Bootstrap Analysis to Compare the Operation of the Drift Gillnet Fishery under Hard Caps Alternatives

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I. Introduction

At its November 2014 meeting, the Pacific Fishery Management Council developed alternative scenarios to reduce interactions in the California drift gillnet (DGN) fishery through the use of hard caps for high priority protected species (marine mammals and sea turtles). Four alternatives for cap levels were proposed for a range of species including fin whale, humpback whale, sperm whale, leatherback turtle, loggerhead turtle, olive ridley turtle, green turtle, short-fin pilot whale, and bottlenose dolphin. Reaching or exceeding any of the hard caps during a fishing season would result in closure for the remainder of the season. In addition, Alternative 2 includes caps for groups of pinnipeds and dolphins. Discussion of the rationale for these alternatives and details of their implementation is provided in the March 2015 HMSMT Report under Council Agenda Item H.4.b; a revised version of the alternatives that reflects March 2015 Council meeting discussion and an additional Alternative 5 is in the June 2015 HMSMT Report under Agenda Item E.3.a.

Table 1: Hard cap levels that would trigger a DGN fishery closure under 100% observer coverage

	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5	
Number of Years	1	5	1	5	1	5	1	2-Year Average	1	2-Year Average
Fin Whale	1	2					2	2	1	1
Humpack Whale	2	4	11	55	5	25	2	2	1	1
Sperm Whale	2	8	2	8	3	15	2	2	1	1
Leatherback Turtle	3	10	3	10	4	13	3	3	1	1
Loggerhead Turtle	3	7	3	7	4	9	3	3	1	1
Olive Ridley Turtle	1	2					2	2	1	1
Green Turtle	1	2					2	2	1	1
Short-fin Pilot Whale CA/OR/WA stock			5	23			5	5	2	2
Bottlenose Dolphin CA/OR/WA stock							6	6	2	2
Pinniped Group			4,316	21,580						
Dolphin Group			13,582	67,910						

Table 1 shows the observed numbers of mortalities and serious injuries (Alternatives 1-4) or entanglements (Alternative 5) that would trigger a closure if the fishery was managed with 100% observer coverage, assuming the issues around managing the fishery in real time using 100% observer coverage can be resolved.

Table 2: Observed hard cap levels that would trigger a DGN fishery closure under 30% observer coverage, assuming an expansion estimator of fishery-wide interactions

	Alternative 1		Alternative 2		Alternative 3		Alternative 4	Alternative 5
Number of Years	1	5	1	5	1	5	1	1
Fin Whale	0.3 (1)	0.6 (1)					0.6 (1)	1
Humpback Whale	0.6 (1)	1.2 (2)	3.3 (4)	16.5 (17)	1.5 (2)	7.5 (8)	0.6 (1)	1
Sperm Whale	0.6 (1)	2.4 (3)	0.6 (1)	2.4 (3)	0.9 (1)	4.5 (5)	0.6 (1)	1
Leatherback Turtle	0.9 (1)	3.0 (3)	0.9 (1)	3.0 (3)	1.2 (2)	3.9 (4)	0.9 (1)	1
Loggerhead Turtle	0.9 (1)	2.1 (3)	0.9 (1)	2.1 (3)	1.2 (2)	2.7 (3)	0.9 (1)	1
Olive Ridley Turtle	0.3 (1)	0.6 (1)					0.6 (1)	1
Green Turtle	0.3 (1)	0.6 (1)					0.6 (1)	1
Short-fin Pilot Whale			1.5 (2)	6.9 (7)			1.5 (2)	2
Bottlenose Dolphin							1.8 (2)	2
Pinniped Group			1,294.8 (1,295)	6,474.0 (6,474)				
Dolphin Group			4,074.6 (4,075)	20,373.0 (20,373)				

Table 2 shows the observed numbers of mortalities and serious injuries (Alternatives 1-4) or entanglements (Alternative 5) that would trigger a closure if the fishery was managed with 30% observer coverage, using an expansion estimator to estimate interactions in the full fishery. Caps for Alternatives 1-4 are calculated as the expected number of observed takes under 30% observer coverage if the corresponding cap in Table 1 was reached (in 100% of effort). The left value shown in each cell of Table 2 under Alternatives 1-4 is the result of multiplying the corresponding 100% cap in Table 1 by 0.3; for nonzero decimal values the caps on observed takes are obtained by rounding up to the next whole number, as shown in adjacent parentheses. Alternative 5 caps do not change between the 30% and 100% observer coverage cases.

A bootstrap simulation analysis has been developed to compare the operation of the DGN fishery under the various proposed hard caps alternatives. A stochastic model of fishing profits and protected species regulation characterizes policy objectives in terms of profitability and interactions mitigation. DGN observer, logbook and landings databases and cost-and-earnings survey data are used to calibrate the model, in order to simulate replicates of a fishing season. Summaries of simulation results compare alternative management scenarios to the status quo fishery in terms of the effects on interactions levels and economic metrics for level of effort, revenues and profitability. The methodology was presented to the Council's Scientific and Statistical Committee (SSC) at their March 2015 meeting. The SSC offered a number of suggestions for potential revisions to the methodology which are reflected in this updated description and presentation of results.

In light of Council discussion regarding potential drawbacks of 5-year caps, the HMSMT developed versions of Alternatives 4 and 5 with two-year caps[1], which are described in the June 2015 Supplemental HMSMT Report under Agenda Item E.3.a. The current version of the analysis includes a "No Action" baseline along with 1-year and 2-year but not 5-year caps alternatives of Alternatives 1-5.

[1] Two-year caps offer the potential advantage of averaging protected species interactions over a longer, more representative period, while avoiding the prospect under 5-year caps of shutting down the fishery for up to five years.

Section II describes revisions to the analysis to address SSC review. Section III describes the model of fishery profits under hard caps. Section IV describes the data used for the analysis. The simulation algorithm is described in Section V. Section VI provides summary tables of results.

II. <u>Revisions to Address SSC Review</u>

The SSC's March 2015 meeting suggestions are shown below in italics, with steps to address them shown in ordinary font.

1. *Need more complete documentation that is provided more broadly than to just the SSC.*

   This document represents a draft version of a report that will be published as a NOAA tech memo. Results will also be incorporated into the economic analysis section of an Environmental Assessment of the regulatory action on hard caps alternatives.

2. *Document the economic data on costs; how collected, which variables were collected and how fixed costs were allocated to this fishery.*

   A cost-and-earnings survey of the DGN fleet representative of the 2008-09 and 2009-10 fishing seasons was conducted to measure economic performance of the fishery. Variable cost data components collected included fuel and oil, food, crew, gear, engine maintenance and replacement, and total vessel repairs and maintenance including haul-out fees.

   Variable costs were averaged over sixteen survey responses for the 2008-2010 period and adjusted for inflation using the GDP implicit price deflator[2] to obtain a vessel-level average variable cost per season in 2009 dollars. This estimate was divided by estimated average number of sets per season and multiplied by an inflation adjustment from 2009 to 2014 dollars to obtain a current dollar estimate of the cost per set of DGN fishing.

   The survey also collected fixed costs of fishing; however survey results do not enable the allocation of fixed costs over the full range of different fishing activities for DGN fishery participants. Hence the profit measure for analysis has been revised from total financial profits to variable financial profits, reflecting variable but not fixed costs.

3. *Future documentation should include detailed rationale for the periods of data used for conducting the bootstrap. Use alternative time-periods as sensitivity analyses to bracket uncertainty.*

   To address the suggestion to use alternative time periods as sensitivity analyses, bootstrap results were also produced using all available observer data back to 1990 and compared to results based on data limited to the period since 2001 when the Pacific Leatherback Conservation Area (PLCA) was established. An examination of interaction rates before and after 2001 shows weak statistical evidence of a change in rates for most species

[2] 2014 HMS SAFE Report Table 30. Inflation adjustment derived from Bureau of Economic Analysis Table 1.1.9 (Implicit Price Deflators for Gross Domestic Product).

subject to caps. While pre-2001 data may be less representative of the recent operation of the fishery, the longer period of observer data may produce more reliable estimates of rates of entanglement and M&SI for species with rare event interactions, which is the case for most protected species proposed for hard caps. Since the alternatives do not include options for reopening the PLCA during the closed season, the pre-2001 data were limited to non-PLCA closure effort as an implicit control on the operating characteristics of the fishery.

4. *Uncertainty in economic data should be included (prices and costs).*

   To better capture economic uncertainty, PacFIN landings data were matched to drift gillnet observer trips using vessel IDs and a comparison of the PacFIN landings date to the last set date indicated on an observer trip record; this procedure resulted in a match of 93.8% of observer trip records to PacFIN landings. Inflation-adjusted revenues in 2014 dollars and landed weight in pounds were attributed to matched observer trips. Landings and revenues for the 6.2% of unmatched observer trips were estimated by the average revenues per set and landed weight per set for matched observer records, multiplied by the numbers of sets on each unmatched trip.

   Cost data were collected at the annual level; hence measures of trip- or set-level cost variation are unavailable. Cost variation is reflected in the analysis by estimating the average cost of a trip as number of sets times estimated variable cost per set.

   To further capture economic uncertainty in the results while reflecting trip-level correlation between interaction risk and economic profitability, effort is resampled in the revised version at the trip-level rather than at the set-level.

5. *Keep tally of catch as well as net profits so that the effect of hard caps on catch can be separated from profitability.*

   Bootstrap estimates of total market species landed weight, revenues and variable profits are included in the revised results.

6. *The hard-caps should be reported in the tables in terms of the corresponding rate of observer coverage.*

   This was done in Table 14 in the June 2015 HMSMT report under Agenda Item E.3.a; it is included above as Table 1.

7. *Suggested use of a Bayesian MCMC approach*

   An SSC member suggested the possible use of a Bayesian Markov-chain Monte Carlo (MCMC) approach as an alternative to the bootstrap, to address the concern that bootstrap estimates of rare event interactions implicitly assume a constant rate of interactions across replicates, and hence underestimate the risk of hitting a cap. While this potential limitation of the bootstrap is acknowledged, the bootstrap methodology was retained in light of concerns raised by another SSC member that MCMC estimation in the version described in Martin et al. may be problematic for some of the species subject to hard caps (e.g. species which have been observed with interactions exceeding 1 on a single set or trip). Use of the bootstrap avoids the need to make strong parametric assumptions about the set- or trip-level interaction rate based on limited observations on species which have been observed with multiple interactions on the same set or trip. Bootstrap results are conservative with respect to estimated interactions incidence, in the sense that estimates reflecting a higher probability of hitting a cap would result in shorter seasons and fewer expected protected species interactions than for bootstrap results.

III. Model of DGN Fishery Operation under Hard Caps

The DGN fishery faces a management challenge of limiting interactions to levels consistent with conservation mandates of the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA) and Magnuson-Stevens Fishery Conservation and Management Act (MSA) while supporting west coast domestic swordfish production with attendant benefits to west coast producers and consumers. A model of fishery profits subject to regulatory constraints is set forth below to describe policy objectives in a framework which is amenable to analysis by bootstrap simulation. Given random variation in revenues, costs, landings and interactions, these quantities are treated as trip-level random variables.

For the fishery to achieve economic viability participants must prosecute effort which generates sufficient revenues to cover both their variable trip costs and their fixed costs of participation in a season of DGN fishing. Letting *i* denote an individual vessel participant in the fishery, for $i = 1, 2, \ldots, L$, vessel-level variable financial profit for a season is

$$\Pi_i(N_i) = \sum_{j=1}^{N_i} \left(R_{ij} - C_{ij}\right),$$

and total fleet variable profits are given by

$$\sum_{i=1}^{L} \Pi_i(N_i) = \sum_{i=1}^{L} \sum_{j=1}^{N_i} \left(R_{ij} - C_{ij}\right),$$

where N_i is the number of trips fished in the season by participant *i*, *L* is the total number of active vessels, R_{ij} is the revenue generated when fisher *i* sold retained market species catch on trip *j* of his fishing season, and C_{ij} is the variable cost of fisher *i*'s effort on trip *j*. For purposes of modeling variable profits, fishers are assumed to be owner-operators, and crew shares are subtracted from profits as an operating cost.

Suppose there are *M* species which are subject to ESA, MMPA or MSA management, and hard caps are used to limit expected fleet-level protected species mortality per season below levels d_1, d_2, ..., d_M, where d_m is the expected limit on mortality or serious injury for species *m*. Let b_1, b_2, ..., b_M, denote corresponding limit reference points on annual drift gillnet rates of interactions which meet compliance standards under applicable conservation law, and X_{ijm} represent species *m* the interactions count by fishery participant *i* on set *j*.

Using the above formulation and assuming a fixed (or maximum) fleet size L, an optimization problem may either be stated in terms of the proposed objectives of maximizing either expected total fleet profits or expected average fleet profits, subject to meeting regulatory constraints. The first objective reflects a societal goal of maximizing aggregate profits due to fishery operation, while the second objective focuses on maximizing the incentive for individual fisher participation. Both optimization problems are formulated by design to meet conservation compliance standards, provided that $d_m \leq b_m$ for capped species m with $1 \leq m \leq M$.

Proposed Objective 1: Choose the alternative A to maximize expected total fleet variable profits subject to regulatory limits:

$$\max_A E\left\{\sum_{i=1}^{L} \Pi_i(N_i)\right\} \text{ subject to}$$

$$E\left\{\sum_{i=1}^{L}\sum_{j=1}^{N_i} X_{ijm}\right\} \leq b_m, \quad m = 1, 2, \ldots, M.$$

Proposed Objective 2: Choose the alternative A to maximize expected average fleet variable profits subject to regulatory limits:

$$\max_A E\left\{\sum_{i=1}^{L} \Pi_i(N_i)\right\}/L \text{ subject to}$$

$$E\left\{\sum_{i=1}^{L}\sum_{j=1}^{N_i} X_{ijm}\right\} \leq b_m, \quad m = 1, 2, \ldots, M.$$

IV. Data

The primary data set used to simulate DGN fishery operation are set-level observer counts of retained target species catch and protected species interactions from the NMFS California Gillnet Observer Database. The observer data used in the analysis are limited to times and locations which remained open after the implementation of ESA regulations which closed the PLCA during the August 15-November 15 period each year since 2001, which substantially altered the operation of the fishery, including protected and market species interaction (catch) rates.

Due to limited or no observed mortality or serious injuries in post-2001 observer data for a number of species proposed for caps, a question arises of whether this reflects decreasing interaction rates for these species or other factors, such as far less DGN fishing effort per season after the PLCA closure was established in 2001. T-tests conducted to test whether interaction rates in species proposed for caps fell significantly proved inconclusive[3]. Although the respective observer samples include 4,204 observations before the 2001-02 season and 2,538 after the 2000-01 season, the cumulative total observed M&SI for the individual species proposed for caps is generally 5 or fewer over the entire range of the observer data on non-PLCA effort back to 1990, including many thousands of observed sets with zero interactions.

[3] Only loggerhead turtles showed a statistically significant decline in interactions rates after 2001, at the 5% but not 1% level of significance. This may reflect unusually high observed loggerhead interactions in the late 1990s due to an El Nino event.

Despite the nominally large sample sizes, the statistical power to detect significant differences in rare event interaction rates across the two periods of the observer data is quite low. Hence two versions of the observer data were used in the analysis: One that includes all years available (since 1990) but excludes time-area combinations disallowed by the 2001 PLCA closure, and a second which only includes post-2001 data.

Additional data included the PacFIN database landings (fish tickets) records for the years from 1990-2014, which were matched to observer trips in order to include trip-level records of landed weights of market species and revenues in the analysis. The results of a 2008-2010 DGN fishery cost-and-earnings study were used to estimate the trip-level average variable cost of DGN fishing, as described above.

V. Methods

Bootstrap analysis is used to simulate the operation of the fishery to explore the effects on profitability and interactions under the range of alternatives under consideration. The alternatives are simulated assuming twenty active vessels ($L = 20$), to reflect recent levels of participation in the fishery. In order to reduce potential confounding extraneous variation between simulations of alternatives, the same simulated season of potential fishing effort is used to analyze all management alternatives under comparison in each bootstrap iteration.

Details of the analysis are described as follows:

1. Trip-level landings (dressed pounds) and revenues (inflation-adjusted using the GDP implicit price deflator to 2014 dollars) from PacFIN were appended to matched observed DGN trips; landings and revenues were then equally apportioned over the sets on matched trips. (Note that set-level landings and revenue data are not available.)

2. The observed (empirical) distribution of recorded landings per season for each active DGN vessel was compiled from PacFIN records for purposes of simulating the number of planned trips fished in a season for a given number of active DGN vessels[4]. With L vessels fishing, the number of trips in a simulated season of effort is $\widehat{N} = \sum_{i=1}^{L} \widehat{N}_i$ where $\widehat{N}_i$ is a random draw for vessel $i = 1, 2, \dots, L$ from the pooled empirical distribution of effort across all active vessels.

3. Draw a random sample with replacement of $\widehat{N}$ draws from the empirical distribution of DGN observer trips (either since 1990, or limited to years since 2001), limited to time-area combinations which remained open after the PLCA closure in 2001. Format the sets corresponding to these trips into a matrix $\hat{S}$ of $\widehat{N}$ rows where columns are landings, revenues and numbers of protected species takes. Each row of $\hat{S}$ represents landed catch and interactions for a simulated set of effort, with potential sets for the season listed in chronological order from top to bottom. Bootstrap replicates for economic variables (landings and revenues) $\hat{Y}_i$ and protected species interactions $\hat{X}_i$ are thereby chosen as random draws from the empirical distribution of post-2001 observed sets for each of the $\widehat{N}$ potential sets of effort in a simulated season. The

[4] This approach may result in a slight overestimate of trips per season, due to rare occurrence of more than one landing from a single trip.

entries in row i are $\hat{S}_i = [\hat{Y}_i\ \hat{X}_i]$, where $\hat{Y}_i$ and $\hat{X}_i$ are respective row vectors for bootstrap replicates of economic metrics and protected species interactions.

4. A side-by-side comparison of management alternatives is made on each bootstrap iteration by determining the number of potential sets of effort that could be fished for the simulated season under each policy:

   i. The full matrix $\hat{S}$ is interpreted as a simulated season of effort for the L active vessels under status quo (No Hard Caps) management.

   ii. To determine the number of sets that would be allowed under annual hard caps, the cumulative sum of simulated protected species interactions is calculated down each column of the matrix $\hat{S}$ for each species or species group that is subject to caps under one of the alternatives. The first row for which the cumulative count equals or exceeds the corresponding hard cap represents the last allowable set of fishing effort under hard cap management. The sub-matrix of $\hat{S}$ which only includes the rows for sets before reaching an annual hard cap is denoted $\hat{S}_H$.

   iii. To simulate the operation of the fishery under partial observer coverage (e.g. 30%), the initial sample of DGN effort to represent a simulated season can be resampled at the specified observer coverage level to represent a simulated observer sample against which caps are applied. Expansion estimators of interactions at each point in a simulated season are calculated as the sum total of observed interactions divided by the coverage level (e.g. 30%), rounded up to reflect current regulatory practice for estimating total interactions from counts based on incomplete observe coverage. The row index in of $\hat{S}$ of the observed set which triggered the cap is treated as the last set in the (full) season for purposes of compiling total retained catch and interactions for the simulated season.

   iv. For alternatives with two-year caps, the previous year's record of observer sets is retained in order to compute two-year cumulative totals of interactions as of each (potential) observed day of fishing in the current season, which are added to observed interactions in the current season to determine whether and when a two-year cap is triggered in the current simulated season. For each simulated season, an additional field representing the number of days since January 1 for each set in the current season (*DayInYr*) is calculated and appended to each row of $\hat{S}$ to enable computation of two-year interaction totals at each point in a simulated season.

      The previous-year observer record is updated at the end of each successive simulated season by replacing the previous simulated season with the current one. A rolling record of the last day fished in the previous season under two-year caps versions of Alternatives 4 and 5 is annually updated to enable repeating this procedure in each subsequent season.

   v. A side-by-side comparison of management alternatives is made for each bootstrap iteration by determining the number of potential sets of effort that could be fished for the simulated season under each policy. For each simulated season, total fleet and average fleet landings, variable profits and interactions impacts are calculated under each management alternative.

5. After the simulation loop finishes executing for the specified number of simulated seasons, summary statistics are compiled to describe the bootstrap distributions of economic and bycatch metrics computed for the simulated seasons.

VI. Presentation of Results

The tables below display results of analysis to compare the fishery under the No Action (No Caps) alternative to Alternatives 1-5, including 2-year cap versions of Alternatives 4-5 and 1-year cap versions of Alternatives 4-5 with 100% observer coverage; 30% observer coverage results are included for the 1-year cap versions of Alternatives 4 and 5. The results represent 10,000 simulated seasons, assuming L = 20 active DGN vessels, in terms of summary statistics for numbers of sets fished, total fleet variable profits, average variable profits per vessel, landings (dressed metric tons) and interactions rates for individual species which are subject to caps under at least one of the alternatives. The first five numeric columns display the fifth, twenty-fifth, fiftieth, seventy-fifth and ninety-fifth percentiles of simulation results (Q5, Q25, …, Q95). The rightmost two columns display the mean and standard deviation of simulation results. The percentile values displayed across the columns are computed independently down the rows of the table for each economic or interactions metric included in the analysis. Percentiles are for sets, total revenues, total variable profits and average variable profits, and simulated mortalities and serious injuries counts of the listed species, reflecting all effort in simulated season (observed and unobserved).

Table 3 shows results for the No Action (Baseline / “No Caps”) scenario and hard caps Alternatives 1 and 2 using post-2000 data and assuming 100% observer coverage would be used to manage the fishery. Table 4 shows comparable results for Alternatives 3-5. Generally speaking, the economic performance of the fishery declines under all of the alternatives under consideration, while conservation impacts in terms of M&SI decrease with the adoption of hard caps, due both to the direct effect of shutting down the fishery once a cap is reached and to the indirect effect of less allowable fishing effort on expected conservation impacts for all protected species. Potential adverse economic affects appear to be limited except for in the case of Alternative 5, which is expected to result in a large loss of allowable fishing effort, total revenues, total and average variable profits and market species landings.

Table 5 shows results for versions of Alternatives 4 and 5 which would apply the caps against the trailing two-year average numbers of interactions. The version of the two-year cap analyzed here assumes the two-year average would be computed on a rolling basis, using the sum total of previous year’s interactions (M&SI for Alt. 4, entanglements for Alt. 5) and current season interactions divided by 2. Results show a slightly higher mean level of allowable effort and economic results for Alternative 4 and considerably higher effort and economic results under Alternative 5 if two-year hard caps were used. This is offset by an increase in the standard deviation of results, likely reflecting the risk that a closure from the previous period may remain in effect or may trigger a closure earlier in the current season than if one-year caps were used.

Table 6 displays the results for analysis of Alternatives 4 and 5 based on 30% observer coverage. Observer data for seasons after 2000 are used to represent recent operation of the fishery. Comparing Table 16 results for Alternatives 4 and 5 to Table 18 results suggests the possibility of a slight decline in economic viability under Alternative 4 with an accompanying reduction in risk (standard deviation / StdDev), with a more substantial decline in economic performance and risk (measured by StdDev) under Alternative 5, reflecting that entanglement caps were not adjusted in moving to 100% observer coverage under Alternative 5, leading to a much greater risk of reaching an entanglement cap based on 100% observer coverage.

To address the SSC's suggestion to use alternative time periods as sensitivity analyses, bootstrap results were also produced using all available observer and related PacFIN data back to 1990. Since the alternatives do not include options for reopening the PLCA during the closed season, the pre-2001 data were limited to non-PLCA closure effort as an implicit control on the operating characteristics of the fishery. While pre-2001 data may be less representative of the recent operation of the fishery, the longer period of observer data may produce more reliable estimates of rates of entanglement and M&SI for species with rare event interactions, such as the high priority protected species proposed for hard caps.

Tables 7-10 show bootstrap results corresponding to those in Tables 3-6, but using all years of data since 1990 in the analysis. The economic results, which average in pre-2001 retained market species catch rates and revenues, are slightly less favorable than if data are limited to post-2000 observations. M&SI statistics are higher for a number of species when pre-2000 data are included; it is not clear whether this reflects significant differences in M&SI for these species over the two periods, or a lack of sufficient data in the post-2000 period to accurately measure M&SI rates for species with rare event interactions. The economic performance results for the impacts of alternatives using all data are qualitatively similar to those using post-1990 data, except that moving from 30% to 100% observer coverage would result in an improvement in mean economic performance under Alternative 4.

Table 3. Bootstrap results for No Action (Baseline) Scenario and Alternatives 1-2 using post-2000 data with 100% observer coverage.

	No Action: No Caps						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	776	1,002	1,187	1,394	1,727	1,211	290
Total Revenues	$1,088,434	$1,448,174	$1,744,482	$2,077,080	$2,600,251	$1,780,480	$460,768
Total Variable Profits	$236,854	$403,446	$537,220	$695,657	$947,411	$558,802	$218,289
Average Variable Profits	$11,843	$20,172	$26,861	$34,783	$47,371	$27,940	$10,914
Landings	175.5	233.7	280.7	333.5	417.1	286.5	73.3
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	4	0.96	1.40
Short-fin Pilot Whales	0	1	1	2	4	1.43	1.24
Bottlenose Dolphins	0	0	0	1	2	0.47	0.70
	Alternative 1: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	668	880	1,058	1,265	1,613	1,086	288
Total Revenues	$895,567	$1,234,906	$1,519,903	$1,854,750	$2,400,286	$1,570,311	$465,088
Total Variable Profits	$171,960	$316,513	$447,449	$602,594	$872,192	$474,699	$216,765
Average Variable Profits	$8,598	$15,826	$22,372	$30,130	$43,610	$23,735	$10,838
Landings	149.1	202.3	246.6	299.6	383.8	254.4	72.5
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	2	0.75	0.97
Short-fin Pilot Whales	0	0	1	2	3	1.05	1.16
Bottlenose Dolphins	0	0	0	1	2	0.47	0.70
	Alternative 2: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	668	880	1,058	1,264	1,611	1,085	287
Total Revenues	$895,567	$1,234,906	$1,519,645	$1,853,814	$2,397,808	$1,569,120	$463,405
Total Variable Profits	$171,960	$316,411	$447,300	$601,880	$871,066	$474,265	$216,098
Average Variable Profits	$8,598	$15,821	$22,365	$30,094	$43,553	$23,713	$10,805
Landings	149.1	202.3	246.6	299.5	383.3	254.2	72.3
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	2	0.75	0.97
Short-fin Pilot Whales	0	0	1	2	3	1.05	1.14
Bottlenose Dolphins	0	0	0	1	2	0.47	0.70

Table 4. Bootstrap results for Alternatives 3-5 using post-2000 data with 100% observer coverage.

	Alternative 3: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	749	974	1,157	1,361	1,697	1,181	289
Total Revenues	$1,038,377	$1,396,800	$1,690,020	$2,023,450	$2,552,470	$1,730,463	$462,641
Total Variable Profits	$220,942	$381,991	$517,283	$675,023	$930,226	$538,980	$219,332
Average Variable Profits	$11,047	$19,100	$25,864	$33,751	$46,511	$26,949	$10,967
Landings	169.4	226.4	272.3	325.4	406.4	278.8	72.9
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	4	0.92	1.30
Short-fin Pilot Whales	0	0	1	2	4	1.34	1.22
Bottlenose Dolphins	0	0	0	1	2	0.47	0.70
	Alternative 4: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	668	880	1,058	1,263	1,611	1,085	287
Total Revenues	$895,567	$1,234,686	$1,519,541	$1,853,576	$2,397,808	$1,568,999	$463,389
Total Variable Profits	$171,960	$316,235	$447,288	$601,749	$871,066	$474,217	$216,083
Average Variable Profits	$8,598	$15,812	$22,364	$30,087	$43,553	$23,711	$10,804
Landings	149.1	202.2	246.6	299.4	383.3	254.2	72.3
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	2	0.75	0.97
Short-fin Pilot Whales	0	0	1	2	3	1.05	1.14
Bottlenose Dolphins	0	0	0	1	2	0.47	0.70
	Alternative 5: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	18	38	115	247	892	217	279
Total Revenues	$4,621	$14,192	$99,747	$257,869	$1,258,430	$255,504	$410,322
Total Variable Profits	-$54,707	-$27,683	-$14,526	$30,165	$374,362	$36,286	$141,261
Average Variable Profits	-$2,735	-$1,384	-$726	$1,508	$18,718	$1,814	$7,063
Landings	1.4	4.3	19.8	45.7	205.4	44.0	66.0
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	0	0	0.06	0.35
Short-fin Pilot Whales	0	0	0	0	1	0.21	0.51
Bottlenose Dolphins	0	0	0	0	1	0.06	0.29

Table 5. Bootstrap results for two-year hard caps alternatives using post-2000 data and 100% observer coverage.

	Alternative 4: 2-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	1	908	1,107	1,318	1,661	1,089	383
Total Revenues	$1,601	$1,283,258	$1,603,594	$1,953,953	$2,494,851	$1,588,766	$591,691
Total Variable Profits	$593	$332,052	$478,515	$640,745	$909,809	$489,864	$244,253
Average Variable Profits	$30	$16,603	$23,926	$32,037	$45,490	$24,493	$12,213
Landings	0.6	209.1	258.8	313.7	397.3	256.4	93.9
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	4	0.82	1.18
Short-fin Pilot Whales	0	0	1	2	3	1.19	1.21
Bottlenose Dolphins	0	0	0	1	2	0.45	0.68
	Alternative 5: 2-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	1	1	140	701	1,247	358	446
Total Revenues	$81	$1,601	$130,487	$943,627	$1,846,407	$483,715	$661,582
Total Variable Profits	-$43,414	-$947	$593	$205,143	$617,472	$122,978	$226,925
Average Variable Profits	-$2,171	-$47	$30	$10,257	$30,874	$6,149	$11,346
Landings	0.0	0.6	24.8	157.5	295.1	79.7	106.1
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	0	2	0.19	0.59
Short-fin Pilot Whales	0	0	0	0	2	0.38	0.77
Bottlenose Dolphins	0	0	0	0	1	0.13	0.42

Table 6. Bootstrap results using post-2000 data with 30% observer coverage.

	Alternative 4: 1-year Caps, 30% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	689	939	1,125	1,337	1,677	1,144	312
Total Revenues	$933,548	$1,339,978	$1,641,406	$1,978,503	$2,521,681	$1,670,955	$497,954
Total Variable Profits	$180,484	$361,332	$497,665	$656,929	$916,629	$516,832	$226,578
Average Variable Profits	$9,024	$18,067	$24,883	$32,846	$45,831	$25,842	$11,329
Landings	153.9	216.7	265.0	317.7	404.0	269.4	78.5
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	2	4	0.84	1.24
Short-fin Pilot Whales	0	0	1	2	3	1.27	1.15
Bottlenose Dolphins	0	0	0	1	2	0.48	0.70
	Alternative 5: 1-year Caps, 30% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	28	165	660	1,076	1,481	659	505
Total Revenues	$8,497	$157,736	$864,623	$1,574,869	$2,220,077	$920,047	$782,379
Total Variable Profits	-$46,075	-$13,086	$171,951	$474,771	$783,430	$255,035	$292,228
Average Variable Profits	-$2,304	-$654	$8,598	$23,739	$39,171	$12,752	$14,611
Landings	2.3	29.7	143.5	253.5	355.9	150.1	124.2
Leatherback Turtles	0	0	0	0	0	0.00	0.00
Loggerhead Turtles	0	0	0	0	0	0.00	0.00
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.00	0.00
Fin Whales	0	0	0	0	0	0.00	0.00
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	0	2	0.40	0.95
Short-fin Pilot Whales	0	0	0	1	3	0.73	1.01
Bottlenose Dolphins	0	0	0	0	1	0.26	0.57

Table 7. Bootstrap results for No Action (Baseline) Scenario and Alternatives 1-2 using post-1990 data with 100% observer coverage.

	No Action: No Caps						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	662	869	1,034	1,221	1,528	1,057	264
Total Revenues	$1,175,298	$1,591,070	$1,921,789	$2,315,402	$2,930,211	$1,976,620	$543,993
Total Variable Profits	$447,685	$681,757	$873,470	$1,100,351	$1,490,127	$910,027	$321,172
Average Variable Profits	$22,384	$34,088	$43,674	$55,018	$74,506	$45,501	$16,059
Landings	166.2	222.8	269.4	323.5	412.0	276.9	75.6
Leatherback Turtles	0	0	0	1	2	0.47	0.68
Loggerhead Turtles	0	0	0	1	2	0.63	0.81
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.15	0.39
Fin Whales	0	0	0	0	1	0.15	0.39
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	3	0.78	1.05
Short-fin Pilot Whales	0	0	1	1	2	0.78	0.91
Bottlenose Dolphins	0	0	0	0	1	0.16	0.40
	Alternative 1: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	504	722	902	1,104	1,403	917	285
Total Revenues	$879,987	$1,309,066	$1,673,641	$2,073,800	$2,713,182	$1,710,958	$581,637
Total Variable Profits	$321,774	$559,666	$754,024	$982,306	$1,370,798	$786,403	$328,569
Average Variable Profits	$16,089	$27,983	$37,701	$49,115	$68,540	$39,320	$16,428
Landings	127.9	187.5	236.4	291.1	379.5	241.6	79.7
Leatherback Turtles	0	0	0	1	2	0.35	0.60
Loggerhead Turtles	0	0	0	1	2	0.57	0.76
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.14	0.34
Fin Whales	0	0	0	0	1	0.14	0.34
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	2	0.60	0.81
Short-fin Pilot Whales	0	0	0	1	2	0.66	0.85
Bottlenose Dolphins	0	0	0	0	1	0.16	0.40
	Alternative 2: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	558	781	954	1,145	1,438	965	282
Total Revenues	$971,689	$1,423,577	$1,775,671	$2,158,178	$2,780,784	$1,804,294	$575,867
Total Variable Profits	$359,201	$607,573	$801,679	$1,028,863	$1,406,157	$830,997	$329,342
Average Variable Profits	$17,960	$30,379	$40,084	$51,443	$70,308	$41,550	$16,467
Landings	141.4	201.9	249.8	302.1	388.8	253.8	79.3
Leatherback Turtles	0	0	0	1	2	0.38	0.62
Loggerhead Turtles	0	0	0	1	2	0.59	0.77
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.15	0.38
Fin Whales	0	0	0	0	1	0.15	0.38
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	2	0.68	0.84
Short-fin Pilot Whales	0	0	0	1	2	0.70	0.86
Bottlenose Dolphins	0	0	0	0	1	0.16	0.40

Table 8. Bootstrap results for Alternatives 3-5 using post-1990 data with 100% observer coverage.

	Alternative 3: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	640	844	1,008	1,195	1,495	1,031	262
Total Revenues	$1,130,586	$1,543,367	$1,877,922	$2,262,079	$2,885,699	$1,928,040	$541,662
Total Variable Profits	$427,282	$661,617	$849,699	$1,080,105	$1,466,067	$888,080	$319,390
Average Variable Profits	$21,364	$33,081	$42,485	$54,005	$73,303	$44,404	$15,970
Landings	161.0	217.1	263.7	316.6	403.8	270.4	74.9
Leatherback Turtles	0	0	0	1	2	0.44	0.67
Loggerhead Turtles	0	0	0	1	2	0.61	0.80
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.15	0.39
Fin Whales	0	0	0	0	1	0.15	0.39
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	3	0.76	0.98
Short-fin Pilot Whales	0	0	1	1	2	0.76	0.89
Bottlenose Dolphins	0	0	0	0	1	0.16	0.40
	Alternative 4: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	552	776	951	1,142	1,433	961	282
Total Revenues	$962,373	$1,416,256	$1,769,063	$2,152,384	$2,773,237	$1,797,253	$576,087
Total Variable Profits	$355,784	$605,093	$798,671	$1,025,836	$1,402,523	$827,660	$329,176
Average Variable Profits	$17,789	$30,255	$39,934	$51,292	$70,126	$41,383	$16,459
Landings	140.1	201.0	249.0	301.4	388.2	252.9	79.3
Leatherback Turtles	0	0	0	1	2	0.38	0.62
Loggerhead Turtles	0	0	0	1	2	0.59	0.77
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.15	0.38
Fin Whales	0	0	0	0	1	0.15	0.38
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	2	0.68	0.84
Short-fin Pilot Whales	0	0	0	1	2	0.69	0.86
Bottlenose Dolphins	0	0	0	0	1	0.16	0.40
	Alternative 5: 1-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	15	35	69	183	640	157	207
Total Revenues	$7,560	$25,035	$61,326	$270,785	$1,201,265	$244,268	$401,865
Total Variable Profits	-$31,482	-$12,187	$117	$77,259	$545,459	$86,232	$200,568
Average Variable Profits	-$1,574	-$609	$6	$3,863	$27,273	$4,312	$10,028
Landings	1.4	5.4	11.3	41.6	171.2	36.9	57.0
Leatherback Turtles	0	0	0	0	0	0.04	0.19
Loggerhead Turtles	0	0	0	1	1	0.26	0.44
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.01	0.09
Fin Whales	0	0	0	0	0	0.01	0.09
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	0	0	0.04	0.22
Short-fin Pilot Whales	0	0	0	0	1	0.13	0.40
Bottlenose Dolphins	0	0	0	0	0	0.02	0.13

Table 9. Bootstrap results for two-year hard caps alternatives using post-1990 data and 100% observer coverage.

	Alternative 4: 2-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	588	829	999	1,189	1,493	1,009	296
Total Revenues	$1,031,928	$1,512,540	$1,858,789	$2,249,912	$2,877,550	$1,886,045	$598,708
Total Variable Profits	$382,041	$643,785	$840,770	$1,072,445	$1,458,185	$868,498	$338,780
Average Variable Profits	$19,102	$32,189	$42,038	$53,622	$72,909	$43,425	$16,939
Landings	147.4	212.5	261.3	315.0	402.8	264.7	83.0
Leatherback Turtles	0	0	0	1	2	0.43	0.66
Loggerhead Turtles	0	0	0	1	2	0.60	0.79
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.15	0.39
Fin Whales	0	0	0	0	1	0.15	0.39
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	3	0.74	0.98
Short-fin Pilot Whales	0	0	1	1	2	0.74	0.89
Bottlenose Dolphins	0	0	0	0	1	0.15	0.40
	Alternative 5: 2-year Caps, 100% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	1	1	45	393	1007	241	358
Total Revenues	$150	$461	$33,823	$663,288	$1,929,369	$427,280	$687,984
Total Variable Profits	-$25,592	-$851	$436	$256,093	$936,483	$184,494	$335,807
Average Variable Profits	-$1,280	-$43	$22	$12,805	$46,824	$9,225	$16,790
Landings	0.0	0.2	6.8	97.5	272.3	61.4	96.5
Leatherback Turtles	0	0	0	0	1	0.07	0.29
Loggerhead Turtles	0	0	0	0	1	0.23	0.48
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	0	0.03	0.19
Fin Whales	0	0	0	0	0	0.03	0.19
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	0	1	0.13	0.45
Short-fin Pilot Whales	0	0	0	0	1	0.18	0.50
Bottlenose Dolphins	0	0	0	0	0	0.04	0.20

Table 10. Bootstrap results using post-1990 data with 30% observer coverage.

	Alternative 4: 1-year Caps, 30% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	52	598	857	1,075	1,393	801	403
Total Revenues	$38,767	$1,065,626	$1,585,987	$2,029,528	$2,687,307	$1,487,795	$803,483
Total Variable Profits	-$15,450	$419,313	$706,922	$957,222	$1,362,226	$680,052	$420,889
Average Variable Profits	-$772	$20,966	$35,346	$47,861	$68,111	$34,003	$21,044
Landings	7.6	152.2	223.2	284.8	374.8	209.8	111.1
Leatherback Turtles	0	0	0	1	1	0.31	0.55
Loggerhead Turtles	0	0	0	1	2	0.53	0.68
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.11	0.33
Fin Whales	0	0	0	0	1	0.11	0.33
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	1	2	0.57	0.89
Short-fin Pilot Whales	0	0	0	1	2	0.58	0.81
Bottlenose Dolphins	0	0	0	0	1	0.13	0.37
	Alternative 5: 1-year Caps, 30% Observed						
	Q5	Q25	Q50	Q75	Q95	Mean	StdDev
Sets	24	84	435	839	1,224	500	419
Total Revenues	$14,715	$78,545	$726,394	$1,563,512	$2,356,504	$901,483	$827,984
Total Variable Profits	-$26,267	$2,373	$280,276	$708,321	$1,175,442	$396,682	$419,309
Average Variable Profits	-$1,313	$119	$14,014	$35,416	$58,772	$19,834	$20,965
Landings	3.0	13.7	108.5	220.3	329.4	128.8	115.0
Leatherback Turtles	0	0	0	0	1	0.18	0.44
Loggerhead Turtles	0	0	0	1	2	0.43	0.63
Olive Ridley Turtles	0	0	0	0	0	0.00	0.00
Green Turtles	0	0	0	0	1	0.06	0.24
Fin Whales	0	0	0	0	1	0.06	0.24
Humpback Whales	0	0	0	0	0	0.00	0.00
Sperm Whales	0	0	0	0	2	0.28	0.67
Short-fin Pilot Whales	0	0	0	1	2	0.39	0.68
Bottlenose Dolphins	0	0	0	0	1	0.08	0.29

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