EFFECTS OF SAMPLE SIZE ON BYCATCH ESTIMATION USING SYSTEMATIC SAMPLING AND SPATIAL POST-STRATIFICATION: SUMMARY OF PRELIMINARY RESULTS

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PURPOSE

The purpose of this analysis is to estimate the effects of sample size on estimates of total bycatches of large fishes in the purse-seine fishery for tunas in the eastern Pacific Ocean.

DATA

Bycatch data for floating object sets, 1996-1999, were used in this analysis. Sampling coverage for the fishery on floating objects (FADs and logs) of purse-seine vessels of more than 363 metric tons fish-carrying capacity varied between 96-98% over this time period. Bycatch data for three different species groups were used: billfishes, sharks and dolphinfish (mahimahi). These three species groups were used because they typify three different distributions of bycatch per set. Bycatch per set of billfishes occurs infrequently, with 65-79% of sets during 1996-1999 involving no bycatch of billfishes. When billfish bycatch does occur, typically no more than two fishes are caught per set. At the other extreme is bycatch of dolphinfish which occurs in at least 80% of all floating objects sets, with catches involving 10's to 100's of fishes or more. It is not known how similar distributions of bycatches for these groupings are to bycatches of particular species of sharks or billfishes; species identification for sharks and billfishes was not always possible with these data.

METHODS

Sampling

Within each year, subsamples of trips were selected using systematic sampling, with the first trip to be sampled for each vessel chosen randomly. Several levels of sampling coverage were simulated: 5% (1 sampled trip in every 20 trips), 10% (1 sampled trip in every 10 trips), 14% (1 sampled trip in every 7 trips), 20% (1 sampled trip in every 5 trips), 25% (1 sampled trip in every 4 trips), 33% (1 sampled trip in every three trips), and 50% (1 sampled trip in every two trips).

Bycatch estimation

Both stratified (post-sampling stratification) and unstratified estimators were used to estimate total bycatch. The unstratified estimator of total bycatch was simply bycatch per set multiplied by total sets, where the bycatch per set was computed as the sum of observed bycatch divided by the number of observed sets. Spatially stratified estimates were obtained by computing total bycatch within spatial strata using the same simple estimator, and then summing the estimates of total bycatch across strata. Spatial strata were determined separately for each year because of the variability in spatial distributions of bycatch per set between years (e.g. see Figure 1). Spatial strata were also determined separately for each subsample so as to simulate the type of results that would be obtained by an actual observer program sampling at low levels of coverage. To determine spatial strata for each subsample, the method of kriging was used to extrapolate observed bycatch per set from the subsample of trips to all 2 degree squares with fishing effort on floating objects. Observed and estimated bycatch per set values were pooled and sorted. Three strata were defined by the 1/3 and 2/3 quantiles of these sorted values. Thus, the spatial strata are not necessarily made up of contiguous 2 degree squares, rather 2 degree squares with 'similar' values of by catch per set.

The ratio of the square root of the mean squared error to the 'known' total bycatch was used to summarize the simulation results at each hypothetical level of sampling coverage for each year. The mean squared error, an overall measure of error, is equal to the sum of the variance and the squared bias. In the absence of bias, the mean squared error is identical to the variance and the ratio used to summarize simulation results would be identical to the coefficient of variation.

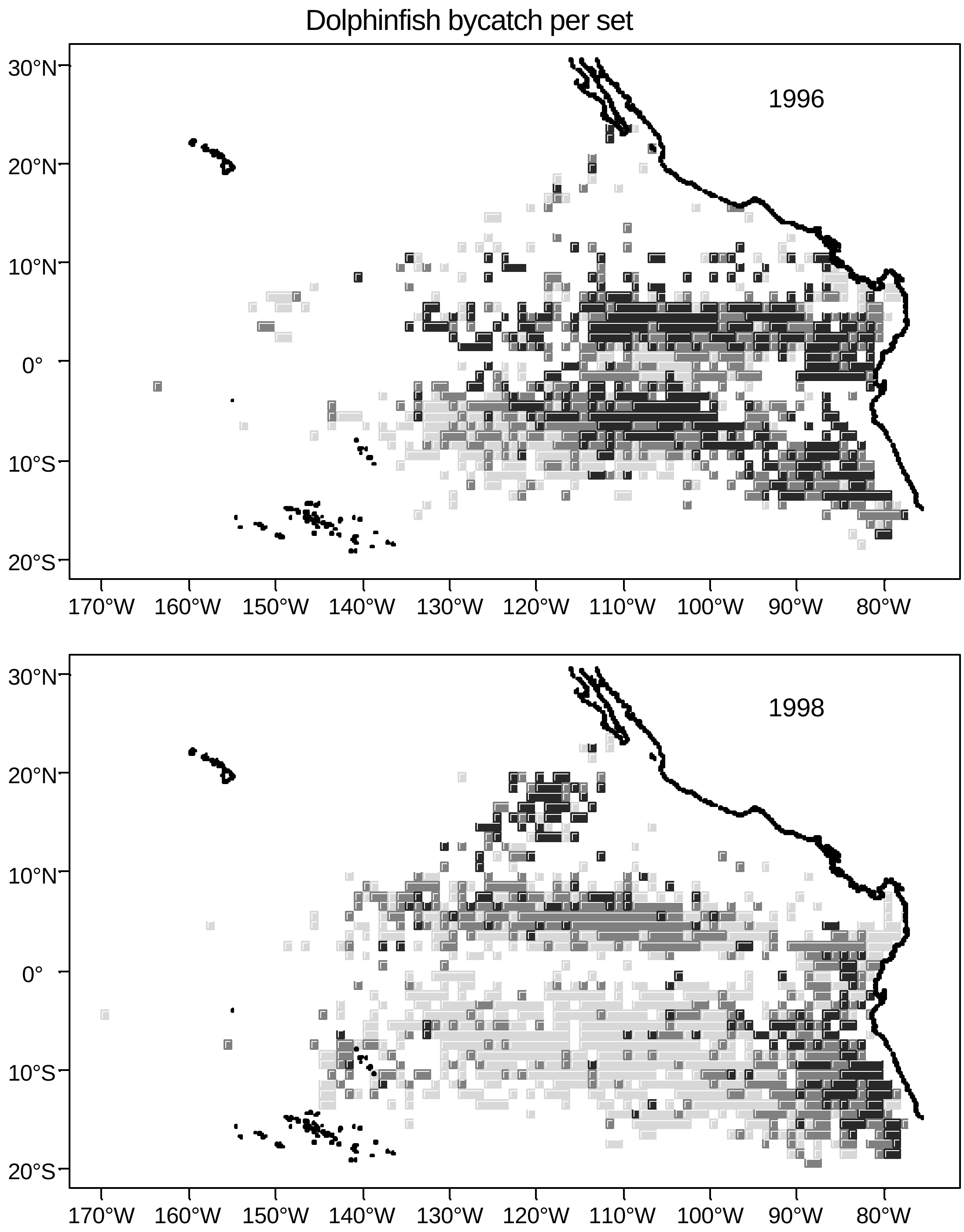
RESULTS AND DISCUSSION

Figures 2-4 show the summaries of the simulation results for each species group. Results based on systematic sampling with the unstratified estimator are generally similar to those obtained previously by randomly sampling trips. To note is that the sampling levels indicated on the x-axis in these figures represent the average sampling coverage; with systematic sampling, the actual coverage level will vary depending on the first trip sampled for each vessel and the number of trips made per vessel (unless sampling coverage were to be adjusted over the course of the year). These results suggest that sampling coverages of 20-33% may provide reasonable results without the additional costs of higher levels of coverage. The large values of the ratio of the mean square error to the know bycatch at low target levels of coverage (5%, 10%) are likely due to the fact that some subsamples yielded actual levels of coverage that were much less than the target level. These small subsamples of trips, some of which included trips with very large bycatch values, introduce more variability into the simulations than occurred when trips were sampled randomly. Differences in simulation results between years may reflect oceanographic effects on variability in bycatch per set as there was an El Niño event in the middle of the time period used for these simulations.

Estimates of total bycatch based on spatial post-stratification are indicated in Figures 3-4 at 10% and 20% sampling coverage by filled triangles (1997 data only). Results for other years for sharks and dolphinfish were generally similar and are not shown. Kriging did not perform well for billfishes because most sets involved no billfish bycatch and results are not shown. In general, the spatially stratified estimator performed poorly compared to the unstratified estimator. There are likely two reasons for this. First, 'edge effects' resulting for estimating bycatch rates in unsampled areas were evident. These edge effects contributed to additional effort in the highest bycatch strata which then contributed to inflated estimates of total bycatch. Methods for estimating bycatch per set in unsampled areas other than kriging can probably be used to reduce this problem. Second, it appears that the spatially stratified bycatch rates obtained at low simulated levels of coverage (e.g., 10%) may not be representative of the actual bycatch rates because of the skewed nature of the bycatch per set distributions. For more Gaussian-like distributions of bycatch, it is likely that spatial post-stratification would yield better results. However, at low levels of bycatch, it appears that it may be difficult to capture the true spatial distribution of bycatch per set because of the severe non-Gaussian behavior of these data. These results suggest that spatial stratification may not lead to improved estimates of bycatch at low levels of sampling coverage when a simple estimator of total bycatch is used (as has been done here). The use of more efficient estimators that are more appropriate for such skewed distributions should be explored with these data.

CONCLUSIONS

These preliminary results suggest that sampling coverages of 20-33% may provide reasonable estimates of total bycatch without the additional costs of higher levels of coverage. These results are applicable to estimation of total bycatch for species with bycatch per set distributions similar the three species groupings used herein; results may not be applicable if species-specific distributions are dramatically different. Further work is needed on the use of more efficient estimators of total bycatch and improved methods for spatial post-stratification. However, given these and previous results, it appears unlikely that more efficient estimators and improved methods of post-stratification will lead to a dramatic reduction in the minimum level of sampling coverage necessary to achieve reasonable estimates of total bycatch.



Dolphinfish bycatch per set
1996
30°N
20°N
10°N
0°
10°S
20°S
170°W
160°W
150°W
140°W
130°W
120°W
110°W
100°W
90°W
80°W
1998
30°N
20°N
10°N
0°
10°S
20°S
170°W
160°W
150°W
140°W
130°W
120°W
110°W
100°W
90°W
80°W

Figure 1.

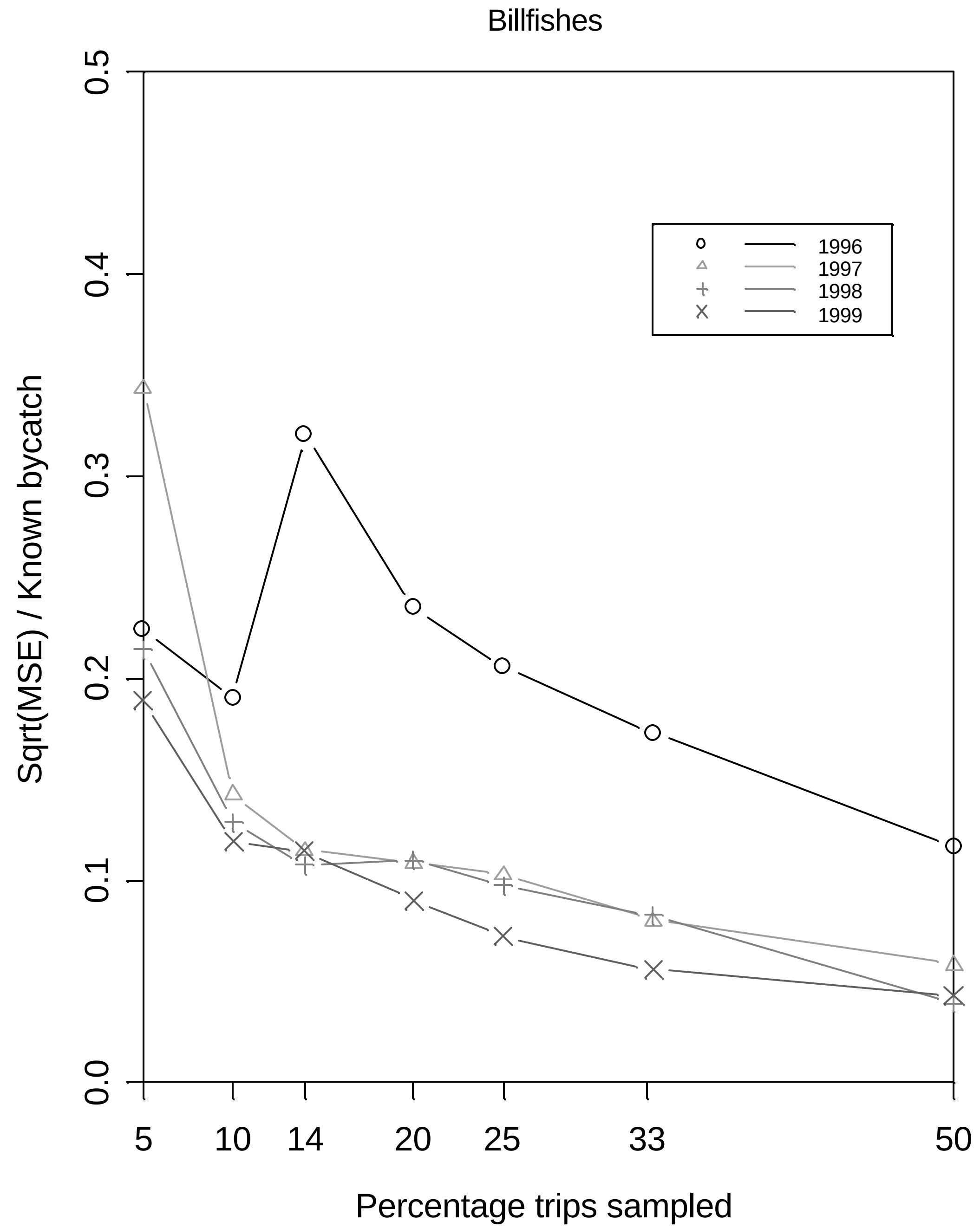

Billfishes
Sqrt(MSE) / Known bycatch
0.0
0.1
0.2
0.3
0.4
0.5
5
10
14
20
25
33
50
Percentage trips sampled
1996
1997
1998
1999

Figure 2.

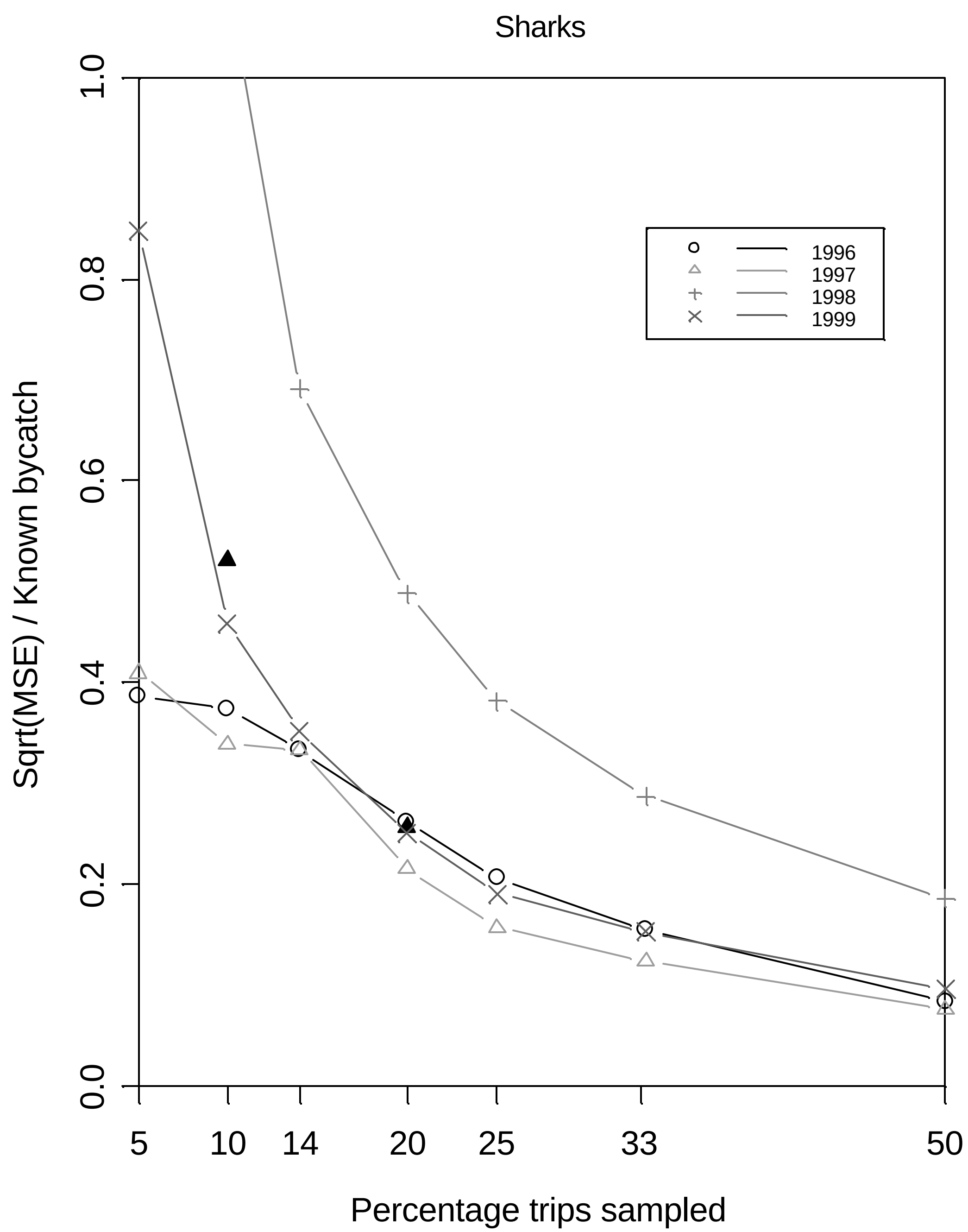

Sharks
1996
1997
1998
1999
Sqrt(MSE) / Known bycatch
0.0
0.2
0.4
0.6
0.8
1.0
5
10
14
20
25
33
50
Percentage trips sampled

Figure 3.

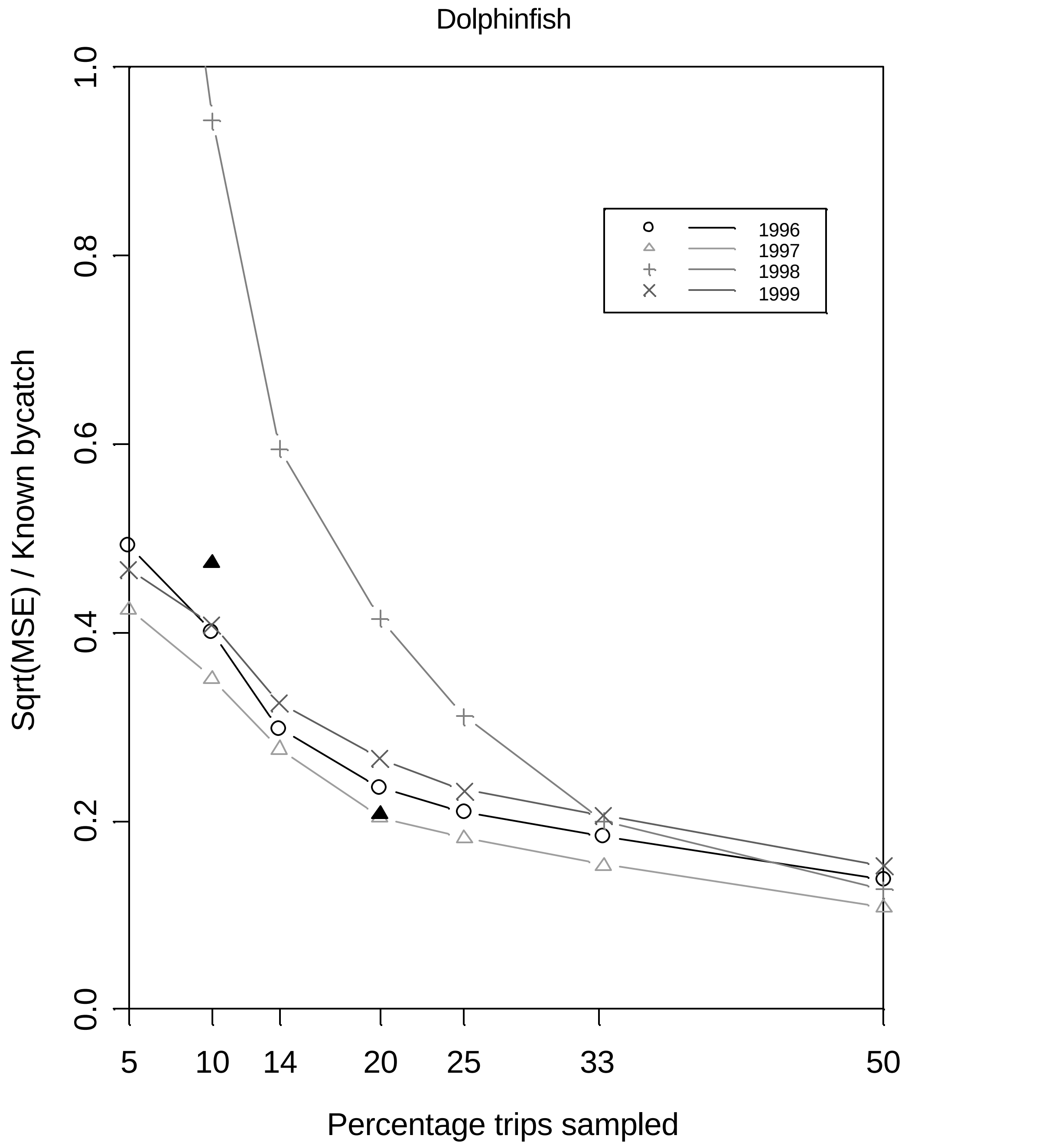

Dolphinfish
1.0
0.8
0.6
0.4
0.2
0.0
Sqrt(MSE) / Known bycatch
1996
1997
1998
1999
5
10
14
20
25
33
50
Percentage trips sampled

Figure 4.