3 STATISTICAL FRAMEWORK

Historical surface spawn assessments have been conducted using an ad hoc sampling regimen, where surveys were often opportunistic given the state of the tide, as well as available sampling tools such as boats, rakes, and viewers. The data are analysed assuming simple random sampling generating an estimate of mean egg density that is likely biased.

In contrast, underwater dive surveys using SCUBA gear instituted in 1988 follow a two-stage systematic sampling design with transects the first stage of sampling, and individual quadrats within transects, the second stage of sampling (Jessen 1978). The mean egg density in each surveyed spawning bed *s* in year *y* can be determined from:

where *Eggdenqt* = egg density per square metre for quadrat *q* in transect *t*, *mt* = number of quadrats in transect *t*, *M* is the number of potential quadrats in transect *t* (the spawn width), and *n* = number of transects sampled per spawn. The estimator is unbiased and the variance can be determined from:

where *T* is the number of potential transects in the spawn (total spawn length), *f1* is the transect sampling fraction *n/T*, and *ft*  is the sampling fraction for each transect *mt/Mt* and *st2* is the within transect variance determined from:

The calculation of the mean egg density for each spawning location requires the total spawn length, an estimate of the mean spawn width, and the length of each transect sampled, as well as the estimated egg density in each sampling quadrat. The sampling protocol to optimize the sampling was determined through a series of studies conducted in the Strait of Georgia in 1981 and 1983, and on the west coast of Vancouver Island in 1982. In the 1981 study the location of transects and sampling along each transect was determined using random allocation (Schweigert et al. 1985). However, this proved to be logistically difficult because neither the length nor the width of the egg bed was known a priori, and divers had difficulty making the necessary calculations once underwater. Nevertheless, the data from these studies were used to calculate an optimal sampling design to estimate the mean egg density with a standard error of no more than 25 percent. The results indicated that the sampling required to achieve this level of precision included surveying 3 transects per km of spawn length and a minimum of 5 quadrat samples per transect. The sampling design was tested during a 1983 survey conducted in the Strait of Georgia that applied a systematic rather than a random sampling protocol to simplify the logistics. It resulted in estimates of variance that were similar to those from the 1981 study. This sampling protocol was further re-evaluated after additional surveys occurred in all areas of the coast during 1984 and 1985 and was found to be robust and has been in routine use since 1988 (Schweigert et al. 1990). Although the samples are collected systematically within each spawning bed, the implicit assumption is that transects and quadrats are located randomly with respect to the underlying spawn distribution and so these estimators are applicable. An analogous approach has previously been adopted in the sampling of various commercial fisheries where vessels arrive in port at random but are sampled in a systematic fashion to obtain a random sample (Quinn et a1. 1983; Sen 1984).

The giant kelp, *Macrocystis sp.* requires a completely different sampling strategy than that used for understory vegetation above. Giant kelp routinely reach heights of 15 m but once weighed down with herring eggs can sink to lay flat on the bottom. After sampling dozens of giant kelp plants covered with herring eggs, it was determined that the plant height, number of fronds per plant, and an estimate of the number of layers of eggs per plant were key counts required to estimate the egg numbers per plant (Haegele and Schweigert 1990). The survey design employed to capture these data for each egg bed rely on determination of the average plant height, number of fronds in each plant holdfast, and number of giant kelp plants occurring within a 1 m swatch on each side of the transect lines. These data are used in the equations in Section 6.3 below to determine the total egg deposition on *Macrocystis sp.* for each spawning location.

Jessen, R.J. 1978. Statistical survey techniques. John Wiley & Sons, New York, NY. 520p.

Quinn, T.J., E.A. Best, L. Bijsterveld, and I. R. McGregor. 1983. Sampling Pacific halibut (*Hippoglossus stenolepsis*) landings for age composition: history, evaluation, and estimation. Int. Pac. Halibut Comm. Sci. Rep. 68: 56pp.

Sen, A. R. 1984. Sampling commercial rockfish landings in California. NOAA

Tech. Mem. NMFS, SWFC 45: 95pp.