i - 1)/(n_i - 1); \qquad (37)$$

where, $n_i$ = the number of herring in the LWS sample from test pound i.

**Fecundity of Female Herring in Pounds**

A linear regression of fecundity and weight provided a reasonable description of fecundity data collected in 1988 and 1989 (Biggs and Funk 1988). A fecundity weight relationship was developed for 1990 using all the fecundity and weight data collected in the northeast area in 1990. Mean fecundity for each test pound was estimated from the fecundity-weight relationship using the average female weight from each test pound as follows:

$$\bar{F}_i = \alpha + \beta\bar{W}_{Fi}; \qquad (38)$$

where, $\overline{W}_{Fi}$ = the mean female weight of herring in test pound i,

$\alpha$ = the Y-intercept, and

$\beta$ = the regression coefficient or slope.

The variance of estimated mean fecundity was approximated by the variance of predicted means from the fecundity-weight linear regression (Draper and Smith 1981):

$$V[F(W_{Fi})] = RMS_F[1/n_F + 1/n_{Fi} + (\overline{W}_{Fi} - \overline{W}_F)^2 / \sum_{f=1}^{n_f}(W_{Ff} - \overline{W}_F)^2]; \qquad (39)$$

where, $RMS_F$ = residual mean square from the fecundity-weight linear regression;

$W_{Ff}$ = individual weight of female herring in the fecundity sample;

$\overline{W}_F$ = mean weight of female herring in the fecundity sample;

$\overline{W}_{Fi}$ = mean weight of female herring in test pound i;

$n_F$ = total number of female herring in the fecundity sample; and

$n_{Fi}$ = total number of female herring sampled in test pound i.

**Egg Retention of Female Herring in Pounds**

A sample of approximately 50 female herring were randomly collected from each test pound prior to release of herring from the test pounds. The female herring were checked for eggs retained. The proportion of herring retaining eggs was estimated from this sample. In addition, the mean number of eggs retained by the female herring was estimated from those herring that retained eggs. From this, the egg retention of female herring in each test pound was estimated as:

$$\overline{ER}_i = \overline{ER}_{Ri}(P_{Ri}); \qquad (40)$$

where, $\overline{ER}_{Ri}$ = the estimate of the mean number of eggs retained by female herring that retained eggs in test pound i, and

$P_{Ri}$ = the proportion of female herring that retained any eggs in test pound i.

The estimates $ER_{Ri}$ and $P_{Ri}$ were assumed to be independent estimates. From this, the variance was estimated using the variance of the product of two independent random variables (Goodman 1960):

$$V[\overline{ER}_i] = \overline{ER}_{Ri}^2 V[P_{Ri}] + P_{Ri}^2 V[\overline{ER}_{Ri}] - V[\overline{ER}_{Ri}]V[P_{Ri}]. \qquad (41)$$

The proportion of female herring in test pound i was estimated by:

$$P_{Ri} = n_{RFi}/n_{Ri}; \qquad (42)$$

where, $n_{RFi}$ = the number of female herring that retained eggs in the egg retention sample from test pound i; and

$n_{Ri}$ = the total number of female herring sampled for egg retention in test pound i.

The variance of $P_{Ri}$ was estimated using the unbiased estimate of the variance of a proportion when the sample size was small compared to population size (Cochran 1977):

$$V[P_{Ri}] = P_{Ri}(1 - P_{Ri})/(n_{Ri} - 1). \qquad (43)$$

The mean number of eggs retained by individual female herring and its' variance was estimated by:

$$\overline{ER}_{Ri} = [\sum_{f=1}^{n_{RFi}}(W_{Rif}\bar{e}_{Rik})]/n_{RFi}; \qquad (44)$$

and

$$V[\overline{ER}_{Ri}] = [\sum_{f=1}^{n_{RFi}}(W_{Rif}\bar{e}_{Rik}) - \overline{ER}_{Ri})^2]/(n_{RFi} - 1)$$

$$+ (\sum_{f=1}^{n_{RFi}}W_{Rif}{}^2V[\bar{e}_{Rik}])/n_{RFi}; \qquad (45)$$

where, $W_{Rif}$ = the total weight of eggs retained in female herring f and test pound i; and

$e_{Rik}$ = the mean number of eggs per gram in sample k and test pound i.

The mean number of eggs per gram in sample k and test pound i and its' variance was estimated by:

$$\bar{e}_{Rik} = [\sum_{l=1}^{n_{RFik}} e_{Rikl}]/n_{RFik}; \qquad (46)$$

with

$$V[\bar{e}_{Rik}] = [\sum_{l=1}^{n_{RFik}}(e_{Rikl} - \bar{e}_{Rik})^2]/(n_{RFik} - 1); \qquad (47)$$

where, $e_{Rikl}$ = the number of eggs per gram in subsample l from sample k and test pound i; and

$n_{RFik}$ = the number of egg subsamples collected from sample k and test pound i.

## RESULTS

A total of 128 permit holders registered for the PWS pound fishery in 1990. Most of the permit holders set up pounds in Valdez Arm (Galena Bay) and Port Fidalgo (Figure 1). A total of 20 groups participated in 1990, with the number of permit holders ranging from 2 to 15 per group. Nineteen of the 20 registered groups produced product in 1990 (Table 1). One group failed to introduce herring into their pounds. In 1990, there were 128 pounds in PWS of which 22 were single pounds and 53 were double pounds.

The 19 groups harvested a total of 268,825.5 lbs (134.4 tons) of spawn-on-kelp product which resulted in a final product weight of 208,809.1 lbs (104.4 tons) (Table 1). Weight loss from harvest to final product varied from 2.0% to 36.5% with a average weight loss of 26.7%. Weight loss was found to be highly dependent upon who processed the spawn-on-kelp product. Fifteen of the groups had their product processed by the same processor. These fifteen groups had an overall weight loss of 26.7%. Five of the groups had their product processed by individuals. The weight loss for these five groups was 8.9%.

Fourteen of the 19 test pounds were brailed to estimate the biomass of herring introduced into each test pound. After brailing was completed, it was found that 2 of the 14 pounds had holes in their net, so accurate brailed estimates of herring placed in these two pounds were not obtained. The biomass of herring introduced into test pounds was also estimated from egg deposition estimates. The mean biomass of herring introduced into the test pounds was 27.1 tons based on egg deposition ($B_i$), but only 22.0 tons based on brailing ($B_{ri}$) (Table 2). The mean ratio of biomass estimates from egg deposition to brailing was 1.37. When biomass estimates were grouped for single and double pounds, there was better agreement between egg deposition and brailed estimates for double pounds than for single pounds. The mean biomass of herring in single pounds was 18.1 based on egg deposition and 10.1 based on brailing. The mean ratio of estimates was 1.66. The mean biomass of herring in double pounds based on egg deposition was 29.3 tons and 26.0 tons from brailed estimates. The mean ratio of the estimates was 1.28.

The amount of spawn-on-kelp product produced in the 19 test pounds averaged 2.17 tons (Table 3). Single test pounds had an average production of 1.55 tons and the double pounds had an average of 2.37 tons. The amount of herring used to produce 1.0 ton of spawn-on-kelp product averaged 13.3 tons based on the egg deposition and 10.0 tons based on brailing. Estimates based on egg deposition ranged from 8.1 to 25.9 tons, while estimates based on brailing ranged from 5.0 to 17.1 tons. The amount of herring used to produce 1.0 ton of spawn-on-kelp product in single pounds averaged 12.3 tons based on egg deposition and 8.1 tons based on brailing. In double pounds, the amount of herring needed to produce 1.0 ton of product was 13.4 tons based on egg deposition and 10.7 tons based on brailing.

The volume of double pounds ranged from 16,874 $ft^3$ to 73,800 $ft^3$ and averaged 39,981 $ft^3$ (Table 4). Volume of single pounds ranged from 11,551 $ft^3$ to 23,400 $ft^3$ and averaged 18,633 $ft^3$. Depths of double pounds ranged from 13.0 to 50.0 ft while depth of single pounds ranged from 12.8 to 30.0 ft. A linear regression comparing pound volume to the amount of spawn-on-kelp product harvested was not significant ($R^2 = 0.0769$).

Most eggs from female herring introduced into the test pounds were either retained or deposited on the net of the pounds. On average, 35% of available eggs were deposited on kelp, 28% were deposited on the net of the pounds, and 37% of the eggs were retained by females (Table 5). The variability was in the number of eggs retained by the female herring. Egg retention for females within individual pounds ranged from 7% to 77%. Of eggs that were actually deposited inside test pounds, 58% were deposited on the kelp and 42% were deposited on the net.

The mean number of blades of *Macrocystis* hung in each test pound was 1,535 (Appendix Table 1). Mean blade weight was 126.7 g. Mean weight of the total number of blades hung in each pound was 194.5 kg.

The mean weight of eggs deposited on kelp in test pounds was estimated to be 1,784 kg (Appendix Table 2). Based on an average of 385.8 eggs/g, the average number of eggs deposited on the kelp in the test pounds was 688,271,800. Based on diver estimates, an average of 525,695,700 eggs were deposited on the net of each test pound (Appendix Table 3). Combining estimates for the number of eggs on kelp and on the net, an average of 1,213,967,500 eggs were deposited within the test pounds.

The mean sex ratio of females to males was 1.940 (Appendix Table 4). Mean weight of herring was 123.4 g for males and 133.9 g for females. Female herring had an average fecundity of 20,524 eggs.

Of the 50 female sampled for egg retention in each of the test pounds, an average of 38.5% of the herring retained eggs (Appendix Table 5). Egg retention for individual females ranged from 7% up to 77%. An average of 7,667 eggs were retained by each female in the test pounds. However, if only herring that retained eggs were considered, an average of 19,909 eggs were retained per female. This was 97% of the eggs herring carried on average.

## DISCUSSION

The wide range of product weight loss among groups was due in part to how they processed their kelp. This included the time kelp was allowed to drain and how extensively blades with poor egg coverage were trimmed. One variable that was not considered was product grade. Weight loss of high quality kelp with several evenly distributed layers of eggs may differ from weight loss in lower quality product having far fewer eggs unevenly distributed on the kelp.

A problem that occurred in 1990 that had not been observed in past years was the separation of the egg mass from the kelp blade ("peelers") after the kelp was taken out of the brine solution. This resulted in high product weight loss for some groups. The weight of eggs that separated from the kelp was reported to ADF&G by the processors, but this may be a conservative estimate since some eggs may have been unintentionally discarded along the processing line before weighing. The total weight of "peelers" reported to ADF&G was 7,400 lbs. This phenomenon may have been caused by the introduction of herring into pounds immediately after kelp was introduced. A mucus layer builds on the kelp blades when they are harvested, and unless enough time is allowed for mucus to wash off, eggs laid on the kelp may peel off during processing.

In general, herring biomass estimates for test pounds based on egg deposition were similar to estimates from brailing. Differences that were observed between the two estimates may have been due to three causes. First, the variance of the herring biomass estimate based on the egg deposition (CV = 42.4%) was larger than anticipated. Second, variability and construction defects resulted in inaccurate brailed weights of herring in some test pounds and may have also affected diver's biomass estimates. Third, the contribution of eggs from wild fish which spawn on the outside of the pound net was unknown and may have caused biomass estimates based on egg deposition to be too large.

Large variances around biomass estimates from spawn deposition data were due largely to inadequate egg retention sample sizes. Prior to this study, egg retention was assumed to be minimal (< 10%) in impounded herring and that this factor would not play a significant role in the final biomass estimate. A 50 fish sample was thought to be large enough to provide an egg retention estimate at the desired level of accuracy and precision. However, egg retention averaged 37 percent in test pounds. An extreme example of this problem was the biomass estimate of herring in Group F (Table 2). The estimate based on egg deposition was 285.3 tons almost 10 times larger than the brailed estimate of 29.2 tons. Egg retention in this pound averaged 70% in the 50 females sampled. Using the average number of eggs retained by females (7,668) for the entire fishery, the biomass estimate for Group F dropped to 27.8 tons, which was similar to the brailed estimate. Sample sizes to estimate egg retention must be increased appropriately in future years to account for this problem and decrease the variance around egg deposition estimates.

Errors in brailed weights of herring in test pounds were due mostly to poor or variable pound construction. For example, the 50 foot depth of the Group D test pound vastly exceeded the depth of the crowding seine (30 ft) used in the brailing operation. Divers estimated that several tons of herring remained in the pound following the brailing procedure. Test pounds A and I had large holes in the net which allowed most herring to escape and resulted in brailed weights of 2.3 tons and 3.1 tons, respectively. Biomass estimates for the same two pounds based on egg deposition were much greater (44.7 tons and 15.1 tons, respectively). Large holes in impoundment nets may also allow additional herring to enter the pound and deposit spawn. This spawn could be mistakenly attributed to originally impounded herring and result in an overestimate of biomass based on egg deposition. Herring which voluntarily enter the pound but do not spawn may also appear in egg retention samples. Estimates of egg retention from these samples would be too great and would result in a biomass estimate which was too great.

The study design in 1990 did not determine how many eggs on the pound net were contributed by herring outside of the pound. This may also be one of the factors which caused biomass estimates based on egg deposition to exceed estimates based on brailing. Test panels will be hung outside pounds in future studies to estimate the contribution of eggs from herring outside of the pounds.

The current production level for this fishery has been set assuming that 12.5 tons of herring are to generate 1.0 ton of spawn-on-kelp product. This estimate appears reasonable, since this study indicated that between 13.3 tons and 10.0 tons were required based on egg deposition and brailing, respectively.

Results of this study also suggested that limiting pound size to control the biomass of herring utilized in the pound fishery would not be practical, since no relationship was found between production and pound size. The relationship between pound size and optimum use of the allocated biomass is also not fully understood. Even if an optimal ratio of pound size to biomass used were known, restricting yearly pound size based on the allocation may not be practical for either the department or pound fishery participants. However, setting a maximum pound size may reduce the tendency of participants to use more than their allocated amount of herring.

Results of this study indicated that the best way to insure high quality harvest, without exceeding the harvest allocation, would be through more efficient use of the allocated herring biomass. Utilization of herring in excess of the allocation does not necessarily improve product volume or quality. Overcrowding of herring may reduce the number of females spawning within a pound and increase post spawning mortality. One way to improve efficiency would be to minimize egg retention. Despite the fact that an average of 37% of the eggs available to the pound fishery in 1990 were retained by the females, many groups were able to harvest their product quota. Reducing egg retention by half would have enabled most groups to produce a high quality product and meet or exceed their harvest allocation.

Egg retention in 1990 ranged from 77% to 7%. The amount of retention may be related to the amount of stress due to handling, overcrowding within pounds, and residence time in pounds. On the other hand, it is possible egg retention rates observed in the pound fishery were not significantly different than those that occurred in naturally spawning herring. Future studies should include a sampling program for non-pounded herring to address this question.

If egg retention is significantly lower in herring outside pounds, then methods need to be found which reduce high retention rates for herring placed in pounds. Developing techniques which reduce the stress associated with handling could reduce egg retention. Such methods might include capturing less herring to minimize crowding in seines and in push pounds. It was observed on several occasions in 1990 that males were releasing milt inside the push pounds. If milt release triggers egg release by females (Hay 1985; Hourston et al. 1977), then the quantity of milt from remaining unspawned males may not be enough to trigger a high proportion of females to release their eggs. Eliminating the use of push pounds may not be feasible since herring are often not available in the vicinity of pounds.

Increasing the length of time herring can be held in pounds may also reduce the number of eggs retained. At present, all herring must be released six days after the first herring are introduced into a pound. Most spawning activity occurs within the first three days, after that sporadic spawning has been observed. Spawn has also been observed at the time of release, but what this additional spawn added to product quality is not known. However, the quality of the *Macrocystis* blades begin to deteriorate with time and the proportion of eyed eggs increases. Both factors lower the quality of the product.

In general, a lower percentage of eggs in pounds hatched than was observed in the wild. The highest total hatch observed within a pound was 25%, but most pounds had a 10% or less total hatch. Natural spawn on kelp in Galena Bay had a total hatching success of 67.5%. Poor hatching seemed to be due to suffocation or imprisonment of larvae within the inner egg layers of a dense mass of eggs. Visual under water observations of eggs on the net, suggested the first egg layers deposited were fertilized while spawns that occurred later were unfertilized and covered the fertilized eggs.

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**TABLES**

Table 1. Estimated weight loss of herring spawn-on-kelp product from the harvest to final product for each group in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| | Total Group Production | | |
|---|---|---|---|
| Group Ident. | Harvest (lbs) | Final (lbs) | Shrinkage (Percent) |
| A | 10,853.0 | 8,149.5 | 24.9 |
| B | 6,421.0 | 5,463.0 | 14.9 |
| C | 43,788.0 | 27,812.0 | 36.5 |
| D[a] | 20,509.0 | 18,930.0 | 7.7 |
| E | 22,201.0 | 16,237.8 | 26.9 |
| F | 18,911.0 | 14,287.0 | 24.5 |
| G[a] | 11,130.0 | 10,912.0 | 2.0 |
| H | 13,319.0 | 10,671.0 | 19.9 |
| I | 9,424.0 | 6,519.8 | 30.8 |
| J[a] | 13,293.0 | 11,513.0 | 13.4 |
| K | 8,336.0 | 6,812.5 | 18.3 |
| L[a] | 13,429.0 | 11,089.0 | 17.4 |
| M | 14,883.0 | 11,124.5 | 25.3 |
| N | 3,452.5 | 2,656.5 | 23.1 |
| O | 13,251.0 | 10,600.5 | 20.0 |
| P[a] | 18,713.0 | 15,810.0 | 15.5 |
| Q | 9,273.0 | 7,340.5 | 20.8 |
| R | 13,003.0 | 9,660.5 | 25.7 |
| S[b] | | | |
| T | 4,636.0 | 3,220.0 | 30.5 |
| <u>Total Group Production</u> | | | |
| Groups | 19 | | |
| lbs | 268,825.5 | 208,809.1 | 22.3 |
| tons | 134.4 | 104.4 | |
| <u>Groups Processed by Processors</u> | | | |
| Groups | 14 | | |
| lbs | 191,751.5 | 140,555.1 | 26.7 |
| tons | 95.9 | 70.3 | |
| <u>Groups Processed by Individuals</u> | | | |
| Groups | 5 | | |
| lbs | 77,074.0 | 68,254.0 | 8.9 |
| tons | 38.5 | 34.1 | |

[a] Product was processed by alternate processors.
[b] No product was produced by this group.

Table 2. Biomass estimates based on egg deposition and brailed estimates of herring introduced into test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Biomass Estimates (tons) | | | | Ratio of Estimates $B_i$ versus $B_{ri}$ |
|---|---|---|---|---|---|
| | Egg Deposition | | | Brailed | |
| | $B_i$ | $SD[B_i]$ | $CV[B_i]$ | $B_{ri}$ | |
| A[a] | 44.7 | 59.1 | 132.2% | | |
| B | 33.9 | 13.3 | 39.1% | 21.2 | 1.59 |
| C | 37.0 | 12.2 | 33.1% | 35.7 | 1.03 |
| D[b] | 18.8 | 6.3 | 33.3% | | |
| E | 53.7 | 17.0 | 31.7% | 33.1 | 1.62 |
| F[f] | 27.8 | 16.8 | 60.4% | 25.1 | 1.11 |
| G[d] | 12.7 | 3.9 | 30.3% | 5.9 | 2.15 |
| H | 29.7 | 10.8 | 36.3% | 31.3 | 0.95 |
| I[a] | 15.1 | 5.5 | 36.1% | | |
| J[ce] | 25.6 | 6.9 | 27.2% | | |
| K[d] | 20.7 | 9.6 | 46.6% | 12.5 | 1.66 |
| L[ce] | 21.1 | 7.3 | 34.6% | | |
| M[d] | 13.8 | 4.0 | 28.9% | 11.8 | 1.17 |
| N[e] | 25.0 | 13.0 | 52.0% | 22.1 | 1.13 |
| O | 32.8 | 17.7 | 54.0% | 23.7 | 1.38 |
| P | 18.2 | 4.9 | 26.7% | 11.1 | 1.64 |
| Q | 31.8 | 20.5 | 64.5% | 31.0 | 1.03 |
| R[cde] | 25.0 | 11.4 | 45.8% | | |
| <u>Mean</u> | | | | | |
| Single | 18.1 | | | 10.1 | 1.66 |
| Double | 29.3 | | | 26.0 | 1.28 |
| All | 27.1 | | | 22.0 | 1.37 |

[a] This pound was not included in $B_{ri}$ average since it had a large hole in the net.
[b] We were unable to brail all or most of herring in the pound since impoundment depth was 50 ft.
[c] Due to time restraints, these pounds were not brailed.
[d] Single pounds.
[e] Divers did not make estimates for these test pounds. Biomass estimates were made by using the mean egg density estimate for the other pounds.
[f] The estimate shown was based on the mean egg egg retention for all the test pounds.The original estimate for Group F based on egg deposition was 285.3 tons. This estimate was thought to be unrealistically high due to problems with determining egg retention.

Table 3. Estimates of the biomass of herring used to produce 1.0 ton of spawn-on-kelp product from test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990. Biomass estimates were based on egg deposition and brailing.

| Group Ident. | Spawn-on-Kelp Product (tons) Harvest | Unharvested | Total | Egg Deposition Estimate (tons) $B_i$ | Brailing Estimate (tons) $B_{ri}$ | Tons of Herring Per Ton Product ($B_i$) | Tons of Brailed Herring Per Ton Product ($B_{ri}$) |
|---|---|---|---|---|---|---|---|
| A[a] | 1.73 | 0.00 | 1.73 | 44.7 | | 25.9 | |
| B | 2.28 | 0.00 | 2.28 | 33.9 | 21.2 | 14.9 | 9.3 |
| C | 4.58 | 0.00 | 4.58 | 37.0 | 35.7 | 8.1 | 7.8 |
| D[b] | 1.78 | 0.00 | 1.78 | 18.8 | | 10.5 | |
| E | 5.11 | 0.00 | 5.11 | 53.7 | 33.1 | 10.5 | 6.4 |
| F[f] | 2.13 | 0.04 | 2.18 | 27.8 | 25.1 | 12.8 | 11.5 |
| G[d] | 0.92 | 0.00 | 0.92 | 12.7 | 5.9 | 13.9 | 6.4 |
| H | 2.53 | 0.00 | 2.53 | 29.7 | 31.3 | 11.7 | 12.3 |
| I[a] | 1.56 | 0.00 | 1.56 | 15.1 | | 9.7 | |
| J[ce] | 2.07 | 0.00 | 2.07 | 25.6 | | 12.4 | |
| K[d] | 1.21 | 0.07 | 1.27 | 20.7 | 12.5 | 16.2 | 9.8 |
| L[ce] | 1.53 | 0.00 | 1.53 | 21.1 | | 13.8 | |
| M[d] | 1.39 | 0.05 | 1.45 | 13.8 | 11.8 | 9.5 | 8.1 |
| N[e] | 1.72 | 0.00 | 1.72 | 25.0 | 22.1 | 14.5 | 12.8 |
| O | 1.38 | 0.00 | 1.38 | 32.8 | 23.7 | 23.8 | 17.1 |
| P | 1.27 | 0.95 | 2.21 | 18.2 | 11.1 | 8.2 | 5.0 |
| Q | 2.12 | 0.19 | 2.31 | 31.8 | 31.0 | 13.8 | 13.4 |
| R[cde] | 2.58 | 0.00 | 2.58 | 25.0 | | 9.7 | |
| **Mean** | | | | | | | |
| Single | 1.52 | 0.03 | 1.55 | 18.1 | 10.1 | 12.3 | 8.1 |
| Double | 2.29 | 0.08 | 2.37 | 29.3 | 26.0 | 13.4 | 10.7 |
| All | 2.10 | 0.07 | 2.17 | 27.1 | 22.0 | 13.3 | 10.0 |

[a] This pound was not included in $B_{ri}$ average since it had a large hole in the net.
[b] We were unable to brail all or most of herring in the pound since impoundment depth was 50 ft.
[c] Due to time restraints, these pounds were not brailed.
[d] Single pounds.
[e] Divers did not make estimates for these test pounds. Biomass estimates were made by using the mean egg density estimate for the other pounds.
[f] The estimate shown was based on the mean egg egg retention for all the test pounds.The original estimate for Group F based on egg deposition was 285.3 tons. This estimate was thought to be unrealistically high due to problems with determining egg retention.

Table 4. Dimensions of test pounds in the herring pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Pound Dimensions Length (ft) | Width (ft) | Depth (ft) | Total Volume ($ft^3$) |
|---|---|---|---|---|
| Double Pounds | | | | |
| A | 79.0 | 21.0 | 40.0 | 66,360 |
| B | 60.0 | 30.0 | 41.0 | 73,800 |
| C | 67.1 | 28.3 | 30.0 | 56,968 |
| D | 29.0 | 25.0 | 50.0 | 36,250 |
| E | 60.0 | 24.0 | 30.0 | 43,200 |
| F | 65.0 | 37.0 | 20.0 | 48,100 |
| H | 44.8 | 24.5 | 25.0 | 27,440 |
| I | 65.0 | 28.8 | 17.0 | 31,824 |
| J | 48.0 | 48.0 | 16.0 | 36,864 |
| L | 77.4 | 25.0 | 12.8 | 24,768 |
| N | 36.5 | 32.0 | 19.0 | 22,192 |
| O | 48.0 | 24.0 | 18.0 | 20,736 |
| P | 48.5 | 36.7 | 13.0 | 23,139 |
| Q | 44.8 | 24.3 | 15.5 | 16,874 |
| Mean | 55.2 | 29.2 | 24.8 | 39,981 |
| Single Pounds | | | | |
| G | 39.0 | 20.0 | 30.0 | 23,400 |
| K | 28.0 | 28.0 | 26.0 | 20,384 |
| M | 38.8 | 17.9 | 23.0 | 15,974 |
| R | 36.5 | 32.2 | 14.0 | 16,454 |
| S | 32.0 | 28.2 | 12.8 | 11,551 |
| Mean | 34.9 | 25.3 | 21.2 | 18,633 |

Table 5. Distribution of herring eggs within test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Percent of Eggs on Kelp | Percent of Eggs on Net | Percent of Eggs Retained by Herring |
|---|---|---|---|
| A | 11 | 17 | 72 |
| B | 30 | 40 | 31 |
| C | 44 | 19 | 38 |
| D | 44 | 49 | 7 |
| E | 48 | 18 | 34 |
| F | 31 | 29 | 40 |
| G | 33 | 55 | 11 |
| H | 38 | 26 | 36 |
| I | 41 | 26 | 33 |
| J | 52 | 35 | 13 |
| K | 10 | 13 | 77 |
| L | 37 | 31 | 33 |
| M | 39 | 42 | 19 |
| N | 27 | 19 | 54 |
| O | 24 | 24 | 53 |
| P | 46 | 30 | 25 |
| Q | 32 | 12 | 56 |
| R | 41 | 14 | 45 |
| Mean Percent of all eggs | 35 | 28 | 37 |
| Mean Percent of eggs deposited in pound | 58 | 42 | |

**FIGURES**

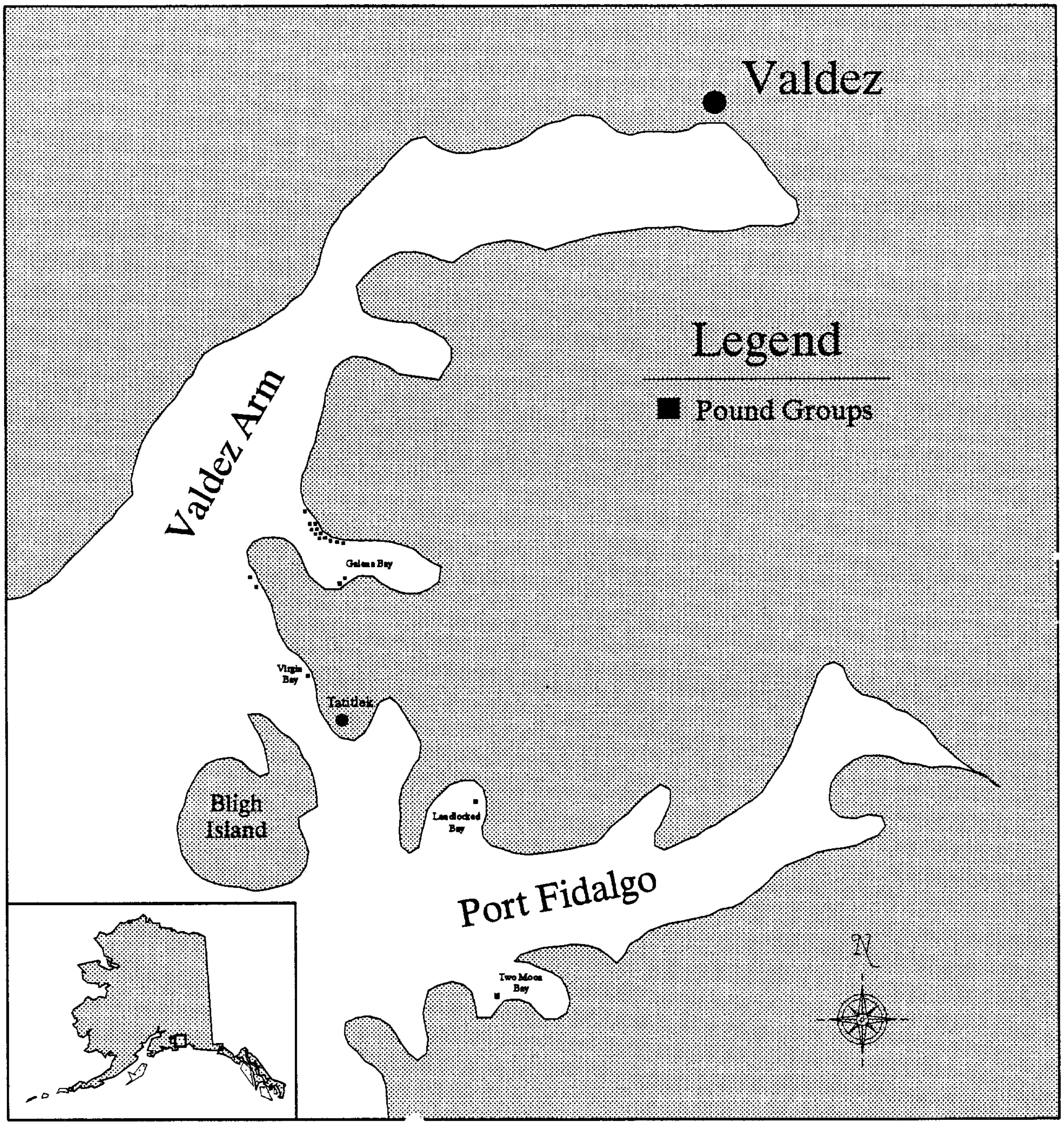


Figure 1. Location of herring pound groups in Prince William Sound, 1990.

APPENDIX TABLES

Appendix Table 1. Number and mean weight of *Macrocystis* blades collected from test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Number of Blades | | Mean Blade Weight (g) $\bar{b}_i$ | $V[\bar{b}_i]$ | Weight of Kelp (kg) $W_{Ki}$ | $V[W_{Ki}]$ |
|---|---|---|---|---|---|---|
| | Hung | Sampled | | | | |
| A | 1,196 | 25 | 120.0 | 789.6 | 144.7 | 1,129.5 |
| B | 1,100 | 25 | 118.2 | 1,539.3 | 130.0 | 1,862.6 |
| C[a] | 2,560 | 0 | 126.7 | 2,599.8 | 324.3 | 17,038.3 |
| D | 2,160 | 25 | 92.8 | 573.1 | 200.4 | 2,673.8 |
| E | 2,006 | 50 | 130.3 | 1,489.1 | 261.3 | 5,992.2 |
| F | 1,900 | 25 | 133.0 | 736.6 | 254.5 | 2,659.2 |
| G | 400 | 25 | 93.0 | 695.8 | 37.2 | 111.3 |
| H | 1,550 | 50 | 144.2 | 1,504.8 | 223.6 | 3,615.3 |
| I | 1,348 | 25 | 104.2 | 736.3 | 140.5 | 1,338.0 |
| J | 2,208 | 25 | 102.2 | 430.0 | 225.7 | 2,096.5 |
| K | 1,014 | 25 | 250.5 | 5,051.6 | 254.0 | 5,194.0 |
| L | 1,680 | 25 | 107.3 | 545.5 | 180.2 | 1,539.5 |
| M | 1,075 | 25 | 103.2 | 820.8 | 111.0 | 948.5 |
| N | 1,600 | 25 | 138.2 | 3,016.6 | 221.1 | 7,722.6 |
| O | 1,140 | 51 | 123.5 | 836.9 | 140.8 | 1,087.6 |
| P | 1,352 | 80 | 142.7 | 1,911.9 | 192.9 | 3,494.8 |
| Q | 1,498 | 25 | 126.8 | 756.6 | 190.0 | 1,697.9 |
| R | 1,850 | 25 | 121.8 | 940.9 | 225.3 | 3,220.4 |
| Mean | 1,535 | 556 | 126.7 | 2,599.8 | 194.5 | 6,128.9 |

[a] No blades were sampled. The mean blade weight and variance from all the pounds was used.

Appendix Table 2. Estimates of the weight and number of herring eggs deposited on kelp in test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Weight of Eggs on Kelp in (kg) $W_{eK1}$ | $V[W_{eK1}]$ | Unadjusted Mean Weight of Eggs per g $e_{uK1}$ | $V[e_{uK1}]$ | Ratio Lab Wt./ Field Wt. $R_{eK1}$ | $V[R_{eK1}]$ | Adjusted Mean Wt. of eggs per g $e_{K1}$ | $V[e_{K1}]$ | Number of Eggs on Kelp (x 1,000) $E_{K1}$ | $V[E_{K1}]$ |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 1,424.3 | 1,129.5 | 443.4 | 4,471.86 | 0.830 | 0.0019 | 368.2 | 3,445.69 | 524,410.3 | 7.1E+09 |
| B | 1,942.4 | 1,862.6 | 425.2 | 5,248.13 | 1.004 | 0.0050 | 427.0 | 6,166.26 | 829,461.5 | 2.4E+10 |
| C | 3,838.3 | 17,038.3 | 374.3 | 3,237.01 | 0.972 | 0.0021 | 364.0 | 3,354.18 | 1,397,204.4 | 5.2E+10 |
| D | 1,421.2 | 2,673.8 | 438.1 | 2,212.33 | 0.854 | 0.0016 | 374.1 | 1,911.69 | 531,591.3 | 4.2E+09 |
| E | 4,380.8 | 5,992.2 | 408.4 | 2,658.62 | 1.009 | 0.0020 | 411.9 | 3,026.31 | 1,804,395.4 | 5.9E+10 |
| F | 1,723.7 | 2,659.2 | 432.2 | 1,733.94 | 0.849 | 0.0059 | 367.1 | 2,344.25 | 632,814.3 | 7.3E+09 |
| G | 796.5 | 111.3 | 382.2 | 1,237.86 | 1.019 | 0.0022 | 389.4 | 1,601.09 | 310,128.6 | 1.0E+09 |
| H | 2,075.7 | 3,615.3 | 618.7 | 3,957.03 | 0.710 | 0.0101 | 439.1 | 5,829.08 | 911,329.4 | 2.6E+10 |
| I | 1,278.4 | 1,338.0 | 403.1 | 8,998.81 | 0.915 | 0.0044 | 368.9 | 8,210.59 | 471,615.4 | 1.4E+10 |
| J | 1,656.2 | 2,096.5 | 513.1 | 5,364.73 | 0.774 | 0.0157 | 396.9 | 7,257.42 | 657,302.5 | 2.0E+10 |
| K | 904.8 | 5,194.0 | 430.5 | 11,642.50 | 0.922 | 0.0108 | 396.8 | 11,769.25 | 359,067.1 | 1.0E+10 |
| L | 1,211.4 | 1,539.5 | 401.5 | 1,693.47 | 0.915 | 0.0057 | 367.4 | 2,320.64 | 445,129.9 | 3.6E+09 |
| M | 1,206.7 | 948.5 | 384.3 | 4,681.01 | 0.896 | 0.0030 | 344.3 | 4,182.24 | 415,525.2 | 6.2E+09 |
| N | 1,339.7 | 7,722.6 | 469.1 | 14,110.81 | 0.805 | 0.0104 | 377.5 | 11,286.53 | 505,740.2 | 2.1E+10 |
| O | 1,113.0 | 1,087.6 | 328.3 | 1,111.14 | 1.245 | 0.0019 | 408.8 | 1,929.21 | 454,917.2 | 2.6E+09 |
| P | 1,820.1 | 3,494.8 | 322.6 | 1,264.77 | 1.122 | 0.0182 | 361.9 | 3,467.48 | 658,713.3 | 1.2E+10 |
| Q | 1,905.6 | 1,697.9 | 484.8 | 11,593.35 | 0.824 | 0.0011 | 399.4 | 8,115.78 | 761,087.9 | 3.0E+10 |
| R | 2,118.0 | 3,220.4 | 397.6 | 7,171.73 | 0.960 | 0.0067 | 381.6 | 7,612.27 | 808,202.5 | 3.5E+10 |
| Mean | 1,784.0 | 6,128.9 | 425.4 | 9,800.15 | 0.924 | 0.0226 | 385.8 | 5,827.59 | 688,271.8 | 1.9E+10 |

Appendix Table 3. SCUBA diver calibrations for the number of eggs deposited on the net of test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Pound Dimensions Length (ft) | Width (ft) | Depth (ft) | Total Area (ft2) | Number of Quadrants Sampled | Adjusted Egg Density (Eggs/g) $E_{qi}$ | $V[E_{qi}]$ | Number of Eggs Deposited on Net (x 1,000) $E_{Ni}$ | $V[E_{Ni}]$ | Number of Eggs Deposited on Kelp and Net (x 1,000) $E_i$ | $V[E_i]$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 79.0 | 21.0 | 40.0 | 8,000.0 | 20 | 100.4 | 4,287.9 | 803,175.4 | 2.7E+11 | 1,327,585.7 | 2.8E+11 |
| B | 60.0 | 30.0 | 41.0 | 7,380.0 | 20 | 150.0 | 2,188.7 | 1,106,941.1 | 1.2E+11 | 1,936,402.6 | 1.4E+11 |
| C | 67.1 | 28.3 | 30.0 | 5,724.0 | 20 | 103.4 | 1,955.4 | 591,737.6 | 6.4E+10 | 1,988,942.0 | 1.2E+11 |
| D | 29.0 | 25.0 | 50.0 | 5,400.0 | 20 | 108.6 | 3,213.6 | 586,480.5 | 9.4E+10 | 1,118,071.8 | 9.8E+10 |
| E | 60.0 | 24.0 | 30.0 | 5,040.0 | 20 | 134.2 | 5,145.0 | 676,302.6 | 1.3E+11 | 2,480,697.9 | 1.9E+11 |
| F | 65.0 | 37.0 | 20.0 | 4,080.0 | 20 | 142.3 | 1,587.2 | 580,586.4 | 2.6E+10 | 1,213,400.8 | 3.4E+10 |
| G | 39.0 | 20.0 | 30.0 | 3,540.0 | 20 | 145.0 | 3,180.7 | 513,406.3 | 4.0E+10 | 823,534.9 | 4.1E+10 |
| H | 44.8 | 24.5 | 25.0 | 3,465.0 | 20 | 176.3 | 4,229.5 | 610,926.9 | 5.1E+10 | 1,522,256.3 | 7.7E+10 |
| I | 65.0 | 28.8 | 17.0 | 3,189.2 | 20 | 95.4 | 861.6 | 304,319.1 | 8.8E+09 | 775,934.5 | 2.2E+10 |
| J[a] | 48.0 | 48.0 | 16.0 | 3,072.0 | | 142.6 | 3,826.5 | 438,034.3 | 3.6E+10 | 1,095,336.8 | 5.6E+10 |
| K | 28.0 | 28.0 | 26.0 | 2,912.0 | 20 | 159.9 | 3,899.8 | 465,738.1 | 3.3E+10 | 824,805.2 | 4.3E+10 |
| L[a] | 77.4 | 25.0 | 12.8 | 2,621.4 | | 142.6 | 3,826.5 | 373,789.3 | 2.6E+10 | 818,919.2 | 3.0E+10 |
| M | 38.8 | 17.9 | 23.0 | 2,608.2 | 20 | 175.8 | 1,536.4 | 458,419.8 | 1.0E+10 | 873,945.1 | 1.7E+10 |
| N[a] | 36.5 | 32.0 | 19.0 | 2,603.0 | | 142.6 | 3,826.5 | 371,159.9 | 2.6E+10 | 876,900.1 | 4.7E+10 |
| O | 48.0 | 24.0 | 18.0 | 2,592.0 | 20 | 177.1 | 3,310.1 | 459,166.4 | 2.2E+10 | 914,083.6 | 2.5E+10 |
| P | 48.5 | 36.7 | 13.0 | 2,215.2 | 20 | 192.0 | 1,609.8 | 425,390.6 | 7.9E+09 | 1,084,103.9 | 2.0E+10 |
| Q | 44.8 | 24.3 | 15.5 | 2,142.1 | 20 | 135.7 | 2,508.1 | 290,776.6 | 1.2E+10 | 1,051,864.5 | 4.1E+10 |
| R | 36.5 | 32.2 | 14.0 | 1,923.6 | | 142.6 | 3,826.5 | 274,284.8 | 1.4E+10 | 1,082,487.2 | 4.9E+10 |
| S[b] | 32.0 | 28.2 | 12.8 | 1,541.1 | | | | | | | |
| Mean | 49.9 | 28.2 | 23.8 | 3,686.8 | 280 | 142.6 | 3,826.5 | 525,695.7 | 5.2E+10 | 1,213,967.5 | 7.1E+10 |

[a] Due to time restraints, no diver estimates were made.
[b] No herring were introduced into pounds.

Appendix Table 4. Number, weight, and estimates of fecundity for herring sampled from test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Number: Males | Number: Females | Sample Size | Sex Ratio ($S_i$) | $V[S_i]$ | Mean Weight (g): Males $W_{Mi}$ | $V[W_{Mi}]$ | Females $W_{Fi}$ | $V[W_{Fi}]$ | Total $W_i$ | $V[W_i]$ | Fecundity $F_i$ | $V[F_i]$ (x 1,000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 81 | 219 | 300 | 1.370 | 0.001695 | 109.7 | 346.99 | 123.1 | 465.3 | 119.5 | 467.6 | 19,134 | 3,652.8 |
| B | 130 | 167 | 297 | 1.778 | 0.004677 | 120.4 | 431.21 | 135.5 | 684.3 | 128.8 | 632.3 | 20,730 | 3,123.2 |
| C | 123 | 176 | 299 | 1.699 | 0.003984 | 113.9 | 367.84 | 125.5 | 410.9 | 120.7 | 424.8 | 19,439 | 3,051.0 |
| D | 111 | 87 | 198 | 2.276 | 0.014740 | 128.6 | 774.01 | 143.4 | 898.3 | 135.1 | 828.6 | 21,742 | 1,918.2 |
| E | 151 | 149 | 300 | 2.013 | 0.006824 | 131.9 | 454.29 | 139.0 | 951.4 | 135.6 | 724.3 | 21,179 | 2,890.2 |
| F | 152 | 147 | 299 | 2.034 | 0.007058 | 109.0 | 769.79 | 122.1 | 337.6 | 116.0 | 368.1 | 19,005 | 2,544.2 |
| G | 151 | 149 | 300 | 2.013 | 0.006824 | 115.1 | 495.20 | 125.3 | 422.8 | 120.2 | 459.2 | 19,416 | 2,633.6 |
| H | 131 | 166 | 297 | 1.789 | 0.004770 | 131.2 | 473.99 | 142.5 | 621.2 | 137.7 | 596.0 | 21,635 | 3,253.2 |
| I | 140 | 160 | 300 | 1.875 | 0.005487 | 125.5 | 503.16 | 131.8 | 798.3 | 128.8 | 660.6 | 20,246 | 2,931.2 |
| J | 200 | 100 | 300 | 3.000 | 0.020067 | 122.2 | 530.10 | 132.5 | 424.9 | 125.6 | 368.1 | 20,340 | 1,995.1 |
| K[a] | | | | 1.940 | 0.000366 | 123.4 | 601.74 | 133.9 | 648.5 | 128.8 | 630.1 | 20,524 | 3,914.1 |
| L | 181 | 118 | 299 | 2.534 | 0.013043 | 127.1 | 699.81 | 139.6 | 411.4 | 132.0 | 621.4 | 21,250 | 2,378.9 |
| M | 138 | 158 | 296 | 1.873 | 0.005547 | 114.3 | 561.94 | 125.6 | 650.0 | 120.3 | 639.0 | 19,452 | 2,776.4 |
| N | 140 | 160 | 300 | 1.875 | 0.005487 | 131.9 | 627.24 | 143.3 | 728.9 | 138.0 | 711.5 | 21,729 | 3,162.9 |
| O | 179 | 121 | 300 | 2.479 | 0.012267 | 118.2 | 427.21 | 124.4 | 335.5 | 120.7 | 398.3 | 19,298 | 2,198.4 |
| P | 131 | 169 | 300 | 1.775 | 0.004602 | 138.3 | 632.90 | 144.0 | 750.9 | 141.5 | 705.3 | 21,831 | 3,338.2 |
| Q | 142 | 158 | 300 | 1.899 | 0.005707 | 124.4 | 368.91 | 133.6 | 462.6 | 129.2 | 438.1 | 20,478 | 2,934.7 |
| R | 135 | 165 | 300 | 1.818 | 0.004975 | 134.4 | 525.40 | 145.4 | 560.9 | 140.4 | 573.1 | 22,000 | 3,294.6 |
| Total | 2,416 | 2,569 | 4,985 | 1.940 | 0.000366 | 123.4 | 601.74 | 133.9 | 648.5 | 128.8 | 630.1 | 20,524 | 3,914.2 |

[a] Data was lost. The mean estimates for sex ratio, mean weight, and fecundity for herring in all the the test pounds were used.

Appendix Table 5. Estimates of egg retention for female herring sampled from test pounds in the pound spawn-on-kelp fishery, Prince William Sound, 1990.

| Group Ident. | Number of Females Sampled $n_{Ri}$ | Number Retaining Eggs $n_{RFi}$ | Percent $P_{Ri}$ | $V[P_{Ri}]$ | Number of Eggs Per Skein $ER_{if}$ | $V[ER_{if}]$ | Mean Number of Eggs Retained Per Female $ER_i$ | $V[ER_i]$ |
|---|---|---|---|---|---|---|---|---|
| A | 50 | 40 | 80.0% | 0.003200 | 17,227 | 79,202,137 | 13,781 | 51,385,553.5 |
| B | 50 | 18 | 36.0% | 0.004608 | 17,656 | 141,151,407 | 6,356 | 19,079,280.2 |
| C | 50 | 19 | 38.0% | 0.004712 | 19,231 | 42,233,428 | 7,308 | 7,642,072.0 |
| D | 50 | 6 | 12.0% | 0.002112 | 13,510 | 57,581,768 | 1,621 | 1,093,037.4 |
| E | 50 | 15 | 30.0% | 0.004200 | 24,324 | 49,444,913 | 7,297 | 6,727,308.5 |
| F[a] | 50 | 35 | 70.0% | 0.004200 | 25,573 | 92,268,426 | 7,668 | 47,570,726.4 |
| G | 50 | 8 | 16.0% | 0.002688 | 13,638 | 91,181,249 | 2,182 | 2,589,127.9 |
| H | 50 | 18 | 36.0% | 0.004608 | 21,481 | 102,182,711 | 7,733 | 14,898,341.0 |
| I | 50 | 19 | 38.0% | 0.004712 | 17,438 | 73,791,310 | 6,626 | 11,740,535.4 |
| J | 50 | 9 | 18.0% | 0.002952 | 14,442 | 89,631,999 | 2,600 | 3,255,172.4 |
| K | 50 | 22 | 44.0% | 0.004928 | 21,752 | 68,839,583 | 9,571 | 15,319,754.6 |
| L | 50 | 18 | 36.0% | 0.004608 | 19,379 | 69,562,572 | 6,977 | 10,425,313.9 |
| M | 50 | 10 | 20.0% | 0.003200 | 18,468 | 123,533,621 | 3,694 | 5,637,440.9 |
| N | 50 | 25 | 50.0% | 0.005000 | 23,459 | 68,257,357 | 11,729 | 19,474,588.1 |
| O | 50 | 22 | 44.0% | 0.004928 | 23,025 | 105,063,772 | 10,131 | 22,435,266.3 |
| P | 51 | 10 | 19.6% | 0.003091 | 27,456 | 90,500,703 | 5,384 | 5,529,738.2 |
| Q | 50 | 28 | 56.0% | 0.004928 | 20,605 | 97,199,553 | 11,539 | 32,094,942.7 |
| R | 50 | 25 | 50.0% | 0.005000 | 19,699 | 87,742,757 | 9,850 | 23,437,251.7 |
| Mean | | | 38.5% | 0.000263 | 19,909 | 20,468,513 | 7,668 | 3,134,752.8 |

[a] Due to the high egg retention in this sample, the mean number of eggs retained per female for all pounds was used.