Southwest Fisheries Science Center
Administrative Report H-98-08

# ESTIMATING ANNUAL TAKES AND KILLS OF SEA TURTLES BY THE HAWAIIAN LONGLINE FISHERY, 1991–97, FROM OBSERVER PROGRAM AND LOGBOOK DATA

Pierre Kleiber

Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
2570 Dole Street, Honolulu, Hawaii 96822-2396

July 1998

NOT FOR PUBLICATION

## INTRODUCTION

On the basis of biological opinions issued under the Endangered Species Act (ESA), an observer program for the Hawaiian longline fishery has been in place since 1994 to record sea turtle interactions. Observed take locations for the first 4 years of the observer program are shown in Figures 1–4, for the turtle species so far observed to interact with the longline gear: loggerhead turtles (*Caretta caretta*), olive ridley turtles (*Lepidochelys olivacea*), leatherback turtles (*Dermochelys coriacea*), and green turtles (*Chelonia mydas*). Hawksbill turtles (*Eretmochelys imbricata*) are also known to exist in the region, but no takes of this species have been observed in the longline fishery.

Because less than 5% of the fishing trips are observed, estimates of interactions in the whole fishery must be extrapolated from observer records. One of the requirements of the observer program is an annual report on the findings of the program. As a contribution to preparation of that report for 1997, this paper presents estimates of turtle take and kill in the fishery through 1997, using observer data, logbook data from the fishermen, and other ancillary data.

## METHODS

Takes and kills were estimated with substantially the same statistical techniques employed in the previous year for the 1994–96 observer data (Skillman and Kleiber, manuscr. in prep.). Observer data and corresponding logbook data for each observed set, 1994–97, were used to construct a predictive model for takes of each turtle species. The data consisted of records of 1,922 sets with information on takes and the condition of turtles as well as 27 independent variables (Table 1) to be tested for significance with a classification and regression tree (CART) model (Clark and Pregibon, 1992). An additional 276 sets had incomplete information on some of the independent variables.

The predictive models were applied year by year, 1991–97, to all the logbook data (observed and unobserved sets) to estimate the takes by year for the whole fishery. To estimate the total number of kills, the expected number of kills per take was first estimated, by species, from information recorded by observers on the condition of the turtles when released (Table 2). The only information available on turtle mortality from longline gear interaction suggests that loggerhead turtles have a 29% probability of dying as a result of ingesting a longline hook (Aguilar, Mas, and Pastor, 1992). Therefore, for a condition recorded as internal (i.e., hook ingested), the mortality was set to 0.29, and this figure was assumed to apply to all turtle species released in this condition. Turtles recorded as dead were assigned a mortality of 1.0, and turtles recorded as OK were assigned a zero mortality, as were turtles hooked external to the throat (external). Turtles hooked in an unknown location (hook) were assigned the average mortality of the turtles of their species with a known hook location, and turtles with unknown condition (code

NR) were assigned the average within species of turtles with condition code OK, internal, or external. In the case of turtles reported as hardshell and with unknown hook location or unknown condition, the averaging was conducted over all turtles except leatherbacks. The total takes and kills of unidentified hardshell turtles were apportioned to the total takes and kills of known hardshell species (Table 2) in proportion to the known takes to yield the kill per take by species (Table 3). Finally, the kill per take figures were multiplied by the take estimates to get estimated kills.

To represent uncertainty in the point estimates, smoothed empirical frequency distributions were obtained from 1,000 bootstrap estimates using a Gaussian kernel technique (Härdle, 1990). The principle change in technique from the previous year's analysis was in the method of drawing and applying bootstrap samples for investigating uncertainty in the estimates. In the present analysis, bootstrap samples were drawn trip by trip rather than set by set as was done previously. Also, the calculation of kill per take was included in the bootstrap procedure, that is, condition tables similar to Tables 2 and 3 were constructed for each bootstrap sample.

## RESULTS

Loggerheads were the only turtle species for which significant independent variables remained in the CART after cross validation and pruning. Sea surface temperature was the most important variable, followed by albacore catch, whereas latitude was the most important variable in the previous year's analysis. Unfortunately, more than one-third of the temperature records are missing in the logbook data, which means that a predictive model with temperature would not be very efficient. There are also some temperature data missing in the observer data. Accordingly, a CART was produced with the temperature variable eliminated. In this analysis, based on a somewhat larger data set, latitude emerged as the primary explanatory variable, in place of temperature, and the resulting model fit somewhat better than the original model. Plots of annual loggerhead take and kill estimated with the restricted model for 1991–97 are given in Figures 5 and 6. These results are tabulated in Table 4.

Like the previous year, CART analysis for olive ridleys picked yellowfin catch as the most important independent variable. However, in contrast to last year the influence of yellowfin catch (or any other variable) was not statistically significant. Therefore, the olive ridley CART was pruned to a single node, i.e., the model was reduced to simply the overall take per set. Plots of annual olive ridley take and kill estimates for 1991–97 are given in Figures 7 and 8. These results are tabulated in Table 5.

Results for leatherback turtles were essentially the same as in last year's analysis: no significant independent variables were found. Plots of annual leatherback take and kill estimates for 1991–97 are given in Figures 9 and 10. These results are tabulated in Table 6.

Likewise, the results for green turtles were essentially the same as in last year's analysis: no significant independent variables were found. Plots of annual green turtle take and kill estimates for 1991–97 are given in Figures 11 and 12. These results are tabulated in Table 7.

## DISCUSSION

In contrast to earlier years, the point estimate of loggerhead takes for 1997 is below the authorized take level for loggerheads stipulated in the Incidental Take Statement of the current NMFS Biological Opinion, though the bootstrap distribution indicates a 22% chance that the real take was above that level. Kill estimates for loggerheads are consistently above the authorized kill level for loggerheads, as they are for olive ridleys, though take estimates for olive ridleys are consistently below the authorized take level for that species. All estimates for leatherback and green turtles are well below authorized levels for those species.

Estimates for 1991–93 are included because logbook data are available for those years, but these estimates are based on 1994–97 observer data. Therefore, these estimates involve an additional level of extrapolation above the 1994–97 estimates and should be interpreted with some caution, as should all the estimates, given the wide confidence intervals.

## REFERENCES

Aguilar, R., J. Mas, and X. Pastor.
1992. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle (*Caretta caretta*) population in the western Mediterranean. Presented at the 12th Annual Workshop on Sea Turtle Biology and Conservation. Feb. 25-29, 1992, Jekyll Island, Georgia.

Clark, L. A., and D. Pregibon.
1992. Tree-based models. Chapter 9. In: J. M Chambers and T. J. Hastie (eds.), Statistical Models in S. Wadsworth & Brooks/Cole. 608 p.

Härdle, W.
1990. Smoothing techniques with implementations in S. Springer-Verlag. 261 p.

Skillman, R.A. and P. Kleiber.
Manuscript in Prep. Estimation of sea turtle take and mortality in the Hawai'i-based longline fishery, 1994–96.

Table 1. Independent variables tested for statistical significance in affecting the probability of longline-turtle interaction.

| | variable | mnemonic | type | notes |
|---|---|---|---|---|
| Location in time and space: | latitude | lat | numeric | degrees N |
| | longitude | lon | numeric | degrees E |
| | year | year | categorical | 94; 95; 96; 97 |
| | month | mon | categorical | Jan -- Dec |
| | time | time | numeric | 0001 - 2400 |
| Condition of gear: | hooks | hooks | numeric | count |
| | hooks/float | hkpfl | numeric | count |
| | bait | bait | categorical | 6 categories |
| | light sticks | stiks | numeric | count |
| Environment: | temperature | btemp | numeric | sea surface temperature |
| | sun elevation | sun | numeric | degrees above horizon |
| | moon phase | moon | numeric | percent full |
| Catch of other species: | bigeye | bet | numeric | catch in # |
| | yellowfin | yft | numeric | " |
| | skipjack | skj | numeric | " |
| | albacore | alb | numeric | " |
| | swordfish | swo | numeric | " |
| | blue shark | blshk | numeric | " |
| | mahimahi | mahi | numeric | " |
| | striped marlin | stmrl | numeric | " |
| | blue marlin | blmrl | numeric | " |
| | wahoo | wahoo | numeric | " |
| | spearfish | spear | numeric | " |
| | opah | opah | numeric | " |
| | albatross | albts | numeric | " |
| Other: | vessel length | veslen | numeric | registered length |
| | target | targ | categorical | 7 categories |

Table 2. Turtle take and kill statistics by condition code from combined observer data, 1994–97. "Kill Rate" is the expected kills per take imputed (see text) from the given condition except in the "Total" column, where it is the sum over condition codes of take times kill rate.

| | | Condition Code | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Statistic | Internal | External | Hook | NR | OK | Dead | Total |
| Loggerhead | Take | 48 | 31 | 2 | 1 | 3 | 0 | 85 |
| | Kill Rate | 0.290 | 0.0 | 0.178 | 0.172 | 0.0 | 1.0 | 14.45 |
| Olive Ridley | Take | 10 | 7 | 0 | 0 | 0 | 2 | 19 |
| | Kill Rate | 0.290 | 0.0 | 0.171 | 0.171 | 0.0 | 1.0 | 4.90 |
| Leatherback | Take | 1 | 20 | 3 | 5 | 3 | 1 | 33 |
| | Kill Rate | 0.290 | 0.0 | 0.014 | 0.012 | 0.0 | 1.0 | 1.39 |
| Green | Take | 0 | 5 | 0 | 0 | 0 | 0 | 5 |
| | Kill Rate | 0.290 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.00 |
| Hard Shell | Take | 3 | 0 | 4 | 2 | 0 | 0 | 9 |
| | Kill Rate | 0.290 | 0.0 | 0.172 | 0.167 | 0.0 | 1.0 | 1.89 |

Condition Codes:

Internal – hook was ingested
External – hooked, but hook not ingested
Hook – hooked in unknown location
NR – condition not recorded
OK – alive and uninjured at release
Dead – dead upon gear retrieval

Table 3. Calculation of overall kill rate (kills per take), takes and kills by species. Based on takes and calculated kills from Table 2 with takes and kills of unidentified hardshell turtles allocated to the other hardshell species in proportion to the recorded takes of those species.

| Species | Takes | Kills | Kill Rate |
|---|---|---|---|
| Loggerhead | 91.0 | 15.9 | 0.175 |
| Olive ridley | 20.6 | 5.2 | 0.254 |
| Leatherback | 33 | 1.4 | 0.042 |
| Green | 5.4 | 0.1 | 0.016 |

Table 4. Loggerhead take and kill estimates with 95% confidence intervals and probabilities that the real takes or kills exceeded the authorized levels (given in parentheses).

| | Takes | | | Kills | | |
|---|---|---|---|---|---|---|
| year | est. | 95% CI | p(>305) | est. | 95% CI | p(>46) |
| 1991 | 355 | [215–472] | 0.66 | 62 | [33–85 ] | 0.83 |
| 1992 | 514 | [295–624] | 0.97 | 90 | [46–117] | 0.98 |
| 1993 | 581 | [360–770] | 0.99 | 102 | [58–145] | 1.00 |
| 1994 | 476 | [237–558] | 0.88 | 83 | [38–103] | 0.93 |
| 1995 | 376 | [191–461] | 0.59 | 66 | [31–83 ] | 0.77 |
| 1996 | 426 | [207–502] | 0.72 | 75 | [32–92 ] | 0.84 |
| 1997 | 284 | [150–435] | 0.22 | 50 | [23–74 ] | 0.50 |

Table 5. Olive ridley take and kill estimates with 95% confidence intervals and probabilities that the real takes or kills exceeded the authorized levels (given in parentheses).

| | Takes | | | Kills | | |
|---|---|---|---|---|---|---|
| year | est. | 95% CI | p(>152) | est. | 95% CI | p(>23) |
| 1991 | 118 | [ 49 – 184 ] | 0.16 | 30 | [ 11 – 50 ] | 0.72 |
| 1992 | 108 | [ 46 – 169 ] | 0.09 | 27 | [ 9 – 46 ] | 0.64 |
| 1993 | 115 | [ 47 – 178 ] | 0.14 | 29 | [ 10 – 48 ] | 0.69 |
| 1994 | 101 | [ 41 – 157 ] | 0.06 | 26 | [ 9 – 43 ] | 0.56 |
| 1995 | 110 | [ 45 – 170 ] | 0.11 | 28 | [ 10 – 47 ] | 0.65 |
| 1996 | 109 | [ 45 – 170 ] | 0.10 | 28 | [ 10 – 46 ] | 0.65 |
| 1997 | 111 | [ 48 – 175 ] | 0.11 | 28 | [ 10 – 47 ] | 0.66 |

Table 6. Leatherback take and kill estimates with 95% confidence intervals and probabilities that the real takes or kills exceeded the authorized levels (given in parentheses).

| | | | | Kills | | |
|---|---|---|---|---|---|---|
| year | est. | 95% CI | p(>271) | est. | 95% CI | p(>41) |
| 1991 | 190 | [ 119 – 268 ] | 0.02 | 8 | [ 0.1 – 21 ] | ~0 |
| 1992 | 173 | [ 108 – 245 ] | 0.00 | 7 | [ 0.1 – 19 ] | ~0 |
| 1993 | 185 | [ 115 – 261 ] | 0.02 | 8 | [ 0.1 – 20 ] | ~0 |
| 1994 | 162 | [ 101 – 229 ] | 0.00 | 7 | [ 0.1 – 18 ] | ~0 |
| 1995 | 176 | [ 110 – 249 ] | 0.01 | 7 | [ 0.1 – 19 ] | ~0 |
| 1996 | 175 | [ 109 – 247 ] | 0.01 | 7 | [ 0.1 – 19 ] | ~0 |
| 1997 | 178 | [ 111 – 251 ] | 0.01 | 7 | [ 0.1 – 20 ] | ~0 |

Table 7. Green turtle take and kill estimates with 95% confidence intervals and probabilities that the real takes or kills exceeded the authorized levels (given in parentheses).

| | Takes | | | Kills | | |
|---|---|---|---|---|---|---|
| year | est. | 95% CI | p(>119) | est. | 95% CI | p(>18) |
| 1991 | 31 | [ 7–58 ] | ~0 | 0.5 | [ 0.04–1.01 ] | ~0 |
| 1992 | 28 | [ 5–52 ] | ~0 | 0.5 | [ 0.04–0.92 ] | ~0 |
| 1993 | 30 | [ 6–56 ] | ~0 | 0.5 | [ 0.04–0.98 ] | ~0 |
| 1994 | 27 | [ 5–49 ] | ~0 | 0.4 | [ 0.03–0.86 ] | ~0 |
| 1995 | 29 | [ 6–53 ] | ~0 | 0.5 | [ 0.04–0.94 ] | ~0 |
| 1996 | 29 | [ 5–52 ] | ~0 | 0.5 | [ 0.03–0.92 ] | ~0 |
| 1997 | 29 | [ 6–54 ] | ~0 | 0.5 | [ 0.03–0.94 ] | ~0 |