**Developing a prior for the dive survey spawn index proportionality constant *q***

The process is:

1. List the factors that affect *q*.
2. Come up with the “best” distribution for each factor. In some cases this will be based on data (not data that is used in the assessment) and in other cases it is a best guess.
3. Estimate the prior distribution for *q* by random sampling from all distributions. That is, for *n* replicates randomly select one value from the distribution for each factor and calculate the resultant *q* for that replicate (multiplying the values for each factor).
4. Fit a parametric model to the resulting distribution of *n* estimates of *q* that can be used as the *q* prior in the assessment.

**Factors that affect *q*:**

In coming up with distributions for these factors we want to estimate the average affect over years, not capture inter-annual variation in them.

**Proportion of total spawn surveyed**:  Has to be less than or equal to 1.  We don’t know how low this may be, but we do know that some spawn events are not surveyed. A uniform distribution with an upper bound of 1 and some lower bound seems appropriate, given we don’t know where the centre of the distribution should be. I would hazard a guess of a lower bound of 0.85, but we could get input on this from people who may have a better basis for their guesses (Chuck Fort, district fishery officers, others?).

Proportion surveyed is likely lower in more remote locations, and the proportion is likely lower when spawn abundance is lower, but I don’t think that is something we can try to account for.

**Egg loss prior to survey**:  This factor accounts for egg loss due to predation (seabirds, invertebrates, marine mammals) and translocation between the time of egg deposition and the spawn surveys. Doug Hay has summarized the herring egg loss literature (Hay et al. 2011, their Appendix 7). I reviewed the annotated summary of the literature and selected all studies conducted on the west coast of North America where total egg loss was estimated over the incubation period. Those criteria substantially reduce the available literature (Appendix 1). While there are some additional studies that estimated egg loss due to a limited number of factors, I don’t think they are useful for our purpose. Of the studies reported in Appendix 1, I suggest excluding: Bishop and Green (2001) because they only consider seabird predation; Outram (1958) because only eelgrass beds were studied; and Paulson (1984) because initial egg densities were extremely low. Egg loss estimates from the remaining studies were standardized to instantaneous (daily) rates (Table 1). I suggest assuming a normal distribution for the daily egg loss rate using the mean and standard deviation given in Table 1.

The second component of estimating egg loss prior to spawn surveys is the average number of days between egg deposition and the surveys. Information to support the distribution of this factor was taken from the herring spawn survey data (spawn biomass for vivian 2010.xls, obtained from Jake Schweigert in 2010). Only “dive” survey records were selected, and numerous error checks imposed to remove erroneous data (Table 2). For each spawn record, the number of days between spawning and survey was estimated as the difference between the mid-spawn date and the mid-survey date. The mean time between spawn deposition and surveys ranges from 6.4 to 9.2 days across the stock assessment regions (Table 3).

I suggest assuming a normal distribution for the average time between spawning and surveys, based on the observed mean and standard deviation across the stock assessment regions (mean=7.7; standard deviation =1.13).

**Bias in mean egg density**:  The equation predicting egg density based on dive survey observations (egg layers and percent cover by vegetation class) is based on field observation-egg count data collected through much of the coast in the mid 1980’s.  The prediction equation is unbiased.  I looked at the predicted mean egg density (from the prediction equation) versus the observed mean egg density (from the egg counts) by stock assessment region/year at the time the Jake/Fournier developed the prediction equation (unfortunately I didn’t publish the analysis). As I remember, there were about 10-15 SAR/year combinations with enough data to look at.  A number of the differences between mean egg density from the counts and from the predication equation were as large as +- 30%.  There were not enough observations to determine if the differences created a bias at the stock assessment region level. I suggest assuming a normal distribution for this factor with mean 1 and standard deviation 0.15. (The analysis could be re-done... but there probably won’t be time for the upcoming assessments).

**Drift in dive survey observations:**  This is the only factor that I can think of that could generate a positive bias in the spawn index *q*.  We have no information on how survey observations may have changed over time, but Doug Hay’s January paper suggests that if there has been drift it is directed towards observations that result in lower density (i.e. increase in “trace” observations.)  I suggest we ignore this factor.

I don’t see that there would be any covariance structure among these factors that we’d need to consider in simulating their joint distribution. The proposed distributions to use in simulating a prior for the dive survey *q* are:

|  |  |  |
| --- | --- | --- |
| **Factor influencing *q* (1988-2011)** | **Distribution** | **Parameters of distribution** |
| Proportion of total spawn surveyed | Uniform | 0.85 – 1.0 |
| Egg loss prior to survey:   * Instantaneous daily egg loss rate (*Z*) * Days between spawn deposition and survey (*d*) | Normal  Normal | Mean 0.075 Std. dev 0.22 Mean 7.7 Std. dev. 1.13 |
| Bias in mean egg density (from prediction equation based on egg layers and % veg. cover observations) | Normal | Mean 1  Std. dev. 0.1 |

**Simulating the dive survey spawn index *q***

Monte-Carlo simulations were conducted randomly sampling from the distributions for each of the factors listed above. For each simulation replicate, egg survival was calculated as . The factor affects are multiplicative, so the *q*s were calculated as the product of the proportion of spawn surveyed, the egg survival rate, and the bias in predicted mean egg density. To generate the distribution for *q*, 10,000 replicates were simulated. The means and standard deviations for the simulated *q*s and the natural log of the simulated *q*s are:

|  |  |  |
| --- | --- | --- |
|  | *q* | ln(*q*) |
| Mean | 0.529 | -0.662 |
| Std. dev. | 0.117 | 0.226 |

The *q* and ln(*q*) distributions are shown in Figure 1, overlaid with normal curves based on the means and standard deviations of the distributions. The simulated *q* distribution is somewhat intermediate between a normal and a lognormal distribution. However, either of these two distributions is likely adequate as a prior for the dive survey spawn index *q*.



Figure : Histograms of the distribution of simulated spawn index *q* estimates (left panel) and the log of the simulated spawn index *q* estimates (right panel) overlaid with the normal distributions based on the mean and standard deviation of the simulated values.

Table : Estimates of the instantaneous daily egg loss rate (Z) from herring egg loss studies conducted in the Pacific Northwest. Note that the Z estimates for the two Haegele and Schweigert studies were calculated from their reported egg loss rates over the study (incubation) period.

|  |  |  |  |
| --- | --- | --- | --- |
| Publication | Study Location | Year | Z |
| Haegele & Schweigert (1991) | SoG | 1989 | 0.056 |
| Haegele & Schweigert (1989) | WCVI | 1988 | 0.083 |
| Rooper et al. (1999) | PWS | 1991 | 0.076 |
| Rooper et al. (1999) | PWS | 1992 | 0.042 |
| Rooper et al. (1999) | PWS | 1994 | 0.096 |
| Rooper et al. (1999) | PWS | 1995 | 0.096 |
|  |  |  |  |
|  |  | Mean | 0.075 |
|  |  | Std. Dev. | 0.022 |

Table : Criteria for selecting herring spawn survey data records for estimating days between spawning and surveys.

|  |  |
| --- | --- |
| Selection criterion | Number of Records |
| Dive survey | 3457 |
| Spawn and survey start/end dates completed | 3188 |
| End spawn date < = start spawn date  End spawn date – start spawn date < 20  Survey days <= 14 | 3130 |
| End spawn date – end survey date<= 2  End survey date – end spawn date < 20 | 3074 |

Table : Average number of days between spawn deposition and spawn survey by stock assessment region and year.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Year | A2W | HG | PRD | CC | SoG | WCVI | A27 |
| 1985 |  |  |  |  | 5.2 | 6.6 | 8.8 |
| 1986 |  |  | 6.0 | 5.5 | 5.8 | 9.2 | 2.2 |
| 1987 |  |  |  |  | 10.6 |  |  |
| 1988 |  | 7.4 | 11.2 | 8.3 | 11.0 | 8.2 |  |
| 1989 |  | 8.2 | 10.8 | 5.8 | 14.5 | 8.6 | 10.7 |
| 1990 | 8.9 | 12.2 | 8.3 | 7.9 | 12.8 | 7.6 | 7.8 |
| 1991 | 10.5 | 5.9 | 7.5 | 11.0 | 12.4 | 9.2 | 2.3 |
| 1992 | 3.6 | 0.1 | 6.6 | 10.0 | 8.1 | 9.4 | 5.7 |
| 1993 | 12.2 | 9.3 | 4.9 | 9.1 | 13.1 | 7.6 | 16.8 |
| 1994 | 4.8 | 12.2 | 10.8 | 8.7 | 12.8 | 6.2 |  |
| 1995 |  | 10.3 | 6.1 | 7.9 | 9.3 | 6.4 | 11.1 |
| 1996 |  | 7.9 | 5.7 |  | 10.2 | 4.5 | 7.9 |
| 1997 |  | 8.6 | 10.3 | 6.1 | 9.4 | 7.5 | 2.8 |
| 1998 | 10.5 | 13.3 | 5.5 | 12.4 | 10.4 | 6.4 | 4.2 |
| 1999 |  | 10.0 | 8.1 | 6.4 | 8.0 | 4.9 |  |
| 2000 | 6.5 | 10.8 | 10.8 | 7.4 | 8.8 | 6.1 | 6.9 |
| 2001 | 9.0 | 7.4 | 8.3 | 6.8 | 8.0 | 6.9 | 3.8 |
| 2002 | 6.5 | 9.0 | 5.7 | 5.6 | 9.9 | 5.5 | 2.3 |
| 2003 |  | 7.5 | 6.2 | 5.0 | 9.5 | 7.0 | 7.3 |
| 2004 | 8.6 | 14.0 | 8.2 | 4.1 | 9.5 | 7.1 | 8.2 |
| 2005 | 6.3 | 9.4 | 8.8 | 9.2 | 5.8 | 5.1 | 3.3 |
| 2006 |  |  | 7.6 | 6.5 | 11.7 | 3.1 | 5.8 |
| 2007 |  | 6.0 | 10.8 | 0.7 | 9.3 | 3.4 |  |
| 2008 |  | 7.4 | 7.2 | 4.3 | 9.5 | 3.8 | 2.0 |
| 2009 | 5.3 | 6.0 | 9.6 | 5.3 | 4.2 | 5.5 | 5.6 |
| 2010 |  |  |  |  | 7.1 | 5.2 |  |
| Mean | 7.8 | 8.7 | 8.3 | 6.8 | 9.2 | 6.6 | 6.4 |

**Appendix 1: Summary of herring egg loss literature selected from Hay et al. (2001)**

**Bishop & Green (2001)**

Estimated 31% of herring egg deposition was consumed by 5 species of birds (1994, Prince William Sound), based on a bioenergetics model.

**Haegele & Schweigert (1991)** *Egg loss in herring spawns in Georgia Strait, BC.*

Estimated 58% herring egg loss over 14 day incubation period (Lambert Channel 1989). Bird and invertebrate predation accounted for 7.1% egg loss; the remainder from physical removal and translocation could not be directly estimated.

**Haegele & Schweigert (1989)** *Egg loss from Pacific herring spawns in Barkley Sound in 1988.*

Estimated 19.5% egg loss from predation based on predator counts and consumption rates (birds and invertebrates). From egg counts, total egg loss is estimated at 68.8% over a 14 day incubation period (based on their egg loss equations in Table 3). They also modelled the change in observations of egg layers over the incubation period: egg layers on sea grasses= 2.17 – 0.07 (day); egg layers on filamentous algae= 3.47 – 0.13 (day)... results in 45% and 52% decrease in egg layers over 14 days, respectively.

**Outram (1958)** *The magnitude of herring spawn losses due to bird predation on the west coast of Vancouver Island.*

Seabird predator exclusion study, 1951-53, West coast Vancouver Island. Overall, estimated 39% egg loss due to seabirds over the incubation period. Total egg loss over incubation period ranged from 56% to 99% (based on change in egg biomass for the control plots). Study was restricted to eelgrass beds.

**Paulson (1984)** *Egg mortality upon natural and artificial substrata within Washington state spawning grounds of Pacific herring.*

Estimated daily egg loss rates from 16.9% to 51.8% (positively correlated with egg density just after spawning). Large predators account for 20% to 50% of daily egg loss. Initial egg densities were very low, ranging from 400 to 80,000 eggs/m2 across 9 study sites.

**Rooper, Haldorson, and Quinn (1999)** *Habitat factors controlling Pacific herring egg loss in Prince William Sound, Alaska.*

Surveys conducted 1991, 1992, 1994 and 1995. Depth is factor that best accounts for egg loss rates (higher egg loss in shallows). Mean daily egg loss rates (Z) were (Table 2):

1990 - 0.076

1991 – 0.042

1994 – 0.096

1995 – 0.096

Note that population was much lower in 1994 and 1995.

From Paulson (1984): 