EFFECTS OF GILLNET ENTANGLEMENT ON MORTALITY OF DUSKY DOLPHINS (*Lagenorhynchus obscurus*)

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

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Wildlife populations are negatively impacted in a variety of ways. Humans, in particular, have played a huge part in species declines today as well as species extinctions in the past due to overexploitation (Coleman and Williams, 2002; Erlandson and Rick, 2010). Recent declines of large marine vertebrates that are of little or no commercial value, such as sea turtles, seabirds, and marine mammals, have focused attention on the ecological impacts of incidental take, or bycatch, in global fisheries. The dusky dolphin (*Lagenorhynchus obscurus*) is a marine mammal that inhabits coastal waters of the Southern Hemisphere which commonly is caught in gillnets. However, the effect of gillnet-related mortality on the population dynamics of this species is unknown. I will conduct a thorough literature review to obtain the best information available related to gillnet entanglement of dusky dolphins as well as the basic demographic data necessary to develop a stochastic population dynamics model. Then, I will use the model to estimate the potential effect of gillnet-related mortality on the population dynamics of dusky dolphins in view of the parametric uncertainty associated with the model. The results indicate that the decline of the *Lagenorhynchus obscurus* population size is due to the negative effects of gillnet entanglement.

CHAPTER I

INTRODUCTION

Wildlife populations are negatively impacted in a variety of ways. A population can decline from factors such as climate change, disease, pollution, or overexploitation. Humans, in particular, have played a huge part in species declines today as well as species extinctions in the past due to overexploitation (Coleman and Williams, 2002; Erlandson and Rick, 2010). Through bycatch in global fisheries, incidental mortality has impacted the recent declines in large marine vertebrates that are of little or no commercial value, such as sea turtles (Lewison et al., 2004; Lewison and Crowder, 2007), seabirds (Belda and Sánchez, 2001; Lewison and Crowder, 2003), and about 78% of the marine mammal species (Schipper et al. 2008).

Marine mammals are a distinct group of animals that inhabit a variety of ocean regions around the world. As apex predators, these populations are important factors in the marine ecosystem. While there are laws (Endangered Species Act and Marine Mammal Protection Act) and other conservation efforts (1999) implemented to protect marine mammals, there has only been a few assessments on the impact of bycatch in North and South America, Europe, Australia, and New Zealand (Read 2008). Such assessments were conducted to calculate the effects of bycatch on population levels of species like *Lissodelphis borealis, Phocoena phocoena*, and *Lagenorhynchus obscurus* (Lewison et al. 2004) and concluded that bycatch has become a major threat to these populations. Immediate action is needed to manage the effects that bycatch has on marine mammals.

Among these marine mammals is the dusky dolphin (Lagenorhynchus obscurus) that commonly is captured in gillnets (Dawson and Slooten, 2005). The species consists of three subspecies that reside mainly in coastal waters of the Indian Ocean, and off the coasts of New Zealand and South America (Bressem and Waerebeek, 1996). The global population of dusky dolphins has been estimated to be less than 30,000 (Culik, 2004). Bycatch of dusky dolphins in gillnets first attracted scientific and management attention in New Zealand in the 1980s (Dawson and Slooten, 2005). From 1984 to 1988, 50 – 150 dusky dolphins were killed each year at Kaikoura, New Zealand in gillnets set at the surface to catch bait for rock lobster (Dawson and Slooten, 2005). Occasionally, dusky dolphins were caught in commercial bottom-set gillnets set for tarakihi (*Nemadactylus macropterus*), rig (*Mustelus lenticulatus*), ling (*Genypterus blacodes*), and groper (*Polyprion oxygeneious*) at Kaikoura. Since the removal of part-time fishermen from the fishery in 1986, when the Quota Management System was established, gillnetting practices appear to have improved, and reports of dusky dolphin catches have dropped substantially (Wilkinson et al., 2003). However, the incidental mortality of dusky dolphins in the trawling fishery in Patagonian, South America is still a well-known problem, especially in the mid-water trawl fisheries for shrimp and anchovy (Dans et al., 2003).

In spite of the recognition of the problem of bycatch, the absence of an observer program and the lack of other systematic attempts to assess the level of bycatch, neither the magnitude of catches nor their population-level impact on dusky dolphin populations is known (Dawson and Slooten, 2005). Surveys in marine habitats are logistically complex and expensive (Lewison et al., 2004), thus bycatch data are sparse and our understanding of the demography of the potentially affected populations is rudimentary. In the present study, I modified the model of Dans et al. (2003) to construct the basic population model of dusky dolphins and then aimed to examine the effects of gillnet entanglement on mortality of dusky dolphins.

CHAPTER II

METHODS

To develop a population dynamics model for the dusky dolphin, I conducted a thorough literature review to obtain the best basic demographic data available. The model is intended to represent the effects of gillnet entanglement on mortality of each stage and was formulated as an age-structured compartment model based on difference equations ($\Delta t = 1$ year), programmed in STELLA®7.0.1. Then, the model was evaluated based on published literature including Dans et al. (2003) and others using estimated potential population growth rates under a variety of assumptions about the gillnet-related mortality on population dynamics (Slooten et al., 2000).

The parameters for the model were obtain using online articles, databases, and government webpages pertaining to dusky dolphins. I constructed the age-structured model to examine the dusky dolphin population dynamics with a variety of ten scenarios of survivorship using the published literature by Dans et al. (2003), Mannocci et al. (2012), and Alonso et al. (1998). Looking at the “Incidental catch of dolphins in trawling fisheries off Patagonia, Argentina: can populations persist?” by Dans and others, I took the rescaled survivorship graph of dusky dolphins (Fig. 1) and calculated the survivor rates of the top and bottom line of the graphs to average dusky dolphin age of 25 years. I developed a table with these rates on Excel (Table 1), then statistically found the average survivorship. Using literature from Dans et al. (2003) and Alonso et al. (1998), I found and subtracted gillnet effective rates from the natural survivorship rates (Table 2). These survivorship rates represented scenarios 1-6 of the dusky dolphin population.

For scenarios 7-10, I used survivorship derived from “Assessing the impact of bycatch on dolphin populations: the case of the common dolphin in the eastern North Atlantic” by Mannocci and others (Fig. 2). Because common dolphins and dusky dolphins are genetically and geographically similar, I decided to use common dolphin survivorships for dusky dolphin as additional scenarios for their population dynamics with the question, “What would the dusky dolphin population look like if they had these survivorship rates?” Theoretically, it make sense in regards of what the dusky dolphin population with look like if they are being affected by gillnet entanglement. From Mannocci’s paper, I configured the natural and effective mortality rates into a table in Excel as initial survivorship without gillnet effects (Table 3). I used effective mortality rates as a different kind of natural survivorship since the paper had just indicated that the rates were caused by some kind of disturbance in the common dolphin population but not sure what. Since the lifespan of common dolphins is about 28 years, I created another table substituting the natural and effective mortality rates of common dolphins’ twenty-eighth year to dusky dolphins’ twenty-forth year (Table 4). I used literature from Mannocci et al. (2012) and Alonso et al. (1998) to find and subtract gillnet effective rates from the natural survivorship rates already in the table (Table 5).

All the scenarios were added into the STELLA®7.0.1 to complete the population dynamics model for the dusky dolphin. The model ran 10 graphs representing the 10 scenarios created from the published literature. The graphs were analyzed to examine gillnet entanglement effects on the dusky dolphin population at each stage as well as a whole in a 20 year time frame.

CHAPTER III

RESULTS

Based on our simulation scenarios, the dusky dolphin population decreased with added gillnet effects to all natural/ initial survivorships. Looking at the dusky dolphin population size using maximum, average, and minimum survivorship as well as gillnet effects (Graph 1, 2, & 3) from Dans et al. (2003) and Alonso et al. (1998), the population is initially decreasing. I can only assume that the dusky dolphin decreasing population size is due to other cumulative effects in Dans et al. (2003) study. However when gillnet effects were added into the model for all the survivorships from Dans et al. (2003) paper, the population had decrease at a higher rate compared to the initial population curves.

As expected when natural survivorship from Mannocci et al (2012) was applied to the model, the population was exponentially increasing (Graph 4) since there was nothing affecting the population from growing. When gillnet effects were added to the natural survivorship, the population was still increasing but at a slower growth rate (Graph 4). Looking at the scenario for effective survivorship (Graph 5), the population shows a decline (from disturbance) at first before increasing again. Once gillnet effects were applied to the effective survivorship, the population rapidly declined.

CHAPTER IV

DISCUSSION

Based on the results, gillnet entanglement has a negative effect on the dusky dolphin population dynamics. Using STELLA®7.0.1, I looked at what the dusky dolphin population size would be in a 20 year time frame using different scenarios of various survivorship from published literature (Dans 2003, Mannocci 2012, Alonso 1998). Comparing the dusky dolphin population size with natural survivorship and survivorship with gillnet effects suggests that there should be more field studies toward this species. There were many limitations with this study due to the due to the lack of data and/or outdated literature about the dusky dolphin species. This brings on a question whether I chose the right species to model for amicable results. I may have not chosen the right species, if it means that I failed to find the best information I could to develop the model after all the time and effort I had put in. What I have learn from this process is that research is not about having success in results but finding that passion working with a species you would like to learn more about. I really think there should be further studies to investigate other anthropological effects on the dusky dolphin species and to develop a risk assessment by looking into related dolphins that are possibly effected by gillnet entanglement in the same regions as *Lagenorhynchus obscurus* to fill in the gap in literature this species has.

CHAPTER V

CONCLUSION

Dusky dolphins (*Lagenorhynchus obscurus*) are among the marine mammals that are possibly affected by incidental bycatch, specifically gillnets. Without further studies, there is an uncertainty if the dusky dolphin population should be of concern or if the population is thriving in the mist of human impacts. In developing the population dynamics model, I was determined to answer the question of uncertainty based on the published literature I found. However, I was unsuccessful to answer such a question with the limitation of the data deficiency to calculate the dusky dolphin population dynamics. With new studies to develop a risk assessment on the dusky dolphins population with possible gillnet entanglement on relative dolphins and to look at their population trends with other factors (environmental or anthropological), there can be more helpful information in determining those effects on the whole population and propose necessary management plans to benefit the *Lagenorhynchus obscurus* species.

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APPENDIX

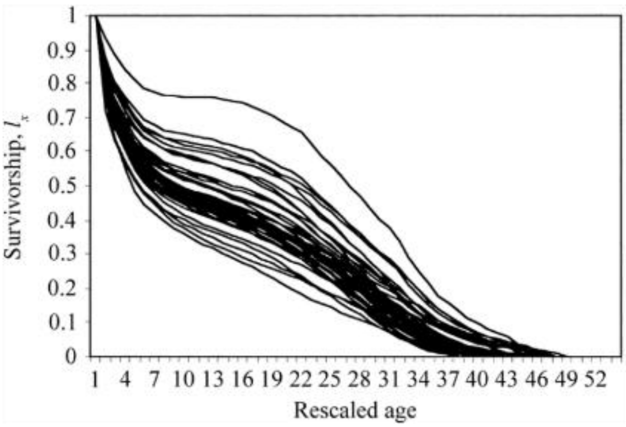


Fig. 1 Survivorship curves generated by Monte Carlo sampling of model life tables and rescaled age for the dusky dolphin. Each curve represents a weighted mean among survivorship values for each model species . (Dans et al. 2003)

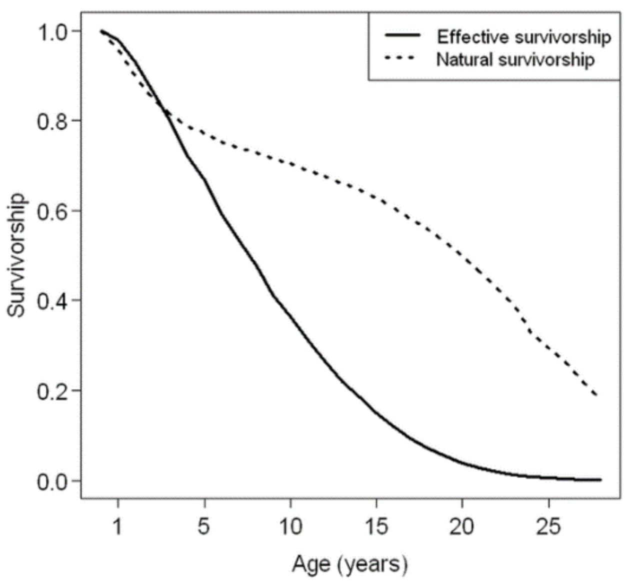


Fig. 2 Effective survivorship for female common dolphins based on a maximum likehood fit of the Siler model. For indication, we also provided natural survivorship estimated with a similar

maximum likelihood fit of the Siler model and based on a sample of bottlenose dolphins stranded in Florida (see [48]). doi:10.1371/journal.pone.0032615.g005 (Mannocci et al 2012).

Year	Maximum SR	Average SR	Minimum SR
1	3,325.00	3,325.00	3,325.00
2	2,997.15	2,357.36	1,717.56
3	2,765.65	1,814.24	1,125.15
4	2,552.70	1,407.34	734.21
5	2,332.66	1,074.43	457.97
6	2,102.41	796.35	265.32
7	1,868.89	573.8	144.74
8	1,701.21	432.7	87.19
9	1,576.34	338.08	56.79
10	1,474.35	267.75	37.55
11	1,382.64	211.61	24.37
12	1,293.27	165.03	15.17
13	1,202.45	126.27	9.01
14	1,116.82	96.27	5.35
15	1,038.88	73.83	3.27
16	968.95	57.09	2.06
17	905.73	44.41	1.32
18	847.31	34.58	0.83
19	792.13	26.81	0.52
20	739.83	20.69	0.31

Table 1 Maximum, Average, and Minimum survivorship (Scenarios 1-3) not including gillnet effects (Dans et al. 2003).

Year	Maximum SR with gillnet	Average SR with gillnet	Minimum SR with gillnet
1	3,325.00	3,325.00	3,325.00
2	2,605.14	1,953.57	1,366.77
3	2,316.77	1,457.51	888.65
4	2,041.54	1,069.27	535.94
5	1,769.80	763.03	303.65
6	1,506.39	524.28	157.17
7	1,260.62	348.8	76.27

8	1,084.85	246.57	42.92
9	951.15	180.9	26.23
10	841.44	134.17	16.05
11	745.58	98.95	9.53
12	657.95	71.7	5.36
13	576.25	50.8	2.85
14	504.14	35.94	1.54
15	441.91	25.66	0.87
16	388.56	18.51	0.51
17	342.48	13.44	0.3
18	302.07	9.76	0.17
19	266.14	7.04	0.1
20	234.18	5.05	0.05

Table 2 Maximun, Average, and Minimun survivorship (Scenarios 4-6) including gillnets effects (Dans et al. 2003 and Alonso et al. 1998).

Age	Effective	Natural
0	0.98007	0.95813
1	0.94882	0.93616
2	0.92843	0.9458
3	0.92633	0.96253
4	0.90338	0.96508
5	0.92224	0.97882
6	0.89122	0.97661
7	0.89849	0.98228
8	0.8928	0.98376
9	0.8649	0.98126
10	0.88127	0.98455
11	0.85519	0.98111
12	0.85357	0.98067
13	0.83109	0.97659
14	0.83701	0.97663
15	0.8131	0.97139
16	0.79106	0.96573
17	0.77855	0.96135

18	0.77271	0.95816
19	0.74313	0.9492
20	0.72125	0.94118
21	0.69742	0.9319
22	0.71614	0.91862
23	0.60362	0.91141
24	0.59772	0.83798
25	0.66349	0.90333
26	0.49282	0.89298
27	0.51169	0.83893
28	0.47415	0.81504

Table 3 Initial natural and effective survivorship configured from Mannocci et al. (2012).

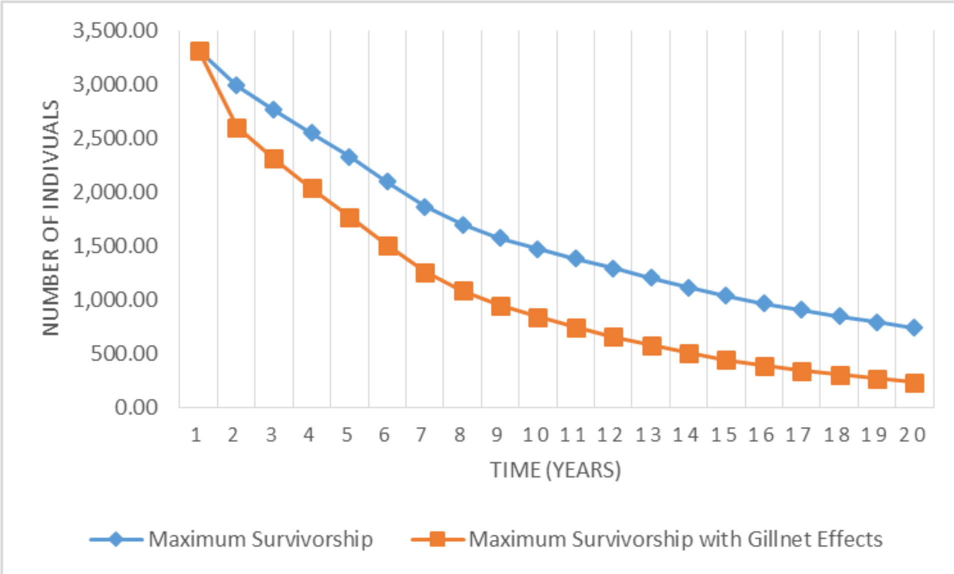
Year	Effective SR	Natural SR
1	3,325.00	3,325.00
2	3,057.51	3,652.29
3	2,898.07	3,953.68
4	2,784.83	4,234.22
5	2,689.25	4,497.43
6	2,597.83	4,745.57
7	2,504.28	4,979.90
8	2,488.21	5,295.20
9	2,512.43	5,681.18
10	2,552.97	6,129.84
11	2,594.24	6,634.70
12	2,626.22	7,190.27
13	2,642.84	7,791.59
14	2,655.26	8,452.60
15	2,668.88	9,184.74
16	2,685.56	9,997.43
17	2,704.94	10,898.38
18	2,725.33	11,893.82
19	2,744.35	12,988.59
20	2,761.78	14,189.94

Table 4 Effective and Natural survivorship (Scenarios 7 & 8) survivorship not including gillnet effects (Mannocci 2012).

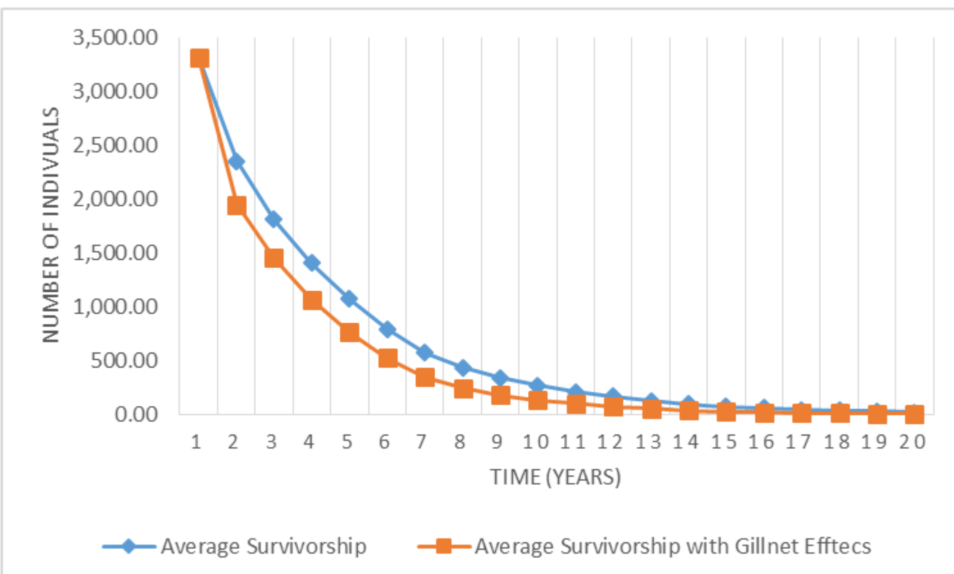
Year	Effective SR with gillnet	Natural SR with gillnet
1	3,325.00	3,325.00
2	2,889.93	3,485.90
3	2,595.64	3,592.28
4	2,363.60	3,657.28
5	2,161.43	3,689.44
6	1,975.55	3,694.98
7	1,800.43	3,678.43
8	1,696.57	3,715.28
9	1,626.31	3,788.88
10	1,568.50	3,886.87
11	1,511.63	3,999.89
12	1,449.95	4,120.75
13	1,381.23	4,243.74
14	1,313.56	4,375.04
15	1,250.08	4,517.97
16	1,191.39	4,673.81
17	1,136.83	4,842.39
18	1,085.20	5,022.58
19	1,035.22	5,212.49
20	986.82	5,411.40

Table 5 Natural and Effective survivorship (Scenarios 9 & 10) including gillnet effects

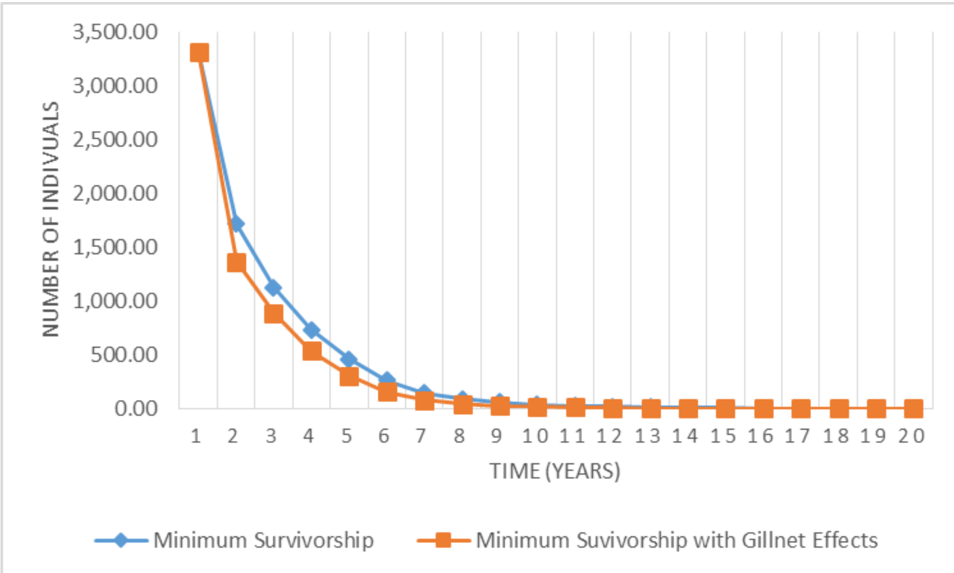
(Mannocci et al 2012 and Alonso et al. 1998).



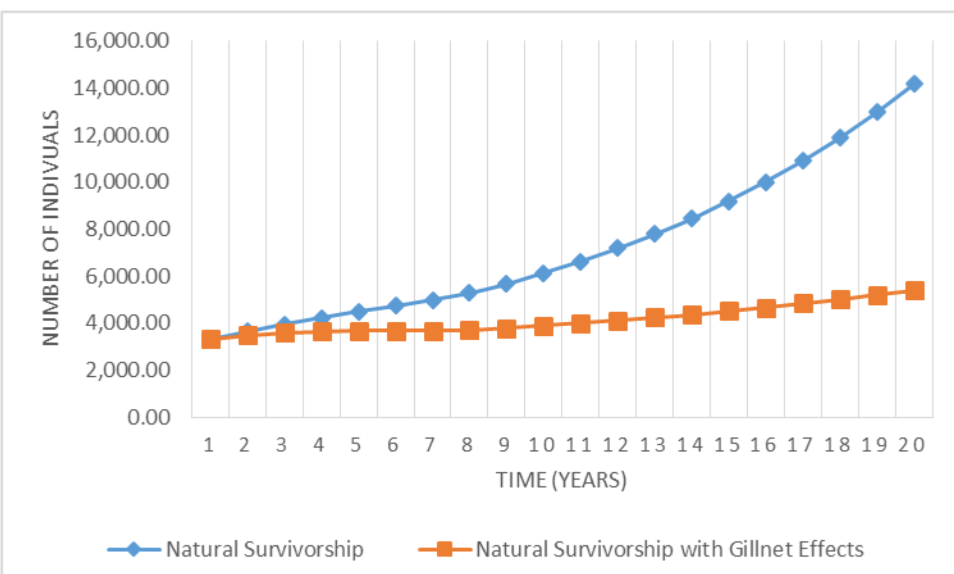
Graph 1 Dusky dolphin population size using maximum survivorship and gillnet effects from Dans et al. (2003) and Alonso et al. (1998).



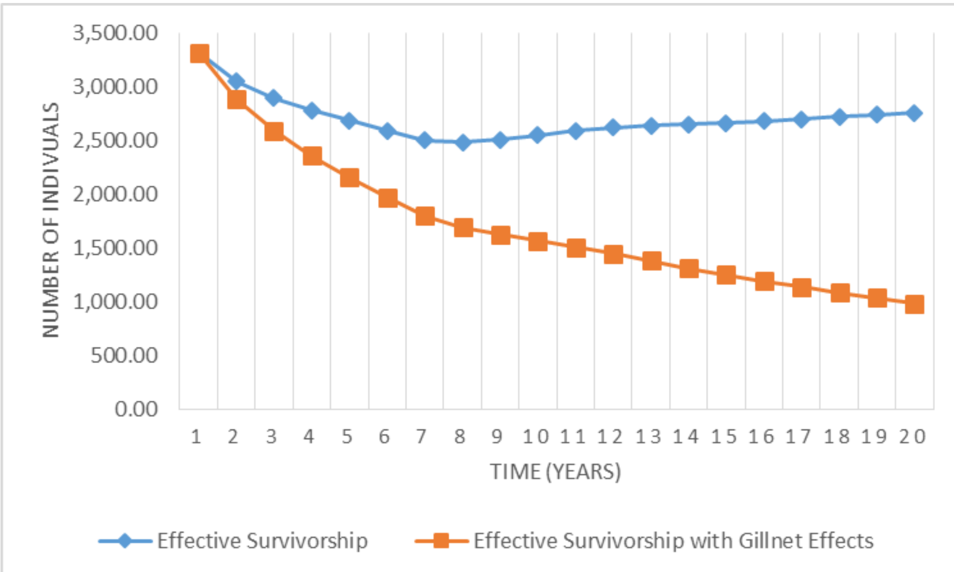
Graph 2 Dusky dolphin population size using average survivorship and gillnet effects from Dans et al. (2003) and Alonso et al. (1998).



Graph 3 Dusky dolphin population size using minimum survivorship and gillnet effects from Dans et al. (2003) and Alonso et al. (1998).



Graph 4 Dusky dolphin population size using natural survivorship and gillnet effects from Mannocci et al. (2012) and Alonso et al. (1998).



Graph 5 Dusky dolphin population size using effective survivorship and gillnet effects from Mannocci et al. (2012) and Alonso et al. (1998).