INTER-AMERICAN TROPICAL TUNA COMMISSION
SCIENTIFIC WORKING GROUP

REVIEW OF DOLPHIN ABUNDANCE ESTIMATES

19-20 October 2000
La Jolla, California, USA

Chairman: Robin Allen

CHAIRMAN'S REPORT

AGENDA

1. Welcome and introduction
2. Comments on the agenda
3. Review of NMFS survey design and results
4. Dolphin stock boundaries and distributions
    i. comparison of tuna and research vessel data on dolphin sightings
5. Discussion of differences amongst surveys:
    i. variability of data
    ii. effective strip width
    iii. herd size
    iv. dolphin distribution
    v. survey effort
    vi. precision of estimates
6. Review of oceanography related to dolphin distributions
7. Potential regime shift in the eastern Pacific Ocean
8. Discussion of inter-annual variability in survey results and oceanography
9. Discussion of other factors potentially affecting survey variability
10. Report of the Chairman
11. Adjournment

APPENDICES

1. List of attendees
2. Report of the line transect expert group

The meeting of the review group was held in La Jolla, California (USA) on October 19 and 20, 2000. It was attended by scientists from IATTC member and observer countries and invited scientists with expertise in estimating population abundance using line transects and in the oceanography of the eastern tropical Pacific Ocean (ETP). The attendees are listed in Appendix 1.

1. Welcome and introduction

Dr. Robin Allen opened the meeting and welcomed the participants, in particular the invited experts, Drs. Steve Buckland, Mary Elena Carr, Jaume Forcada, Salvador Lluch and Tore Schweder.

Dr. Allen explained the background for the meeting. The US National Marine Fisheries Service (NMFS) is currently conducting a three-year series of surveys to determine the abundance of dolphin populations in the ETP. The IATTC had discussed the preliminary estimates and requested that its staff coordinate a review of the methodology and results of the cruises completed in 1998 and 1999.

2. Agenda

The provisional agenda was approved as presented.

3. Review of NMFS survey design and results

Dr. Tim Gerrodette of the NMFS described the field techniques, detection functions, herd size estimation and adjustment procedures, survey effort, and abundance estimates. Three ships and four geographic strata were used in 1998, but only two ships and two strata in 1999. This led to more effort, lower coefficients of variance (CVs), and greater coverage of the coastal zone in 1998.

Because research-vessel observer estimates tend to underestimate dolphin herd sizes, a correction factor is applied by calibrating their estimates with counts from aerial photographs of the same herds. This adjustment was inadvertently not applied to the initial 1999 estimates of herds of eastern spinner and unidentified dolphins, however, resulting in lower preliminary estimates of abundance. Applying the adjustment factors increases the eastern spinner estimate by about 140,000 dolphins and those of the other stocks slightly.

Dr. Gerrodette cautioned that these revised estimates are still preliminary, pending the final report to the US Congress. The whole series of NMFS surveys will likely be revised once more-sophisticated techniques are used to generate improved estimates.

4. Dolphin stock boundaries and distributions

Dr. Michael Scott, of the IATTC staff, reviewed the characteristics and distributions of the stocks of spotted and spinner dolphins. Examination of the tuna-vessel observer data (TVOD) suggested that there were no large-scale distribution shifts outside the survey area between 1998 and 1999. Dolphin movements could occur across the boundaries at 5°N and 120°W that demarcate the core (high-effort) area from the low-effort areas.

5. Discussion of differences between 1998 and 1999 surveys

Dr. Buckland presented the report (Appendix 2) of the group of experts (Drs. Buckland, Jaume Forcada, Cleridy Lennert-Cody, and Schweder) who, with Dr. Gerrodette, had met before the meeting of the review group to examine the abundance estimation methods used to generate the 1998 and 1999 results. He stressed the importance of not focusing on the results for a single year, given the variability among surveys and that a single year's survey results are only a part of a series to measure long-term trends in abundance.

The expert group had focused on the estimates for the eastern spinner dolphin, as they showed a significant difference between 1998 and 1999. An adjustment technique for herd size estimation used for the analyses in 1998 had been omitted in 1999, and applying that correction increased the population estimate for 1999 from 198,000 to 338,000 dolphins. The group suggested several changes in analytical methods that could produce large changes in the estimates and reduce the difference between the estimates for the two years. The group observed that the CVs were underestimated and could be improved with an analysis using covariates, and also noted that the low effort in the outside stratum was problematic for obtaining estimates for eastern spinners whose range extends into that stratum: in 1998 the outside stratum accounted for about 200,000 eastern spinner dolphins, or about 20% of the estimated abundance of the stock, while the corresponding estimate for 1999 was zero.

The review group made several additional suggestions for analyzing the 1998-2000 data: integrating the analysis with a population dynamics model to limit the annual population change and to allow the variance to be estimated from the modeling process (this could include surveys prior to 1998); stratifying effort by Beaufort number, and maintaining the two coastal strata after 1998 for consistency. It was also suggested that the long tail in the herd size distribution be modeled, and that a covariate analysis be used to quantify additional sources of variation for components of the analysis.

The group suggested that in future studies the effort in the outside area be concentrated in buffer areas around the core area.

6. Review of oceanography related to dolphin distributions

Dr Paul Fiedler reviewed the NMFS studies of oceanography associated with dolphin survey cruises. Oceanographic factors could contribute to the imprecision of the surveys or cause real changes in dolphin abundances. Environmental variability can occur at seasonal, interannual, climatic, or geological time scales, but these studies focus on the interannual scale, which has been dominated by El Niño-Southern Oscillation (ENSO) events.

The surveys conducted in 1986-1990 covered a wide range of environmental conditions: 1987 was an El Niño year, while 1988 was a La Niña year. There was a strong El Niño in 1997, the year before the current series of surveys began. The first survey was conducted in 1998, a transitional year when there was still residual warm water in the core area, but cooling along the equator. Further cooling was seen in 1999. The same patterns were seen in sea surface temperature, thermocline depth, and chlorophyll production.

Using a model based on previous data, the amount and location of habitat favorable for spotted and spinner dolphins were predicted. The amount of area was greater in 1998 than in 1999, but in both years the predicted habitat for eastern spinner dolphins did not extend beyond the core area. The predicted habitat for spotted dolphins was broader in 1998 than in 1999. It is possible that movements across the stock boundary could occur, particularly to the west.

The time lag by the dolphins in response to environmental changes was discussed. The assumption of a rapid response time was questioned, although the TVOD indicated a time lag of about six months. It was noted that apparent shifts in the distribution of common dolphins corresponding with El Niño events have been maintained, even years after the event. It was suggested that, given the approximate lag time of one year between the increases in chlorophyll and fish production, analyses of the relationship between dolphin abundance and the environment should consider the environmental indices of the previous year.

There is no simple correlation between ENSO indices and dolphin abundances. ENSO events differ from one another, and indicators may not predict the effects on dolphins and other organisms, and the food-chain relationships in the ETP are poorly understood.

Dr. Fiedler noted that the determinations included in the analyses sent to Congress were preliminary, and that they would be changed in the final report.

7. Potential regime shift in the eastern Pacific Ocean

Dr. Salvador Lluch reviewed evidence that suggests that environmental changes occur at the decadal scale, including shifts in local SSTs (*e.g.,* the coastal area near the Gulf of Tehuantepec) and the changes in the ENSO baselines in the 1970s *vs.* the 1980s and 1990s. Decadal-scale shifts may also be apparent in trade winds and tuna recruitment.

8. Discussion of inter-annual variability in survey results and oceanography

Dr. Mary Elena Carr presented a time series of satellite data on SST, chlorophyll (ocean color), and wind speed. The satellites provide extensive and frequent spatio-temporal coverage, consistent methodology, and resolutions of 1 km. Satellite data are particularly useful for long-term assessments.

SST data indicate that 1998 was a transitional year; warm water temperatures were still present in January, but cold-water anomalies began to appear in May. In 1999, there were strong cold-water anomalies and prominent tongues of cold water extending westward. There was about a 2°C difference in temperature between 1998 and 1999. In 1998, high concentrations of chlorophyll appeared in April along the equator but not further north, whereas in 1999 they were present throughout the core area.

Dr. Carr concluded that 1998 and 1999 were very different years, oceanographically, during the period of the surveys. She suggested that it would be appropriate to consider oceanographic variables beyond the averages obtained during the period of the surveys, and, given that the biological changes are not instantaneous, a comparison of the years should include consideration of the differences in the periods preceding them. The satellite data showed very large differences in several variables in the months preceding the surveys.

It was suggested that the satellite oceanographic data be integrated with satellite tagging and tracking of dolphins to correlate dolphin movements with environmental conditions, and that habitat-based models might be applicable. It was also pointed out the importance of knowing whether the differences between 1998 and 1999 were significant enough to change the dolphins' visibility or to cause them to move.

9. Discussion of other factors potentially affecting survey variability

Dr. Schweder summarized the work to be completed if covariate analysis were to be used for the survey data, and noted the importance of starting on the following projects soon:

1) calibration of the observer's estimatess directly, possibly with a separate study;
2) modeling the long tail of the herd size distribution;
3) initiating the covariate analysis;
4) looking at effective strip area because effective strip width may vary with the covariates;
5) selection of an appropriate detection model;
6) incorporating herd-size variability into the overall variance.

Dr. Buckland argued that a covariate analysis would allow pooling of data across years to improve consistency. Dr. Reilly indicated that NMFS was interested in using prior data as part of the scheme for estimating population statistics, but the method had not yet been developed and no resources were currently available to develop it.

10. Report of the Chairman

The Report of the Chairman will be presented to the Commissioners, and will include the minutes of the meeting and the report of the invited line transect experts. An informal report will be available for the 67th meeting of the IATTC on 27 October.

11. Adjournment

The meeting was adjourned at 2:45 pm on October 20, 2000.

Appendix 1.

INTER-AMERICAN TROPICAL TUNA COMMISSION
COMISION INTERAMERICANA DEL ATUN TROPICAL

SCIENTIFIC WORKING GROUP -- GRUPO DE TRABAJO CIENTÍFICO

REVIEW OF DOLPHIN ABUNDANCE ESTIMATES
REVISION DE LAS ESTIMACIONES DE ABUNDANCIA DE DELFINES

October 19-20, 2000 – 19 y 20 de octubre de 2000
La Jolla, California, USA

ATTENDEES - ASISTENTES

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KATE O’CONNELL
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Appendix 2.

REPORT OF THE EXPERT GROUP ON THE NMFS ESTIMATES OF DOLPHIN ABUNDANCE BASED ON THE 1998 AND 1999 RESEARCH VESSEL SURVEYS

Introduction

In the two days preceding the meeting of the Scientific Working Group, the invited experts reviewed the U.S. National Marine Fisheries Service (NMFS) provisional abundance estimates, and identified issues for further examination. In the process of exploring the analyses conducted by the NMFS, two problems were discovered that necessitated reanalysis of the data. The first was that, due to a change in the default settings in Microsoft *Excel,* the routine to calculate confidence intervals, which had worked when the 1998 survey data were analyzed, had produce erroneous intervals for analyses carried out subsequently. The other was that herd sizes in data supplied to the experts were not in agreement with those used in the preliminary analyses. Investigation by the NMFS revealed that herd size estimates for eastern spinner and unidentified dolphins in 1999 had not been calibrated to take account of bias in observers' estimates. The NMFS undertook to revise the preliminary abundance estimates ahead of the workshop. The group also noted that there were small revisions to calibrated herd size estimates for 1998, arising from updating of the calibration equations, given the 1999 data.

Before the discovery that herd sizes had not been calibrated, the invited experts decided to concentrate their attention on estimates of eastern spinner dolphin, because the estimates for 1998 and 1999 disagreed to an extent that seemed implausible. By contrast, the estimates for the other stocks (including the northeastern offshore stock of spotted dolphins) did not differ significantly between years. That is, the estimates for all stocks other than the eastern stock of spinner dolphins were consistent with the assumption that there had been no change in abundance between years.

The following issues were identified for discussion: modeling the probability of detection of dolphin herds; estimating and modeling herd size; quantifying the precision of the abundance estimates; survey design; and spatial modeling. We summarize our findings on each of these issues below.

Modeling detection probability

Detection probability depends on many variables, including distance of the herd from the vessel, herd size, sea state, observer, etc. In conventional line transect sampling, all of these dependencies except distance of the herd from the trackline are ignored, relying on 'pooling robustness'. However, effective width of search can be correlated with herd density, for example if regions that typically have poor sighting conditions also have lower densities. In this circumstance, estimated densities are biased. Software for modeling recorded covariates will soon become readily available, and the group expressed strong support for the NMFS' plans to incorporate covariates into their models, once the current set of three surveys have been completed.

A crude way of dealing with the above problem is to stratify data by those factors which appear to affect detection probabilities. However, small samples in these surveys preclude effective use of this strategy when many factors may be involved. In the NMFS analyses, estimates were obtained independently for each year. Thus in effect, analyses were stratified by year (in addition to stratification by geographic region). Because data were sufficient to examine the implications of pooling data across years (1998 and 1999), but stratifying them according to another factor, we considered two options: stratifying detections by sighting cue (birds or other; birds are more readily visible than other cues, and may be less correlated with herd size); and according to whether the herd was a mixed herd or a herd comprising only eastern spinner dolphins. Stratification by whether herds were mixed proved less satisfactory than stratification by year (as judged by Akaike's information criterion, AIC). However, stratification by whether the sighting cue was birds proved marginally preferable to stratification by year. Our preliminary, unchecked analyses suggested that such a decision would reduce the difference between the eastern spinner dolphin estimates for 1998 and 1999 by about 180,000 animals. (The 1998 estimate would decrease, while that for 1999 would increase.)

In the NMFS preliminary analyses, a hazard-rate detection function was fitted to the 1998 distance data for eastern spinners and a half-normal was fitted to the 1999 data. Some of the difference in abundance estimates between years therefore may be because these different models yield different biases. Because field methods were comparable between years, it would seem preferable to fit the same model to both years' data. AIC indicated that, if we use the same model for both years, the half-normal model is preferred to the hazard-rate model. Our unchecked analyses indicated that, if we replace the hazard-rate fit by the corresponding half-normal fit for the 1998 data, the difference between the eastern spinner dolphin estimates for 1998 and 1999 is reduced by over 100,000 animals.

A further assessment of whether a single detection function could be fitted to data pooled across the two years was carried out. AIC suggested that the detection function should be fitted separately for each year, although the reduction in AIC by doing this was not large.

We believe that the above issues should be examined. However, our findings, when taken in conjunction with the revision of estimates noted in the Introduction, lead us to conclude that the final estimates of eastern spinner dolphin abundance for 1998 and 1999, once they are generated, are unlikely to differ significantly.

Herd size

Observer counts

The high degree of variability in the best estimates of herd size for the same herd among observers, and the consistent tendency of observers to underestimate herd size, suggests that revisions to the observer training procedures for herd size estimation could be beneficial. Current practice is to avoid giving observers feedback, to seek to ensure that a given observer's estimates do not show a trend over time. Because errors in the estimation of mean herd size can have considerable effect on the estimates of total abundance, the added expense of additional training seems warranted. This might involve trials (possibly opportunistic) at sea on herds of dolphin for which aerial photos, or precise estimates by an observer of proven ability, are available. The policy of not giving feedback to observers should be reviewed; the group is not aware of any study that demonstrates that the merits of no feedback outweigh the major disadvantage of high variability between observers in herd size estimation.

Calibration

Calibrated herd size is obtained by applying the calibration routine to independent estimates made by two observers. The calibration function is obtained by regression. The regressors in these analyses are, however, subject to measurement error. The original calibration based on photogrammetric counts might not be much affected by this, but when new observers are calibrated against previously-calibrated observers, the measurement errors in the regressor are likely to be substantial, and the calibration becomes biased. In future surveys, we recommend that calibration experiments be conducted concurrently.

Size bias

It may be worthwhile investigating modifications to the current size-bias correction methods so that total herd size is used in the regression method, with subsequent adjustment for the proportion of a species or stock in the herd. A very preliminary analysis of the relationship between the proportion of eastern spinners and total herd size in herds with eastern spinner dolphins present showed a tendency for smaller herds to be herds of pure eastern spinners and large herds to be mixed herds. Since the detectability of eastern spinners in mixed herds is likely a function of the total herd size, it might be best to model detectability as a function of total herd size, rather than of the number of eastern spinner dolphins present. The estimate of mean total herd size might then be corrected for mixed species herds by using a ratio estimator of the proportion of the herd that was eastern spinner.

In addition, we found that the presence of individual animals (herd size = 1 animal) had a dramatic effect on the bias-corrected estimate of mean herd size because these points made a considerable contribution to the bias correction when back-transforming from log herd size. Possible solutions to this problem include (1) excluding the smallest herds from the estimation of mean herd size, (2) use of GLM techniques for fitting the relationship between herd size and detection probability, and (3) using a covariate approach to estimate mean herd size (thiswill be available in the new version of the *Distance* software (4.0)). We believe that the best long-term solution is the latter. Use of a covariate approach may also allow for a consistent method for size-bias correction across years and spatial strata; the current size-bias correction method is only used when the slope estimate is significant. Pooling herd size data across years to improve sample size and hence model fit may prove feasible, provided a covariate approach is adopted.

Mixed herds

When mixed herds are encountered, their total size is estimated, as is the fraction of the herd consisting of each species. By multiplying the total by the fraction, estimated numbers of dolphins of each species are obtained. There is variability in both the total and the fraction estimates. The product will thus be more variable than an estimate of the size of a pure herd of the same size. In the core stratum (including the coastal strip in 1998), 72% of herds with eastern spinner dolphins were of mixed composition, while the number for 1999 was 84%. Due to the high number of mixed herds, variability in herd size estimates is increased, and the variability is larger in 1999.

Large herds

A few large herds may be very influential in estimating mean herd size and hence abundance. If a significant proportion of a population occurs in a few large herds, and if survey effort is such that only two or three of these herds are expected to be detected, then chance may dictate that none of them are detected in a given year. In this circumstance, the variance of the abundance estimate will be underestimated. A preliminary analysis, in which herds of size >700 were deleted, suggested that estimation in 1998 and 1999 was unlikely to have been seriously affected by this, except for the coastal strip; in 1998, two herds out of 13 in this strip exceeded 1000 animals, and abundance was sensitive to whether these were included. In 1999, no large herds were detected within the coastal strip, perhaps because of the reduction in effort in this stratum relative to 1998.

Modelling herd size distributions

Herd size seems to be similarly distributed in 1998 and 1999, at least for identified eastern spinner dolphins. It is a very long-tailed distribution. That the right tail of the distribution is long means that there are some very large herds, but their density is very low. The size of the largest herds observed will be subject to large statistical variability. As noted above, these largest herds may have a substantial impact on the resulting abundance estimate. There may be some merit in modeling the herd size distribution, to gain insights to sensitivity of the abundance estimate and its corresponding variance estimate to sampling variation in observed herd sizes.

When modeling the herd size distribution, it is problematic to recreate the variability in the size of the largest herds. One suggestion was to take a semi-parametric approach in which three features of the distribution are modeled: the structure of the distribution for most of the herds, say the smallest 75%; the structure of the right tail; and variation in the distribution between years. The reference probabilities of the smallest herds (say of size 1, 2, 3) might be empirically modeled, using perhaps the observed distribution of 1998 and 1999. The shape of the reference distribution, say from 4 and to the 75% point, might be assumed to be log-normal, and fitted by a qq-plot. The upper 25% might be assumed to follow the extreme-value distribution (or the Pareto distribution), identified by fitting to the observed data via a qq-plot. This leaves us with a reference distribution, with probability $f(x)$ that a herd is of size x. To introduce a year-specific parameter θ, an option is to assume an exponential class model in log herd size:

$f(x, \theta) = x^{\theta} f(x)$.

Variance estimation

Herd size

Factors affecting reliability of the herd size component of abundance estimates were the large differences in estimates both within and among observers (due in part to lack of feedback), the variability in the species proportion estimates in mixed herds, the high variability in actual herd sizes, the effect of large herd sizes, and the non-normality of the herd size distribution. These issues are considered in the herd size section above.

Bootstrap

The nonparametric bootstrap used to estimate the variance cannot account for the poor spatial coverage in 1999. For the resampled days of effort to provide a reasonable estimate of variance, it must be assumed that the daily transects are randomly distributed within the survey area. This assumption seems defensible in the core area, but clearly is not in the outer area. A possible alternative to variance estimation is the parametric bootstrap, but the effort in the outer area would have to be pooled across years to give reasonable spatial coverage. Spatial modeling might also improve the abundance estimates in the outer area, but again, data from different years would have to be combined.

Extra variability

In line transect studies, the nominal CV is usually an underestimate of the true variability in the abundance estimates. Movement between years might contribute to the extra variability. If some animals move out of the survey area, say into the Colombian EEZ in 1999, they will not contribute to the estimate, and the nominal estimate is thus a negatively biased estimate of total abundance that year.

In 1999, any movement between the core area and the outer area might cause a similar problem. The amount and distribution of effort in the outer area (see survey design section) was insufficient in 1999 to produce an adequate sample to estimate eastern spinner abundance and its variance for this stratum. Because no eastern spinner dolphins were detected in the outer area in 1999, it is only possible to estimate that none were present, with zero variance. However, given the distribution of effort in 1999, relative to where eastern spinner dolphins were recorded by research vessels in 1998, and by tuna vessel observers in 1999, it seems possible that well in excess of 100,000 animals might have been present in the outer area.

Measurement errors in distance and in herd size contribute to extra variability, with herd size being the more important source. The long tail of the herd size distribution might be a contributing factor. Instead of running a pure nonparametric bootstrap to estimate the variability, a partially parametric bootstrap based on the estimated reference distribution might produce a more realistic estimate of variability in abundance estimates.

To address measurement errors in radial distance and angle estimates, experiments to assess the size of these errors, and possibly to calibrate estimates from individual observers, might be beneficial.

Survey design

Choice of geographic strata

The definition of geographic strata and subsequent allocation of effort was constrained by assumed stock boundaries. The amount of effort in the core area was adequate in both years, but in the outer area it was insufficient in 1999. In 1998, around 20% of the abundance estimate of eastern spinner dolphins was in the outer area. In 1999, the survey design was not robust to clustering of a stock in the outer area. The lack of sightings was likely caused by the lower effort. Given that insufficient effort could be conducted in 1999 to allow reliable estimation in the outer area, a better strategy might have been to define a ‘buffer zone’ around the core area, spanning those parts of the range of eastern spinner dolphin that extend beyond the core area. This range might be assessed from tuna vessel observer data. The effort expended in the outer area in 1999, though inadequate to provide abundance estimates through that outer area, would have been ample to estimate abundance with adequate precision within such a buffer zone. Such a design might be considered for any future surveys for which the primary aim is to quantify abundance of the eastern stock of spinner dolphin and the north-eastern offshore stock of spotted dolphin.

Closing mode procedure

According to present instructions, after the vessel has closed with a detection, the survey resumes parallel to the nominal trackline for that day, but shifted to one side. This procedure will on average tend to move the vessel towards areas of higher density. This seems to be an unnecessary source of positive bias in the abundance estimate, although we would not expect the bias to be large in these surveys.

Modeling spatial structure

The spatial pattern of distribution for spotted and spinner dolphins seems to display interesting stability and variability. A spatial model for this pattern and its variability over the years, incorporating response to environmental changes, would be of biological interest and of great help for planning future surveys and interpreting survey results.