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Contribution to Manual on ICNAF Groundfish Surveys

by

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II Survey Design and Statistical Considerations

A The distribution of groundfish, even in a small area of bottom, is far from uniform and up to 75% coefficients of variation for numbers caught of one species in replicate hauls at the same station are common (Barnes and Bagenal 1951). Due to this large variability, estimates of abundance are worth little without an indication of their precision. Knowledge of the relative precision and likely sources of bias is essential for resolving conflicts and combining with appropriate weight alternative independent indicators of the state of fish stocks.

The need for valid estimates of sampling errors led to the replacement of line transect and systematic surveys with stratified random surveys during the late 1960's due largely to the work of Grosslein (1971). Line transect surveys suffer from the possibility of large sampling biases due to the concentration of trawling in a few restricted and selected areas as well as the lack of a measure of precision of estimation. Systematic sampling can be very efficient, leading to precise estimates, however, without replication no valid estimate of precision can be made without further assumptions.

Although groundfish abundance is highly variable even in small areas, large scale trends related to hydrographic conditions are nevertheless evident. To exploit these trends for improving the precision of abundance indices, stratification of possible trawl station locations is appropriate. A stratified random sampling scheme has a number of advantages over a purely random scheme:

1. Sampling is spread out over the whole area of the survey by assuring a required number of trawl stations in each stratum.

2. Sampling rates in terms of stations per unit area can be varied to improve the precision of estimates for a few key species. This is also an advantage compared to systematic sampling.

3. Strata can be agregated to form domains of study corresponding to the ranges of various stocks. Thus, statements about abundance can be made for subsections of the survey area.

The use of stratified random sampling enables the size of the contribution of sampling error to be controlled and estimated and avoids possible biases in station selection. These biases are most evident in surveys where searching for fish using acoustic or test fishing methods is practiced.

While in the latter case commercially important groundfish concentrations may be located, no statements about the overall size of a stock in a wider area are possible.

IIB Factors Influencing Design Procedures

Any information promising even rough predictions of catch sizes can be used to improve the efficiency of a survey design. Another use for such knowledge is to reduce possible biases due to systematic variation in the availability of fish to the trawl. Surveys aimed at one species (especially a limited age range of one species) are better able to profit from such knowledge than are general surveys for all species present in an area.

One of the most important factors affecting the availability of fish to the gear is the diel vertical migrations which sometimes occur. When fish are not on or within a few meters of the bottom, they cannot be sampled by the bottom trawl except during the brief period of shooting and hauling back. Unless trawling is restricted to times of day when fish are on the bottom, serious biases in abundance estimates can arise. The degree of vertical movement can vary with age as well as species. In general surveys where this source of variation cannot be simultaneously controlled for all species, careful choice of time of year and repetition of surveys at the same time of year in different years can minimize the adverse effects.

Species such as silver hake are found close to but not exclusively on the bottom. To sample such stocks and semi-pelagic age groups of other stocks trawls with high headropes are desirable. In some species such as cod, juveniles may be pelagic in distribution, such stock components are outside the scope of groundfish surveys as presently conceived and are more properly sampled as part of pelagic surveys.

Variation in availability to the gear between species and between ages due to different behaviour patterns may introduce biases into comparisons of relative abundance. Little can be done about this at the design stage although the use of repeated surveys at comparable times of the year makes intercalibration possible.

Species and age composition of groundfish stocks differ in the differing ecological communities found on rough and smooth bottom. Unfortunately, areas of bottom so rough as to damage a trawl are widespread and not entirely evident from charts. The inability to sample such areas leads to an underrepresentation of such communities and overrepresentation of the communities associated with smooth bottom. It is possible to reduce this bias and at the same time to effect minor gains in efficiency by employing bottom sediment type in the analysis of survey data although this approach has not been used to date.

Seasonal migration patterns can be utilized to reduce biases and increase sampling efficiency by executing single species surveys at a time and place when the stock is concentrated in an area suited to trawling. When comparisons from year to year of estimates from multispecies surveys are aimed at, repeated surveys should take place at the same phase of migration patterns of the major stocks. The gains in efficiency expected due to reduced steaming between stations when a stock is concentrated may be offset by increased variability between tows.

Customarily, stations are connected by a cruise track in such a way as to minimize steaming time. It may be desirable to add hydrographic stations between trawl stations when the gaps are large or as part of an ongoing systematic hydrographic sampling scheme.

IIC Statistical Considerations

Trawl surveys of demersal fish, like all sample surveys, are subject to two types of error. One type is a persistent error or bias in the availability of fish to the gear or in the estimated fishing power of the gear. The other type is a cancelling error due to the varying concentrations of fish at different trawl stations. The precision of an estimate indicates the likely size of the second source of error while the accuracy refers to the closeness of the estimate to the "true value" and includes both sources of error.

The main purpose of survey design theory is to estimate and control the mean squared error of estimation achieving high accuracy. Unfortunately, with the current state of knowledge of the fishing power of gear and of the effects of herding by the gear and vertical migration of fish, unknown and possibly large biases in estimates of total abundance exist. Because of these and other sources of bias, trawl survey catches are ordinarily used as indices of abundance to measure relative changes from year to year. In this situation, a constant proportional bias is acceptable.

In view of the unknown biases in absolute abundance estiamtes, catch data is often transformed by logarithms before averaging to calculate an index of abundance. This method has the advantage of reducing the sensitivity of estimates of means and especially variances to a few very large observations. Proportional changes in abundance are indicated by equal increments of the index. One possible drawback of this method is that changes in the patterns of fish distribution giving rise to different patterns of large and small catches can result in substantial changes in the index without parallel changes in the total stock size. Thus the logarithmic index measures catch variability as well as average catch size.

With the resources usually deployed in trawl surveys, confidence intervals are from ±25% to ±50% so that the many possible biases in measurement do not invalidate the results. However, if greater accuracy is desired control of the persistent sources of error will be essential.

IIF Station Selection Procedure

Station selection is performed stratum by stratum by selecting stations from a list using random numbers. The stratum is divided into narrow rectangular strips with length equal to the distance trawled over in one set. 2½' lat. by 2' long. is one size in current use. The rectangles should all have the same area in one stratum although it is permissible to vary the area of rectangles from stratum to stratum.

In some instances, care should be taken in marking off equal areas on a chart since the area of a rectangle on the globe may not be proportional to its image on the chart. If the chart is a projection of the earth onto a cylinder whose axis is parallel to that of the earth, then at a latitude θ, the unit of distance is expanded by a factor of $\sec\theta$ relative to the same unit at the equator. Thus equal areas on the chart at latitudes 30°N and

$31^{o}N$ correspond to areas on the earth differing by 2% while at $65^{o}N$ and $66^{o}N$ the difference is 8% and at $61^{o}N$ and $63^{o}N$ the difference is 14%. This consideration is relavent in strata covering more than 1^{o} of latitude especially in northern areas.

Once the chart has been divided into rectangles, the rectangles are given consecutive numbers starting with 1. The selection of stations is then a simple matter of selecting random numbers from a table until the required number of trawl stations appear as random numbers.

It sometimes happens that a trawl station, when occupied, has bottom unsuitable for trawling. Ordinarily an alternative station from that stratum is then chosen, either at random as before or by choosing the first nearby station in the direction of the planned cruise track. There are two sources of bias here. Firstly areas of rough bottom are likely to have differing abundance and composition of groundfish communities than areas of smooth bottom so that extrapolation of observed catches to areas unsuitable to trawling is hazardous. Secondly, if an alternative station is chosen nearby, then areas near stations with rough bottom are more likely to be sampled than areas farther away from stations with rough bottom. Thus, in the second case the sample is not representative of trawlable stations. There is no theoretically sound solution to this dilemma and the choice of methods depends on judgement whether the nearby station introduces more or less bias than a replacement chosen at random.

It is common in current practice not to draw stations independently within a stratum. Instead, strata are divided into large rectangles which are sampled without replacement and then subsampled with one station per large rectangle. The rationale for this is that nearby stations should have similar catches so that information is gained by spreading the stations more widely. In view of the large variance in replicated hauls at the same station, the gain in efficiency of this procedure is marginal and the validity of variance estimates is reduced. This technique leads to overestimates of sampling error which conceal whatever gains in precision occur.

Another modification of the stratified random sampling scheme is to select most of the stations at random and then to add stations to fill in gaps between some pairs of stations. This invalidates the sampling scheme and is worthwhile only for hydrographic observations in which systematic geographic variation is much greater than local sampling errors.

Areas of groundfish investigation strata of the Scotian Shelf, Bay of Fundy, and southern Gulf of St. Lawrence.

Stratum No.	Area (square nautical miles)	Stratum No.	Area (square nautical miles)
15	764	52	345
16	1,067	53	259
17	525	54	499
18	394	55	2,122
19	443	56	955
20	773	57	811
21	329	58	658
22	1,244	59	3,148
23	3,211	60	1,344
24	1,050	61	1,154
25	630	62	2,116
26	388	63	302
27	951	64	1,297
28	202	65	2,383
29	1,696	66	226
31	1,419	70	920
32	301	71	1,004
33	1,188	72	1,249
34	1,211	73	265
35	639	74	161
36	958	75	156
37	495	76	1,478
38	168	77	1,232
39	353	78	233
40	924	80	655
41	1,000	81	1,875
42	1,437	82	1,042
43	1,318	83	532
44	3,925	84	2,264
45	1,023	85	1,582
46	491	90	601
47	1,616	91	687
48	1,449	92	1,086
49	144	93	533
50	383	94	417
51	147	95	584

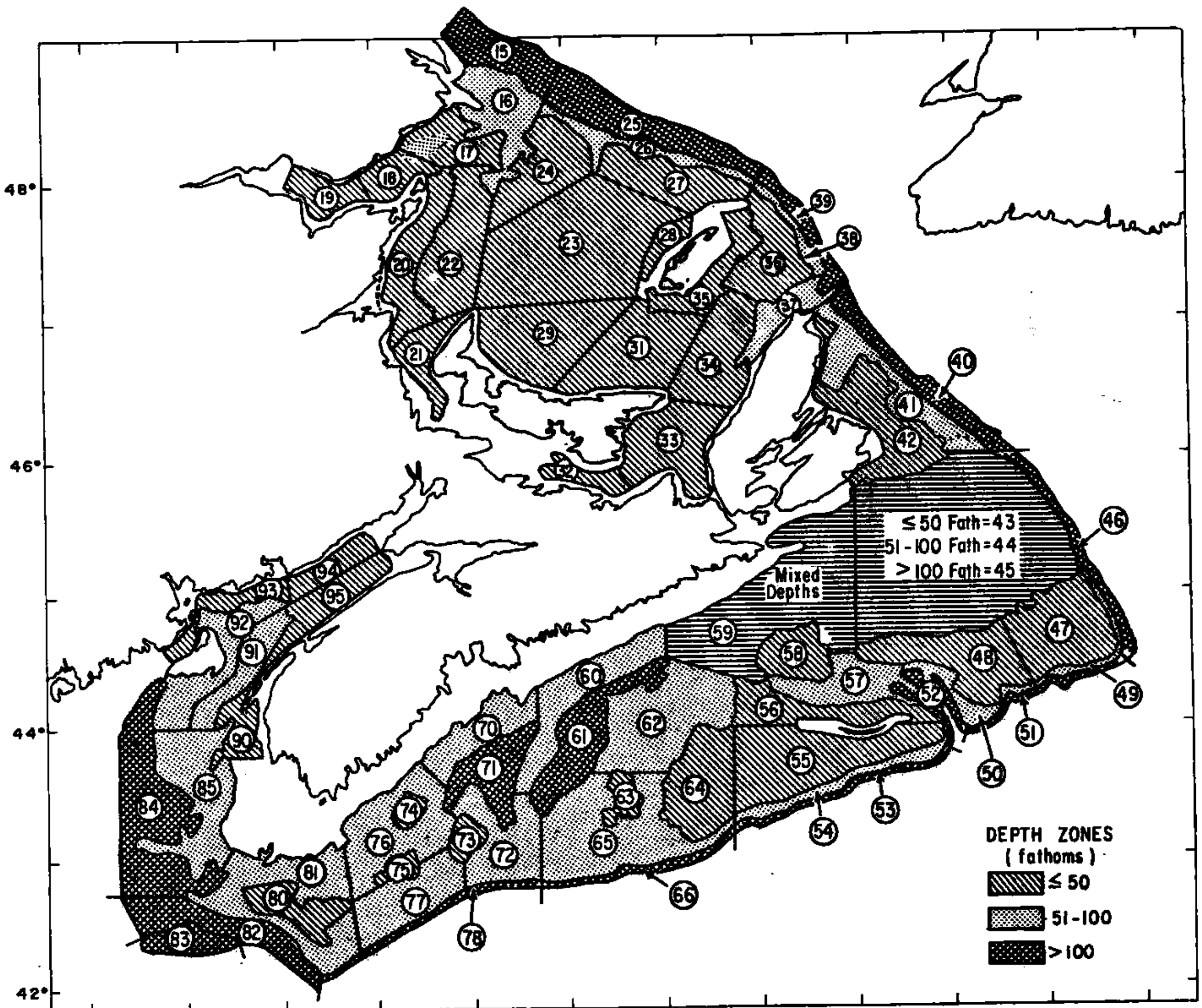
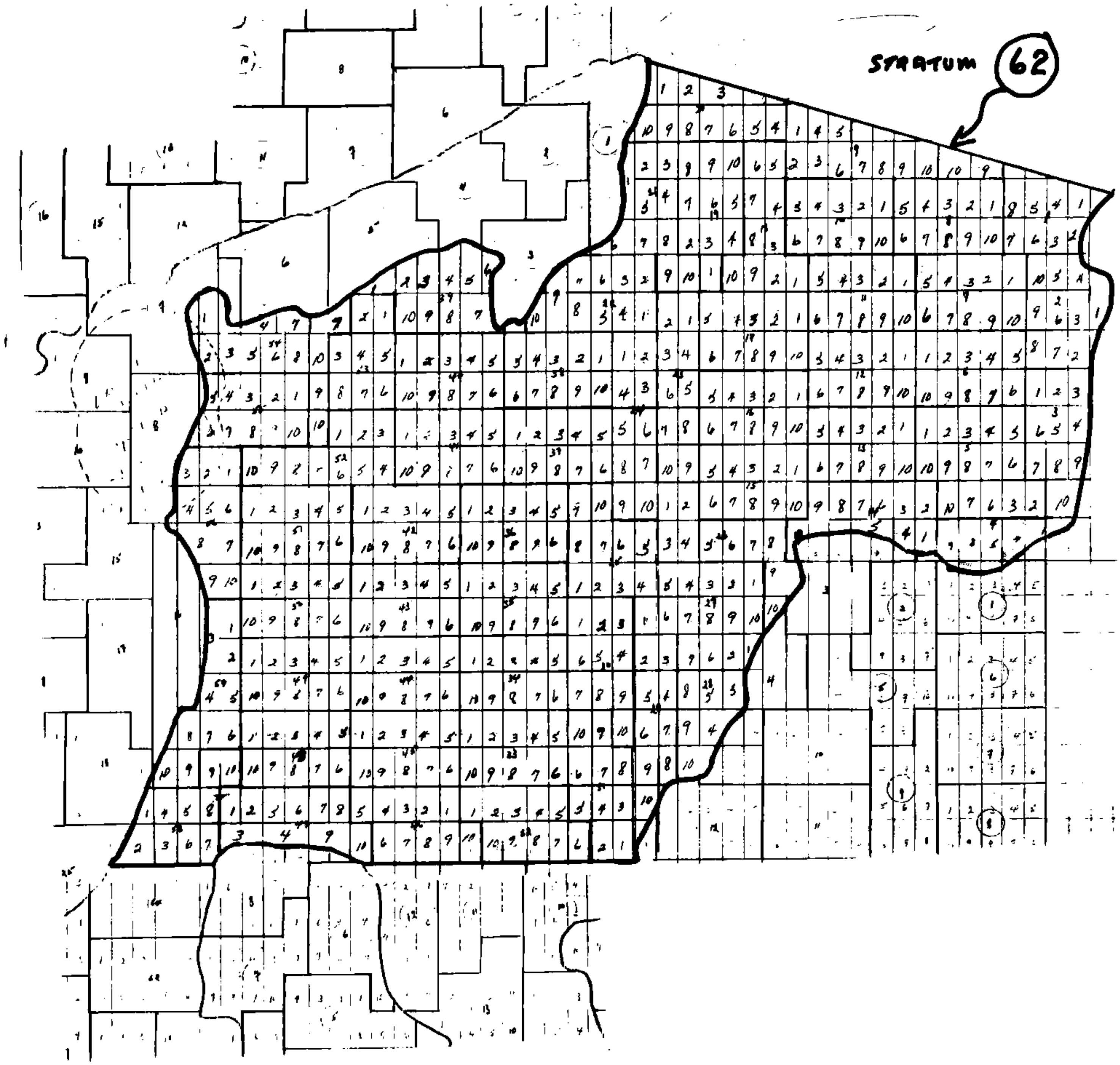


Fig. 1. Stratification and numbering system of ICNAF Div. 4T-V-W-X adopted January 1970.


STRATUM 62