PACIFIC HERRING POUND SPAWN-ON-KELP FISHERY IN PRINCE WILLIAM SOUND, ALASKA, 1991

REGIONAL INFORMATION REPORT 2A95-21

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Alaska Department of Fish and Game
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333 Raspberry Road
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OEO/ADA STATEMENT

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ABSTRACT

A total of 23 groups comprised of 126 permit holders participated in the 1991 pound spawn-on-kelp fishery for Pacific herring *Clupea pallasi*. The size of the groups ranged from 1 to 14 permit holders. Twenty-two of the twenty-three groups harvested spawn-on-kelp product totaling 319,840 lbs (145,077.4 kg). The loss from harvest weight to final product weight varied from 3.5% to 40.0% within the groups and averaged 18.6% overall. Weight loss depended on 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 the overall weight loss was 8.9%. One test pound was be sampled from each of 23 groups. The spawn-on-kelp product produced in the test pounds averaged 1.9 tons. The amount of herring utilized in each test pound averaged 44.1 tons based on spawn deposition surveys and 26.4 tons based on brailing. The spawn deposition's biomass estimate averaged 2.06 times larger than the brailed biomass estimates. The amount of herring used to produce 1.0 ton of spawn-on-kelp product was 21.2 tons using the spawn deposition survey estimate and 11.1 tons using the brailed estimate. Fifty percent of the herring introduced into the pounds were female. The female herring had a mean weight of 135.3 g and mean fecundity of 20,701.5 eggs. An estimated 38.5% of the female herring introduced into the pounds retained their eggs. The average number of eggs retained by female herring which did not deposit their eggs retained 22,012.1 eggs. Based on all the female herring introduced into the pounds, the mean number of eggs retained by each female was 8,475.6. Female herring retained 37.0% of their eggs, 58.6% were deposited on the kelp and 41.4% were deposited on the net of the pounds.

KEY WORDS: Pacific herring, *Clupea 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 for food. 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 PWS beginning in 1969. Spawn on kelp was 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%. Although 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 the increasing importance of the pound spawn-on-kelp fishery, a research program was to be started in 1989. However, all spring herring fisheries in PWS were closed in 1989 due to the *T/V Exxon Valdez* oil spill. The study was delayed until the spring of 1990 (Morstad *et al.* 1992) and 1991.

Five commercial fisheries harvest herring and spawn on kelp in PWS: (1) purse seine sac roe fishery, (2) gillnet 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 PWS are managed on a sustained yield basis such that the combined harvest of all five fisheries does not exceed 20% of the total spawning biomass in years when the projected spawning biomass reaches the 42,000 ton threshold. A detailed stock assessment program is conducted 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 Commissioner's permit. The permit specifies the tonnage of herring and number of *Macrocystis* blades each permit holder is allowed to introduce into each pound 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) all lines of kelp must be labeled with permit holders name and the number of blades attached to the line; (3) the permit holder must be physically present when introducing kelp and herring into a pound and when harvesting spawn on kelp from a pound; 4) pounds must be located east of a line from Porcupine Point to Point Freemantle (Figure 1); 5) herring can be held a maximum of six days within a pound structure; 6) 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 transport 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 6 to 12 inches apart on poly-line. The lines are strung in the pounds at depths varying from one to three meters below the water surface. As soon as the seining of herring for introduction into pounds is opened, 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 remain in the water for four to six weeks to allow viable eggs to hatch.

Specific objectives of the study were to estimate: (1) the amount of herring introduced into the pounds, (2) the amount of spawn deposited 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.

METHODS

The sampling program was designed to sample one single, double, or triple pound from each group. A single pound was a structure that was utilized by one permit holder; a double pound was a structure shared by two permit holders; and a triple pound was a structure shared by three permit holders. Sampling was 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 calculated 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 7 April 1991. Sampling crews were based on a chartered vessel anchored in Galena Bay. Two small skiffs were used to transport crews to the test pounds. A test pound summary completion list provided a record of event sampling dates for each test pound.

By 1 March 1991, 127 of the 128 CFEC permit holders had registered. Permit holders were required to declare their group affiliation when they registered. A total of 23 groups declared for the 1991 season. Of the 23 groups, 2 consisted of a single permit holder.

Number and Weights of Kelp

The arrival of *Macrocystis* began on 6 April from Southeast Alaska and continued until 13 April. Test pounds were selected by the sampling crew when the *Macrocystis* was being distributed into pounds. Of the 23 test pounds selected, 12 were single pounds, 10 were double pounds, and 1 was a triple pound. 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 test pound. 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. Additionally, all permit holders were required to record the number of blades on each line in their pound.

SCUBA Diver Estimation of Eggs on Net

SCUBA divers conducted 20 egg density estimates per pound in 18 of the 22 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 panel 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 19 of the 22 test pounds prior to spawning. Length and sex (LS) information were collected from each herring sampled. Weights were determined from a length-weight relationship developed from the standard age, weight, length, and sex (AWLS) data collected in the 1991 pound and purse seine fisheries in PWS. These samples were collected in the general vicinity of the pounds in the Northeast portion of PWS during the same time period. All LS sampling was conducted at the ADF&G laboratory in Cordova.

Weight and Sex Ratio of Females

The sex ratio of the females in each test pound was estimated from a sample of 300 fish. This provides an estimate of the sex ratio within 5% of the true value 95% of the time. A ratio of 50:50 would result in 150 females being measured for a mean length used to estimate a mean weight from a weight-length relationship.

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, 300 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. In 1990, 50 females were collected from each test pound to determine egg retention. Assuming egg retention was less than 10 percent and assuming a CV of 35% for egg retention, a sample size of 50 was determined to be adequate to estimate egg retention to within 10% of the true value 95% of the time (Cochran 1977). However, in 1990, egg retention averaged 38%. The sample size was increased to 300 females in 1991 to account for the higher egg retention.

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 the web inside the impoundment at the time cf harvest in each test pound. All samples were weighed to the nearest 1.0 gram, stored in Gilson's solution, and counted in the department's laboratory in Cordova.

Harvested Product

The total number and weight of blades harvested from each test pound were collected from each group representative. Blades were removed from the pound, 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. The spawn on kelp remained in brine solution for up to six days. All blades introduced were harvested.

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, herring catch date, location, estimated biomass, 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 11 of the 22 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 26 feet deep. To determine the water weight within each brail, 5 to 10 brail loads were weighed, then held until no water remained and weighed again. The percentage water weight was subtracted from the total weight of herring brailed. Biomass estimates were determined for 22 test pounds.

Egg Survival

To estimate the survival of eggs deposited on net, 30 mortality frames were placed in 13 pounds at 3 depths; 0.3 m, 3.0 m, and when possible 6.0 m below the surface. When the pound depth was less then 6.0 meters, the mortality frame was placed at the bottom of the pound. Three observations were made over a 30-day period. Divers collected three samples of 100 eggs from each frame. Divers identified eggs as dead, alive or unfertilized. If the eggs were alive, they were further classified as uneyed, eyed or hatched.

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 from the test pound as:

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

where,

n_{tp} = the number of test pounds.

The variance 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;

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

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

$\bar{R}_{BBR}$ = 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:

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

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:

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

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

$$CV[B_i] = SD[B_i]/B_i. \tag{7}$$

<u>Total Number of Eggs Deposited in Pounds</u>

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

$$E_i = E_{Ki} + E_{Ni}; \tag{8}$$

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:

$$V[E_i] = V[E_{Ki}] + V[E_{Ni}]. \tag{9}$$

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

$$E_{Ki} = W_{eKi}\bar{e}_{Ki}; \tag{10}$$

and,

$$W_{eKi} = W_{Hi} + W_{Ri} - W_{Ki}; \tag{11}$$

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:

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

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

$$W_{Ki} = N_{Bi}\bar{b}_i; \tag{13}$$

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:

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

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

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

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:

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

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

$$\overline{e}_{Ki} = \overline{R}_{Ki}\overline{e}_{uKi}; \quad (17)$$

where,

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

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

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 its variance were calculated from each sample as follows:

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

with

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

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:

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

with the variance estimated as:

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

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

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

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

with the variance estimated as:

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

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:

$$E_{Ni} = A_i\overline{E}_{qi}; \tag{25}$$

where,

$\overline{A}_i$ = the total area (ft^2) of net that was used in test pound i; and

$\overline{E}_{qi}$ = 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:

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

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

$$A_i = 2(L_iD_i + 1/2W_iD_i); \tag{27}$$

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:

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

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 Gilson's 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:

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

where,

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

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

α = a constant;

β_{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

ϵ = a normally distributed random variable with mean 0 and variance σ^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:

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

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 σ^2 were known. Laurent (1963) gave an exact expression for the bias correction that incorporated additional terms when σ^2 was estimated from a sample. However, for diver calibration data in the spawn deposition survey in PWS, the biases in estimating σ^2 from a sample were less than 5% (Biggs and Funk 1988). Because of this, the estimates were adjusted as follows:

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

where,

MSE = the mean square error from the linear regression.

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

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

Mean Weight of Herring in Pounds

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

$$\overline{W}_i = (\sum_{f=1}^{n_i} W_{if})/n_i \quad (34)$$

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

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

The mean weight and variance of female herring ($\overline{W}_{Fi}$) was also estimated for each test pound and 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 sample collected from each test pound as the number of herring in the 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:

$$S_i = 1/p_i; \tag{36}$$

where,

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

The variance of S_i was simply:

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

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 1991 using all the fecundity and weight data collected in the northeast area in 1991. Mean fecundity for each test pound was estimated from the fecundity-weight relationship using the average female weight from each test pound as follows:

$$\overline{F}_i = \alpha + \beta\overline{W}_{Fi}; \tag{38}$$

where,

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

α = the Y-intercept, and

β = 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):

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

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 300 female herring were randomly collected from each test pound immediately prior to release. The female herring were checked for eggs retained. The proportion of herring retaining eggs and 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):

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

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

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

and

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

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

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:

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

with

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

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 127 permit holders registered for the PWS pound fishery in 1991; of those, 126 permit holders participated in the fishery. A total of 51 permit holders operated single pounds, 72 permit holders operated in conjunction with another permit holder to create 36 double pounds; and 3 permit holders operated a triple pound. Most of the permit holders set up pounds in Valdez Arm (Galena Bay) and Port Fidalgo (Figure 1). A total of 23 groups participated in 1991, with the number of permit holders ranging from 1 to 14 per group. Twenty-two groups produced product in 1991 with one group failing to introduce herring (Table 1).

The 22 groups successful in producing product harvested 398,862.0 lbs of initial spawn-on-kelp product which resulted in a final product weight of 319,840.6 lbs (Table 1). Weight loss from harvest to final product varied from 3.5% to 40.0% with an average of 18.6%. Weight loss was highly dependent upon how accurate the individual groups were in weighing the raw kelp and which processor processed the spawn-on-kelp product. Fifteen groups selling to the same processor had an overall weight loss of 23.0%. Six groups sold to a separate processor and had an overall weight loss of 11.8%. Two groups processed their own product.

Eleven of the twenty-three test pounds were brailed to estimate the biomass of herring introduced into each test pound. The biomass of herring introduced into test pounds was also estimated from spawn deposition estimates. The mean biomass of herring introduced into the test pounds was 44.1 tons based on spawn deposition (B_i) and 26.4 tons based on brailing (B_{ri}) (Table 2). The mean ratio of biomass estimates from egg deposition to brailing was 2.01. When biomass estimates were categorized in 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 28.8 tons based on spawn deposition and 15.4 tons based on brailing. The mean ratio of estimates was 2.22. The mean biomass of herring in double pounds based on spawn deposition was 50.0 tons and 31.0 tons from brailed estimates. The mean ratio of the estimates was 1.67.

The amount of spawn-on-kelp product produced in the 23 test pounds averaged 1.9 tons (Table 3). Single test pounds had an average production of 1.4 tons, double pounds had an average of 2.6 tons, and triple pound produced 4.9 tons. The amount of herring used to produce 1.0 ton of spawn-on-kelp product averaged 20.6 tons based on spawn deposition and 11.1 tons based on brailing. Estimates based on spawn deposition ranged from 12.5 to 33.7 tons, while estimates based on brailing ranged from 6.0 to 15.1 tons.

The amount of herring used to produce 1.0 ton of spawn-on-kelp product in single pounds averaged 20.4 tons based on spawn deposition and 10.2 tons based on brailing. In double pounds, the amount of herring needed to produce 1.0 ton of product was 19.8 tons based on spawn deposition and 11.9 tons based on brailing. In triple pounds, the amount of herring needed to produce 1.0 ton of product was 31.4 tons based on spawn deposition and 12.0 tons based on brailing.

Volume of single pounds ranged from 22,968.0 ft^3 to 50,400 ft^3 and averaged 35,707.3 ft^3 (Table 4). Volume of double pounds ranged from 29,232.0 ft^3 to 85,410.0 ft^3 and averaged 52,270.0 ft^3. Depths of single pounds ranged from 22.0 ft to 39.0 ft while depth of double pounds ranged from 20.0 ft to 46.0 ft.

Eggs from female herring introduced into the test pounds were either deposited on kelp, deposited on the net of pounds, or retained by the female herring. On average, 41.0% of available eggs were deposited on kelp, 29.9% were deposited on the net of the pounds, and 29.0% of the eggs were retained by females (Table 5). The variability was in the number of eggs retained by the female herring. Of eggs that were actually deposited inside test pounds, 58.6% were deposited on the kelp and 41.4% were deposited on the net.

The mean number of blades of *Macrocystis* hung in a single pound was 1,173; 2,350 in a double pound, and 3,600 in a triple pound (Appendix Table 1). Mean blade weight was 121.80 g. Mean weight of the total number of blades hung in a single pound was 144.8 kg, 279.3 kg in a double pound, and 477.3 kg in a triple pound.

The mean weight of eggs deposited on kelp in test pounds was estimated to be 1,306.7 kg in single pounds, 2,852.9 kg in double pounds, and 5,391.7 kg in triple pounds (Appendix Table 2). Based on an average of 491.55 eggs/g in a single pound, the average number of eggs deposited on the kelp was 643,160,800. In double pounds, an average of 482.64 eggs/g equated to 1,349,952,600 eggs deposited on kelp, and in triple pounds, an average of 543.92 eggs/g equated to 2,932,623,800 eggs deposited on kelp. Based on diver estimates, an average of 613,115,800 eggs were deposited on the net of each single pound, 650,989,600 eggs on the net of each double pound, and 1,275,927,600 on the net of each triple pound (Appendix Table 3). Combining estimates for the number of eggs on kelp and on the net, an average of 1,256,276,600 eggs were deposited within each single pound, 2,000,942,100 eggs deposited in each double pound, and 4,208,551,400 eggs deposited in each triple pound.

The mean sex ratio of females to males was 2.005 (Appendix Table 4). Mean weight of herring was 124.6 g for males and 135.3 g for females. Female herring had an average fecundity of 20,702 eggs.

Of the 300 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 pounds with female herring that retained eggs ranged from 19% up to 70% with an average of 8,475.6 eggs retained by each female in the test pounds. If only herring that retained eggs were considered, an average of 22,012.1 eggs were retained per female which was slightly higher then the average female fecundity.

Twenty-four of the thirty mortality frames were recovered, but only two of the three observation intervals were completed (due to time restrictions the third observation was not possible). During the first observation in Galena Bay, less than 1% of the eggs were dead and on the second observation 32% of the eggs were dead, 58% eyed and 10% hatched (Table 6). During the first observation in Picnic Cove, 3% of the eggs were dead and on the second observation 45% of the eggs were dead, 36% eyed, and 17% hatched. During the first observation in Boulder Bay, 2% of the eggs were dead and on the second observation 62% of the eggs were dead, 13% eyed, and 28% hatched. During the first observation in Landlocked Bay, less than 1% of the eggs were dead and on the second observation 59% of the eggs were dead, 22% eyed, and 16% hatched.

DISCUSSION

The wide range of product weight loss among groups can be attributed to how individual groups processed their kelp. This includes 1) time kelp was allowed to drain; 2) how extensively blades were trimmed; 3) how accurate the individual groups weigh the harvested kelp; and 4) weight loss between product grade. Weight of high quality kelp with evenly distributed layers of eggs may differ from weight loss of lower quality product having far fewer eggs distributed on the kelp. Also occurring in 1991 was the slippage of egg layers reported in 1990 (Morstad *et al.* 1992). The reported slippage for 1991 was 5,940.85 kg.

Based on the two biomass estimates, spawn deposition versus brailing, the quantity of herring captured and placed into test pounds had a ratio between the two estimates of slightly more than two for all test pounds combined during 1991. The ratio between the two estimates in 1990 was only 1.37. Eliminating the one triple pound from 1991's total mean production, the ratio between the two estimates dropped slightly to 2.0. Based on the size and depth of the triple pound, seining and brailing the pound structure was not effective.

The accumulation of dead herring (deadloss) at the bottom of pounds was observed in 1990 but was not considered a problem. During the 1991 season, an increase in the deadloss was observed and measurements were made to estimate the amount. When the deadloss was estimated and added to the brailed estimate, the ratio between the spawn deposition biomass and brailed estimates decreased to 1.49. The contribution of eggs from wild fish which may have spawned on the outside of the pound net which was unknown, may have increased the biomass estimates based on spawn deposition. Finally, the accuracy of weighing the harvested spawn on kelp on the grounds varied greatly among groups. The weight of the product harvested was collected from the individual permit holder. Method of weighing and accuracy of the scales were not checked as part of the study. If the weights were not accurate that would influence the final results of the biomass estimate.

Large variances for our biomass estimates from the spawn deposition data in 1990 were thought to be due largely to inadequate egg retention sample sizes collected in 1990 (Morstad *et al.* 1992). The sample size was increased in 1991 from 50 to 300 female herring from each test pound. The percent of females retaining eggs in 1991 was 38.5% compared to 37.0% in 1990. The coefficient of variation for the 1991 estimates ranged from 23% to 92%.

Errors in brailed weights of herring in test pounds were due mostly to poor or variable pound construction. For example, 6 of the 11 test pounds which were brailed had depths greater than the 26 ft depth limit of the crowding seine used in the brailing operation. Divers estimated several tons of herring remained in several pounds following the brailing procedure. The herring remaining in the pounds after brailing could have spawned on the nets prior to the spawn on the web estimates completed by the divers. The additional spawn on the web after brailing would increase the biomass estimates based on spawn deposition.

The study design in 1990 and 1991 did not adequately determine how many eggs on the pound net were contributed by herring outside of the pound. Frames placed on the outside of the test pounds collected minimal eggs. With the configuration of the pound rafted to other pounds, the frames were covered by the neighboring pounds. Additional frames need to be placed on the outside of pounds to adequately address the contribution of outside spawning. If outside spawning is significant, this may be one of the factors which caused biomass estimates based on egg deposition to exceed estimates from brailing.

The current production level for this fishery has been set assuming that 12.5 tons of herring generates 1.0 ton of spawn-on-kelp product. This estimate appeared reasonable in 1990 (Morstad *et al.* 1992) and continued in 1991 with 11.0 tons need to produce 1.0 ton of spawn-on-kelp product (based on brailed biomass estimates) for single pounds, 11.9 tons for double pounds, and 12.0 tons for triple pounds.

One of the regulations in effect in 1990 but not in 1991, was restricting each permit holder to a specified amount of harvested product. Any amount produced above the allocation remained in the pound. This regulation eliminated any incentive to produce more than the allocated amount by improving the standards of one ton of product for 12.5 tons of herring. However, this regulation changed during the winter of 1990-91 and the fishery is now regulated by the amount of herring and the number of kelp blades allowed to be introduced into a pound. All product produced is harvested.

Results of this study suggested that the best way to insure high quality harvest would be through more efficient use of the allocated herring. Introducing herring in excess of the allocation, or even less than the allocation, into a small pound does not increase the amount or quality of the product. Overcrowding of herring may reduce the number of females spawning within a pound and also increase mortality. One way to increase egg deposition would be to reduce egg retention. Despite the fact that an average of 29.0% of the eggs available to the pound fishery in 1991 were retained by the females, many groups were able to harvest their quota of spawn-on-kelp product. One area of interest pertaining to egg retention was that individual female herring either retained all of their eggs or were totally spawned out. There appeared to be no partially spawned out females. There may also be indication that the older aged females retained their eggs at a higher rate than the younger aged females. The average number of eggs retained by females that did not spawn was 22,000. Yet, the average fecundity per female in the pound fishery was 20,700. This observed difference was not formally tested during this study and may be due to sampling error. However, if the observed difference was statistically different or not, it is our recommendation that future studies collect scales from female herring retaining eggs to determine their age and see if older herring really do retain there eggs at a higher rate.

Egg retention in 1991 ranged from 19% to 70%. The amount of retention may be related to the amount of stress due to handling, overcrowding within pounds, and residence time in pounds. However, egg retention rates observed in the pound fishery may not be significantly different than those that occur 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 to reduce the high egg retention rates for herring placed in pounds should be investigated. Developing techniques which reduce the stress associated with handling by minimizing overcrowding in both the pounds and push-pounds. Also, possibly selecting younger aged herring for impoundments could reduce the number of females retaining eggs. Such methods might include capturing less herring to minimize crowding in seines and in push-pounds, test sampling herring prior to placement into pounds, and building pound structures which can be altered easily depending on the herring allocation each year.

Little can be summarized from the mortality study due to not completing the third and final observation, which would have followed hatching. At this time, it can be summarized that more than 90% of eggs were fertilized but to what extent those eggs hatch is not known. This portion of the study should be continued to determine what portion of the eggs that are spawned on the net actually contribute to the wild herring population.

LITERATURE CITED

Biggs, E.D., and F. Funk. 1988. Pacific herring spawning ground surveys for Prince William Sound, 1988, with historic overview. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Informational Report 2C88-07, Anchorage.

Brady, J., S. Morstad, E. Simpson, and E. Biggs. 1991. Prince William Sound area annual finfish management report, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2C90-07, Anchorage.

Brady, J.A. 1985. Investigations of kelp used in closed pounding operations, Prince William Sound, 1983 and 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Area Data Report 85-03, Cordova.

Cochran, W.G. 1977. Sampling Techniques. Third Edition, Wiley and Sons, New York.

Draper, N.R., and H. Smith. 1981. Applied regression analysis. John Wiley and Sons, New York.

Goodman, L.A. 1960. On the exact variance of products. Journal of the American Statistical Association 66:708-713.

Hay, D.E. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). Canadian Journal of Fisheries and Aquatic Sciences 42(Suppl.1):111-126.

Laurent, A.G. 1963. Lognormal distribution and the translation method: description and estimation problems. Journal of the American Statistical Association 58:231-235.

Morstad, S., T.T. Baker, J.A. Brady. 1992. Pacific herring pound spawn-on-kelp fishery in Prince William Sound, Alaska, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-02, Anchorage, AK.

TABLES

Table 1. Group and test pound production and estimated weight loss of herring spawn-on-kelp product from initial harvest to final product for each group in the pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

		Total Group Production					Test Pound Production	
Group	Type of	Initial Harvest		Final Product		Shrinkage	Initial Harvest	
Identification	Pound	(kg)	(lbs)	(kg)	(lbs)	(%)	(kg)	(lbs)
Single Pounds								
A	Single	4,735.1	10,439.0	4,317.3	9,518.0	8.8%	1,543.1	3,402.0
B	Single	6,734.5	14,847.0	6,502.0	14,334.5	3.5%	1,589.8	3,504.9
C	Single	5,271.2	11,621.0	4,185.3	9,227.0	20.6%	1,213.8	2,676.0
D	Single	9,752.2	21,500.0	7,868.5	17,347.0	19.3%	1,451.5	3,200.0
E	Single	7,173.1	15,814.0	6,106.7	13,463.0	14.9%	1,131.3	2,494.1
F	Single	18,890.8	41,647.0	16,225.0	35,770.0	14.1%	1,797.1	3,961.9
G	Single	5,405.0	11,916.0	5,038.1	11,107.0	6.8%	1,565.3	3,450.9
H	Single	7,681.1	16,934.0	6,906.9	15,227.0	10.1%	1,846.1	4,069.9
I	Single	4,616.7	10,178.0	4,185.8	9,228.0	9.3%	1,154.8	2,545.9
J	Single							
K	Single	1,632.9	3,600.0	1,481.0	3,265.0	9.3%	1,632.9	3,599.9
L	Single	1,043.3	2,300.0	1,003.3	2,212.0	3.8%	1,043.3	2,300.1
Double Pounds								
M	Double	4,911.5	10,828.0	3,219.5	7,097.8	34.5%	3,347.5	7,380.0
N	Double	10,946.6	24,133.0	7,993.2	17,622.0	27.0%	4,891.1	10,783.0
O	Double	20,766.4	45,782.0	15,051.3	33,182.5	27.5%	3,204.6	7,064.9
P	Double	6,966.3	15,358.0	6,333.7	13,963.5	9.1%	4,008.4	8,837.0
Q	Double	12,378.6	27,290.0	10,792.3	23,793.0	12.8%	1,901.9	4,193.0
R	Double	5,348.3	11,791.0	3,562.5	7,854.0	33.4%	2,054.8	4,530.1
S	Double	11,987.6	26,428.0	8,248.1	18,184.0	31.2%	2,266.6	4,997.0
T	Double	9,472.4	20,883.0	7,878.9	17,370.0	16.8%	2,870.8	6,329.0
U	Double	9,476.0	20,891.0	7,307.3	16,109.8	22.9%	4,258.3	9,387.9
V	Double	6,500.0	14,330.0	3,900.7	8,599.5	40.0%	2,518.1	5,551.5
Triple Pounds								
W	Triple	9,231.5	20,352.0	6,969.9	15,366.0	24.5%	5,869.0	12,938.9
Mean Production								
Single Pounds	12	6,630.5	14,617.8	5,801.8	12,790.8	12.5%	1,451.7	3,200.5
Double Pounds	10	9,875.4	21,771.4	7,428.8	16,377.6	24.8%	3,132.2	6,905.3
Triple Pounds	1	9,231.5	20,352.0	6,969.9	15,366.0	24.5%	5,869.0	12,938.9
Total	23	8,124.5	17,911.4	6,612.3	14,577.5	18.6%	2,091.3	4,610.6
Total Production								
Single Pounds	12	72,935.9	160,796.0	63,819.8	140,698.5	12.5%	15,969.0	35,205.6
Double Pounds	10	98,753.5	217,714.0	74,287.7	163,776.1	24.8%	31,322.1	69,053.4
Triple Pounds	1	9,231.5	20,352.0	6,969.9	15,366.0	24.5%	5,869.0	12,938.9
Total	23	180,921.0	398,862.0	145,077.4	319,840.6	18.6%	53,160.1	117,197.9

Table 2. Biomass estimates based on spawn deposition survey and brailing of herring introduced into test pounds in the pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

Group	Biomass Estimates						Ratio of Estimates
	Spawn Deposition Survey					Brailed	Bi versus
Identification	Bi (tonne)	V[Bi]	SD[Bi]	CV[Bi]	Bi (ton)	Bri (ton)	Bri
Single Pounds							
A	21.1	343.4	18.5	87.8%	23.3	23.1	1.01
B	25.6	35.6	6.0	23.3%	28.2	13.8	2.05
C	19.4	40.3	6.4	32.8%	21.4		
D	21.8	49.5	7.0	32.2%	24.1		
E	25.3	74.8	8.7	34.2%	27.8	7.8	3.57
F	31.9	138.7	11.8	36.9%	35.2	25.2	1.40
G	21.1	43.8	6.6	31.3%	23.3		
H	28.2	88.9	9.4	33.4%	31.1		
I	19.3	45.8	6.8	35.0%	21.3	6.9	3.07
J							
K	49.9	2,111.9	46.0	92.0%	55.1		
L	23.6	73.7	8.6	36.3%	26.0		
Double Pounds							
M	47.8	154.4	12.4	26.0%	52.7		
N	71.2	380.2	19.5	27.4%	78.5		
O	47.8	186.8	13.7	28.6%	52.7		
P	56.8	909.3	30.2	53.1%	62.6	53.2	1.18
Q	40.0	200.9	14.2	35.4%	44.1		
R	31.6	51.6	7.2	22.7%	34.8	22.7	1.53
S	23.9	44.2	6.7	27.8%	26.4		
T	46.0	417.5	20.4	44.5%	50.7	29.6	1.71
U	57.3	294.8	17.2	30.0%	63.1	30.4	2.08
V	31.8	130.7	11.4	36.0%	35.0	19.0	1.84
Triple Pounds							
W	139.3	4,703.3	68.6	49.2%	153.6	58.5	2.63
Mean Production							
Single Pounds	26.1	354.2	18.8	72.1%	28.8	15.4	2.22
Double Pounds	45.4	478.8	21.9	48.2%	50.0	31.0	1.67
Triple Pounds	139.3	4,703.3	68.6	49.2%	153.6	58.5	2.63
Total	40.0	125.7	11.2	28.0%	44.1	26.4	2.01

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, Alaska, 1991.

Group Identification	Spawn-on-Kelp Product (ton) Initial Harvest	Spawn-on-Kelp Product (ton) Final Product	Spawn Deposition Estimate B_i (ton)	Brailing Estimate B_{ri} (ton)	Tons of Herring Per 1 Ton of Harvest	Brailed Herring Per 1 Ton of Harvest	Tons of Herring Per 1 Ton of Product	Brailed Herring Per 1 Ton of Product
Single Pounds								
A	1.7	1.6	23.3	23.1	13.7	13.6	15.0	14.9
B	1.8	1.7	28.2	13.8	16.1	7.9	16.7	8.1
C	1.3	1.1	21.4		16.0		20.1	
D	1.6	1.3	24.1		15.0		18.6	
E	1.2	1.1	27.8	7.8	22.3	6.3	26.2	7.3
F	2.0	1.7	35.2	25.2	17.8	12.7	20.7	14.8
G	1.7	1.6	23.3		13.5		14.5	
H	2.0	1.8	31.1		15.3		17.0	
I	1.3	1.2	21.3	6.9	16.7	5.5	18.5	6.0
J								
K	1.8	1.6	55.1		30.6		33.7	
L	1.2	1.1	26.0		22.6		23.5	
Double Pounds								
M	3.7	2.4	52.7		14.3		21.8	
N	5.4	3.9	78.5		14.6		19.9	
O	3.5	2.6	52.7		14.9		20.6	
P	4.4	4.0	62.6	53.2	14.2	12.0	15.6	13.2
Q	2.1	1.8	44.1		21.0		24.1	
R	2.3	1.5	34.8	22.7	15.4	10.0	23.1	15.1
S	2.5	1.7	26.4		10.6		15.3	
T	3.2	2.6	50.7	29.6	16.0	9.3	19.2	11.2
U	4.7	3.6	63.1	30.4	13.4	6.5	17.4	8.4
V	2.8	1.7	35.0	19.0	12.6	6.8	21.0	11.4
Triple Pounds								
W	6.5	4.9	153.6	58.5	23.7	9.0	31.4	12.0
Mean Production								
Single Pounds	1.6	1.4	28.8	15.4	18.1	9.2	20.4	10.2
Double Pounds	3.5	2.6	50.0	31.0	14.7	8.9	19.8	11.9
Triple Pounds	6.5	4.9	153.6	58.5	23.7	9.0	31.4	12.0
Total	2.3	1.9	44.1	26.4	16.8	9.1	20.6	11.1

Table 4. Dimensions of test pounds in the herring pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

Group Identification	Pound Dimensions						Total Area		Total Volume	
	Length		Width		Depth					
	m	ft	m	ft	m	ft	(m2)	(ft2)	(m3)	(ft3)
Single Pounds										
A	9.3	36.5	8.0	31.5	8.9	35.0	307.1	4,760.0	659.4	40,241.3
B	7.9	31.0	13.2	52.0	6.1	24.0	257.0	3,984.0	634.0	38,688.0
C	8.9	35.0	7.6	30.0	6.1	24.0	201.3	3,120.0	413.0	25,200.0
D	8.9	35.0	7.6	30.0	6.1	24.0	201.3	3,120.0	413.0	25,200.0
E	12.2	48.0	9.4	37.0	6.9	27.0	296.1	4,590.0	785.8	47,952.0
F	12.3	48.5	9.4	37.0	7.1	28.0	308.9	4,788.0	823.4	50,246.0
G	14.7	58.0	4.6	18.0	5.6	22.0	215.7	3,344.0	376.4	22,968.0
H	10.2	40.0	5.1	20.0	9.1	36.0	278.7	4,320.0	471.9	28,800.0
I	9.9	39.0	4.6	18.0	9.9	39.0	286.8	4,446.0	448.6	27,378.0
J										
K	6.1	24.0	15.2	60.0	8.9	35.0	379.4	5,880.0	825.9	50,400.0
L							311.1	4,822.5	765.2	46,694.0 [a]
Double Pounds										
M	15.7	62.0	8.1	32.0	5.6	22.0	266.8	4,136.0	715.3	43,648.0
N	15.2	60.0	9.5	37.5	6.4	25.0	314.5	4,875.0	921.8	56,250.0
O	17.3	68.0	7.9	31.0	5.1	20.0	255.5	3,960.0	690.9	42,160.0
P	24.9	98.0	6.6	26.0	5.6	22.0	352.0	5,456.0	918.6	56,056.0
Q	13.7	54.0	7.6	30.0	11.7	46.0	498.6	7,728.0	1,221.2	74,520.0
R	12.2	48.0	7.4	29.0	5.3	21.0	208.6	3,234.0	479.0	29,232.0
S	16.5	65.0	9.3	36.5	9.1	36.0	471.5	7,308.0	1,399.6	85,410.0
T	16.3	64.0	6.1	24.0	8.6	34.0	386.1	5,984.0	855.8	52,224.0
U	13.2	52.0	7.1	28.0	6.4	25.0	258.1	4,000.0	596.5	36,400.0
V	13.2	52.0	9.1	36.0	6.4	25.0	283.9	4,400.0	766.9	46,800.0
Triple Pounds										
W	18.3	72.0	10.2	40.0	8.9	35.0	505.8	7,840.0	1,651.8	100,800.0
Mean Production										
Single Pounds	10.0	39.5	8.5	33.4	7.5	29.4	273.2	4,235.2	585.1	35,707.3
Double Pounds	15.8	62.3	7.9	31.0	7.0	27.6	329.6	5,108.1	856.6	52,270.0
Triple Pounds	18.3	72.0	10.2	40.0	8.9	35.0	505.8	7,840.0	1,651.8	100,800.0
Total	13.2	51.9	8.3	32.5	7.3	28.8	311.1	4,822.5	765.2	46,694.0

[a] Test pound not sampled. Mean for all pounds used.

Table 5. Distribution of herring eggs within test pounds in the pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

	Total Number of Eggs (x 1,000)						
Group Identification	On Kelp	%	On Net	%	Retained by Female Herring	%	Total
Single Pounds							
A	813,300.9	34.3%	812,416.5	34.3%	745,933.7	31.5%	2,371,651.0
B	702,172.7	44.3%	576,384.4	36.3%	308,009.2	19.4%	1,586,566.4
C	529,856.4	38.0%	437,793.6	31.4%	424,996.6	30.5%	1,392,646.6
D	673,541.6	46.3%	351,373.1	24.2%	429,053.5	29.5%	1,453,968.1
E	472,067.5	26.8%	844,397.0	47.9%	445,778.9	25.3%	1,762,243.4
F	702,700.8	35.4%	649,607.2	32.7%	633,962.9	31.9%	1,986,270.8
G	716,426.7	41.4%	488,095.1	28.2%	525,803.4	30.4%	1,730,325.1
H	837,090.5	41.7%	559,621.7	27.9%	608,561.9	30.3%	2,005,274.0
I	469,234.1	28.2%	741,653.1	44.5%	455,988.6	27.4%	1,666,875.8
J							
K	718,890.8	32.5%	606,243.2	27.4%	885,735.8	40.1%	2,210,869.8
L	439,486.7	27.9%	676,689.1	43.0%	456,982.4	29.0%	1,573,158.3
Double Pounds							
M	1,187,016.2	49.3%	552,229.8	22.9%	670,060.3	27.8%	2,409,306.3
N	2,074,951.0	52.8%	702,690.9	17.9%	1,149,645.7	29.3%	3,927,287.6
O	1,507,286.5	50.9%	555,661.1	18.8%	899,443.9	30.4%	2,962,391.6
P	1,830,455.7	47.8%	798,279.4	20.8%	1,203,205.3	31.4%	3,831,940.4
Q	805,366.7	30.2%	1,084,381.1	40.7%	773,696.7	29.0%	2,663,444.5
R	965,738.3	60.6%	392,695.5	24.7%	233,916.4	14.7%	1,592,350.3
S	1,135,830.4	51.0%	477,461.5	21.4%	615,616.2	27.6%	2,228,908.1
T	1,193,242.9	45.6%	612,119.8	23.4%	810,891.7	31.0%	2,616,254.4
U	1,738,766.7	50.6%	717,592.2	20.9%	977,502.1	28.5%	3,433,861.0
V	1,060,871.0	48.0%	616,784.4	27.9%	533,839.6	24.1%	2,211,494.9
Triple Pounds							
W	2,932,623.8	43.3%	1,275,927.6	18.8%	2,565,908.6	37.9%	6,774,460.0
Mean Production							
Single Pounds	643,160.8	35.9%	613,115.8	34.2%	535,080.3	29.9%	1,791,356.9
Double Pounds	1,349,952.6	48.8%	650,989.6	23.5%	764,945.9	27.7%	2,765,888.0
Triple Pounds	2,932,623.8	43.3%	1,275,927.6	18.8%	2,565,908.6	37.9%	6,774,460.0
Total	927,531.0	41.0%	676,689.1	29.9%	656,796.5	29.0%	2,261,016.6

Table 6. Survival of eggs deposited on frames placed in pounds of the spawn-on-kelp in pounds fishery, Prince William Sound, Alaska, 1991.

		Date	Frame	Depth	Egg Condition					Total Eggs
Group	Location	Examined	#	(m)	Unfertilized	Uneyed	Eyed	Hatched	Dead	Examined
P	Galena Bay	April 21	1	0.3	0	300	0	0	0	300
			2	3.0	0	300	0	0	0	300
			3	4.3	0	300	0	0	0	300
		May 13	1	0.3	25	0	25	120	130	300
			2	3.0	0	0	60	16	224	300
			3	4.3	0	0	145	0	155	300
R	Galena Bay	April 21	1	0.3	0	300	0	0	0	300
			2	3.0	10	290	0	0	0	300
			3	6.0	0	300	0	0	0	300
		May 13	1	0.3	0	0	212	62	26	300
			2	3.0	0	0	238	33	29	300
			3	6.0	0	0	294	0	6	300
U	Galena Bay	April 25	1	0.3	0	300	0	0	0	300
			2	4.0	0	298	0	0	2	300
			3	6.0	0	300	0	0	0	300
		May 13	1	0.3	0	0	115	5	180	300
			2	4.0	0	0	226	17	57	300
			3	6.0	0	0	254	16	30	300
A	Picnic Cove	April 24	1	0.3	19	281	0	0	0	300
			2	3.0	112	142	0	0	47	301
			3	4.3	38	251	0	0	11	300
		May 14	1	0.3	0	0	0	63	237	300
			2	3.0	0	0	12	66	222	300
			3	4.3	1	0	16	46	237	300
H	Picnic Cove	April 24	1	0.3	0	300	0	0	0	300
			2	3.0	0	300	0	0	0	300
			3	6.0	0	300	0	0	0	300
		May 14	1	0.3	0	17	222	59	2	300
			2	3.0	2	0	198	37	63	300
			3	6.0	2	7	206	43	42	300
B	Boulder Bay	April 24	1	0.3	0	286	0	0	14	300
			2	1.5	136	159	0	0	5	300
			3	4.0	0	297	0	0	3	300
			1	0.3	0	0	4	97	199	300
			2	1.5	0	0	38	4	258	300
			3	4.0	0	0	77	121	102	300
W	Landlocked Bay	April 24	1	1.5	0	300	0	0	0	300
			2	3	0	300	0	0	0	300
			3	4.3	0	300	0	0	0	300
		May 14	1	1.5	0	0	0	40	260	300
			2	3	1	0	6	99	185	291
			3	4.3	55	0	163	55	27	300
T	Landlocked Bay	April 24	1	0.3						a
			2	3						a
			3	5.3	28	268	0	0	4	300
		May 14	1	0.3	0	0	0	0	300	300
			2	3	0	0	20	0	280	300
			3	5.3	5	0	202	85	8	300

a Did not locate frames in during first observation.

FIGURES

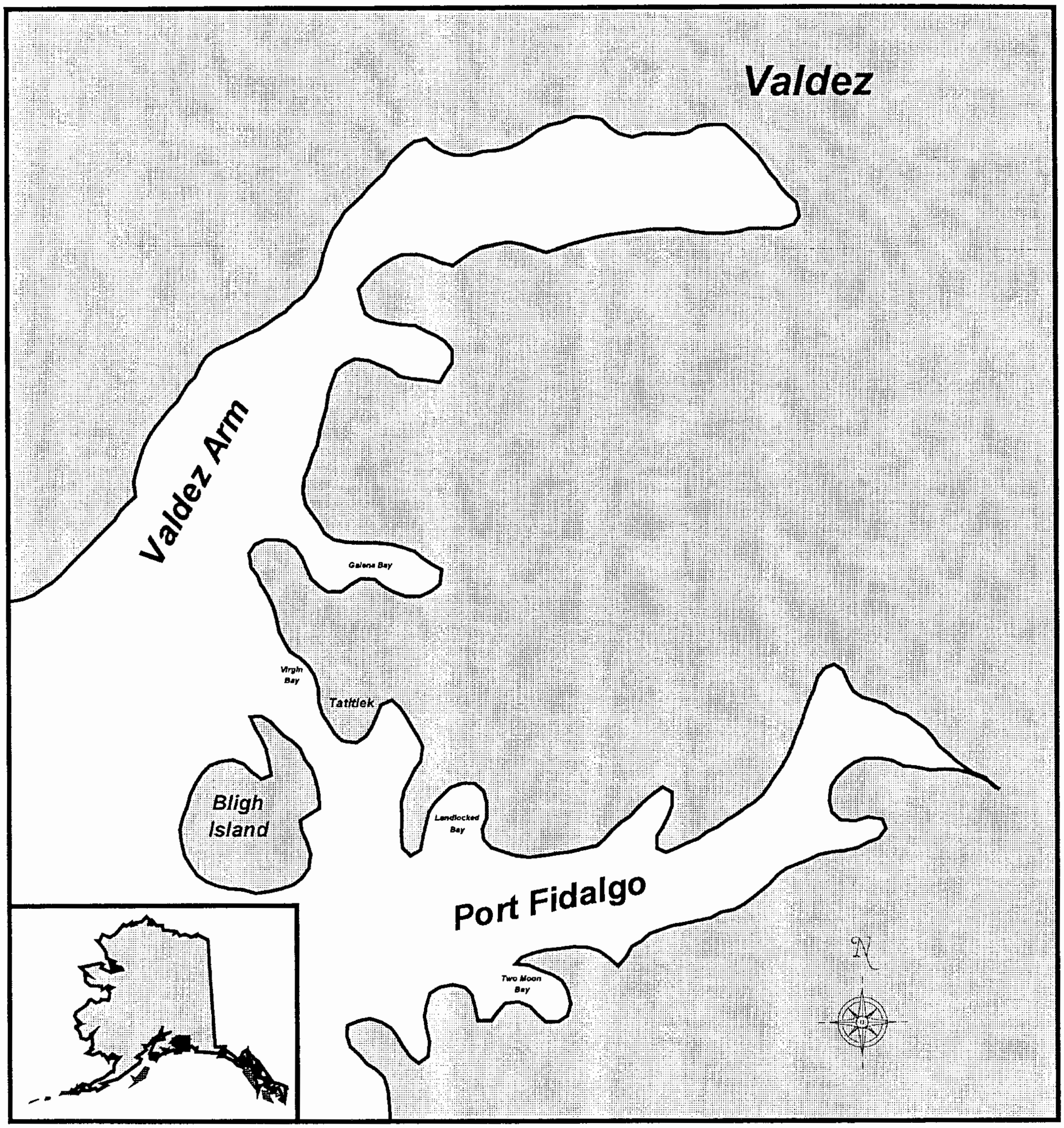

Figure 1. Location of herring pound fishery in Prince William Sound, 1991.

APPENDICES

Appendix Table 1. Number and mean weight of *Macrocystis* blades collected from test pounds in the pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

Group Identification	Total Blades in Test Pound	Number of Blades Sampled	Mean Blade Weight bi (g)	V[bi]	Total Weight of Kelp WKi (kg)	V[WKi]
Single Pounds						
A	900	50	111.40	1,554.37	100.3	1,259.0
B	1,200	25	113.64	551.82	136.4	794.6
C	1,200	25	110.16	757.31	132.2	1,090.5
D	1,200		121.80	1,201.65 [a]	146.2	1,730.4
E	1,196	25	120.52	1,085.93	144.1	1,553.3
F	1,200	25	173.68	1,184.48	208.4	1,705.6
G	1,200	50	119.50	1,027.56	143.4	1,479.7
H	1,200	50	114.44	750.33	137.3	1,080.5
I	1,180	50	114.86	932.98	135.5	1,299.1
J	1,200	25	118.32	606.06	142.0	872.7
K	1,200	51	137.84	1,282.25	165.4	1,846.4
L	1,200		121.80	1,201.65 [a]	146.2	1,730.4
Double Pounds						
M	2,400	25	141.04	1,070.37	338.5	6,165.4
N	2,400	50	108.74	790.16	261.0	4,551.3
O	2,400	50	108.20	702.61	259.7	4,047.0
P	2,400		121.80	1,201.65 [a]	292.3	6,921.5
Q	2,400	52	111.75	878.86	268.2	5,062.2
R	2,400	50	115.20	596.16	276.5	3,433.9
S	2,400		121.80	1,201.65 [a]	292.3	6,921.5
T	2,400	50	110.12	895.37	264.3	5,157.3
U	1,900	63	130.48	678.00	247.9	2,447.6
V	2,400		121.80	1,201.65 [a]	292.3	6,921.5
Triple Pounds						
W	3,600	52	132.60	1,436.76	477.3	18,620.3
Mean Production						
Single Pounds	1,173	376	123.16	1,011.37	144.8	1,370.2
Double Pounds	2,350	340	119.09	921.65	279.3	5,162.9
Triple Pounds	3,600	52	132.60	1,436.76	477.3	18,620.3
Total	1,625	768	121.80	1,201.65	197.9	3,173.3
Total Production						
Single Pounds	14,076	376	1,477.97	12,136.40	1,737.4	16,442.3
Double Pounds	23,500	340	1,190.94	9,216.49	2,793.0	51,629.3
Triple Pounds	3,600	52	132.60	1,436.76	477.3	18,620.3
Total	41,176	768	2,801.51	22,789.65	5,007.7	86,692.0

[a] Test pounds not sampled. Mean for all test pounds 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, Alaska, 1991.

Group Identification	Weight of Eggs on kelp WeKi (kg)	V[WeKi]	Mean Number of Eggs/g eKi (g)	V[eKi]	Number of Eggs on Kelp (x 1,000) EKi	V[EKi]
Single Pounds						
A	1,442.9	1,259.0	563.67	6,514.23	813,300.9	13,953,447,010.8
B	1,453.4	794.6	483.11	5,660.72	702,172.7	12,139,042,860.8
C	1,081.6	1,090.5	489.88	6,607.89 [a]	529,856.4	7,984,908,822.9
D	1,305.3	1,730.4	515.99	3,239.27	673,541.6	5,974,490,687.9
E	987.2	1,553.3	478.21	5,506.46	472,067.5	5,712,608,959.7
F	1,588.7	1,705.6	442.32	2,595.57	702,700.8	6,880,270,582.7
G	1,421.9	1,479.7	503.85	4,615.76	716,426.7	9,700,951,437.0
H	1,708.8	1,080.5	489.88	6,607.89 [a]	837,090.5	19,546,543,141.5
I	1,019.3	1,299.1	460.37	3,496.21	469,234.1	3,903,001,779.8
J						
K	1,467.5	1,846.4	489.88	6,607.89 [a]	718,890.8	14,661,144,604.8
L	897.1	1,730.4	489.88	6,607.89 [a]	439,486.7	5,722,183,987.3
Double Pounds						
M	3,009.0	6,165.4	394.49	1,256.63	1,187,016.2	12,329,476,055.2
N	4,630.1	4,551.3	448.14	3,853.58	2,074,951.0	83,509,777,337.3
O	2,944.9	4,047.0	511.83	3,925.38	1,507,286.5	35,087,402,008.9
P	3,716.1	6,921.5	492.58	5,912.38	1,830,455.7	83,283,543,364.6
Q	1,633.7	5,062.2	492.97	4,599.67	805,366.7	13,483,337,483.8
R	1,778.3	3,433.9	543.06	4,779.37	965,738.3	16,110,678,371.1
S	1,974.3	6,921.5	575.32	3,622.87	1,135,830.4	16,386,859,683.5
T	2,606.5	5,157.3	457.79	1,643.22	1,193,242.9	12,236,244,918.9
U	4,010.4	2,447.6	433.56	3,564.85	1,738,766.7	57,785,830,512.2
V	2,225.8	6,921.5	476.63	1,698.97	1,060,871.0	9,977,454,464.3
Triple Pounds						
W	5,391.7	18,620.3	543.92	11,795.05	2,932,623.8	348,170,344,946.4
Mean Production						
Single Pounds	1,306.7	1,415.4	491.55	5,278.16	643,160.8	9,652,599,443.2
Double Pounds	2,852.9	5,162.9	482.64	3,485.69	1,349,952.6	34,019,060,420.0
Triple Pounds	5,391.7	18,620.3	543.92	11,795.05	2,932,623.8	348,170,344,946.4
Total	1,893.4	3,173.3	489.88	6,607.89	927,531.0	24,429,369,014.8
Total Production						
Single Pounds	14,373.6	15,569.6	5,407.03	58,059.78	7,074,768.6	106,178,593,875.0
Double Pounds	28,529.1	51,629.3	4,826.37	34,856.93	13,499,525.5	340,190,604,199.7
Triple Pounds	5,391.7	18,620.3	543.92	11,795.05	2,932,623.8	348,170,344,946.4
Total	48,294.4	85,819.3	10,777.32	104,711.76	23,506,917.9	794,539,543,021.1

[a] Test pounds not sampled. Mean for all test pounds used.

Appendix Table 3. SCUBA diver estimates of the number of eggs deposited on the net of test pounds in the pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

Group Identification	Number of Quadrats Sampled	Adjusted Egg Density (Eggs/q) E_{qi}	$V[E_{qi}]$	Number of Eggs Deposited on Net (x 1,000) E_{Ni}	$V[E_{Ni}]$	Total Number of Eggs Deposited (x 1,000) E_i	$V[E_i]$
Single Pounds							
A	20	170.7	1,764.4	812,416.5	39,976,493,295.3	1,625,717.4	53,929,940,306.1
B	20	144.7	3,423.6	576,384.4	54,340,216,585.0	1,278,557.2	66,479,259,445.8
C		140.3	2,900 [a]	437,793.6	28,226,649,436.6	967,650.0	36,211,558,259.5
D	20	112.6	2,552.5	351,373.1	24,846,675,062.4	1,024,914.6	30,821,165,750.3
E	20	184.0	2,765.4	844,397.0	58,262,773,188.4	1,316,464.5	63,975,382,148.0
F	20	135.7	3,054.5	649,607.2	70,024,283,112.0	1,352,307.9	76,904,553,694.6
G	20	146.0	2,293.3	488,095.1	25,644,990,082.0	1,204,521.7	35,345,941,519.0
H	20	129.5	1,861.7	559,621.7	34,744,332,194.6	1,396,712.2	54,290,875,336.1
I	20	166.8	985.4	741,653.1	19,479,041,512.8	1,210,887.2	23,382,043,292.5
J							
K	20	103.1	1,496.7	606,243.2	51,746,361,425.2	1,325,133.9	66,407,506,030.0
L		140.3	2,900 [a]	676,689.1	67,437,102,554.1	1,116,175.8	73,159,286,541.4
Double Pounds							
M	20	133.5	2,040.6	552,229.8	34,907,691,286.6	1,739,246.0	47,237,167,341.8
N	20	144.1	2,240.1	702,690.9	53,238,244,590.5	2,777,641.9	136,748,021,927.8
O		140.3	2,900 [a]	555,661.1	45,471,629,048.0	2,062,947.6	80,559,031,056.8
P	20	146.3	1,473.5	798,279.4	43,862,622,459.9	2,628,735.2	127,146,165,824.5
Q		140.3	2,900 [a]	1,084,381.1	173,174,669,833.2	1,889,747.8	186,658,007,317.0
R	20	121.4	385.6	392,695.5	4,032,616,445.1	1,358,433.9	20,143,294,816.2
S	20	65.3	876.5	477,461.5	46,810,804,912.2	1,613,291.9	63,197,664,595.7
T	20	102.3	1,457.0	612,119.8	52,172,613,180.2	1,805,362.7	64,408,858,099.1
U	20	179.4	1,760.2	717,592.2	28,163,718,761.7	2,456,358.9	85,949,549,273.9
V	20	140.2	5,654.7	616,784.4	109,475,405,949.4	1,677,655.4	119,452,860,413.7
Triple Pounds							
W	20	162.7	2,487.9	1,275,927.6	152,920,625,382.4	4,208,551.4	501,090,970,328.8
Mean Production							
Single Pounds	180	143.1	2,363.4	613,115.8	43,157,174,404.4	1,256,276.6	52,809,773,847.6
Double Pounds	160	131.3	2,168.8	650,989.6	59,131,001,646.7	2,000,942.1	93,150,062,066.7
Triple Pounds	20	162.7	2,487.9	1,275,927.6	152,920,625,382.4	4,208,551.4	501,090,970,328.8
Total	360	140.3	2,900	676,689.1	67,437,102,554.1	1,604,220.1	91,866,471,568.9

[a] Test pounds not sampled. Mean for all test pounds used.

Appendix Table 4. Number sampled, mean weight, and estimates of fecundity for herring sampled from test pounds in the pound spawn-on-kelp fishery, Prince William Sound, Alaska, 1991.

Group	Number		Sample	Sex Ratio		Mean Weight (g)						Fecundity	
						Males		Females		Total			
Identification	Males	Females	Size	S_i	$V[S_i]$	W_{Mi}	$V[W_{Mi}]$	W_{Fi}	$V[W_{Fi}]$	W_i	$V[W_i]$	F_i	$V[F_i]$
Single Pounds													
A	167	130	297	2.285	0.009915	136.0	627.2	144.0	728.9	138.0	711.5	21,824.2	2,652,162.7
B	131	169	300	1.775	0.004602	138.0	525.4	144.0	560.9	140.4	573.1	21,824.2	3,337,163.4
C	133	167	300	1.796	0.004785	118.2	427.2	124.4	335.5	120.7	398.3	19,297.5	2,889,310.9
D	146	154	300	1.948	0.006177	125.5	503.2	131.8	798.3	128.7	654.7	20,246.2	2,834,680.6
E	153	145	298	2.055	0.007302	122.2	530.1	132.5	424.9	125.6	368.1	20,339.7	2,703,692.7
F	145	155	300	1.935	0.006056	138.3	632.9	144.1	750.9	141.5	705.3	21,830.7	3,090,665.8
G	110	190	300	1.579	0.003057	115.1	495.2	125.3	422.8	121.6	449.3	19,416.0	3,263,102.3
H	137	163	300	1.840	0.005174	114.3	561.9	125.6	650.0	120.3	639.0	19,452.3	2,853,107.5
I	104	173	277	1.601	0.003487	120.5	431.2	135.5	684.3	128.8	632.3	20,730.5	3,223,137.7
J													
K				2.005	0.000395	124.6	588.0	135.3	618.9	129.0	605.0	20,701.5	3,747,911.9 [a]
L				2.005	0.000395	124.6	588.0	135.3	618.9	129.0	605.0	20,701.5	3,747,911.9 [a]
Double Pounds													
M	140	85	225	2.647	0.019464	134.4	525.4	145.4	560.9	140.4	573.1	21,999.6	1,907,311.5
N	174	126	300	2.381	0.010997	124.4	368.9	133.6	462.6	129.2	438.1	20,477.7	2,417,357.5
O	118	107	225	2.103	0.010353	113.9	367.8	125.5	410.9	120.7	424.8	19,439.4	2,008,930.0
P	139	157	296	1.885	0.005658	127.1	699.8	139.6	411.4	132.0	621.4	21,250.3	3,036,914.0
Q				2.005	0.000395	124.6	588.0	135.3	618.9	129.0	605.0	20,701.5	3,747,911.9 [a]
R	203	96	299	3.115	0.022101	122.2	530.1	132.5	424.9	125.6	368.1	20,339.7	1,934,359.4
S	99	131	230	1.756	0.005794	121.0	769.8	147.0	337.6	116.0	368.1	22,211.2	2,718,984.6
T	163	137	300	2.190	0.008714	131.9	454.3	139.0	951.4	135.6	724.3	21,179.3	2,687,731.6
U	159	132	291	2.205	0.009157	131.2	474.0	142.5	621.2	137.7	596.0	21,634.6	2,662,477.6
V	152	148	300	2.027	0.006963	131.2	474.0	142.5	621.2	137.7	596.0	21,634.6	2,939,129.0
Triple Pounds													
W	140	131	271	2.069	0.008188	109.7	347.0	123.1	465.3	119.5	467.6	19,133.7	2,325,610.6
Mean Production													
Single Pounds	1,226	1,446	2,672	1.848	0.000587	125.2	537.3	134.3	599.5	129.4	576.5	20,578.6	3,122,077.0
Double Pounds	1,347	1,119	2,466	2.204	0.000587	126.2	525.2	138.3	542.1	130.4	531.5	21,086.8	2,606,110.7
Triple Pounds	140	131	271	2.069	0.001076	109.7	347.0	123.1	465.3	119.5	467.6	19,133.7	2,325,610.6
Total	2,561	2,548	5,109	2.005	0.000395	124.6	588.0	135.3	618.9	129.0	605.0	20,701.5	3,747,911.9

[a] Test pounds not sampled. Mean for all test pounds 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, Alaska, 1991.

Group Identification	Number of Females Sampled nFi	Number Retaining Eggs nERi	Proportion Retaining Eggs PERi	V[PERi]	Number of Eggs Retained Per Skein ERRi	V[ERRi]	Egg Retention ERi	V[ERi]
Single Pounds								
A	274	114	0.416	8.899E-04	24,068.0	81,050,200.1	10,013.7	14,473,545.3
B	350	95	0.271	5.666E-04	19,369.9	45,244,244.1	5,257.5	3,520,259.8
C			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
D			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
E	314	94	0.299	6.701E-04	23,006.8	78,020,531.8	6,887.4	7,294,478.2
F	333	149	0.447	7.447E-04	22,872.5	21,010,767.1	10,234.2	4,580,489.3
G			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
H			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
I	215	76	0.353	1.068E-03	22,084.3	60,350,473.5	7,806.6	7,997,427.9
J								
K	225	157	0.698	9.414E-04	19,830.3	66,424,506.9	13,837.1	32,649,361.3
L			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
Double Pounds								
M			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
N			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
O			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
P	319	162	0.508	7.860E-04	19,152.8	104,028,994.9	9,726.5	27,035,466.6
Q			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
R	314	59	0.188	4.875E-04	18,639.9	63,507,765.2	3,502.4	2,380,609.8
S			0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7 [a]
T	333	120	0.360	6.943E-04	26,398.1	119,523,056.1	9,512.8	15,922,049.5
U	305	111	0.364	7.615E-04	23,656.6	31,142,941.7	8,609.4	4,527,257.4
V	333	113	0.339	6.753E-04	20,287.2	74,624,119.1	6,884.3	8,820,585.4
Triple Pounds								
W	308	145	0.471	8.116E-04	24,779.4	32,501,945.8	11,665.6	7,675,435.2
Mean Production								
Single Pounds	1,711	685	0.400	1.404E-04	21,935.7	37,353,550.3	8,764.9	6,049,360.5
Double Pounds	1,604	565	0.352	1.423E-04	21,819.5	45,161,520.7	8,061.3	5,664,803.8
Triple Pounds	308	145	0.471	8.116E-04	24,779.4	32,501,945.8	11,665.6	7,675,435.2
Total	3,623	1,395	0.385	6.537E-05	22,012.1	11,757,665.9	8,475.6	1,774,049.7

[a] Test pounds not sampled. Mean for all test pounds used.