

Population Viability Analysis of the Kemp's Ridley Turtle

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The Kemp's ridley, Lepidochelys kemp, is the most endangered species of marine turtle and is literally on the brink of extinction. The only type of population estimate for Kemp's ridleys is based on the number of females that come ashore to nest. There is no way to accurately estimate the number of immature turtles and adult males due to their relative inaccessibility in open waters. Since the late 1940's, the nesting population of Kemp's ridleys has decreased from 40,000 nestings in a single day to less than 700 during the entire nesting season (Ross et al., 1989).

Certain characteristics of this species made it vulnerable to a rapid reduction in numbers. The most significant of these is the apparent existence of only one reproducing population (Márquez , 1984). The nesting beaches (rookeries) of Kemp's ridleys are only found in the western Gulf of Mexico and 95% of the nesting effort occurs on a 25 km stretch of beach near Rancho Nuevo, Stat of Tamaulipas, Mexico (Márquez, 1989). The distribution of Kemp's ridleys is restricted to the Gulf of Mexico and the northern Atlantic Ocean. Another peculiarity of the Kemp's ridley and its congeneric the olive ridley, Lepidochelys olivacea, is that they typically nest during the daylight hours in nesting aggregations known as arribadas (Spanish for "arrival"). A combination of these characteristics and human impacts on various life history stages have resulted in the decline of the Kemp's ridley.

The location of Kemp's ridley rookeries were unknown prior to 1963, when a documentary film made in 1947 was "discovered" by

marine turtle biologists (Carr, 1963; Hildebrand, 1963). In this film, an estimated 40,000 females nested in a single arribada. By 1966, when the Mexican government established the first protection camp at Rancho Nuevo, these arribadas only reached 2,000 turtles (Márquez, 1984). This rapid decrease in numbers was attributed to decades of heavy human exploitation of adult females and their eggs, coupled with the natural predation of this species, which resulted in virtually no recruitment to the aging adult population. Protection of the nesting beach by Mexican authorities has halted the exploitation of the females and their nests. A hatchery program operated by Mexican and American biologists has produced 20,000 hatchlings annually from 1966-78 and 50,000 annually thereafter (Márquez, 1984). However, the total number of females has decreased at a constant rate of 3.9% annually, and during recent years no arribada has had more than 200 females (Márquez, 1989).

A number of human activities threaten the recovery of the Kemp's ridley turtle despite the conservation efforts at the nesting beach. After leaving the nesting beach, juvenile Kemp's ridleys are dispersed as passive migrants in major oceanic currents where they are likely to encounter marine debris and pollution. Intestinal blockage resulting from the ingestion of plastics and tar is a known cause of mortality in sea turtles (Balazs, 1985; Carr, 1987). Subadult and adult Kemp's ridleys foraging in the coastal-benthic habitat are subject to incidental capture and drowning in commercial fishing operations. A number of studies have demonstrated a significant correlation between

shrimp trawling and marine turtle strandings (Ruckdeschel and Zug, 1982; Murphy and Hopkins-Murphy, 1989; Schroeder, 1988). Recent regulations requiring the use of Turtle Excluder Devices (TEDs) should lower the mortality of subadult and adult Kemp's ridleys. Gill and pound nets have been identified as other sources of marine turtle mortality. Tighter restrictions on these fisheries for the conservation of their fish stocks will lower their impact on the Kemp's ridley (Ross et al., 1989).

The Kemp's ridley population has undergone major demographic changes over the past several decades. Estimates of population persistence are crucial for the protection and management of this endangered species. Márquez et al. (1982a and 1982b) developed a theoretical population model for the evaluation of the olive ridley in the west Pacific and the Kemp's ridley throughout its range. Population viability analyses have been applied to other endangered species, such as the Florida panther (Seal and Lacy, 1989) and the red-cockaded woodpecker (Reed, 1988). This paper presents the results of computer simulations of demographic changes in a hypothetical Kemp's ridley population.

## MATERIALS AND METHODS

The VORTEX program (Lacy, 1991) was used to simulate a history of stochastic demographic effects. The following parameters were applied to each input file:

- + One population was simulated over a period of 100 years with extinction reports at 10 year intervals. A population size of 500 turtles was used due to the program's carrying capacity limit of 9,999 animals. Age distribution of the population was determined automatically by the program.
- + Reproduction was assumed to be density independent with no inbreeding depression. The effects of environmental variability were included in the simulations.
- + Two types of catastrophes were included in the model; one simulating an event at the nesting beach (ex. hurricane) where reproduction is reduced and another simulating an event at the foraging grounds (ex. freeze, oil spill, etc.) where survival and reproduction are reduced. Both catastrophes were given a 1% probability of occurrence.
- + Breeding was presumed to be polygynous with an equal sex ratio (50:50). All adult males were included in the breeding pool and mating success of the males was assumed to follow a Poisson distribution.
- + Growth curves from skeletochronological age estimates of Kemp's ridleys on the Atlantic coast suggest that sexual maturity is not attained in less than 10 years (Zug, 1990). Growth data for suadults foraging on Florida's west coast

correspond with this estimate (Schmid, unpubl. data).

- + There is no data available on the age of senescence for Kemp's ridleys. A maximum age of 20 and 30 years were used for comparative purposes.
- + A maximum clutch size of 160 eggs and clutch size distribution (Table 1) were obtained from Pritchard and Márquez (1973). In order to apply these data to the VORTEX program, percentages of each size class were divided by 10 and distributed evenly among the clutch sizes for a given size class.
- + Life history stages for the Kemp's ridley were based on age estimates (Zug, 1990) and field data (Pritchard and Márquez, 1973; Schmid and Ogren, 1990 and 1992): hatchling and pelagic juvenile (0-2 years), early subadult (3-4 years), mid to late subadult (5-9 years), and adult (10+ years). Variations in the mortality rates of the different age classes were manipulated to model the effects of exploitation, incidental capture, and subsequent conservation measures.

Each simulation was repeated for 5 or 10 runs, depending upon limitations with processing the input. Output from each simulation included: population growth rate ( $r$ ), rate of population change ( $\lambda$ ), net reproductive rate ( $R_0$ ), population size at 10 year intervals, mean time to first extinction, mean final population size for successful cases, and probabilities of extinction and success.

Table 1. Clutch size distribution for nesting Kemp's ridley turtles at Rancho Nuevo, Mexico (Pritchard and Márquez, 1973).

<u>Range</u>	<u>Frequency</u>	<u>Percentage</u>
51-60	2	1.2
61-70	0	0
71-80	4	2.4
81-90	13	7.6
91-100	25	14.7
101-110	40	23.5
111-120	43	25.3
121-130	26	15.3
131-140	13	7.6
141-150	3	1.8
151-160	1	0.6

## RESULTS

### High hatchling and juvenile mortality/Age of senescence 20 years

Hatchling and juvenile (0-2 years) and early subadult (3-4 years) age classes were kept constant at 90% and 40%, respectively. The mortality of the mid-subadult to adult (5-20 years) age classes were varied in three simulations of 20%, 10%, and 7.5%. Mortality of 5% resulted in the computer prompt "too many animals". Results of the three simulations are graphed in Figure 1. Population parameters are summarized in Table 2. Values of  $r$ ,  $\lambda$ , and  $R_0$  indicated a declining population in each simulation. However, the degree of decline was lessened as subadult/adult mortality was decreased from 20% to 7.5%. Conversely, the mean time to first extinction in each simulation increased from 28.8 to 83.4 years with decreasing subadult/adult mortality. All three simulations had high probabilities of extinction.

### High hatchling and juvenile mortality/Age of senescence 30 years

Mortalities of the various age classes were the same as above and age of senescence was increased to 30 years. Results of the three simulations are graphed in Figure 2 and summarized in Table 3. Subadult/adult mortalities of 20% and 10% resulted in an overall decline in the populations. Nonetheless, decreasing mortality from 20% to 10% resulted in an increased mean time to first extinction and a significant increase in the probability of success. Further decreasing mortality to 7.5% resulted in

Fig. 1. Simulation of high hatching/juvenile mortality, varied subadult/adult mortality and 20 years senescence age.

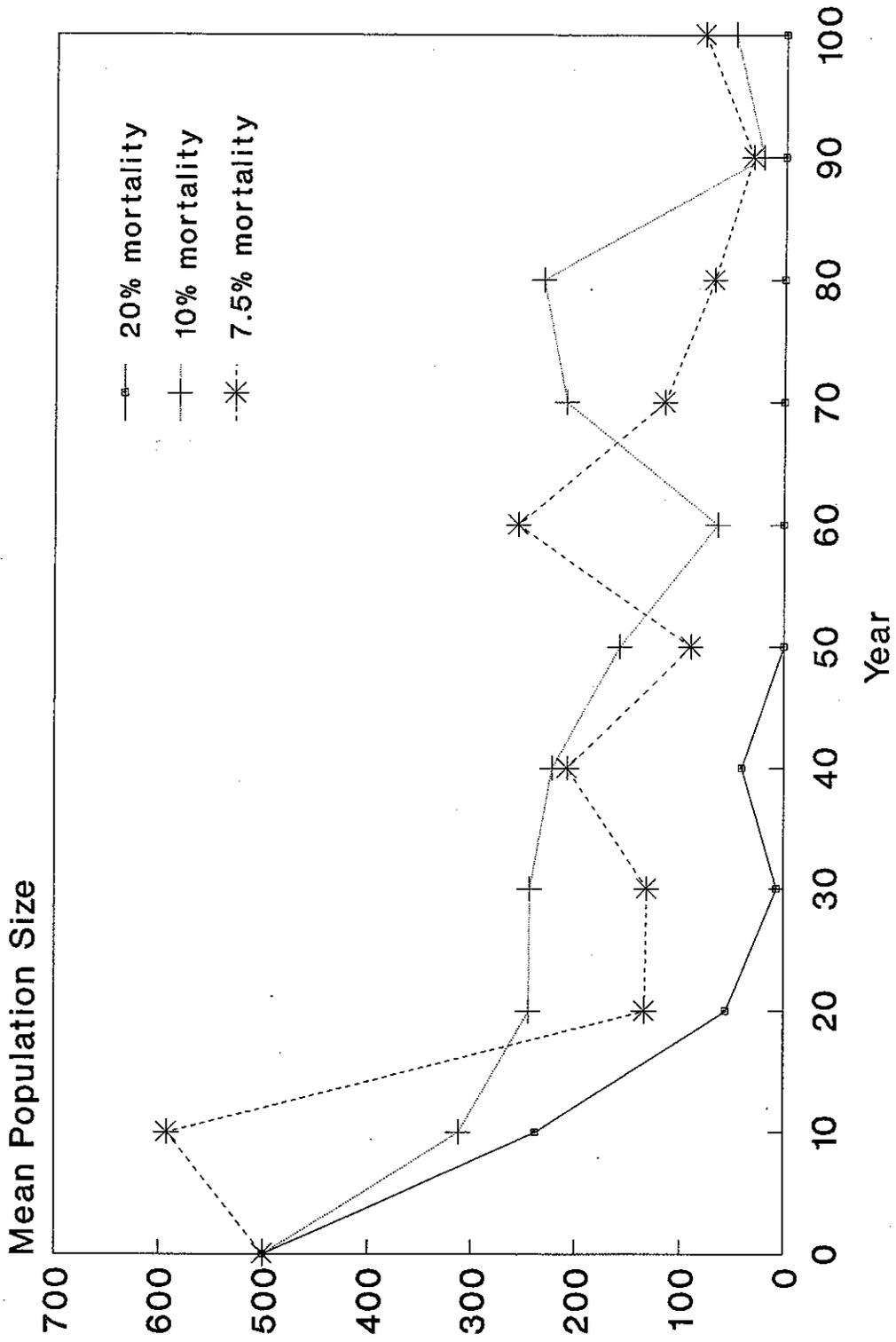


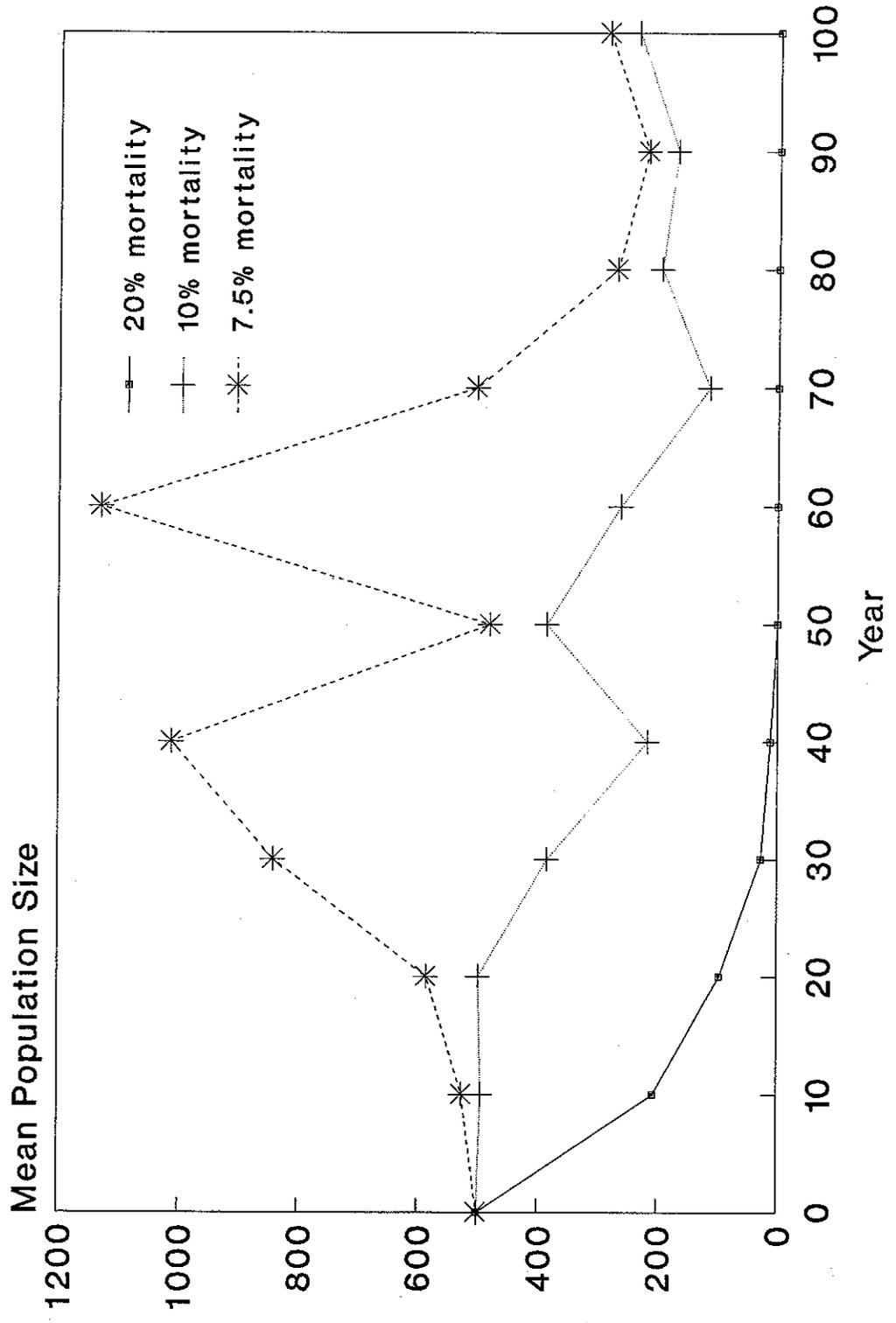
Table 2. Population parameters for simulations of high hatchling and juvenile mortality with age of senescence at 20 years (standard errors in parentheses).

Percent mortality	$r$	$\lambda$	$R_0$	Mean time to extinction	Mean final pop. size	Prob. of extinction	Prob. of success
20%	-0.114	0.893	0.219	28.8 (2.66)	0.00 (0.00)	1.00 (0.0000)	0.00 (0.0000)
10%	-0.029	0.971	0.662	52.86 (11.96)	48.67 (45.67)	0.70 (0.1449)	0.30 (0.1449)
7.5%	-0.010	0.990	0.872	83.44 (4.75)	78.00 (0.00)	0.90 (0.0949)	0.10 (0.0949)

Table 3. Population parameters for simulations of high hatchling and juvenile mortality with age of senescence at 30 years (standard errors in parentheses).

Percent mortality	$r$	$\lambda$	$R_0$	Mean time to extinction	Mean final pop. size	Prob. of extinction	Prob. of success
20%	-0.099	0.906	0.236	33.40 (2.17)	0.00 (0.00)	1.00 (0.0000)	0.00 (0.0000)
10%	-0.010	0.990	0.849	79.33 (3.53)	234.71 (45.67)	0.30 (0.1449)	0.70 (0.1449)
7.5%	0.011	1.011	1.202	0.00 (0.00)	284.60 (184.4)	0.00 (0.0000)	1.00 (0.0000)

Fig. 2. Simulation of high hatchling/juvenile mortality, varied subadult/adult mortality and 30 years senescence age.



population parameters indicating an increase in population and a 100% chance of success. Graphic representation of this population over 100 years, however, shows an increase in mean population size to year 40, followed by large fluctuations in numbers and an eventual decrease in population size.

#### Comparison of 20 vs 30 years age of senescence

Increasing age of senescence had little effect on the simulation with 20% subadult/adult mortality. However, increasing age of senescence in the simulations with 10% subadult/adult mortality increased mean time to first extinction from 52.86 to 79.33 years, and increased probability of success from 30% to 70%. The simulation with 7.5% subadult/adult mortality and 20 years age of senescence indicated a declining population, while increasing age of senescence to 30 years resulted in a simulation with an increasing population.

#### Reduced hatchling/juvenile mortality with increased mortality on subadult/adult age classes (20 vs. 30 years age of senescence)

Mortality in the hatchling/juvenile age classes was decreased to 50%, while mortalities of subadult/adult age classes were increased to 30% and 40%. Early subadult mortality was kept constant at 40%. Results of four simulations are graphed in Figure 3 and Figure 4, and summarized in Table 4. Reducing hatchling/juvenile and increasing subadult/adult mortalities to 30% resulted in increasing populations at both 20 and 30 years age of senescence. Both of the populations began to approach the program's carrying capacity by the end of the 100 year

simulations. Increasing subadult/adult mortality to 40% caused the populations to go extinct by 35.8 years (20 years age of senescence) and 30.7 years (30 years age of senescence).

Probability of population success decreased from 100% to 0% as a result of increased subadult/adult mortality.

Fig. 3. Simulation of reduced hatchling/juvenile mortality, 30% subadult/adult mortality and varied senescence age.

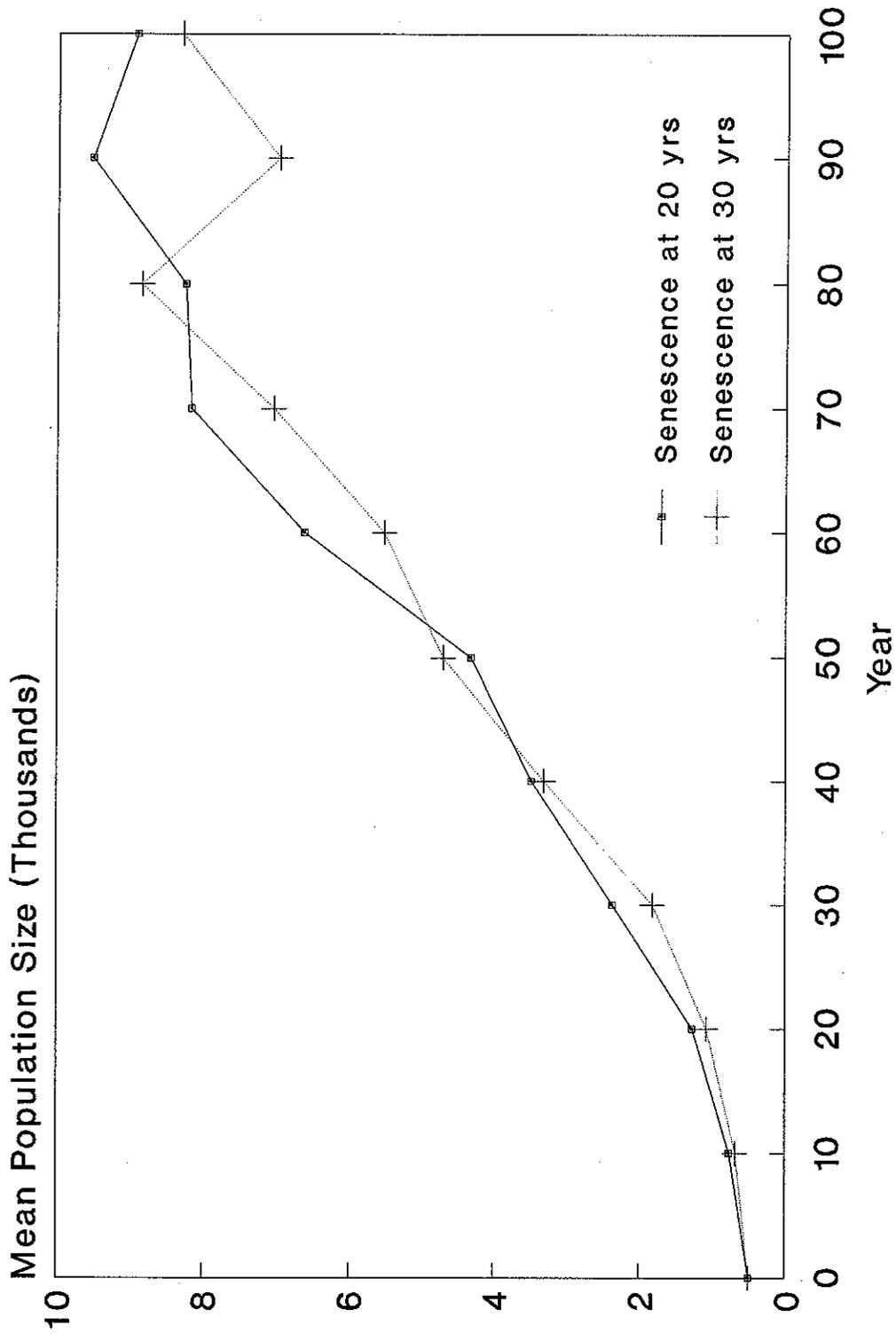


Fig. 4. Simulation of reduced hatchling/juvenile mortality, 40% subadult/adult mortality and varied senescence age.

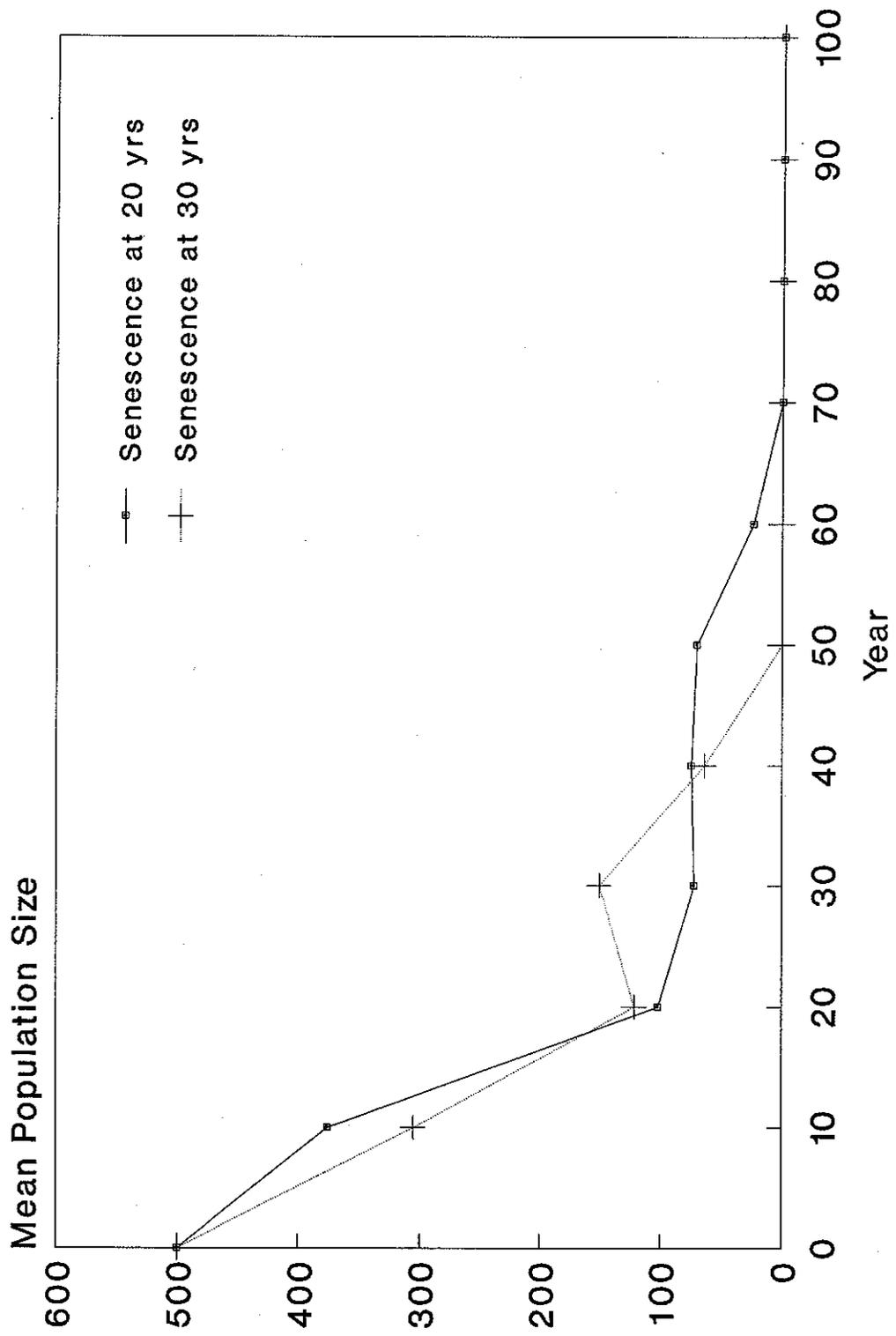


Table 2. Population parameters for simulations of reduced hatchling/juvenile mortality and increased subadult/adult mortality (standard errors in parentheses).

<u>Percent mortality</u>	<u>r</u>	<u><math>\lambda</math></u>	<u><math>R_0</math></u>	<u>Mean time to extinction</u>	<u>Mean final pop. size</u>	<u>Prob. of extinction</u>	<u>Prob. of success</u>
30% 20 Years	0.047	1.048	1.762	0.00 (0.00)	8340.8 (845.01)	0.00 (0.0000)	1.00 (0.0000)
30% 30 Years	0.048	1.049	1.795	0.00 (0.00)	8927.0 (528.36)	0.00 (0.0000)	1.00 (0.0000)
40% 20 Years	-0.054	0.947	0.534	35.8 (3.78)	0.00 (0.00)	1.00 (0.0000)	0.00 (0.0000)
40% 30 Years	-0.054	0.948	0.536	30.7 (2.45)	0.00 (0.00)	1.00 (0.0000)	0.00 (0.0000)

## DISCUSSION

Prior to protection of the nesting beach at Rancho Nuevo, there was essentially 100% mortality on the nests of Kemp's ridleys. Computer simulations with hatchling/juvenile mortality of 90% indicate that this type of population will decline to extinction in as little as 50 years, despite low levels of mortality on subadults and adults. In fact, the population trajectory for 7.5% subadult/adult mortality and 30 years age of senescence is quite similar to the recorded decline of the Kemp's ridley nesting population. Increasing survivorship of the model's early age classes allowed the hypothetical population to tolerate higher levels of subadult/adult mortality before extinction. This was a simulation of nesting beach protection and high levels of subadult mortality due to commercial fisheries and predation. By decreasing the mortality on the later age classes, the population increased to the model's carrying capacity at the end of the 100 year simulation.

The applicability of the Vortex program to the Kemp's ridley population is constrained by a number of limitations with both the model and the available data. The main limitation with the model is the artificially low population size that must be used as a result of the four-digit carrying capacity. Boosting the carrying capacity to five or six-digits would greatly enhance the program's usefulness in analyzing this species. The model is also limited to a yearly reproductive cycle. The period between nesting is nearly annual in the Kemp's ridley (1.304 nests per

turtle per season), with a small percentage of the population nesting biennially and triennially (Márquez et al., 1982b). The lack of specific data on natural sex ratios and age structure of the Kemp's ridley population further reduces the applicability of the program.

The results of this analysis stress the importance of the various life history stages in the conservation of this species. The most obvious stages, nesting females and their eggs have received the most attention. Protection of the nesting beach has significantly increased hatchling survivorship over the past 25 years and, as might be expected, an increasing number of subadult Kemp's ridleys have been observed in coastal foraging grounds (Ogren, 1989). However, levels of subadult mortality were relatively high during this period due to incidental capture and drowning in commercial fishing operations. This may account for the continued decline of nesting females. Given the increased restrictions on commercial fisheries, recruitment to the nesting population should increase over time. In order to evaluate the future of this species, long-term censusing studies are needed to monitor trends in abundance and shifts in size class distribution. Population parameters requiring further research include establishing subadult sex ratios (in progress) and correlating age with size class distribution.

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