Estimating Effort and Leatherback Take Experience for the DGN Fishery EFP

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1. Introduction

The proposed EFP for the California Drift Gillnet (DGN) Fishery considers a range of alternatives which would generally permit an increase in DGN fishing effort in the leatherback conservation area north of Point Conception which is currently closed to fishing between August 15 and November 15. Many of the alternatives under consideration involve a constraint on effort in the form of a leatherback take cap[1]. Because leatherback take is inherently random, a probability model is used here in an attempt to quantify the likely range of possible outcomes for fishing effort and leatherback takes under the various alternatives. The following section summarizes the approach to estimating DGN effort. Subsequent sections provide the details of probability calculations used for estimating effort and leatherback take experience under different alternatives.

2. Summary of Effort Estimates

Our analysis was based on estimates of the change in effort which would occur under each of the proposed alternatives. The various EFP alternatives all include a set limit, a leatherback cap, or both as measures to mitigate leatherback take risk. Each EFP alternative includes geographic restrictions on fishing. The alternatives also include cases which restrict the EFP area or change the boundary of the currently closed area (through a regulatory amendment). The approach to estimating effort under the various alternative combinations of constraints is described below.

For all alternatives under consideration, we estimated that effort South of Pt. Conception would not be affected by implementation of any of the EFP alternatives. This approach was based on three reasons: (1) The approach is conservative, in the sense that the direction of the effect of any change in effort South of Pt. Conception under EFP alternatives is likely to be negative, due to a transfer of effort into the leatherback conservation area; (2) Larger-sized boats are normally used for fishing North of Pt. Sur than for fishing to the South, resulting in a degree of independence between effort levels North and South of Pt. Conception; (3) We have no way to

[1] A leatherback take cap is the maximum allowable number of observed leatherback turtle takes before EFP fishing effort is halted for the season.

reliably predict any shift in effort which would take place to the South of Pt. Conception in response to the various EFP alternatives.

For EFP alternatives, we assumed that fishing effort would continue until the first of a set limit or a leatherback cap was reached. For sub-alternatives with only set limits, the set limit was directly used as the estimated effort. Effort subject to a leatherback cap was estimated using a probability model which delivers an estimate of the expected number of sets which could be fished until a specified number of leatherback takes occurred. Based on a conservative 70% mortality rate assumption, we translated leatherback mortality caps of 1, 2, and 3 into corresponding take caps of 1, 3 and 4. We then calculated the expected effort up to the point the take cap (1, 3, or 4 leatherbacks) would be reached in order to compute the corresponding leatherback cap constraint on effort. Effort levels under alternatives with both leatherback caps and set limits were estimated as the expected fishing effort until the first of the leatherback cap or the set limit is reached.

For alternatives with area restrictions on EFP effort or boundary changes in the current leatherback conservation area, we used historic logbook effort to scale the anticipated effort under the various alternatives. We first used an analysis of logbook effort to determine the historic proportion of all DGN effort, from 1991-2000, which occurred in the leatherback conservation area and the historic proportion of fishing effort in each of the more restrictive areas under consideration. We estimated potential new effort under Alternative 7 based on an assumption that effort in the leatherback conservation area would revert from the baseline level[2] in proportion to its historic share of total logbook effort. The calculation used was *(Alternative 7 Effort) = (Baseline Effort) X [p / (1-p)]*, where *p* = 25.7% was the historic proportion of logbook effort in the leatherback conservation area. Effort under Alternative 6 was estimated by scaling down the Alternative 7 effort estimate by the ratio of historic effort in the Boundary Change Option 2 area to the amount of historic effort in the entire leatherback conservation area. It should be noted that historic effort in this area is based upon the entire area north of Pt Conception being open and utilized by the DGN fishery. It is not known how re-opening only a fraction of the currently closed area may affect effort and whether the historic proportions appropriately reflect future effort in this area. For EFP alternatives which included a boundary change (Alternatives 4 and 5), the estimated effect of Boundary Change Option 1 was added to the estimated EFP effort subject to leatherback caps or set limits.

Area restriction effects for EFP alternatives with area restrictions were estimated in a similar fashion to the effects of Boundary Changes 1 and 2, taking into consideration historic effort within the applicable restricted area as a share of historic effort in the entire leatherback conservation area. The area restrictions were assumed to have no effect under EFP alternatives where the area restriction estimate of effort exceeded the expected effort subject to the leatherback cap / set limit constraints; in cases where estimated effort subject to the area restriction was lower than estimated effort subject to only a leatherback cap / set limit combination, EFP effort was estimated at the average of area restriction constrained effort and leatherback cap / set limit constrained effort.

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[2]The baseline level was estimated using average effort measured from historical observer records. A detailed discussion of the baseline level calculation is provided in the Environmental Assessment.

Other defensible approaches are possible to estimate effort when all three types of constraint apply; for instance, we could either apply the estimated effort change subject to the area restriction as an additional binding limit on estimated effort for EFP alternatives with area restrictions, or chose to ignore the area restriction effect on EFP effort. While using the averaging approach is *ad hoc*, due to the unknown effect on effort of combining area restrictions with set limits and leatherback caps, it is at least consistent in direction with the known qualitative effects of area restrictions on the level of effort, thereby facilitating comparison of alternatives where the area restriction is the only difference between them (i.e., Alternatives 1 – 3, and Alternatives 4 – 5).

Given the inherent uncertainty in regulating a fishery contingent on variation in a small number of leatherback takes, the estimates under the various alternatives are not intended to provide a precise forecast of what effort will actually occur, but rather a reasonable estimate of potential effort which orders the estimates to agree with the theoretical effects of the various constraints under each alternative, and which reflects historical information about the distribution of DGN effort. The approach taken is deliberately conservative, reflecting a lack of prior knowledge about how the combined impact of overlapping constraints will affect EFP effort. Several other known factors which might further reduce effort are not taken into consideration, including permit limits on the number of potential EFP participants, limits in the number of available observers to satisfy the 100% observer coverage requirement, and potential transfer of effort from the currently open area into either the EFP or into the part of the area open to all fishing under alternatives with boundary changes.

3. <u>Probability Model for Estimating Effort and Leatherback Take Experience</u>

The inherent randomness and unpredictability of leatherback take experience requires the use of a probability model to describe the random variation for proposed alternatives which depend upon leatherback take. The probability model used to estimate fishing effort and leatherback takes under the various proposed alternatives is based on three simplifying assumptions:

1) DGN fishing effort will continue until the point when a policy constraint requires fishing to stop.

2) Leatherback takes follow a binomial distribution with a fixed rate parameter, where the number of Bernoulli trials is equal to the number of sets fished, and the binomial take rate parameter is estimated by the historical take rate.

3) Since the number of sets fished is generally large and the take rate is small, the Poisson approximation to the binomial distribution will provide a sufficiently accurate probability calculation for the number of takes.

Under the above assumptions, the probability model for leatherback take may be described with an equation which describes the take distribution conditional on number of sets fished. Let n represent the number of sets fished and y the number of leatherback takes in a given season. Using the Poisson approximation to the binomial distribution, the probability distribution for the number of takes is given by

$$f(y \mid n) = e^{-n\theta} \frac{n\theta^{y}}{y!},$$

where θ is the take rate parameter. The probability model for the number of takes assumes that conditional on the level of effort, n, the realized number of leatherback takes is analogous to the number of heads in a series of n coin tosses, with independent probability θ of heads (analogous to a leatherback take) on each coin toss (analogous to a DGN set).

4. Does the Poisson Model Agree With Historical Data?

Use of a Poisson probability model is a standard approach for describing random count data. However, whether using a Poisson model with constant CPUE parameter is adequate for modeling leatherback take experience in the DGN fishery is an empirical question, which can be addressed using a Chi square goodness of fit test. This was done for the case at hand using annual data on the number of takes and sets for the seasons from 1990-2005. These data and the result of the Chi square test are displayed in the table shown below:

		Takes		
Year	Sets	Observed (o)	Expected (e)	$(o-e)^2/e$
1990	94	1	0.6842	0.1457
1991	210	1	1.5286	0.1828
1992	431	4	3.1373	0.2373
1993	446	2	3.2464	0.4786
1994	265	1	1.9289	0.4474
1995	282	5	2.0527	4.2318
1996	237	2	1.7251	0.0438
1997	292	4	2.1255	1.6532
1998	235	0	1.7106	1.7106
1999	153	1	1.1137	0.0116
2000	141	0	1.0263	1.0263
2001	35	0	0.2548	0.2548
2002	46	0	0.3348	0.3348
2003	13	0	0.0946	0.0946
2004	5	0	0.0364	0.0364
Total	2885	21	21	10.8897

The calculations shown above and through the remainder of this paper use an estimated leatherback CPUE parameter of $\theta = 21 / 2885 \approx 7.279$ leatherback takes per 1000 sets of DGN effort[3], based on 21 observed takes out of 2885 observed sets in the DGN fishery from 1990 through 2005. The table breaks out the number of historically observed sets and leatherback takes which occurred in the area North of Pt. Conception by year from 1990 through 1994. The expected number of takes in each is computed as the number of sets fished in that year multiplied by the CPUE.

The rightmost column computes a statistical measure of the difference between observed and expected numbers of takes in each year, under the null hypothesis that the Poisson model with fixed CPUE parameter $\theta = 21/2885$ is the underlying data generating process, computed as the squared difference between the observed and expected numbers of takes for that year divided by expected takes[4]. The rightmost column sums to a value known as Pearson's chi square statistic, which provides a measure of statistical agreement between the historically observed numbers of takes in each year and the expected number of takes under the null hypothesis; small values of this statistic are consistent with a close fit of the model to the data, while large values are indicative of disagreement. Under the null hypothesis, this statistic has an approximate Chi square distribution with 15 – 2 = 13 degrees of freedom[5]. The p-value for a one tailed Chi square test using the computed test statistic is 0.62, which indicates the historical data are consistent with the null hypothesis under conventional significance levels. On the basis of this result, the hypothesis that the data generating process is a Poisson distribution with fixed CPUE parameter $\theta = 21/2885$ is accepted and used to compute probability estimates for future DGN effort and take experience for alternatives which are impacted by leatherback caps, with individual sets each facing an independent probability of $\theta = 21/2885$ that a leatherback take will occur.

5. Estimating Effort under Proposed Alternatives with Leatherback Take Caps

The probability framework described above may be used to describe a related probability model for estimating the level of effort under alternatives which are subject to leatherback take caps. The applicable model is the *negative binomial distribution*, which describes the number of sets which could be fished up until the point when a leatherback take cap prohibits further fishing effort. Let c denote the leatherback take cap. Assuming an independent probability of θ for a take on each set, and that effort will continue until a leatherback cap is reached, the negative binomial probability that n sets are fished by the time c leatherback takes have occurred is given by

$$h(n \mid c) = \binom{n-1}{c-1} \theta^{c} (1-\theta)^{n-c},$$

reflecting the occurrence of $c-1$ leatherback takes over the first $n-1$ DGN sets, followed by a final take on the n^{th} set.

[3] The CPUE estimate here differs slightly from the estimate of 0.0077 used in the context of the discussion of protected species take experience in the EA, as the latter is based on bootstrap simulation, while the CPUE used in this report is the ratio of observed leatherback takes to observed DGN sets. The discrepancy does not have a material effect on results.
[4] Small values of $(o-e)^2/e$ reflect close agreement between the observed and expected numbers of takes.
[5] As discussed in Lindgren, the degrees of freedom are k – 1 – r, where k is the number of cells in the table and r is the number of estimated parameters (r = 1 in this case).

For alternatives with only a leatherback take cap, effort was estimated as the expected number of sets, assuming effort would continue until the limit is reached, and the probability distribution of effort is given by the above formula. For alternatives with both set limits and leatherback take caps, effort was estimated as the expected number of sets over the probability of effort with upper truncation at the set limit, resulting in lower estimated effort than for the corresponding case with no set limit. The resulting EFP effort estimates are displayed in the following table.

Expected Limit on the Number of EFP Sets					
	Leatherback Take Cap				
Set Limit	1	2	3	4	None
300	100	160	197	220	300
500	125	221	289	337	500
600	131	240	323	384	600
No set limit	137	275	412	550	NA

For example, with a set limit of 300 and a leatherback take cap of three, the expected limit on the allowable number of EFP sets is 197. Raising the leatherback take cap to four increases the expected limit on EFP sets to 220. Without a leatherback take cap, the allowable number of EFP sets is given by the set limit of 300.

6. Estimating Leatherback Take Experience under Proposed Alternatives

In this section, we use the probability framework described above to develop estimates of leatherback take experience under the DGN alternatives. The basic strategy is to use the probability distribution for the number of leatherback takes conditional on effort to estimate the probability that no more than three leatherback takes will occur under each EFP alternative[6].

For alternatives involving a leatherback take cap as well as a set limit, we assume that the leatherback take cap imposes a binding constraint on the number of leatherback takes. Under the assumptions that observer coverage measures the number of leatherback takes without error, and that effort will cease once a take cap is reached, the probability of no more than three leatherback takes equals 100%.

Under alternatives where only a set limit applies, we assume that fishing continues up until the set limit is reached[7]. The Poisson distribution of the number of takes conditional on effort may be used in these cases to estimate the probability that three or fewer leatherback takes will occur, assuming effort continues until either the applicable leatherback cap or the set limit is reached. The results of these calculations are shown in the table below.

[6] Using an assumed mortality rate of 70%, three leatherback takes correspond to an expected mortality of 2.1 (70% X 3). Since we have no methodology in place for considering the take experience without set limits or take caps, we did not analyze take experience under regulatory amendments to change the Southern Boundary of the closed area.

[7] The assumption that effort will continue up until a set limit is reached is deliberately conservative as a precautionary measure to limit the number of leatherback takes. Fishing effort depends on a number of unforeseeable factors, and it is entirely possible that effort would cease before a set limit was reached.

Probability of 3 or Fewer EFP Leatherback Takes					
	Leatherback Take Cap				
Set Limit	1	2	3	4	None
300	100%	100%	100%	89%	82%
500	100%	100%	100%	73%	51%
600	100%	100%	100%	66%	37%
No set limit	100%	100%	100%	0%	NA

Consider, for example, a set limit of 300. When the leatherback take cap is three, the probability is 100% that three or fewer leatherback takes will occur due to EFP fishing effort with 100% observer coverage. With a leatherback take cap of four, the probability of three or fewer leatherback takes falls to 89%; conversely, there is an 11% chance that more than three leatherbacks will be taken.

The result of these calculations indicates that a set cap alone is not sufficient to guarantee that fewer than three leatherback takes will occur. Even at the lowest set limit under consideration of 300, there is an 18% chance that more than three leatherback takes would occur.

7. Illustrative Example

An example is presented here to illustrate the relevance of the above results to choosing an EFP alternative. For purposes of discussion, suppose that fishing industry representatives are interested in maximizing the expected policy limit on effort (whether due to a leatherback take cap or a set limit), and species protection concerns dictate that the chance of exceeding three leatherback takes be reduced to an acceptable level. The probability table presented in section 6 shows that, assuming no observer error, a leatherback take cap of 3 or fewer achieves the species protection objective with 100% probability, while a higher take cap than three results in a significant probability that more than three leatherback takes would occur; for instance, even with a low set cap of 300, there is an 11% (= 100% - 89%) probability that the cap will be reached with a leatherback take cap of four, and an 18% probability that four or more leatherback takes will occur without any leatherback take cap.

Under the alternatives which guarantee that three or fewer leatherback takes will occur, the most advantageous alternative for fishing opportunity is the case with a leatherback take cap of three and no set limit, which results in an expected allowance of 412 sets of fishing under the assumption that effort continues up until the point when the third leatherback take occurred[8]. By contrast, with a set limit of 600 and a leatherback take cap of three, the expected effort allowance would drop to 323 sets, reflecting that effort would be limited to 600 sets regardless of whether the leatherback take limit had been reached.

[8] This assumption that effort continues until the third leatherback take occurs is used to calculate the expected limit on effort, and should not be misconstrued to imply that three leatherback takes would occur with certainty under this alternative.

8. Summary

The dependence of effort and leatherback take experience on a small number of random events requires the use of a probability model to adequately describe the range of potential variation in experience under the various proposed EFP alternatives. The discussion here provides a description of how this was done for purposes of analyzing the potential random variation in effort and leatherback take experience which could occur if an EFP were adopted.

The probability estimates of effort and leatherback takes are based on simplifying assumptions which may not perfectly describe the actual operation of the DGN fishery. The assumption that fishing effort will continue up until a policy constraint (leatherback cap or set limit) is reached is conservative in the sense that a number of other factors may ultimately limit effort, including logistical constraints on effort such as the limited three month length of the fishing season, and the potential for 100% observer coverage requirements to constrain effort. Further, the level of effort is a choice variable for fishermen, and it is possible that economic conditions will result in fishermen choosing a lower level of effort than what is permitted. Since we have no way to predict the effect of these other factors which may limit effort, we have adopted a conservative approach which reflects precaution with respect to predicting the level of leatherback bycatch and mortality.

No attempt was made to produce probability estimates of leatherback take for an increase in non-EFP effort due to a regulatory amendment which changes the Southern Boundary of the existing closure, as we have no methodology in place for reliably predicting the take experience given the many uncertainties which could impact future take experience under these alternatives. However, the HMS Team is concerned that unregulated effort due to a change in the Southern Boundary could result in an unacceptably high level of leatherback take, with no constraint on effort under this contingency.

The use of a Poisson model to describe probabilities which affect experience under the various EFP alternatives represents an attempt to improve on the questionable assumption that potential experience can be deterministically predicted based on historical experience. The simplicity of this Poisson modeling framework makes the analysis highly tractable and hopefully transparent, but it is worth considering what elements are left out of the model, and how these could potentially affect the analysis. One simplifying assumption is that the estimated take rate and mortality rate parameters are sufficiently accurate to safely ignore sampling variability[9]. A second simplifying assumption is that the variables[10] which govern the future variation in leatherback take and mortality are sufficiently stationary so that past experience offers a useful foundation from which to estimate future experience. Departure from these assumptions would likely result in a greater variance in the distributions of leatherback take and effort subject to a leatherback take cap.

[9] The Chi square test results show this assumption is consistent with historical data.
[10] Among other factors, these would include environmental conditions, climatic variation, and changes in leatherback population size and migration behavior.

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