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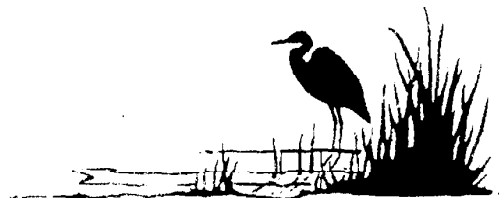
Message HERE IS THE Red-footed Booby
ESTIMATE WITH Chuck McKinley's
suggested REVISIONS.

I ALSO E-MAILED THIS DOCUMENT

Drew

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LAST PAGE MIS-FED 2ND TRY.

To: Beth Flint, Kevin Foster, and Roger Helm
 From: Drew Laughland
 Date: May 17, 1999

Subject: **Tesoro SPM Hose Oil Spill - Calculation Red-footed Booby Damage and Credit**

Here is a summary of how I calculated the lost bird services from Red-footed Boobies attributable to the Tesoro spill. The general concept is that oiling shortens the bird's life so society is denied the services that the bird would have provided if it had lived a normal life span. In addition, society is denied the services of its first generation progeny. I have relied on life history information regarding Red-footed Boobies which Beth Flint supplied to calculate discounted, lost bird-years.

Table 1 summarizes the information from Beth Flint's note and Darcy Elizabeth Hu's thesis. Hu quotes Nelson's estimated first year mortality as 50 percent with 20 percent mortality in the second year (page 19). Both Hu and Nelson found adult mortality about 10 percent per year (page 19). This mortality pattern does not quite kill off all of the birds by the longest observed booby life span of almost 22 years. So, I increased mortality in the 20th and 21st years. This pattern also results in a population that is about 46 percent non-breeders (<4 yrs) and 54 percent breeders or roughly half and half as Beth Flint suggested. The survivorship information leads directly to estimates of life expectancy and remaining years of life.

Table 1. Red-Footed Booby Life Table

| Age | Survivorship | Number Surviving to age: | Proportion Surviving to age: | Survival Probability Distribution | Life Expectancy at age: | Remaining Years of life at age: |
|---------|--------------|--------------------------|------------------------------|-----------------------------------|-------------------------|---------------------------------|
| Fledged | | 100 | 1.000 | 0.203 | 5.64 | 5.64 |
| 1 | 0.5 | 50 | 0.500 | 0.101 | 7.07 | 6.07 |
| 2 | 0.8 | 40 | 0.400 | 0.081 | 7.95 | 5.95 |
| 3 | 0.9 | 36 | 0.360 | 0.073 | 8.74 | 5.74 |
| 4 | 0.9 | 32 | 0.324 | 0.066 | 9.51 | 5.51 |
| 5 | 0.9 | 29 | 0.292 | 0.059 | 10.27 | 5.27 |
| 6 | 0.9 | 26 | 0.262 | 0.053 | 11.01 | 5.01 |
| 7 | 0.9 | 24 | 0.236 | 0.048 | 11.74 | 4.74 |
| 8 | 0.9 | 21 | 0.213 | 0.043 | 12.46 | 4.46 |
| 9 | 0.9 | 19 | 0.191 | 0.039 | 13.16 | 4.16 |
| 10 | 0.9 | 17 | 0.172 | 0.035 | 13.85 | 3.85 |
| 11 | 0.9 | 15 | 0.155 | 0.031 | 14.52 | 3.52 |
| 12 | 0.9 | 14 | 0.139 | 0.028 | 15.18 | 3.18 |
| 13 | 0.9 | 13 | 0.126 | 0.025 | 15.82 | 2.82 |
| 14 | 0.9 | 11 | 0.113 | 0.023 | 16.45 | 2.45 |
| 15 | 0.9 | 10 | 0.102 | 0.021 | 17.06 | 2.06 |
| 16 | 0.9 | 9 | 0.092 | 0.019 | 17.65 | 1.65 |
| 17 | 0.9 | 6 | 0.082 | 0.017 | 18.23 | 1.23 |
| 18 | 0.9 | 7 | 0.074 | 0.015 | 18.81 | 0.81 |
| 19 | 0.9 | 7 | 0.067 | 0.014 | 19.39 | 0.39 |
| 20 | 0.5 | 3 | 0.033 | 0.007 | 20.09 | 0.09 |
| 21 | 0.1 | 0 | 0.003 | 0.001 | 21.00 | 0.00 |
| | | | | 1.000 | | |

The ideal data would have shown the number of oiled birds by age. As that is not available, I assumed that all of the oiled birds were breeders. The average age of breeding boobies is 9.51 years. Table 2 shows lost bird-years assuming all of the oiled birds died at age 9. Of the 1,368 killed, 137 would have died of natural causes that year anyway so only 1,231 direct bird-years were lost. The following year another 123 would have died so only 1,108 bird-years were lost that year. The third column shows losses from the birds directly oiled by the spill.

In addition to the birds killed directly, it is appropriate to consider their first generation progeny. Hu found that young breeders had less reproductive success than older birds (page 21). Seasonal breeding success was 50 percent for young adults and 80 percent for old adults. I assumed that half the oiled birds were young and half old at the time of the spill. Over 5 years the birds would have aged and become more successful. Thus in year 0 the 1,231 killed birds would have fledged 400 chicks $((1,231 * .5 \text{ young} * .5 \text{ successful}) + (1,231 * .5 \text{ old} * .8 \text{ successful})) / 2$ birds per breeding pair. By the 5th year, all of the survivors are old so each adult produces 0.4 progeny, 0.8 successful/2 birds per pair. The progeny would have provided additional bird-years so column 5 calculates the number of lost progeny services from the life table. Half the progeny from year 0 would have died by year 1 naturally so only 577 progeny bird-years $(=377+400/2)$ are lost in year 1. All of the birds directly injured by the spill would have died off by year 11 anyway but some of their progeny would have survived 21 more years so lost bird-years extend 32 years. The last column shows these losses discounted at 3 percent assuming compensation is agreed to in year 1. The total discounted lost bird-years due is 20,322.9.

Table 2. Tesoro Spill Injuries - Red-footed Boobies
Birds oiled 1,368

| Year from Spill | Expected Natural Deaths | Excess Lost Bird-Years | Number of Progeny Lost | Lost Progeny Bird-Years | Total Lost Bird-Years | Discounted Lost Bird-Years |
|-----------------|-------------------------|------------------------|------------------------|-------------------------|-----------------------|----------------------------|
| 0 | 137 | 1,231 | 400 | 400 | 1,631 | 1,680.3 |
| 1 | 123 | 1,108 | 377 | 577 | 1,685 | 1,684.9 |
| 2 | 111 | 997 | 354 | 702 | 1,700 | 1,650.2 |
| 3 | 100 | 898 | 332 | 804 | 1,701 | 1,603.7 |
| 4 | 90 | 808 | 311 | 884 | 1,692 | 1,548.2 |
| 5 | 81 | 727 | 291 | 945 | 1,672 | 1,485.9 |
| 6 | 73 | 654 | 262 | 981 | 1,635 | 1,410.3 |
| 7 | 65 | 589 | 236 | 999 | 1,588 | 1,329.8 |
| 8 | 59 | 530 | 212 | 1,004 | 1,534 | 1,247.0 |
| 9 | 53 | 477 | 191 | 998 | 1,475 | 1,164.0 |
| 10 | 48 | 429 | 172 | 983 | 1,412 | 1,082.1 |
| 11 | 215 | 215 | 86 | 892 | 1,107 | 823.4 |
| 12 | 215 | 0 | 0 | 760 | 760 | 548.9 |
| 13 | | | | 680 | 680 | 476.6 |
| 14 | | | | 612 | 612 | 416.5 |
| 15 | | | | 550 | 550 | 363.9 |
| 16 | | | | 495 | 495 | 318.0 |
| 17 | | | | 446 | 446 | 277.9 |
| 18 | | | | 401 | 401 | 242.8 |
| 19 | | | | 361 | 361 | 212.1 |
| 20 | | | | 314 | 314 | 179.3 |
| 21 | | | | 262 | 262 | 145.2 |
| 22 | | | | 215 | 215 | 115.7 |
| 23 | | | | 174 | 174 | 91.0 |
| 24 | | | | 139 | 139 | 70.3 |
| 25 | | | | 108 | 108 | 53.0 |
| 26 | | | | 81 | 81 | 38.8 |
| 27 | | | | 59 | 59 | 27.4 |
| 28 | | | | 40 | 40 | 18.2 |
| 29 | | | | 25 | 25 | 10.9 |
| 30 | | | | 12 | 12 | 5.1 |
| 31 | | | | 3 | 3 | 1.4 |
| 32 | | | | 0 | 0 | 0.1 |
| Totals | 1,368 | 8,663 | | 15,907 | 24,570 | 20,322.9 |

Credits

The calculation of credit bird-years is parallel to the calculation of the debit compensation due. Beth Flint outlined a possible "Fisherman Education" project that would reduce the take of boobies by anglers trolling offshore. Her assumptions for the purposes of this exercise were that 45 Red-footed Boobies per year would be saved. To compare the compensation to the injury we need to calculate the number of discounted bird-years gained by saving 45 birds and their progeny.

Assume that all birds age 1 or older are vulnerable to sportfishing injury. From the life table, the average age of birds 1 year or older is 7 years. Giving credit for each extra years these birds would have lived if not hooked yields column 2 in Table 3.

As we debited the spill for the progeny lost from the premature death of breeding birds, we need to credit the compensation with the additional progeny saved. From Hu, boobies have three life stages: prebreeding (age 0-3), young breeder (4-8), and old breeder (9+). Prebreeders don't produce progeny. Young breeders have a 50 percent fledging success rate and old breeders have an 80 percent fledging success rate. Using the proportions in each group in the life table adjusted for dropping the age 0's, the number of successful fledglings can be calculated for the first year. That is 15 (32 percent) are prebreeders, 15 (8 pairs; 34 percent) are young breeders which produce 4 fledglings, and 15 (also 8 pairs; 34 percent) are old breeders which produce 6 fledglings for a total of 10 progeny. Each succeeding year the population of birds saved by the education program ages so prebreeders become breeders and young breeders become old breeders until the whole population is old breeders. In the second year, for example, 23 percent are prebreeders, 27 percent are young breeders and 40 percent are old breeders. The number of progeny each year is shown in column 3 of Table 3 and the additional bird-years of services from them is in column 4. Bird-years of service is calculated in the same way as lost progeny bird-years was calculated in Table 2.

Column 5 of Table 3 shows the total bird-years saved by one year of the project for each year after the project year. Because the savings occur over time into the future they must be discounted to present value. Column 6 shows the discounted value of the future savings using a 3 percent discount rate. The total, 706.6, can be compared to the total discounted lost bird-years in Table 2, 20,322.9.

Obviously, it will take many years of the angler education project to equal the compensation due. As each year's benefits are farther in the future the 706.6 must be discounted in turn. As a result, if the education program is started in 2000 and saves 45 birds per year, it will need to be continued to 2067 to provide 20,322 compensatory bird-years. (Consider that 45 is only one 30th of 1,368, so on a raw bird-for-bird basis the program would have needed to run more than 30 years.) A more successful program could be shorter or other compensatory projects could be added to offset the debit bird-years due.

Table 3. Tesoro Compensation from Angler Education Project
 Bird-Years from saving 45 birds in one year

| Year from Project | Bird-years from Original Birds | Number of Progeny Saved | Saved Progeny Bird-Years | Total Saved Bird-Years | Discounted Saved Bird-Years |
|-------------------|--------------------------------|-------------------------|--------------------------|------------------------|-----------------------------|
| Project Year | 45 | 10 | 10 | 55 | 55.0 |
| 1 yr after | 41 | 10 | 15 | 56 | 54.1 |
| 2 | 36 | 10 | 20 | 56 | 52.8 |
| 3 | 33 | 11 | 24 | 56 | 51.7 |
| 4 | 30 | 10 | 27 | 56 | 49.8 |
| 5 | 27 | 9 | 29 | 55 | 47.6 |
| 6 | 24 | 9 | 30 | 54 | 45.4 |
| 7 | 22 | 8 | 31 | 53 | 43.1 |
| 8 | 19 | 8 | 32 | 52 | 40.9 |
| 9 | 17 | 7 | 33 | 50 | 38.4 |
| 10 | 16 | 6 | 32 | 48 | 35.8 |
| 11 | 14 | 6 | 32 | 46 | 33.3 |
| 12 | 13 | 5 | 31 | 44 | 30.9 |
| 13 | 6 | 3 | 28 | 35 | 23.7 |
| 14 | 1 | 0 | 25 | 25 | 16.6 |
| 15 | | | 22 | 22 | 14.0 |
| 16 | | | 20 | 20 | 12.3 |
| 17 | | | 18 | 18 | 10.7 |
| 18 | | | 16 | 16 | 9.4 |
| 19 | | | 14 | 14 | 8.2 |
| 20 | | | 13 | 13 | 7.0 |
| 21 | | | 11 | 11 | 5.8 |
| 22 | | | 9 | 9 | 4.8 |
| 23 | | | 8 | 8 | 3.9 |
| 24 | | | 6 | 6 | 3.1 |
| 25 | | | 5 | 5 | 2.4 |
| 26 | | | 4 | 4 | 1.9 |
| 27 | | | 3 | 3 | 1.4 |
| 28 | | | 2 | 2 | 1.1 |
| 29 | | | 2 | 2 | 0.8 |
| 30 | | | 1 | 1 | 0.5 |
| 31 | | | 1 | 1 | 0.3 |
| 32 | | | 0 | 0 | 0.1 |
| | 343 | 112 | 554 | 897 | 706.6 |