**Tortuga Trouble: A New Survey Method**

New Mexico

Supercomputing Challenge

Final Report

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Team 33

Deming High School

Team Members:

Rocky Navarrete

Gabriela Anguiano

Mentor:

Creighton Edington

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**Abstract**

Population surveys of wildlife are a time consuming and costly task. However, to properly manage wildlife habitats, biologists need to have reliable population data. This project addresses that need by providing a method to compile a quick and accurate data for Western Ornate box turtles populations at a minimal cost.

Tortuga Survey is a program that allows wildlife management personnel a more effective and efficient method than traditional methods while maintaining a relatively amount of accuracy. By including a dead-turtle on the road count with a live turtle count, and looking at the most common intersection of these two values, the population density of a given area can be determined more accurately.

The surveying method that have been implied in this program has been validated by comparing the results from it against data collected in the field and against published expected minimum and maximum population density.

Tortuga Survey is a program that shows merit as a use biological survey management tool.

**Introduction**

To effectively manage ecosystems, wildlife biologists conduct plant and animal surveys. Surveys provide the data needed to understand the species occupying a habitat, the population size, and the movement of individuals. Surveying wildlife species is time consuming and expensive. In radio telemetry, for example, there are several steps and each step requires time and money. First, the animal is trapped and tagged. Second, telemetry equipment is used to monitor the animal. Finally, the data is analyzed. In addition, the entire procedure requires qualified personnel and vehicles. Consequently, federal and state wildlife agencies focus on certain species. The “popular” species like Bighorn sheep and Bald eagles tend to take the most attention and funding.

Unlike the “popular” species, turtles tend to be overlooked. Little research has been done on turtles like the Western Ornate box turtle. There are two species of box turtles in the United States, the Eastern box turtle (*Terrapene Carolina*) and the Western box turtle (*Terrapene ornata*). There are two subspecies of Western box turtles, the Western Ornate box turtle (*T. ornata ornate*) and the Desert box turtle (*T. o. luteola*).

The Western Ornate box turtle grows up to 14 cm in length and has 4 claws on each hind foot (Zuppa, 2003). According to Zuppa, “The pattern is of radiating lines on an olive to brown ground colored carapace. The carapace is also less domed on top than the other box turtle species, and its face and forelimbs are marked with yellow colorations”. The Western Ornate box turtle is found in “ the lower Rio Grande valley, inhabiting plains and prairies in areas of scrub and low brush thickets” (Gurley, 2007). Western box turtles are listed by The Convention of International Trade in Endangered Species of Fauna and Flora (C.I.T.E.S.) as a threatened species (Jacob, 2010).

Western Ornate box turtles are surveyed using several methods including radio telemetry, dogs, highway sightings and field surveys. In the first method, a radio transmitter is attached to the turtle's carapace near the head (Nieuwolt, 1997). In the second method, detector dogs are used to locate turtles and their burrows (Converse and Savidge, 2003). The third method is used after it rains. The turtles are more active at this time so biologists can estimate the population density by counting live turtles along a highway. In the final method, biologists use standardized transects or walking through a field and count the turtles sighted (Redder et al, 2006).

We chose to name our computer project, Tortuga Trouble: A New Survey Method, because when working with NetLogo "turtle" is a primitive reporter so we named our primary agents tortugas instead.

**Problem**

My objective is to provide a less expensive method of acquiring the data needed to understand a species like the Western Ornate box turtle. Instead of using the methods previously described, a biologist can drive down the highway, count the live and dead turtles, put the numbers into my computer program and the program will provide an estimate of the number of turtles in that area. In my model the area is one square mile. It's important to count the dead turtles to reduce the margin of error. Counting just the live turtles, results in a huge variation. Counting the live and dead turtles provides more of an average. It is also necessary to know how many cars travel on the highways during a 24 hour period of time. If 20% of the motorists run over turtles, and you know how many motorists use the highway, you can estimate the turtle population. In addition, the accuracy is further increased by the fact that the average maximum time span for a dead turtle to remain intact on the highway is five days. Further, the Western Ornate box turtle only moves at certain times of the year. Specifically, they are most active during the rainy season in the summer (May-June) when they are looking for mates.

**Methods**

The basic concept of our program is to set up a scale-model of a one square mile area. Then, we will have tortugas travelling at scale speed and cars travelling at scale speeds and record their interactions.

### Program

There are many different programs used to create computer models. We chose NetLogo because it's the program we are most familiar with and it would be compatible with our project. NetLogo is also a good choice because it is a well known program so other people can look at our program and easily understand it.

For our interface, we have a slider to control the cars-per-hour and a slider to control the Tortugas per hectares.

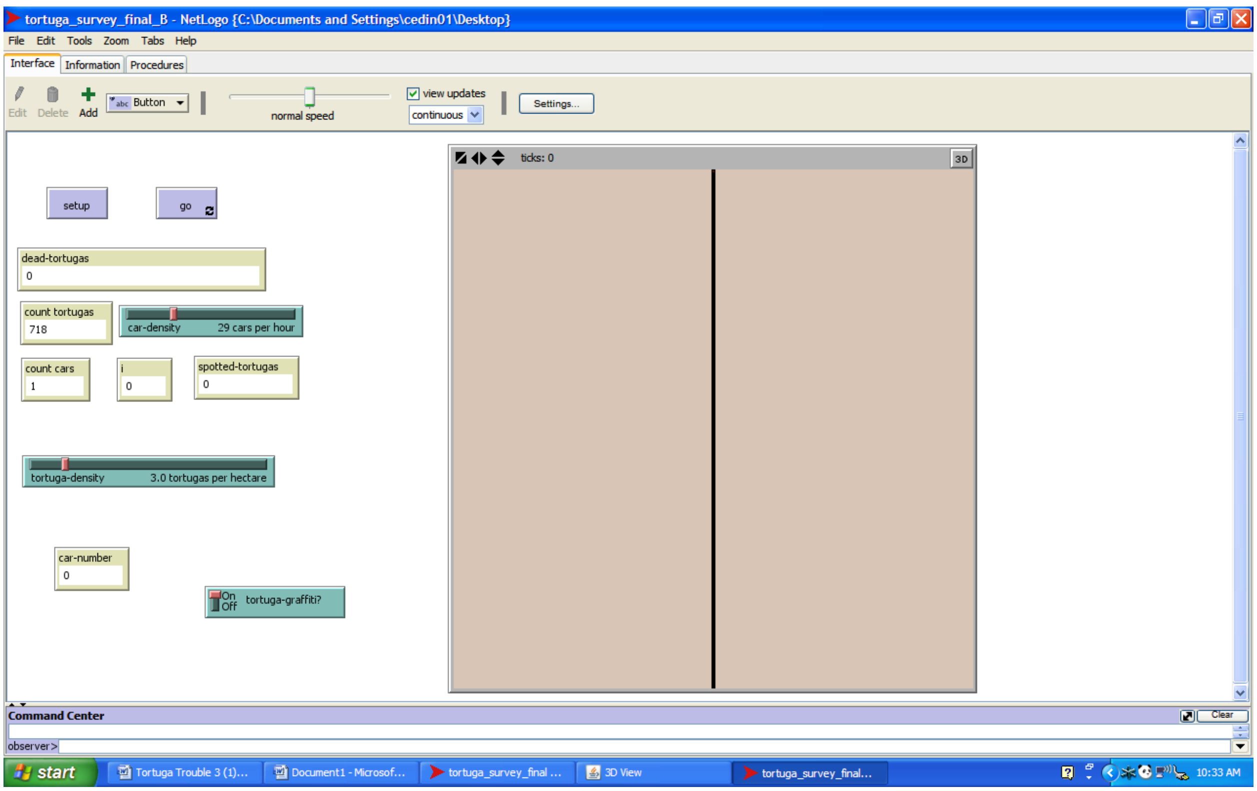


Figure 1 – Screenshot of Program Interface

### Calculations

To accurately scale the computer simulation, we used a road width of 40 feet for the base reference for our scale. We set 40 feet equal to one patch and one patch equal to one pixel. Because we wanted to have the population study area equal to one square mile, we determined the size for our simulation area to be 17, 424 total patches (132 x 132 patches). This is the total area of our simulation. We determined this by taking 5,280 feet (the number of feet in a mile) and dividing it by 40 feet (which is the width of the road). To determine the scale speed for our model, we wanted our car to have a velocity of 60 miles per hour. Therefore, our speed would be equivalent to one mile per minute, and the car would be at a patch rate of 1/60 times the world's height. This being equal to one mile, we then set up the car to travel at one tick increments. Concluding that 60 ticks are equal to one minute and one hour equals 3,600 ticks (60 X 60), the car will be moving at 2.2 patches per tick.

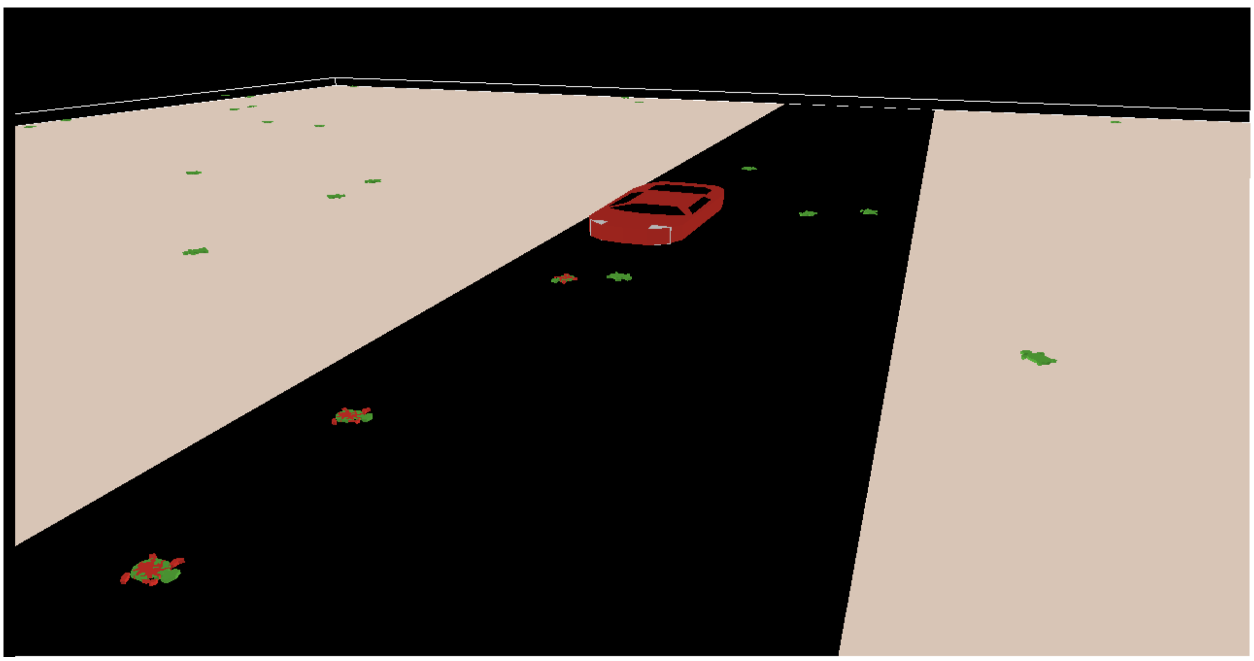

Figure 2. View of 3-D interface of draft of program.

A turtle's speed is 0.49 miles per hour (Dodd, 2002). To convert this speed to the scale of the model, we took the speed of the car and divided it by 60. This gave us a tick unit equal to one mile per hour. We then multiplied 0.49 by this unit. This gave us a scale model speed for the turtle equivalent to the rate that the turtles will be moving, at 0.018 patches per tick.

The chances of a turtle being killed by a car is based on field data (Edington, 2001). A total of 29 car were observed that had a chance of hitting a turtle. Out of 29 cars-turtle interactions, eight turtles were killed. We used this as the bases of the probability of a turtle being killed in the program.

### Program Modifications

While developing the program, we ran it at different stages to check the results. The first results we got were counting live turtles only. These results were somewhat consistent with the observations made in the field (Edington, 2001) but they weren't as close as they needed to be. We decided to add the number of dead turtles to get a more accurate population count. At this point, we realized that turtles were being counted more than once. We revised the previous data collected by the program and we noticed that the previous data also was counted the turtles more than once. We changed the program so that it only counts each turtle once. We ran the program again. The results were still unrealistic so we added another attribute: the turtles only move during the daylight. Further, we set the variable that makes the turtles go in random directions and the variable that the turtles will travel to a more open place. With these changes, the turtles are constantly moving, except at night. Finally, in this program the turtles look for the cars instead of the cars looking for the turtles. We did this because the car would need more patches to look for the turtles and therefore would count the turtles which are not on the road. And then we made the speed of the cars vary by plus or minus five miles per hour.

## Results

According to our research, the live turtle only count is not adequate for determining the population density of an area. When a biologist drives down the road and counts the turtles sighted, they are counting the live turtles and not the dead turtles. Tortuga Trouble is an effective computer model because it includes the live and dead turtles thus reducing the margin of error. Using the data collected in the field (Edington, 2001) we were able to determine if our results were accurate, by comparing our simulation times and compared the results to the field data.

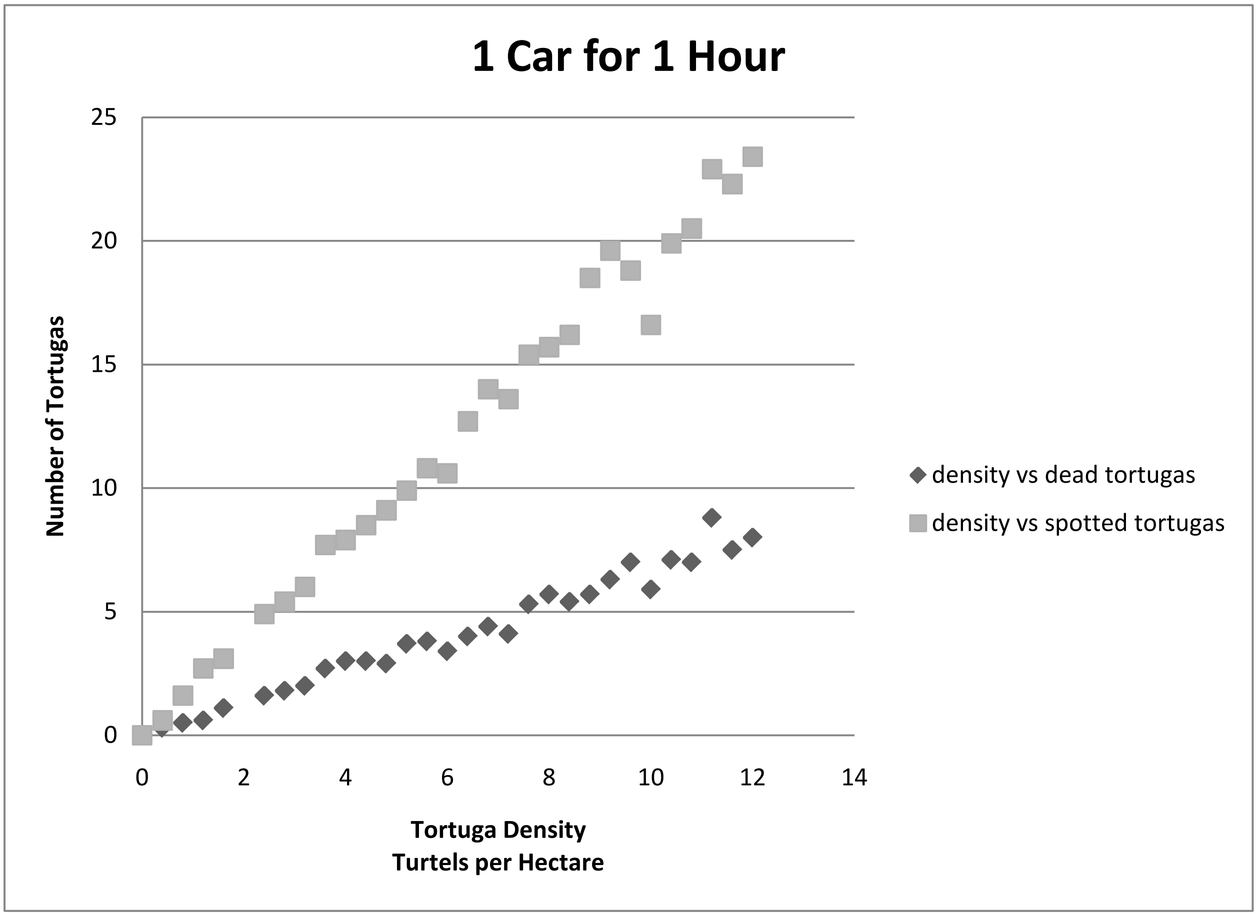


**Figure 3. Graph showing the average of 90 simulation runs.**

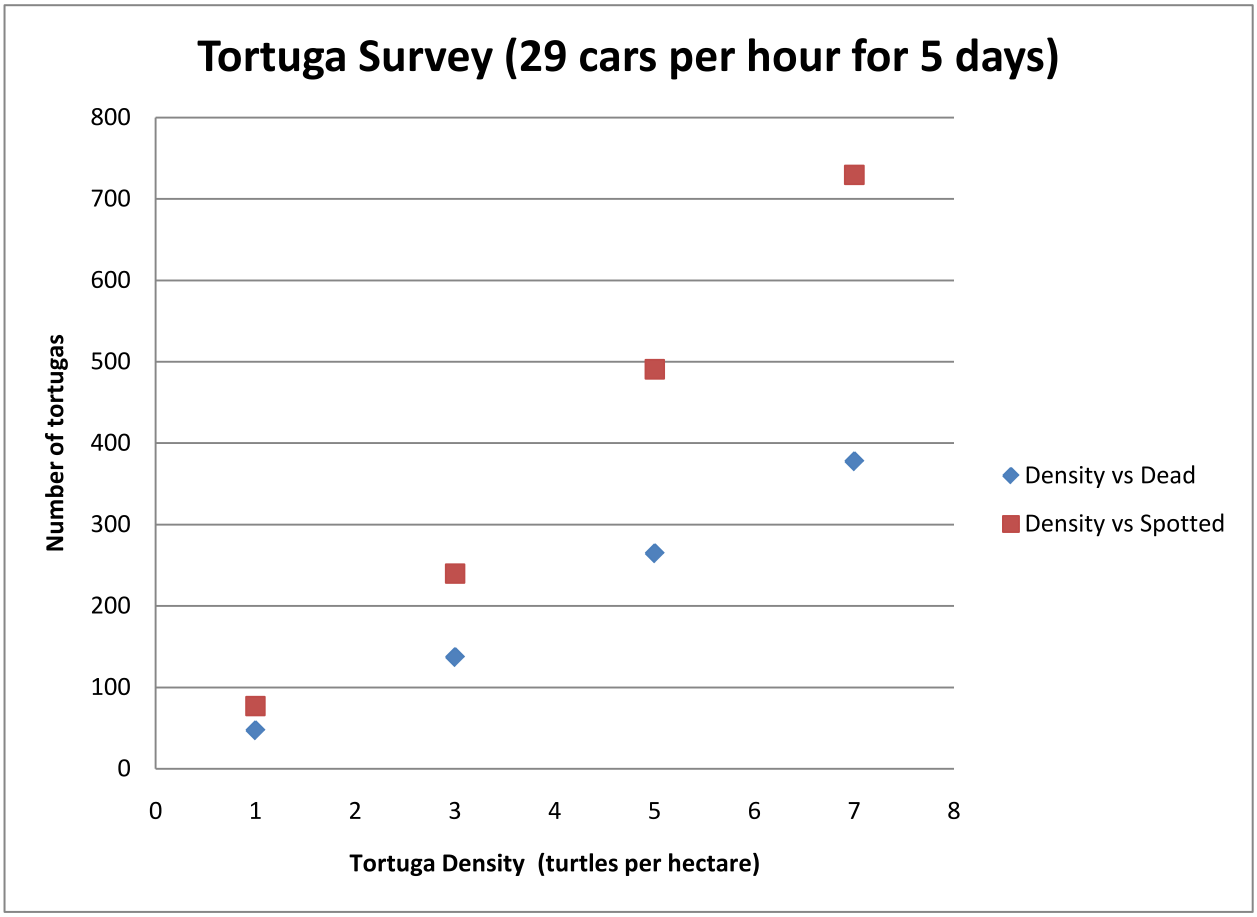


**Figure 4. Graph showing average (30 runs) five-day dead-tortuga count.**

## Conclusion

To reduce the margin of error and to get an accurate population density, you can't just count the live turtles; you have to also include the dead turtles. Also, our program is able to collect data that is consistent with data collected in the field. In order to make this program better we need to include the entire ecosystem. The greatest need for this is when the density is less than 1.2 turtles per hectare.

Our simulation, we need to test what the patch range for the tortuga-car interaction is to more accurately reflect the true death-rate of the turtles.  Once this is done, Tortuga Trouble should be a producing useful, real-world data that biologists should be able to use for wildlife management.

**Extension**

With further research, the program could be modified with a selector switch that would allow for other species to be input into the program to increase it’s usability.

| Turtles per hectare | One Car per Hour | | 29 Cars per Hour in 5 Days |
| --- | --- | --- | --- |
| tortuga-density | dead-tortugas | spotted-tortugas | dead-tortugas |
| 0 | 0 | 0 | |
| 0.4 | 0.3 | 0.6 | |
| 0.8 | 0.5 | 1.6 | |
| 1 | | | 47.4 |
| 1.2 | 0.6 | 2.7 | |
| 1.6 | 1.1 | 3.1 | |
| 2.4 | 1.6 | 4.9 | |
| 2.8 | 1.8 | 5.4 | |
| 3 | | | 137.2 |
| 3.2 | 2 | 6 | |
| 3.6 | 2.7 | 7.7 | |
| 4 | 3 | 7.9 | |
| 4.4 | 3 | 8.5 | |
| 4.8 | 2.9 | 9.1 | |
| 5 | | | 264.6 |
| 5.2 | 3.7 | 9.9 | |
| 5.6 | 3.8 | 10.8 | |
| 6 | 3.4 | 10.6 | |
| 6.4 | 4 | 12.7 | |
| 6.8 | 4.4 | 14 | |
| 7 | | | 377.5 |
| 7.2 | 4.1 | 13.6 | |
| 7.6 | 5.3 | 15.4 | |
| 8 | 5.7 | 15.7 | |
| 8.4 | 5.4 | 16.2 | |
| 8.8 | 5.7 | 18.5 | |
| 9.2 | 6.3 | 19.6 | |
| 9.6 | 7 | 18.8 | |
| 10 | 5.9 | 16.6 | |
| 10.4 | 7.1 | 19.9 | |
| 10.8 | 7 | 20.5 | |
| 11.2 | 8.8 | 22.9 | |
| 11.6 | 7.5 | 22.3 | |
| 12 | 8 | 23.4 | |

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Appendix A (Creighton Edington's Field Note)

27 MAY 01

| mile marker | live turtles | <6 hours fresh kill | day kill | ~2 days old | greater than 2 days old | total |
|---|---|---|---|---|---|---|
| 23 | | | | | | |
| 24 | 2 | 2 | 2 | 5 | 10 | 21 |
| 25 | 5 | 6 | 1 | 7 | 5 | 24 |
| 26 | 4 | 2 | 2 | 8 | 12 | 28 |
| 27 | 8 | 2 | 1 | 3 | 5 | 18 |
| 28 | 7 | 0 | 2 | 10 | 7 | 26 |
| 29 | 3 | 5 | 5 | 12 | 7 | 32 |
| 30 | 10 | 2 | 1 | 13 | 2 | 28 |
| 31 | 2 | 7 | 2 | 7 | 3 | 21 |
| 32 | 1 | 1 | 3 | 5 | 8 | 15 |
| 33 | 5 | 3 | 2 | 10 | 7 | 27 |
| 34 | 3 | 6 | 1 | 2 | 5 | 17 |
| 35 | 7 | 1 | 5 | 0 | 4 | 17 |
| 36 | 0 | 5 | 7 | 2 | 3 | 17 |
| 37 | 6 | 3 | 8 | 5 | 0 | 22 |
| 38 | 1 | 0 | 1 | 3 | 0 | 5 |
| 39 | 5 | 2 | 2 | 2 | 1 | 12 |
| 40 | 2 | 5 | 1 | 1 | 2 | 11 |
| 41 | 7 | 7 | 2 | 5 | 3 | 24 |
| 42 | 0 | 5 | 3 | 2 | 4 | 14 |
| 43 | 3 | 2 | 2 | 7 | 1 | 15 |
| 44 | 1 | 7 | 4 | 8 | 5 | 25 |
| 45 | 2 | 2 | 7 | 9 | 12 | 32 |
| 46 | 5 | 3 | 8 | 8 | 2 | 26 |
| 47 | 7 | 5 | 2 | 2 | 5 | 21 |
| 48 | 3 | 2 | 7 | 1 | 3 | 16 |
| 49 | 2 | 1 | 3 | 5 | 2 | 13 |
| 50 | 1 | 3 | 4 | 3 | 0 | 10 |
| 51 | 0 | 2 | 5 | 2 | 1 | 10 |
| 52 | 5 | 7 | 2 | 1 | 8 | 23 |
| 53 | 10 | 0 | 2 | 6 | 2 | 20 |
| 54 | 8 | 1 | 1 | 1 | 3 | 14 |
| 55 | 9 | 5 | 2 | 2 | 1 | 19 |
| 56 | 6 | 2 | 1 | 3 | 5 | 17 |
| 57 | 4 | 3 | 2 | 4 | 2 | 15 |
| 58 | 3 | 2 | 3 | 5 | 2 | 15 |
| 59 | 1 | 2 | 1 | 2 | 1 | 7 |
| 60 | 0 | 3 | 0 | 1 | 0 | 4 |
| 37 | 148 | 116 | 107 | 171 | 143 | |

Road + Shoulder 34 ft ≈ 10.34 meters

Road + Shoulder + Side 40 ft ≈ 12.19 meters

| Cars | Turtles Killed | dodged Turtles | moved turtles |
| --- | --- | --- | --- |
| ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ \|\|\|\| | ~~||||~~ \|\|\| | ~~||||~~ ~~||||~~ | \|\| |
| 29 | 8 | 10 | 2 |

9 cars no difference?

**Appendix B – source code**

;; program written by Rocky Navarrete
;; supervised by Mr. Edington
;;
;; this program was written to simmulate population density. since doing population surveys is time consuming and expensive. so this
;; program was written to provide a new survey method
;;
;; scale of program
;; The scale of this program is one mile square. The width of the road is 40 feet. Using this two numbers this program was scaled to size.
;; One mile is 5280 feet, 5280ft./40ft.= 132 this was to see how many roads wide could fit in the necessery to be used. For the speed of
;; the cars is (1/60)132 and that is the speed of the cars in miles per hour. for the speed of the turtles is (car speed/60)0.026. This
;; calculations are right as long as the patch size stays as one. 60 ticks represents one minute. 3600 ticks represents one hour. the
;; measurements or results are compared to population surveys they have made. we use car-density = (( i * (car-density * car-density)) / 3600)
;; to have the count of the cars in one hour which can be change by using the slider. also we use the spotted-tortugas spotted-tortugas + 1 to
;; keep a count on the turtles seeen near the road since the program include dead and live turtles. Then we used the turtle density to put the
;; turtles in a given area.
;;
;; this program works by collecting data and then putting them in a the computer simulation(number of cars in one hour, the number of live and
;; dead turtles) then hit go and it should give an accurate estimate of the population density. this progam will provide the number of turtles
;; seen, number of dead turtles, how many cars pass in one hour, the total number of turtles in the mile square area, and also it provides the
;; counter for i which is just saying when is the next car going to appear.
;;
;; when the program is running the turtle can hardly be seen because they were rezize to scale along the rest of the program, and the same goes
;; for the cars. also this program has to be compared to real data to check for the accurracy of the program.

```
globals                                   ;; sets the variables that are used constantly
 [
  car-speed                                ;; variable for speed
  spotted-tortugas                           ;; variable for turtles
```

```
  dead-tortugas                                   ;; variable for dead turtles
  i                                               ;; variable for i
  daylight                                        ;; variable for daylight
  car-number                                      ;; variable for car
 ]

breed [ cars car ]                                ;; sets up the cars in the simulation
breed [ tortugas tortuga ]                        ;; sets up the turtle in the simulation


tortugas-own                                      ;; variales for turtles only
 [
  counted                                         ;; keep count of turtles
  home-range                                      ;; variable for the range of the turtles
  travel-range                                    ;; variable for the traveling range
  neighbor-count                                  ;; sets count for sourrounding turtles
 ]


turtles-own                                       ;; this sets the variables for the turtles
 [
  speed                                           ;; variable for speed
  time                                            ;; variable for time
 ]

to setup                                          ;; this represents a button when pushed
does the below
  clear-all                                       ;; clears and rests all previous things within
the world
  reset-timer                                     ;; resets timer to zero, for speed d = r / t
purposes
  ask patches                                     ;; gives the command to the ground in the
world
  [
    world                                         ;; it creates a world with previous
command
    road                                          ;; creates a road also within the world
  ]

  set-default-shape cars "car top"                ;; this will set the shape of the car
  create-car                                      ;; creates a car

  set-default-shape tortugas "turtle"             ;; this sets the shape of the turtle
  create-tortuga                                  ;; creates a turtle
```

```
  set car-speed (1 / 60) * world-height                                   ;; this sets the speed of the car,
world height is 132
end



to create-car                                                            ;; Creates and initializes a cars and sets
position, size and the heading
  create-cars 1                                                          ;; creates 2 cars
    [
     set color red                                                       ;; sets color of car
      setxy 0  66                                                        ;; sets location of cars
      set heading 180                                                    ;; sets the heading of the cars
      set size 0.3                                                       ;; sets the size of the car
      set speed ((1 / 60) * world-height)                                ;; this sets the speed of the car,
world height is 132
      set car-speed speed                                                ;; this sets the speed of the car, world
height is 132
    ]
end



to create-tortuga                                                        ;; this creates turtles, sets position, size
and heading
 ask patches                                                             ;; gives command to patches to do the
following
   [                                                                     ;; asks patches for the following commands
   if (random (68 * 10) < ( tortuga-density * 10))                       ;; ask to roll a dice if odds
are in favor it does the following
     [
       sprout-tortugas 1                                                 ;; makes turtle appear in patches
        [                                                                ;; tells the turtles to apear in the patch
        set color random 139                                             ;; sets the color of the turtle that
appeared in that patch
        set heading random 360                                           ;; sets the dirrection of turtles to be
random
        set size 0.0125                                                  ;; sets the size of the turtle that appeared
in the patch
        set counted 0                                                    ;; count number is zero
        set speed ((car-speed / 60) * 0.49)                              ;; sets speed of the turtle
        set home-range patch-here                                        ;; tells the patch if it is thehome
range if it is then dothe following
        set travel-range (patch-at-heading-and-distance (random 360) (10 + (random 10)))      ;;
makes the choise which dirrection to take and sets the range of traveling
```

```
      set neighbor-count ((sum [count turtles-here] of neighbors) + count turtles-here)     ;; adds a
count to the neighbor-count
      ]
    ]
  ]
end



to move-cars                                          ;; this tells the car to move at a certain
speeed which alternates within the parameters
  ask cars                                            ;; gives a comand to a car
  [
   ifelse (ycor >= -63)                               ;; if statement is true do the following
    [
     forward ( car-speed + (one-of list (random -18 / 100) (random 18 / 100)))   ;; forward and
choises the diffrent speed of the car between 55 mph and 65 mph
    ]
    [
     die                                              ;; command to disappear
    ]
  ]
end



to move-tortuga                                       ;;this tells the turtles to move at certain
speed
  ask-concurrent tortugas                             ;; gives a command to the turtles to
take turns
  [
   if (tortuga-graffiti?)                             ;; switch in the interface if it is on then
do the following
      [
       pen-down                                       ;; tracking command
      ]

   ifelse (shape = "turtle")                          ;; if shape is turtle do the following

   [
    forward ((car-speed / 60 ) * 0.49 )               ;; tells turtle to move at certain
speed

    if (( (sum [count turtles-here] of neighbors) + count turtles-here) <  neighbor-count)      ;; if
there are more turtles that the HA can't contain then turtle moves out
      [                                               ;; to be more spacious
```

```
      set home-range patch-here                              ;; sets home range so turtles return
to birth place
     ]
   if (patch-here = travel-range)                           ;; if the patch is = to the traveling
capacity then do the following
    [
     set heading towards home-range                          ;; tells turtles to go backto their
placeof birth
     forward ((car-speed / 60) * 0.99)                       ;; move forward at certain speed
to reach home range
    ]
   if (patch-here = home-range)                              ;; if the patch is the home range
then do the following
    [
     set travel-range (patch-at-heading-and-distance (random 360) (10 + (random 10)))     ;;
changes dirrection to a diffrent area
     set heading towards travel-range                              ;; goes to the
dessignated area
     set neighbor-count ((sum [count turtles-here] of neighbors) + count turtles-here)    ;;
counts again how many turtles around
     forward ((car-speed / 60) * 0.99)                             ;; then turtle keeps
moving at normal speed
   ]
  ]
  [
  forward 0                                              ;; moves forward 0
  ]
]
end


to check-tortuga                                         ;; continously checks the turtles
 ask-concurrent tortugas                                   ;; ask turtles to alternate the
following steps
 [
 if (pcolor = black)                                     ;; if the turtle is in black then does the
following
  [
   if (any? other (cars in-radius 1.5))                     ;; turtle checks for the car if it is
in radius do the following
     [
     ask one-of tortugas-here                              ;; asks one turtle an action
      [
      if (counted = 0)                                   ;; if it is not yet counted then do the
following
       [
```

```
          set spotted-tortugas spotted-tortugas + 1                    ;; add 1 to the turtle count
          set counted 1                                          ;; set turtle count to 1
         ]
          if (shape = "turtle")                                  ;; if shape is turtle do the following
            [
             if (any? other (cars in-radius .3))                      ;; asks the turtle to check again if
their are cars if yes do the following
             [
             if random 29  < 8                                   ;; rolls dice if stament is true do the
following
              [
              set shape  "turtle-dead"                              ;; set the shape to turtle dead
              set dead-tortugas dead-tortugas + 1                       ;; add 1 to the turtle count
              set counted 1                                      ;; sets count to 1
              ]
             ]
           ]
        ]
      ]
    ]
  ]
end


to go                                                         ;; this is the button that allows the
following to take action
  tick                                                        ;; when go is pressed the ticks is a
measurement of time
  set daylight daylight + 1                                          ;; sets daylight variable
  if (daylight <= 43200)                                             ;; if daylight variable hold true go to
thenext command
    [
      move-tortuga                                                ;; gives the command to move the
turtle
    ]
   if (daylight >= 86400)                                            ;; if daylight holdstrue the dothe
following
    [
      set daylight 0                                             ;; sets the daylight to 0
    ]
  move-cars                                                   ;; gives the command to move the car

  check-tortuga                                                ;; gives the command to continually
check the turtles
  set i i + 1                                                 ;; sets variable command to i in the
interface
```

```
  if(( (i * car-density * car-density) / 3600)  >= car-density  )                ;; this is to see how many
cars in one hour travel if true go to the next one
    [
    create-car                                                          ;; creates car
    set car-number car-number + 1                                                ;;and sets the number for car to
one
    set i 0                                                          ;; sets i to 0
    ]
end


to world                                                                ;; this will alow to put a map without
importing any drawing and sets color to
 set pcolor 38                                                            ;; this sets the worlds color
end


to road                                                               ;; this tells road where and color to appear
as
   if ( pxcor = 0 )                                                       ;; this is to make a road within the
parameters of the world and set it
    [                                                                     ;;accordingly to the x cordinate
     set pcolor black
    ]                                                             ;; this sets the color of the road to black
end
```