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Sustainable Whale-watching for the Philippines: A Bioeconomic Model of the Spinner Dolphin (Stenella Longirostris)

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SUSTAINABLE WHALE-WATCHING FOR THE PHILIPPINES: A BIOECONOMIC MODEL OF THE SPINNER DOLPHIN (*STENELLA LONGIROSTRIS*)

By
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Abstract

Whale-watching provides economic opportunities worldwide and particularly proliferates in developing countries, such as the Philippines. The sustainability of whale-watching is increasingly debated as these activities also negatively impact cetaceans through changes in behavior, communication, habitat use, morbidity, mortality, and life-history parameters. This study evaluated the total annual cost, revenue, and profit of whale-watching operators in Bais, Philippines, and predicted the changes in the population for spinner dolphin *Stenella longirostris* with varying levels of whale-watching effort. Total revenue was 3,805,077 PHP ($92,478 USD) while total cost was 5,649,094 PHP ($137,294 USD) with a discount rate of ten percent. The total annual profit of whale-watching in Bais was – 1,844,017 PHP (– $44,817 USD). On average, each operator in Bais lost 160,350 PHP ($3,897 USD) per year from whale-watching. Through time, the spinner dolphin population decreased as it was exposed to more vessels, causing effort to increase, and thus decreased profit for operators. Under current whale-watching effort, the spinner dolphin population was predicted to decrease by 94 percent in 25 years. If Bais reduced effort in their operations to only three vessels whale-watching per day, the spinner dolphin population increased to 80 percent of its initial population size. This was the first study to predict the spinner dolphin population and estimate the total annual profit from whale-watching in Bais, Philippines. It provided data to locals for efficient, profitable, and sustainable decisions in whale-watching operations.

Keywords: bioeconomics, population modelling, population dynamics, spinner dolphin, Philippines, whale watching, dolphin watching

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Within these years of studying Marine Biology, I have seen things I thought I could only dream of…from searching stranded pilot whales in the far-off Everglades, to guarding endangered sea turtle hatchlings as they wobble through the sands of Fort Lauderdale, or rushing out of the CoE to catch a glimpse of the manatees. But these moments would not have meant as much as the people behind my adventurous story of graduate school. I could not have done this without you all. To my roommates, labmates, Title V mentors (Team Diversity!), and fellow OC students, it has been wonderful to discover friendships that have been filled with nerdy humor and conversations of saving the world! I am indebt to professionals whom have influenced my concepts of science. Dr. Bernhard Riegl, your encouragement, patience, honesty, and opportunities have helped me tremendously during times of growth, writer's block, and stubborn code. Thank you so much for opening the doors for me to population modelling! Dr. Lem Aragones, thank you for an unforgettable experience in the hidden gem of the Philippines, helping me understand my other culture, and improving my eyes. Many thanks Dr. David Kerstetter for taking my writing to the next level and your expertise in fisheries economics. Dr. Michael Horn, your tea meetings have made it possible to endure graduate school/ask and answer the right questions. Dr. Keith, your inspiration while initiating this project has guided me along the way…you live in the smiles of Bais. Thank you Apple and the Amor family, whale-watching operators, Tourism Office of Bais City and volunteers for your warmth and hospitality. And lastly, I want to express my gratitude to my family, whom have provided endless support throughout my non-medical professional interests ;) Thank you for just being my family!

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1. Introduction

Whale-watching is defined as commercial tourism that allows people to observe, swim with, listen to, touch, or feed wild cetaceans from shore, sea, or air (Hoyt 2001, IWC 2004). The term includes the watching of all cetaceans - whales, dolphins, and porpoises. The whale-watching industry exceeds $2.1 billion United States Dollar (USD) per annum, involving 87 countries and territories, 13 million whale watchers, and providing 13,000 jobs (Hoyt 2009, 2001; O'Connor *et al*. 2009). The average annual growth rate of whale-watching is 3.7 percent worldwide, however, regional growth rates of whale-watching are higher in developing regions (O'Connor *et al.* 2009). Whale-watching in Asia grows 17 percent per year, making it the world's important new whale-watching destination (O'Connor *et al.* 2009). An additional $413 million and 5,700 jobs could be gained in the global whale-watching industry, with much of these opportunities available to developing countries (Cisneros-Montemayor *et al*. 2010).

Despite economic benefits, whale-watching can negatively impact cetaceans. These include injury, fatality, aggression between humans and cetaceans, avoidance of swimmers or vessels, and changes in respiration, behavioral state, acoustic behavior, movements, and habitat use. More evidence shows that repeated exposure to whale-watching vessel traffic can compromise the fitness of individual cetaceans and this can lead to population-level effects (Lusseau 2003 & 2004, Constantine 2001). Research related to negative effects of whale-watching in several species of cetaceans are listed in Table 1.

Table 1. Negative effects related to whale-watching. Reported short-term and long-term impacts in species of cetaceans.

Effect of whale-watching	**Species**	**References**
	Short-term effects	
Behavioral state Feeding Resting Socializing	Bottlenose dolphin (*Tursiops* spp.) Common dolphin (*Delphinus delphis*) Spinner dolphin (*Stenella longirostris*)	Kassamali-Fox *et al.* 2015, Meissner *et al.* 2015, Christensen *et al.* 2010, Constantine *et al.* 2004, Mann & Kemps 2003, Wursig 1996
Avoidance	Bottlenose dolphin Hector's dolphin (*Cephalorbynchus hectori*) Killer whale (*Orcinus orca*)	Lusseau 2003, Williams *et al.* 2002, Nowacek *et al.* 2001, Bejder *et al.* 1999
Aggression	Beluga (*Delphinapterus leucas*) Short-finned pilot whale (*Globicephala macrorhynchus*) *Stenella* spp.	Shane *et al.* 1993, Samuels *et al.* 2000
Respiration	Bottlenose dolphin Humpback whale (*Megaptera novaeangliae*)	Hastie *et al.* 2003, Janik & Thompson 1996, Baker & Herman 1989
Acoustics	Bottlenose dolphin Short-finned pilot whale Sperm whale (*Physeter macrocephalus*)	Teilmann *et al.* 2015, Luís et *al.* 2014, Jensen *et al.* 2009, Gordon *et al.* 1992
Habitat use	Bottlenose dolphin Humpback whale	Allen & Read 2000, Salden 1988
Injury or fatality	Bottlenose dolphin Fin whale (*Balaenoptera acustorosrata*) Hector's dolphin Humpback whale Minke whale (*Balaenoptera physalus*)	Laist *et al.* 2001, Stone & Yoshinaga 2000, Wells & Scott 1997, Samuels *et al.* 2000
	Long-term effects	
Daily behavioral budget	Bottlenose dolphin	Lusseau 2003 & 2004, Constantine 2001
Patterns of residency	Bottlenose dolphin	Lusseau 2005
Energetics	Killer whale	Williams *et al.* 2006
Relative abundance	Bottlenose dolphin	Bejder *et al.* 2006, Fortuna 2006, Lusseau *et al.* 2006

The economic use of biological resources, such as whale-watching, is studied in bioeconomics. Bioeconomics involves two traditional disciplines, biology and economics, and describes how living resources are exploited in a non-sustainable manner. The economic impacts of whale-watching has been mainly examined in the estimation of direct and indirect expenditures, of which include ticket sales, accommodation, meals, transportation, communication, and souvenirs (Mustika *et al.* 2012, Cisneros-Montemayor *et al.* 2010, O'Connor 2009, Orams 2002, Hoyt 2001). A different approach was taken by Schwoerer 2003, which incorporated the change of economic parameters over time to evaluate the economic value of local whale-watching communities in Baja Mexico. It is important to consider the combination of biological and economic parameters of whale-watching that change over time as they can affect the dynamics of a cetacean population and economy. Living resource populations – and the economies that depend on them – can both decline if the resource is not sustainably managed. In particular, sustainable management is critical for businesses in developing countries that rely on natural resources for their income. Therefore, it is important to study the bioeconomics of whale-watching in developing countries.

The objective of this study was to describe local whale-watching in Bais, Philippines, evaluate its annual cost and revenue, and predict the population of spinner dolphin (*Stenella longirostris)* with varying levels of whale watching effort. A simple bioeconomic model of whale-watching on the spinner dolphin in the southern Tañon Strait, Philippines, was constructed to develop tools for producing economically and biologically sound whale watching management guidelines.

1.1 Whale-watching in the Philippines

While whale-watching provides economic opportunities to developing countries, developing countries have insufficient legal and managerial structures and capacity to control growth for whale-watching (Lusseau and Bejder 2010; O'Connor *et al*. 2009). The tropical, archipelagic nature of the Philippines provides an extensive diversity of habitats for cetaceans, and thus allows Filipinos to produce economic benefits from whale-watching. However, there is an overall lack of baseline data on cetacean habitat, abundance, and distribution in the Philippines because of the expensive cost of traditional surveys (Dolar *et al*. 2006).

The Tañon Strait (Figure 1) is a deep, narrow channel, with an area of 4,544 km^2, located between Negros and Cebu islands in the Visayas province of the Philippines (Aragones and Keith 2007). It supports 11 out of the 27 documented cetacean species in the Philippine waters (Aragones and Keith 2007), with its very steep slopes, submarine terraces, and narrow shelf. It also supports coral reefs, mangroves, seagrasses, squid, nautili, more than 70 species of fish and over 20 species of crustaceans (Dolar *et al.* 2006). Threats to cetaceans in the region include habitat degradation and incidental catch by extensive fisheries. Because of its high diversity and abundance of marine life, the region was proclaimed as the Tañon Strait Protected Seascape (TSPS) in 1998 by Executive Order #1234 and signed by President Fidel Ramos (GOVPH 1998). A protected seascape is defined by the International Union for Conservation of Nature (IUCN) as "a protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural, and scenic value and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values" (Phillips 2002).

The city of Bais (See Figure 1) is located in Negros Oriental along the southern region of Tañon Strait. It was one of the first local government units in the Philippines to implement whale-watching as a tourist attraction (Evacitas 2001). Bais was estimated to attract 4,935 whale-watchers in 1998, which was a 51% and 88% increase over 1997 and 1996, respectively (Evacitas 2001).

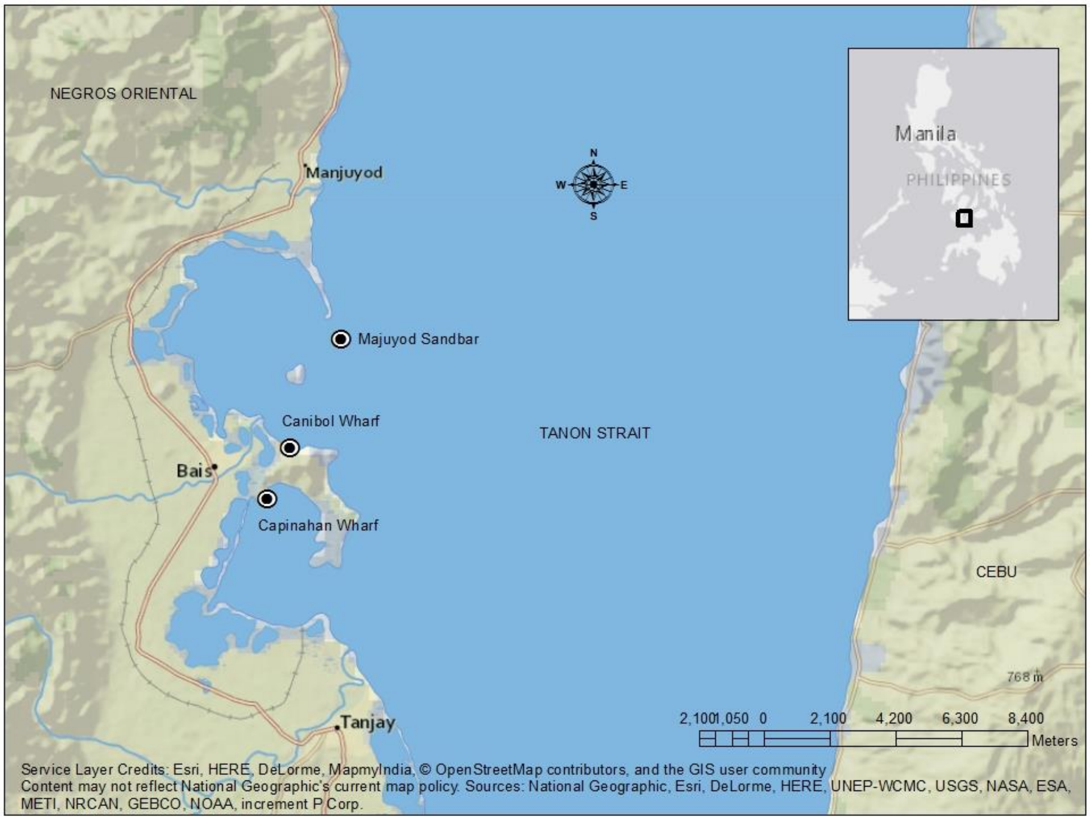

Figure 1. Map of study site in the southern Tañon Strait, Philippines. Whale-watching vessels embark from Canibol or Capiñahan Wharf in Bais City and anchor at Majuyod Sandbar for lunch.

Whale-watching vessels in Bais are motorized boats with outriggers and are called ‘bancas’ by locals (Figure 2). When whale-watching initiated in 1995, two large (~30 feet long) vessels operated, each accommodating 20 people (plus crew) (Evacitas 2001). Now, there are 16 known vessels conducting whale-watching in Bais. Vessels owned by the city government are named *Dolphin I* and *Dolphin II*. The following vessels are privately owned: *Alfer*, *Aroma*, *Cristy I, Cristy II, Dolly, Dolphin Adventure, Ezhra, Niko 3, Ocean Adventure, Queen Mary, Rebecca, Santo Niño*, and *Vios*. The vessels that regularly operate in the Bais area charge 2,500 to 3,500 Philippine pesos PHP ($52 – 74 USD, 1 USD = 46 PHP in 2015) per trip and allow a maximum capacity of 15 to 30 passengers (Evacitas 2001). Large vessels currently charge 4,000 PHP for 20 people per trip (i.e. $4 USD per person). Prices have remained about the same and these are not cheap by Philippine standards (Aragones *et al*. 2013). In comparison, the average ticket price in California, the oldest established whale-watching industry in the world, is $50 USD per adult (O’Connor *et al.* 2009 and Hoyt 2008). Whale-watching crews in the Philippines obtain a daily wage of 136 to 215 PHP ($3-5 USD) (Evacitas 2001).

Figure 2. Example of a typical whale-watching vessel in Bais, Philippines.

Whale-watching season in the Philippines is during the monsoon off-season (March to October) when seas are calmer and visibility is clearer (O'Connor *et al.* 2009). In the southern Tañon Strait, whale-watching is available year-round (Aragones *et al*. 2013). During peak season (April – May), an average of 1 to 2 trips occur each day per vessel, while 2 to 3 trips every 15 days occur during the low season (Evacitas 2001). Tourists embark on government vessels at Capiñahan Wharf or private vessels at Canibol Wharf (see map in Figure 1). Vessels anchor at Majuyod Sand Bar where tourists enjoy lunch and swim by a stretch of abandoned stilt houses after whale-watching. Trips run from 0700 AM to 1500 PM. The Bais Tourism Extension Office coordinates reservations, scheduling, and conducting whale-watching trips that are available daily (Evacitas 2001 and personal communication). The tourism office records tourist attendance each month and year and reports to the city's Philippine Coast Guard.

The high demand for whale-watching operators and the absence of regulations eventually attracted the activity of non-registered vessels and untrained operators in the Philippines (Sorongon *et al*. 2010). The Department of Tourism (DOT) and Department of Agriculture's Bureau of Fisheries and Aquatic Resources (DA-BFAR) established the Joint Administrative Order No. 1 (JAO 1) to regulate human interaction with whales, dolphins and porpoises (Sorongon *et al.* 2010). JAO 1 controls licensure, boat dispatch schedules, training and seminars to promote compliance and conservation of cetaceans (Sorongon *et al.* 2010). From 2004 to 2006, seminars and workshops on whale-watching protocols, management, and guided tours were held for local officials, fishermen, and interest groups of Bais (Aragones *et al.* 2013). Although the Tañon Strait was declared as a Protected Seascape, it took 17 years to assemble a stakeholder's summit of government agencies, academia and non-governmental organizations to conserve the Tañon Strait. In 2015, a “Tañon Declaration”, TSPS Protected Area Management Board (TSPS PAMB), TSPS management plan and website were created for the preservation of the Tañon Strait (Reyes 2015). TSPS PAMB members include all local government officials of the provinces of Cebu, Negros Oriental and Negros Occidental, 42 cities and 289 districts. Despite efforts to govern whale-watching in Bais, investment or operation only requires a vessel to be registered with the Maritime Industry Authority (Evacitas 2001 and personal communication) and there are no total vessel limitations for whale-watching. Few operators comply with safe boat approaches that are set by the JAO 1 because few operators voluntarily receive training and there is a lack of enforcement by authorities. The spinner dolphin was chosen for this study because it is the most commonly-sighted cetacean species in the Tañon Strait. It may be the cetacean species that is most exposed to whale-watching over time in the Philippines. They are the most abundant cetacean species in the Tañon Strait, with an estimated population of 3,489 and a mean school size of 17.4 individuals (Dolar *et al*. 2006). Aragones *et al.* (2013) reported that the spinner dolphin population has been slightly declining since 2007.

The spinner dolphin is a slender dolphin species with a slim head at the apex of the melon and a very long, thin beak (Jefferson *et al*. 2008). The upper jaw is dark, the lower jaw is mostly white and the beak tip is usually dark. The spinner dolphin displays a tripartite color pattern (dark gray cape, light gray sides and white belly) and dark eye-to-flipper stripes. The flippers and dorsal fin are quite small, and the dorsal fin varies from falcate to triangular. Lastly, the post-anal hump is small to non-existent.

Spinner dolphin are one of the most aerial of the dolphins and distinguished for their habit of leaping from the water and spinning multiple times on their long axis (Jefferson *et al*. 2008). They also display breaches, side-slaps and fluke-slaps and are lively bowriders (Jefferson *et al*. 2008). Spinner dolphin are often associated with dwarf sperm whale (*Kogia sima*) and pantropical spotted dolphin (*Stenella attenuata*) in the Philippines. Spinner dolphin occur in shallow and deep waters, foraging in the upper 200 m and sometimes as deep as 400 m (Dolar *et al*. 2006). They also socialize and rest during the day and forage at night.

1.2 Bioeconomics

1.2.1 Population Dynamics

Bioeconomic models have been applied to living resources for exploitation such as forests for paper, elephants for ivory, and whaling for oil. However, few studies have modeled the dynamics of populations exposed to whale-watching in the long-term as it is difficult to measure indirect effects of whale-watching (Bejder *et al.* 2006, Fortuna 2006, and Lusseau *et al.* 2006). Failure to include biological parameters, such as growth rate, survival, mortality, and carrying capacity, can lead to serious miscalculations when modeling the exploitation of a living resource. Large, slow-growing mammals, like the spinner dolphin, tend to exhibit a density-dependent population growth rate. In simple terms, the population growth rate tends to slow and hit an asymptote as the population size reaches the *carrying capacity*, the upper limit to the density that the area can sustain. Resource limitations result in overcrowding or food shortages, as well as decreases in birth and survival rates, until the death rate equals the birth rate and population increase ceases (Norman Owen-Smith 2007). Consequently, the population abundance follows an S-shaped or sigmoid trajectory over time.

A population is considered at equilibrium when the growth rate is zero (Brassil 2012). The equilibrium population sizes are at extinction (0) and carrying capacity (*k*). When a population is perturbed from equilibrium by external forces, the abundance of the population changes. Stability analysis evaluates the slope around equilibrium points, or the derivative of growth rate with respect to population size. A population is at stable equilibrium if the slope is negative, in which the population returns to equilibrium after the population is increased or decreased away from the equilibrium. Conversely, a population is at unstable equilibrium if the slope is positive, in which the population moves away from equilibrium after changes in population size. Zero equilibrium is considered unstable and carrying capacity equilibrium is stable.

1.2.2 The Gordon Model

One of the first bioeconomic models was the *Gordon model* (Gm), created by H.S. Gordon, that introduced the concept of economic overfishing in open-access fisheries (Gordon 1954). *Open-access fisheries* are those that lack regulation and fishing is uncontrolled. Open-access fisheries harvest a *common-property resource,* of which has two main characteristics: 1) the level of exploitation by one user affects the ability of another user to exploit the resource and 2) the control of access by users is problematic due to the physical nature of the resource (Feeny *et al.* 1990).

In the case of open-access fisheries, the amount of fish caught by one fisherman decreases the availability of fish for others because the supply of fish is finite. Access to fish, a migratory resource that inhabits large bodies of water, is available to everyone in open-access fisheries (Fuller 2013 and Feeny *et al*. 1990). Moreover, additional fishermen entering the fishery and increased investment in capital can cause fishermen to compete with each other. As a result, unproductive levels of fishing effort lead to depletion or extinction of fish populations and ultimately drive economic profits to zero, as expected in the Gm.

Under the Gm, the *harvest* of a wildlife resource is defined as the rate of removals. For fishing, harvest is the total number or weight of fish caught and held from an area over a unit of time. Harvest is also dependent on effort and catchability. *Effort* is an index of total economic inputs to harvest practices. Examples of effort include the number of vessels actively fishing or the number of active elephant poachers in one time unit. *Catchability* is a measurement of interaction between the resource and effort. Fishing catchability is a constant of fishing mortality caused on a stock by one unit of effort or the fraction of the stock caught by a fishing vessel in one time unit.

Sustainable and non-sustainable harvest strategies can be modeled to exploit a population. Sustainable harvesting means that a certain constant catch or yield can continuously be taken from a stock, provided that the harvest is less than the population size. The largest harvest rate that can be sustained indefinitely is called the *Maximum Sustainable Yield (MSY)* (Clark 2010 and Blackhart *et al.* 2006*).*

1.2.3 The Whale-watching Model

Although the Gm is a fisheries model, whale-watching in Bais, Philippines, can be modeled similarly to the Gm, because of the following reasons: 1) whale-watching practices in Bais are open-access, 2) the harvest from fishing and whale-watching are fundamentally similar, 3) parameters from the Gm match those to a whale-watching model.

Whale-watching in Bais show the characteristics of an open-access practice. Similarly with fish, controlled access is challenging with cetaceans as they are also migratory common-property resources that are distributed in large marine ranges. Access to cetaceans is available to anyone in Bais due to the absence of contiguous regulation and lack of compliance with established codes of conduct. Also, studies show that the number of whale-watching vessels adversely affects the presence of cetaceans (Allen and Read 2000 & Salden 1988). Therefore, the presence of one whale-watching vessel reduces the availability of cetaceans for other operators.

Wildlife viewing, like whale-watching, has been misleadingly assumed as a benign, 'non-consumptive' activity. In comparison, the instant and fatal results of hunting a harvest (in the case of the Gm, fishing) has been termed 'consumptive' (Knight 2009, O'Connor *et al.* 2009, & Duffus and Dearden 1990). However, viewing can be consumptive harvesting. Wildlife viewing has been considered as a type of 'ocular consumption', in which animals are susceptible to the tourist gaze (Lemelin 2006 and Urry 2002). Consumption by the human eye may be harmless, but wildlife viewing is still reliant on transportation, accommodations, and services that are possibly unsustainable, and therefore, detrimental to animal populations.

Knight (2009) reports that hunting and viewing are essentially related in the pursuit of wild animals. Specifically for whale-watching, operators that search for animals nearby must detect and approach focal animals. This involves the same means as the fishermen. Both methodically detect, identify, and pursue target animals. Recall that the harvest in fishing is the total number of fish caught and held from an area over time. Similarly, viewing cetaceans often involves close-up and prolonged interactions in which cetaceans are surrounded and followed by multiple swimmers and vessels in a given area. Whale-watching operators and fishermen also activate anti-predatory responses in the animals that avoid detection and minimize interaction (Higham *et al*. 2014 and Knight 2009). The exposure cetaceans receive from whale-watching diminishes the survival of cetaceans; that is, the resource is 'used up' through consumptive harvesting. As whale-watching and fishing are considered as consumptive practices, the Gm can be applied to a model of whale-watching in Bais.

Parameters used in the Gm parallel those applied to a bioeconomic model of whale-watching. Under whale-watching, *harvest* is the rate of cetaceans from the stock that are highly exposed to whale-watching vessels. Harvest is also dependent on whale-watching effort and catchability. *Effort* is the number of vessels whale-watching at a given time and *catchability* is the constant of whale-watching mortality caused on a stock by one unit of effort. To avoid the misconception that cetaceans are literally "caught" by whale-watching, catchability was referred as *vulnerability* for this thesis.

Moreover, it is important to note that individual cetaceans may have higher fitness with whale-watching exposure; individuals may not contribute equally to the detrimental population effects. Thus, *vulnerability* is dependent on the following parameters: 1) *vessel exposure*, the ratio of cetaceans that are highly exposed to whale watching vessels, and 2) *unsuccessful reproduction*, the ratio of watched cetaceans that have zero reproduction rate or reproduction rate that produces calves of which do not survive.

1.2.4 Economics (Revenue and Cost)

To sustain a cetacean population under whale-watching activity, operators must have an incentive, that is to produce high economic return. Evaluation of the revenue and cost of each whale-watching operator enables the government agencies, as well as the scientific and local communities, to target potential improvements in earnings and improve the sustainability of whale-watching activities.

The Gm accounts for revenue and cost in terms of fisheries; for example, revenue is in ex-vessel fish product sales. In the case of whale-watching activities, total revenue are ticket sales earned from whale-watching while total cost are operating costs, fixed costs and capital charges. *Operating costs* are expenses that maintain the business, including fuel costs and opportunity costs of labor. *Opportunity costs* of labor are spent on additional business operations that exclude whale-watching such as fishing. *Fixed costs* include those that do not change as whale-watching services increase or decrease such as the lease of office buildings, office expenses, wages, travel, advertising, insurance, boat repair, boat transportation, and permit fees (Clark 1990).

Capital charges are purchased assets such as land, buildings, equipment, and supplies that are necessary for the company to be operable and incorporate the change in value of assets over time. This thesis calculated future value and discounting as property such as vessels, motors and radios change in monetary value over time. *Future value* is defined as the value of an asset at a date in the future that is equivalent in value to a specified sum today. *Discounting* is based on the principle that a dollar received today is worth more than a dollar received in the future. It converts all costs into the current value of an amount of money in the future. In resource economics, the optimal exploitation approach is usually strongly affected by the rate of discount (Clark 2010). Thus, sensitivity analyses of discount rate are applied to examine the cash flow of a business and determine accurate representation of an assumed discount rate. A lower discount rate is applied to a model that favors long-term conservation as high discount rates favor rapid depletion of the resource stock (Clark 2010). Private businesses tend to have large discount rates for development and investment plans. Moreover, businesses from developing regions discount future rates much more than the market rates of interest because they lack the funds for high initial costs. Poverty, the lack in adequate financial, consumptive, political, educational, social, or health resources, drives individuals and regions to center on immediate survival, even at the risk of more shortages in the future (Wagle 2002). Long-term resource conservation may be only affordable to those whose survival does not depend on immediate access to the resource (Clark 2010; Reardon & Vosti 2007; de Janvry & Garramon 1977).

Under the Gm, fishing effort in an open-access fishery is inclined to reach an equilibrium where total revenue equals the total cost *(TR = TC).* The Gm can be similarly applied to open-access whale-watching, in which whale-watching effort is inclined to reach an equilibrium where total revenue equals the total cost *(TR = TC).* A comparison of the bioeconomic parameters used in the Gm and whale-watching models for the exploitation of open-access resources is presented in Table 2.

As whale-watching in Bais harvests an open-access, consumptive resource similar to fishing, it is expected that the open-access industry of whale-watching in the Tañon Strait currently follows the Gordon model, in which *TR = TC* and the annual profit to zero. Resource depletion of spinner dolphins is expected to occur under current levels of whale-watching effort over time. When effort is restricted, the population is predicted to increase and harvest under whale-watching is expected to be less than the maximum sustainable yield.

Table 2. Comparison of bioeconomic parameters used in the Gordon model and whale-watching model for the exploitation of open-access resources. Measured units are in parentheses.

Gordon Model Parameters	Whale-watching Model Parameters
Stock Biomass of fish (*tons*)	**Stock** Population of cetaceans *(number of cetaceans)*
Effort Number of standard vessels actively fishing at one time unit *(standard vessel units SVU)*	**Effort** The number of vessels actively whale-watching at one time unit *(total operating vessels or max vessels seen)*
Catchability Constant of fishing mortality caused on a stock by one unit of effort (SVU^{-1} *x time* $unit^{-1}$)	**Vulnerability** Constant of whale-watching morality caused on a stock by one unit of effort (*mean group size x mean number of groups whale-watched x vessel exposure x unsuccessful reproduction/vessel x time*)
Harvest Total number of fish caught and held from an area over a unit of time (*tons/time*)	**Harvest** Total number of female cetaceans from the stock that are highly exposed to whale-watching and have unsuccessful reproduction *(number of cetaceans/time)*
Maximum Sustainable Yield The largest harvest rate that can be sustained indefnitely *(tons/time)*	**Maximum Sustainable Yield** The largest harvest rate that can be sustained indefinitely *(number of cetaceans/time)*
Total Revenue Fish sales from the fishery *($/SVU x time)*	**Total Revenue** Ticket sales from all trips by the fleet *($/vessel x time)*
Price Price of fish (*$/ton*)	**Price** Price of ticket *($/trip)*
Total Costs Cost of effort (*$/SVU x time*)	**Total Costs** Cost of effort (*$/vessel x time*)
Operating Costs Fuel and opportunity costs of labor	**Operating Costs** Fuel and opportunity costs of labor
Fixed Costs Fishing supplies (e.g. bait, ice, storage), food for crew, wages, insurance, maintenance, permit and other fees	**Fixed Costs** Advertising, wages, insurance, maintenance, permit and other fees
Capital Costs Fishing gear, electronics (e.g. fishfinder and radio), safety equipment, vessel, motor	**Capital Costs** Electonics (e.g. hydrophone and radio), safety equipment, vessel, motor

2. Methodology

2.1 Data collection

2.1.1 Sighting Surveys

Sighting survey methods, in which animals are counted to assess their density, were adopted from Dawson *et al.* 2008 and Aragones *et al.* 2007 to estimate the abundance of spinner dolphins whale-watched and whale-watching activity around the southern Tañon Strait. To simulate the typical whale-watching route, data was collected on a local whale-watching vessel. Surveys were for 10 days, on 16 – 20, 22, 24 – 26, 28, and 30 April 2013, during the break between the two monsoon seasons, and only in suitable sighting conditions (Beaufort Sea State 0 – 4). The Beaufort Sea State Code approximated a description of sea conditions, wind speed, and wave height. The small vessel could not withstand sea conditions greater than small waves, frequent white caps, wind speed of 11 – 16 knots, and wave height of one meter (i.e. Beaufort 4).

Six volunteers recorded both the whale-watching activity and the species composition, group size, and size-class counts of cetaceans that were sighted along the transect line (i.e. the path of the vessel). Observer training and review were provided prior to the survey to improve the volunteers' skills in identification of cetaceans and estimation of distances.

During daylight hours, observers rotated through the following watch positions, shifting every 30 minutes: 1) port bow binoculars, observing cetaceans, 2) starboard bow binoculars, observing cetaceans, 3) starboard beam binoculars, observing other whale-watching vessels in the area, 4) data recorder. One identification specialist with experience in the survey area and survey methods was on watch at all times and decided when the team would go on and off effort.

Observers searched from directly ahead to abeam of their corresponding sides (i.e. 90° to the left or right) within 300 m of the transect line (600 m survey zone) through handheld binoculars (Bushnell Marine Binocular, 7 X 50 mm). A 10° overlap at the bow between the port and starboard observers ensured that all vessels and cetaceans were sighted. During a sighting, all observers were alerted to the animal/vessel's location, and searching effort was suspended. Vessel position was obtained and recorded from Garmin eTrex 20, sighting angles were measured with angle boards and sighting distances were estimated by naked eye and confirmed with a laser range finder (Simmons, model LRF 600). Repeated vessel sightings per day were excluded from average vessel sighting calculations.

Sightings were then approached parallel to the animal and species identifications was confirmed by the crew. Codes of conduct advised operators to use parallel and back of pod boat approaches as these avoid forcing an individual or pod to change direction or separate (Sorongon *et al*. 2010). Counts were recorded by each observer in personal notebooks, which were entered into the database by a non-observer scientist at the end of each day. Each observer made three estimates of abundance for each age class and group size: "best", "high", and "low". The high and low estimates defined the confidence of the observer's estimates. For whale-watching activity, the number of sightings of whale-watching vessels, vessel type(s), and number of passengers were recorded in each observer's notebook. After data collection was completed for a sighting, the trackline continued towards the end of the trackline leg to avoid potential repeated sightings.

Animals were assigned to calf, juvenile, or adult age classes according to length because the exact ages of animals could not be determined. The cow/calf swimming formation was characterized by two animals of unequal lengths swimming in tandem, with the calf oriented on the same horizontal plane as the cow or oriented below the cow with the calf's melon near the cow's abdomen (Cramer and Perryman 2002). For spinner dolphins, neonates are about half of the adult length (75 – 80 cm), display a muted color pattern, and commonly have fetal folds and a folded fluke and dorsal fin (Jefferson *et al*. 2008). Calves are usually less than three-quarters of the adult length, display a relatively muted color pattern, and have a comparatively large head. Juveniles are usually greater than three-quarters of the adult length and have a slimmer body than adults. Adult females are 1.39 – 2.04 m and have a more erect dorsal fin than juveniles. Adult males are 1.60 – 2.08 m and have a slightly more erect dorsal fin, deepened tail stock, and enlarged post-anal hump. Body lengths of sexually and physically mature males and females in the Philippines have been determined from specimens incidentally caught from fisheries in Negros Oriental, Bohol, and Mindanao. Sexually mature males are 160 – 194 cm while physically mature males are 181 – 191 cm. Sexually mature females are 147 – 195 cm and physically mature females are 167 – 195 cm (Perrin *et al*. 1999).

2.1.2 *Questionnaires*

Economic data was collected through questionnaires of whale-watching operators in Bais, in April 2013 (Appendix 1). The study was approved under expedited review with Nova Southeastern University's Institutional Review Board (IRB) because it was a study with human subjects. My committee (Drs. Aragones, Kerstetter, and Riegl) and I completed the Collaborative Institutional Training Initiative (CITI) training that was required by the IRB.

I administered questionnaires at Capiñahan Wharf, where whale-watching vessels embark. Full completion and time limitation of the questionnaire were not required. An incentive payment of 1000 PHP was given to each operator after completion. Operators had the option to complete a written survey or vocal interview of the same questionnaire. A vocal interview was recorded electronically and later transcribed. In the event vessel operators chose not to participate in the questionnaire, all whale-watching vessels were observed during survey days. Whale-watching time, vessel name, number of passengers, sighting time, sighting distance, sighting angle, and vessel behavior towards cetaceans were recorded for vessel sightings.

2.2 Analyses

2.2.1 Economics (Revenue and Cost)

Revenue and cost were calculated from the questionnaires. Questionnaire findings expressed in Philippine peso (PHP) were converted into US Dollar (USD) with the appropriate monthly PHP – USD exchange rates (1 USD = 41.1459 PHP in April 2013). Inflation was corrected to express monetary values from previous years into the current year equivalent. Operators that provided inconsistent responses were eliminated from data analysis. Averages of annual fuel, wages, assets, trip price, number of trips, and number of crew were calculated for operators that did not provide data. Each vessel's revenue, cost, and profit were examined. The number of vessels owned per operator varied, thus data analysis was performed for each vessel rather than each operator.

Sensitivity analysis was performed on the total profit of all whale-watching vessels in response to changes in discount rate.

Whale-watching in Bais received benefits from all operators *m* that were equal to total revenue *TR*:

$$TR = \sum_{mi} p * y \qquad (1)$$

where *p* was the price per whale-watching trip and *y* was the number of annual trips provided by the industry. The whale-watching ticket price per unit harvest was considered a constant as ticket price had not changed much since whale-watching began in Bais (Aragones *et al.* 2013 and pers. obs.).

Total cost *TC*, was the sum of all individual operators' *i*, annual operating costs *OC*, annual fixed cost *F*, annual capital charges *K*:

$$TC = \sum_{mi} OC + F + K \qquad (2)$$

Annual operating costs was the sum of all individual operators' annual fuel costs C_F and opportunity costs of labor C_{oL} . Fuel cost was based on different trip lengths, engine types, gasoline, and motor oil, of which were all incorporated in the annual fuel values provided from the operators' responses.

$$OC = \sum_{mi} C_F + C_{oL} \qquad (3)$$

Opportunity cost of labor was based on wages and percentage of work the operators spent on activities other than whale-watching (Clark 1990). It was the sum of all individual operators' product of wages *w*, annual trips *y*, and percent of non-whale-watching operations *l*.

$$C_{oL} = \sum_{mi} w * y * l \qquad (4)$$

Fixed cost F for whale-watching was the sum individual operators' advertising a, insurance i, maintenance m, permit and other fees o, and total wages w of all crew.

$$F = \sum_{mi} a + i + m + o + w \qquad (5)$$

Capital charges included initial capital investments and capital investments that substituted the assets once they reached their life (Schwoerer 2003). The future value FV of all operators m, was the ongoing capital replacement that varied according to a schedule. The initial price P of each asset j was discounted at rate d according to the asset's replacement schedule R, and was summed for all types of assets s, of each operator i . In this thesis, discount rate was set to ten percent. It was reasonable to assume that the discount rate was high in Bais, a developing region. Most of the city's whale-watching businesses were privately owned and may only afford low initial investments.

$$FV = \sum_{mi} \sum_{sj} P * (1 + d)^R \qquad (6)$$

The annual capital K was the future value FV of an asset discounted at rate d according to the lifespan t of each asset and was summed for all types of assets, for each operator.

$$K = \sum_{mi} \sum_{sj} FV * \frac{d*(1+d)^t}{(1+d)^{(t+1)-1}} \qquad (7)$$

The Gm of an open-access fishery described net profit as a function of Total Revenue TR and Total Costs TC, given by

$$Net\ Profit = TR - TC \qquad (8)$$

2.2.2 Population Model

A bioeconomic model was produced to determine the optimal level of whale-watching effort so as to sustain the spinner dolphin population. The logistic equation described the change in population size at each time step and was written as the following differential equation:

$$\Delta N = rx\left(1 - \frac{x}{K}\right) \tag{9}$$

where *x* represented the population's size, *r* represented the maximum proportional growth rate and *K* represented the carrying capacity. For the deterministic model built for this study, each time step represented one year. Growth rate was set to 0.04, a conservative default value for cetaceans (Taylor *et al.* 2000 and Slooten 1991). The carrying capacity was assumed to be 637 (+/- S.E. 189), the most current estimate of spinner dolphins in the southern Tañon Strait (Aragones *et al.* 2013). The initial population of spinner dolphins was set at a conservative value that was half of the assumed carrying capacity.

When the spinner dolphin population was harvested under whale-watching at a rate *h(t)*, the logistic growth dynamics equation took the form:

$$\frac{dx}{dt} = rx(t)\left(1 - \frac{x(t)}{K}\right) - h(t, x) \tag{10}$$

Whale-watching started at an initial time t and continued up to a terminal time T. For this study, the model was set to predict bioeconomic optimization for 30 years, the approximate lifetime of a fishery. The lifetime of a fishery was defined as the length of time over which it produced catches and was obtained from Worm *et al.* 2007, of which global fisheries catch data from the United Nations Food and Agriculture Organization (FAO) and other sources.

Conservative values of effort were compared (i.e. total number of vessels operating in Bais each year and maximum number of vessels seen per day). For future years, effort was set to a level that increased the dolphin population to sustainable levels.

Vulnerability q was set to the mean group size multiplied by the mean number of groups seen per survey. The vessel exposure *v* from an Indo-Pacific bottlenose dolphin (*Tursiops* spp.) population in Shark Bay, Australia, was used as a proxy value due to the lack of long-term studies of cetaceans in the Philippines (Bejder 2005). *Unsuccessful reproduction b* was set to the ratio of watched female dolphins that had zero reproduction rate or reproduction rate that produced calves of which did not survive more than 3 years. The unsuccessful reproduction rate of the bottlenose dolphin in Shark Bay was also applied to the model. Only a proportion of whale-watched individuals survived and reproduced successfully after cumulative whale-watching exposure. Thus, the proportion of females with high cumulative vessel exposure v and the proportion of females with high cumulative vessel exposure that reproduce unsuccessfully b were multiplied by the vulnerability (Bejder 2005).

The ratio of yield to effort, $\frac{h(t)}{E(t)}$, was an indication of the number of cetaceans affected by the whale-watching vessel, $qvbx(t)$.

$$h(t) = qvbE(t)x(t) \tag{11}$$

Substituting for $h(t)$, the logistic growth dynamics of the spinner dolphin under harvesting became:

$$\frac{dx}{dt} = rx(t)\left(1 - \frac{x(t)}{K}\right) - qvbE(t)x(t) \tag{10}$$

Harvesting at MSY h_{MSY}, when the resource stock was half its carrying capacity $\frac{K}{2}$ and its maximum growth rate $\frac{rK}{4}$, allowed the population to persist at that level since $\frac{dx}{dt} = 0$.

$$h_{MSY = \frac{rk}{4}} \tag{12}$$

Harvesting under whale-watching was set under the following scenarios: $h < \frac{rK}{4}$ and $h > \frac{rK}{4}$. The resource was overexploited when the population declined below its MSY.

Stability analysis of the slope around equilibrium points was performed to examine growth rate relating to changes in population size. This derivative of growth rate with respect to population size was represented by lambda λ and was calculated by,

$$\lambda = \pm\sqrt{r^2 - \frac{4rh}{k}} \qquad (13)$$

provided that $h < \frac{rk}{4}$. Data was prepared in Microsoft Excel. Statistical analysis was performed in R 3.2.1 Program and the population model was produced in MATLAB R2011b.

3. Results

3.1 Economics

A total of 12 whale-watching operators (16 vessels) were reported to operate whale watching in Bais. Of these, nine operators completed written questionnaires and one operator completed an interview. Data analysis was performed on 12 vessels. One vessel was assigned the label "*Unknown*" in the analysis as the vessel's name was not provided in the questionnaire. Since vessels from the city started whale-watching in 1996, the total number of vessels significantly increased (See Figure 3) (p-value = 1.9 e -10). The total revenue of whale-watching in Bais did not equate to its total cost. Total revenue was 3,805,077 PHP ($92,478 USD) while total cost was 5,649,094 PHP ($137,294 USD) with a discount rate of ten percent. The total annual profit of whale-watching in Bais was – 1,844,017 PHP (– $44,817 USD). On average, each operator in

Bais lost 160,350 PHP ($3,897 USD) per year from whale-watching.

Total annual revenue and cost of each whale-watching vessel in Bais are in Figure 4. Bais' government operated vessels (*Dolphin I* and *Dolphin II*) produced the most revenue and cost. *Dolphin I* and *Dolphin II* also generated the largest mean annual trips (238.67 SE +/- 57.10 +/- 129.86, n = 6; 254.25 SE +/- 55.47+/- 110.94, n = 4 for *Dolphin I* and *Dolphin II* respectively), of which were significantly different than the means of other vessels' annual trips (p-values < 0.05).

However, 83% of the surveyed vessels displayed higher costs than revenue and thus resulted in an annual economic loss. Most vessels spent more than 50% in costs. Vessels *Cristy I* and *Cristy II* had the highest percentage of costs while *Rebecca* and *Unknown* displayed the highest percentage of revenue. *Rebecca* and Unknown were the only vessels that displayed positive profit from whale-watching each year (Figure 5). Vessel *Aroma* displayed the least annual profit from whale-watching.

Total operating costs were the least spent of all cost types; Vessel *Vios* displayed the highest percentage of operating costs (See Figure 6). *Dolphin I* and *Dolphin II* displayed the least percentage of operating costs in comparison to all private vessels. Total fixed costs were the most spent of all cost types; Vessel Unknown displayed the highest percentage of fixed costs. Vessels *Cristy I, Cristy II, Ezhra, Queen Mary*, and *Niko* displayed higher costs in capital. Results of mean annual revenue and cost parameters per vessel each year are summarized in Table 3. The sensitivity of total annual profit to changes in discount rate is shown in Table 4. Profit from whale-watching increased as the discount rate decreased. However, profit remained negative even when the discount rate was set to only one percent.

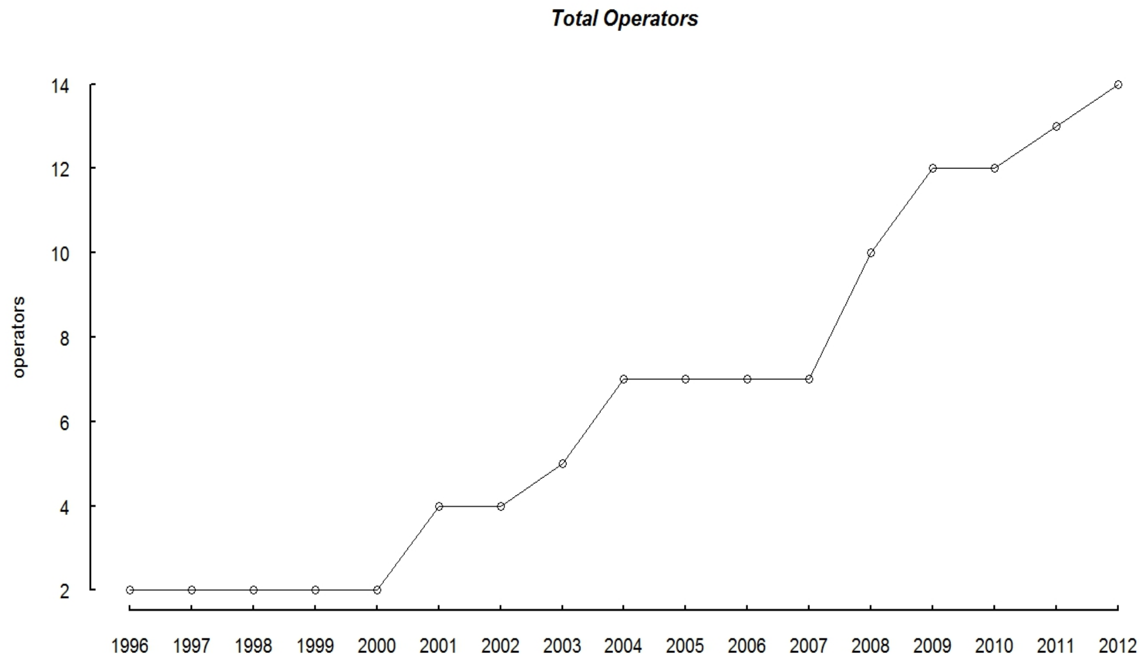

Figure 3. Total number of reported whale-watching vessels in Bais, Philippines, each year, since practices began in 1996.

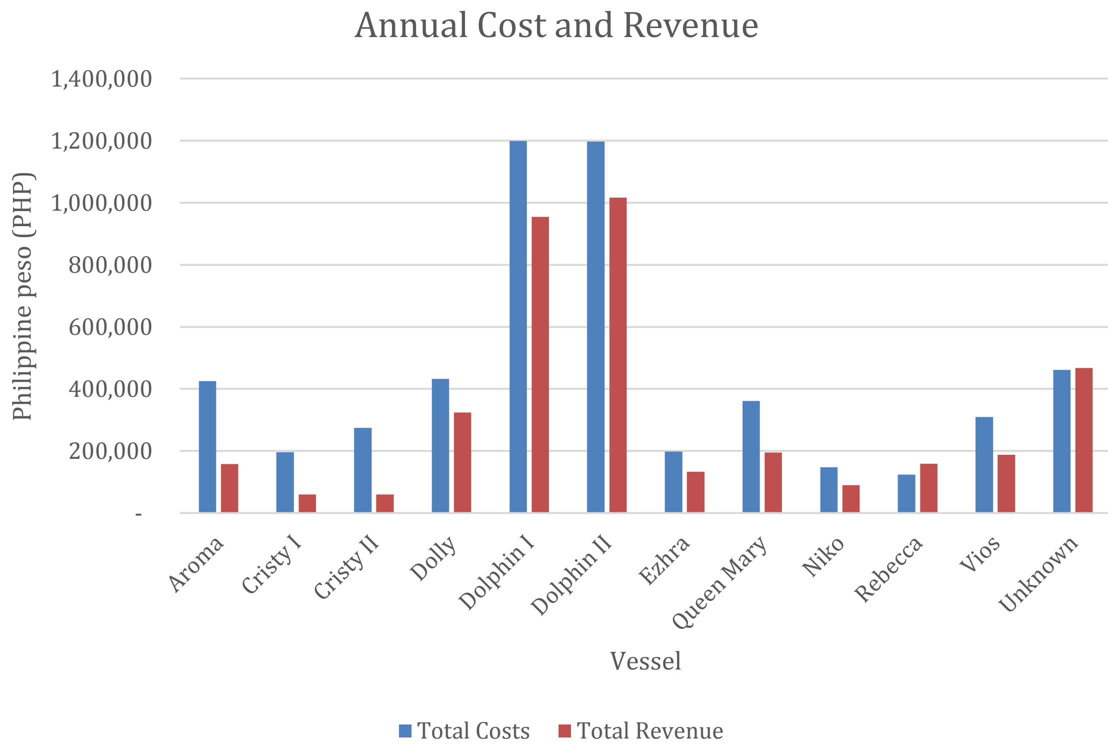

Figure 4. Annual revenue and cost in Philippine peso of each whale-watching vessel from Bais, Philippines.

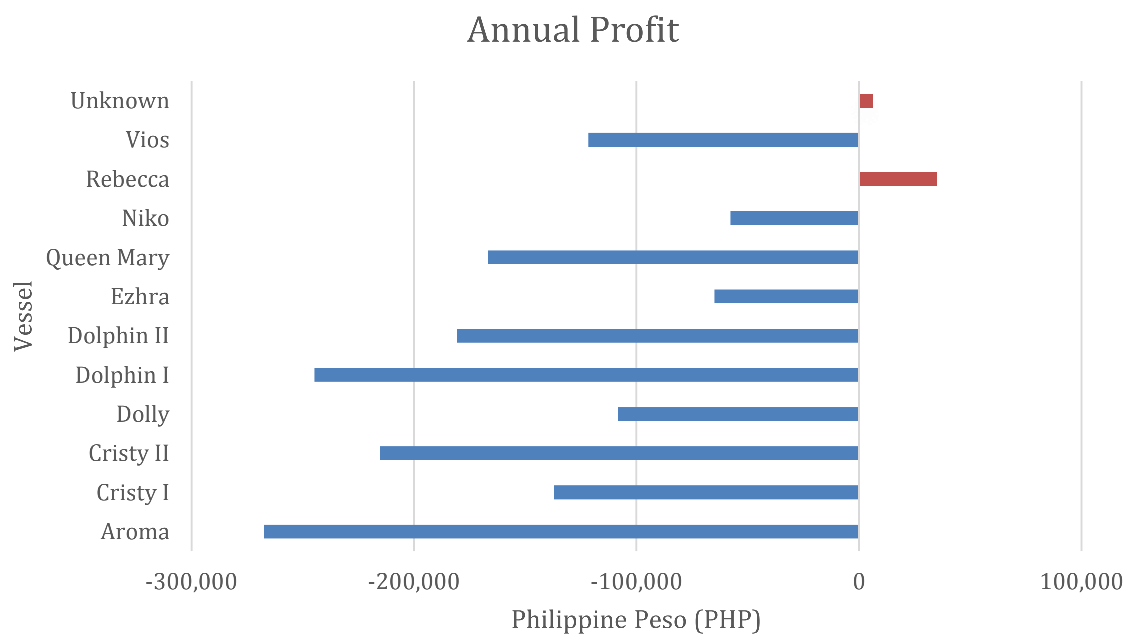

Figure 5. Annual profit in Philippine peso of each whale-watching vessel in Bais, Philippines.

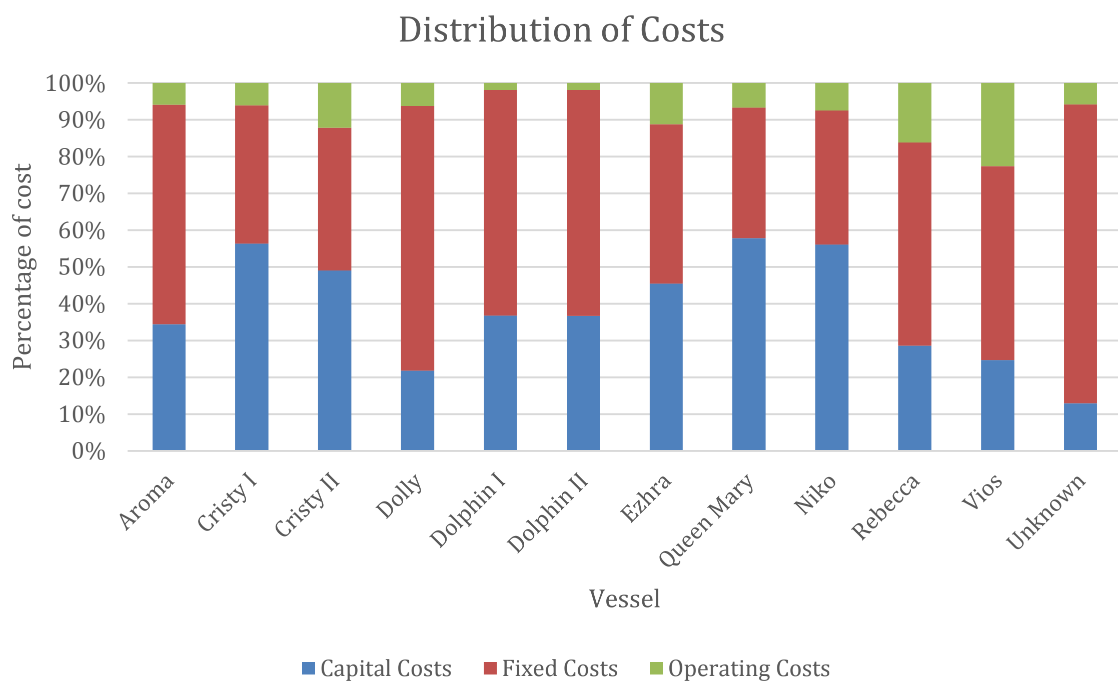

Figure 6. Percent distribution of total capital, fixed, and operating costs for each whale-watching vessel in Bais, Philippines.

Table 3. Economic parameters of whale-watching vessels in Bais, Philippines, each year in Philippine Peso (PHP) and United States Dollar (USD). Mean values are per vessel each year. Total values are of all vessels per year.

Parameter	**Variable**	**PHP**	**USD**
Mean Revenue (per vessel)	*R*	292,698	7,114
Price per Trip (for total passengers)	*p*	3,900	95
Number of Trips	*y*	73.38	
Mean Cost (per vessel)	*C*	470,758	11,441
Operating Costs	*OC*	28,583	695
Fuel Costs	*CF*	26,780	651
Opportunity Costs of Labor	*CoL*	2,170	53
Percent of non whale-watching operations	*l*	10%	
Fixed Costs	*F*	282,167	6,858
Wage	*w*	134,870	3,278
Insurance	*i*	21,408	520
Advertising	*a*	2,600	63
Maintenance	*m*	55,917	1,359
Permit and Other Fees	*o*	19,081	464
Capital Charges	*K*	160,008	3,889
Vessel			
Initial Asset Price	*P*	376,250	9,144
Future Value	*FV*	1,022,359	24,847
Capital	*Kj*	118,343	2,876
Motor			
Initial Asset Price	*P*	56,667	1,377
Future Value	*FV*	66,000	1,604
Capital	*Kj*	34,571	840
Radio			
Initial Asset Price	*P*	7,650	186
Future Value	*FV*	13,395	326
Capital	*Kj*	1,780	43
Lifejackets			
Initial Asset Price	*P*	13,813	336
Future Value	*FV*	16,966	412
Capital	*Kj*	5,166	126
Total Revenue	*TR*	3,805,077	92,478
Total Costs	*TC*	5,649,094	137,294
Total Operating Costs		342,990	8,336
Total Fixed Costs		3,386,005	82,293
Total Capital Costs		1,920,099	46,666
Total Profit		– 184,4017	–44,817

Table 4. Sensitivity analysis of annual profit from whale-watching as a function of the discount rate in Philippine Peso (PHP) and United States Dollar (USD).

Discount rate	Profit PHP	Profit USD
1%	-717,660	-17,442
3%	-852,731	-20,725
5%	-1,035,607	-25,169
10%	-1,844,017	-44,817
20%	-7,513,048	-182,595

3.2 Bioeconomic model of spinner dolphins with to whale-watching

A total of 100 hours of data were collected during sighting surveys. The Kruskal-Wallis Test or chi-square test showed that there was a significant difference in species distribution. Spinner dolphins resulted in 50 percent of total sightings. Other cetacean species observed during the survey were pantropical spotted dolphin (*Stenella attenuata*) (20% of total sightings), dwarf sperm whale (*Kogia sima*) (10%), Risso's dolphin (*Grampus griseus*) (9%), and Fraser's dolphin (*Lagenodelphis hosei*) (1%). Unidentified species were ten percent of sightings. Box plots of each species' group size displayed outliers in sightings of spinner dolphins. Excluding outliers, group size of spinner dolphins displayed a normal distribution, with a majority of 20 to 30 individuals. Mean group size of spinner dolphins was 30.75 +/- SE 1.99 +/- 12.91, n = 42. Mean number of spinner dolphin groups per survey was 4.67 +/- SE 1.07 +/- 3.20, n = 9. Stage classes of spinner dolphins were 12.91%, 48.86%, and 38.24% of calves, juveniles, and adults respectively, however the harvest logistic model did not incorporate stage growth due to low sample numbers of each stage. An average of 4.36 whale-watching vessels and maximum of 10 vessels were seen per survey, excluding repeated vessel sightings. A maximum of 6 vessels were seen per cetacean sighting.

To provide alternative exploitation scenarios of whale-watching in Bais, conservative and non-conservative levels of effort were applied to a harvest logistic model of the population of spinner dolphins. Under the non-conservative scenario, effort was set to the total number of vessels reported to whale-watch each year, beginning at the year of the most recent abundance estimate of spinner dolphins in the southern Tañon Strait. Effort then remained at the current effort reported to whale-watch (E = 16), assuming all vessels operated each day and no new vessels were added to the whale-watching fleet in the future. If effort remained at current levels, the harvest logistic model predicted the spinner dolphin population to decrease to 19 individuals after 30 years whale-watching (See Figure 7). This was a 94 percent decrease in half the assumed carrying capacity of the population in the southern Tañon Strait.

Under conservative exploitation, current effort was limited to the average number of whale-watching vessels seen per day (i.e. 5 vessels at current year) and was kept at the level for the rest of 30 year simulation. The population initially decreased dramatically during previous years of open-access whale-watching and continued to decrease when effort was reduced (N_{30} =168) (See Figure 8).

However, when effort was restricted to three vessels at the current year and was kept at the level for the rest of the simulation, then the population increased (N_{30} = 237) (See Figure 9). The population initially decreased as effort restrictions were applied after the initial years of open-access whale-watching. Over a 100 year simulation, a constant effort of three vessels at current year allowed the spinner dolphin population recover to 80 percent of half its carrying capacity levels (N_{100} = 256) (See Figure 10). Population numbers before effort restrictions were during the initial years of unrestricted whale-watching.

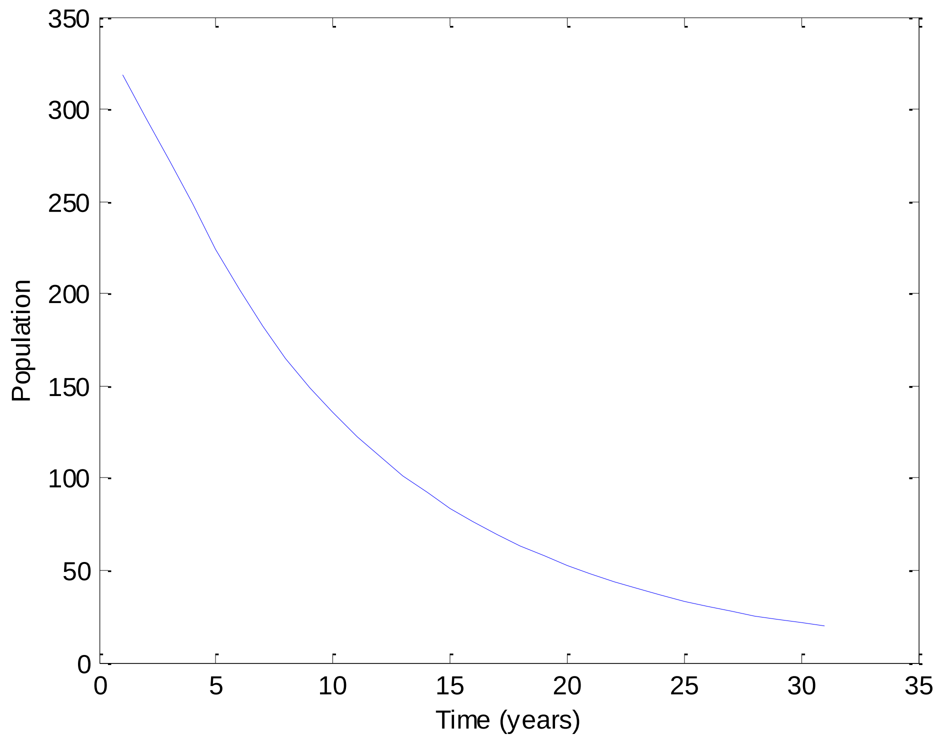

Figure 7. Predicted spinner dolphin population with whale-watching effort set to total number of operating vessels each year. N_1= 1/2k = 318, r = 0.04, q = 0.23, v = 0.07, b = 0.52, h > rk/4.

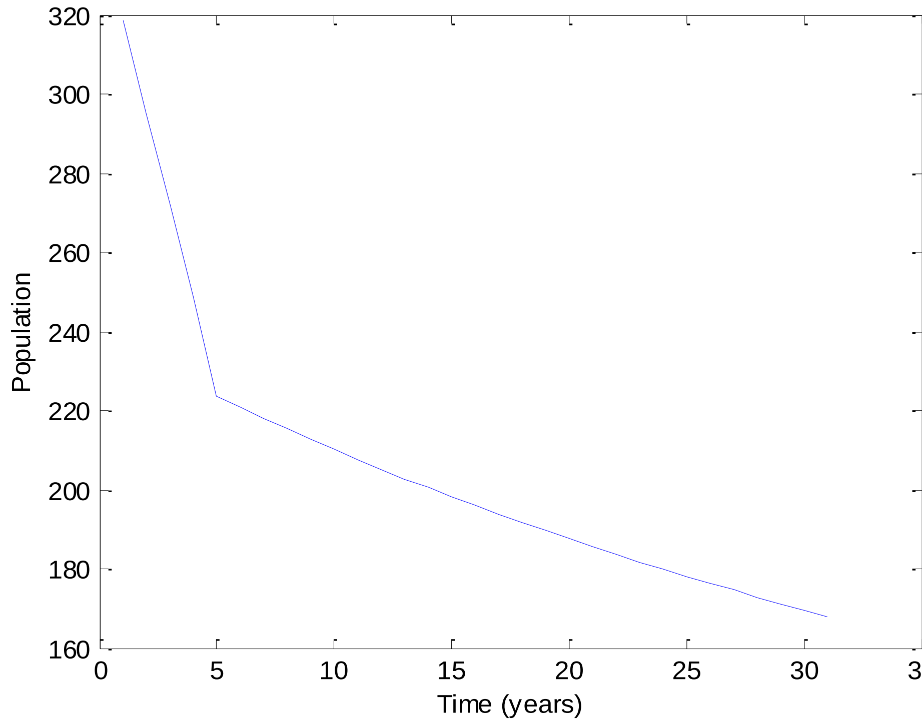

Figure 8. Predicted spinner dolphin population with previous effort set to total number of operating vessels each year and current effort restricted to average number of vessels seen per day. $N_1 = 1/2k = 318$, $r = 0.04$, $q = 0.23$, $v = 0.07$, $b = 0.52$, $h > rk/4$.

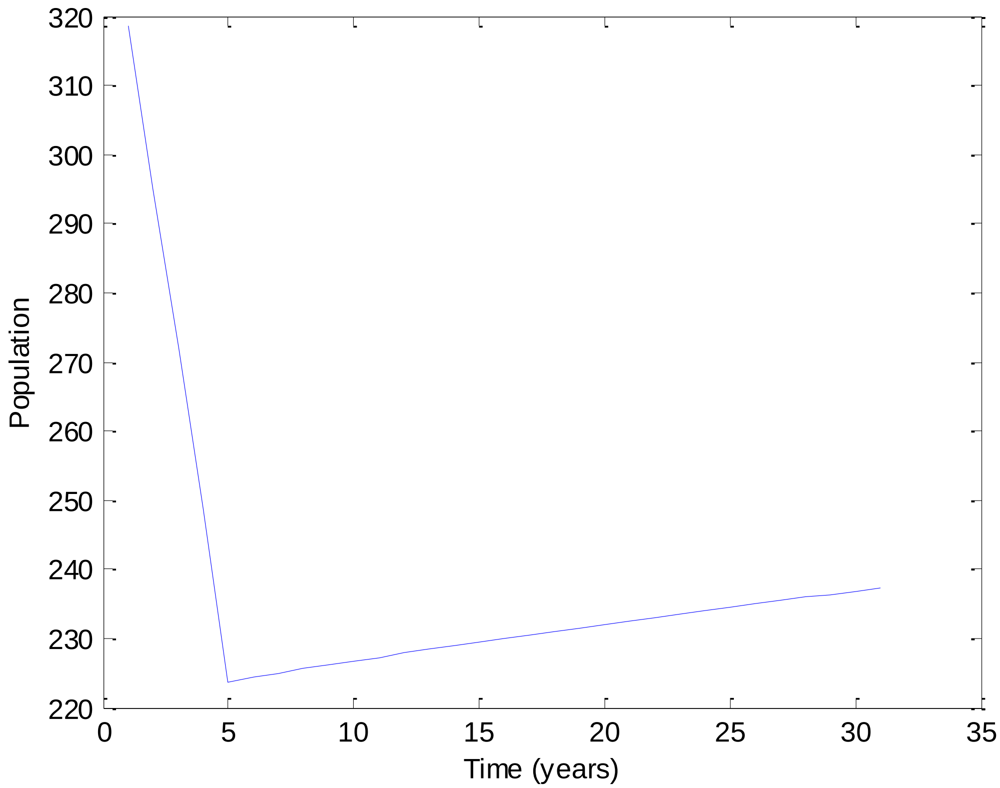

Figure 9. Predicted spinner dolphin population with previous effort set to total number of vessels operating each year and current effort restricted to 3 vessels per day. $N_1 = 1/2k = 318$, $r = 0.04$, $q = 0.23$, $v = 0.07$, $b = 0.52$, $h < rk/4$.

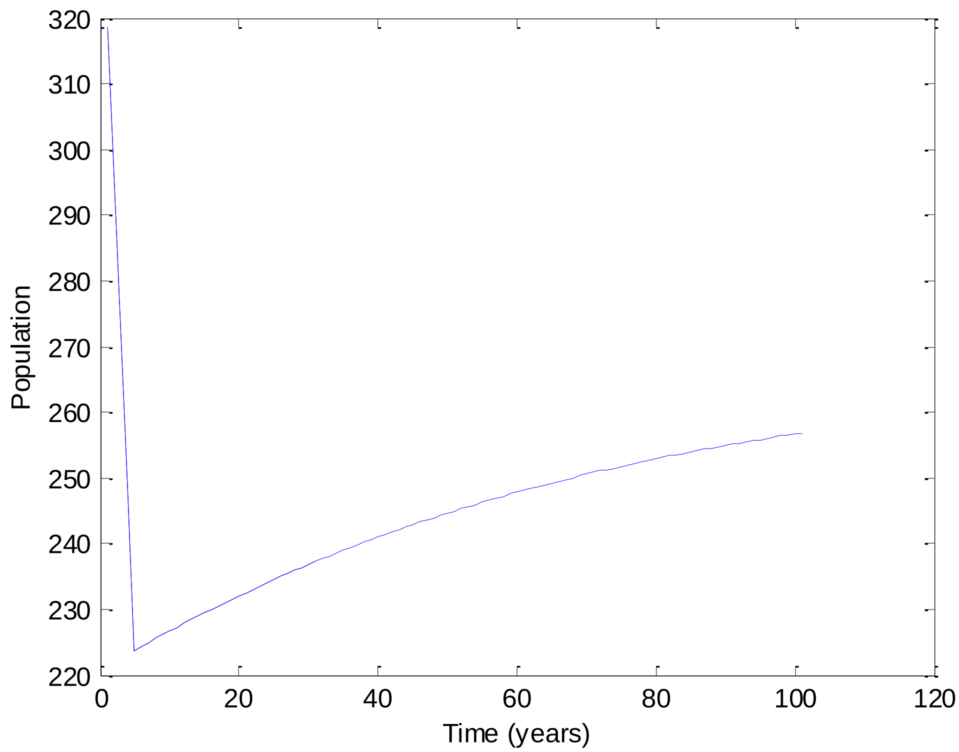

Figure 10. Predicted spinner dolphin population within 100 years of whale-watching with previous effort set to total vessels operating and current effort restricted to 3 vessels per day. $N_1 = 1/2k = 318$, $r = 0.04$, $q = 0.23$, $v = 0.07$, $b = 0.52$, $h < rk/4$.

Assuming all vessels did not operate each day, effort was set to the maximum number of vessels seen per day (i.e. E = 10 vessels each year, starting at the year of the most recent abundance estimate of spinner dolphins in the southern Tañon Strait). The population models produced similar results. When effort was kept at the maximum number of vessels seen per day, the population continued to decrease after 30 years of operation (See Figure 11). The population decreased 77 percent of half the carrying capacity (N_{30} = 73).

When effort was restricted to the average number of whale-watching vessels seen per day (i.e. 5 vessels at the current year) and was kept at the level for the rest of the simulation, the population still decreased (N_{30} = 173) (See Figure 12). The population initially decreased quickly during the initial years of open-access whale-watching. When effort was restricted to three vessels at the current year and was kept at the level for the rest of the simulation, then the population increased 70 percent of half the carrying capacity (N_{30} = 238) (See Figure 13). The population initially declined during the first few years of open-access whale-watching. Over a 100 year simulation, a constant effort of three vessels (starting at current year) allowed the spinner dolphin population to recover as well (N_{100} = 257) (See Figure 14). Population numbers before effort restrictions were during the initial years of whale-watching.

Stability analysis of lambda revealed that harvest was less than MSY ($h < rk/4$) when effort was restricted to three vessels. Negative values of lambda indicated increases in the population size and negative growth. Conversely, positive values of lambda indicated decreases in the population size and positive growth. The resulting population size after 30 years of whale-watching was near $k/2$. Similarly, the population approached *k/2* after 100 years of whale-watching (*N* = 237 – 257). The results of the bioeconomic models that predict the spinner dolphin population over time with variable whale-watching exploitation scenarios are summarized in Table 4.

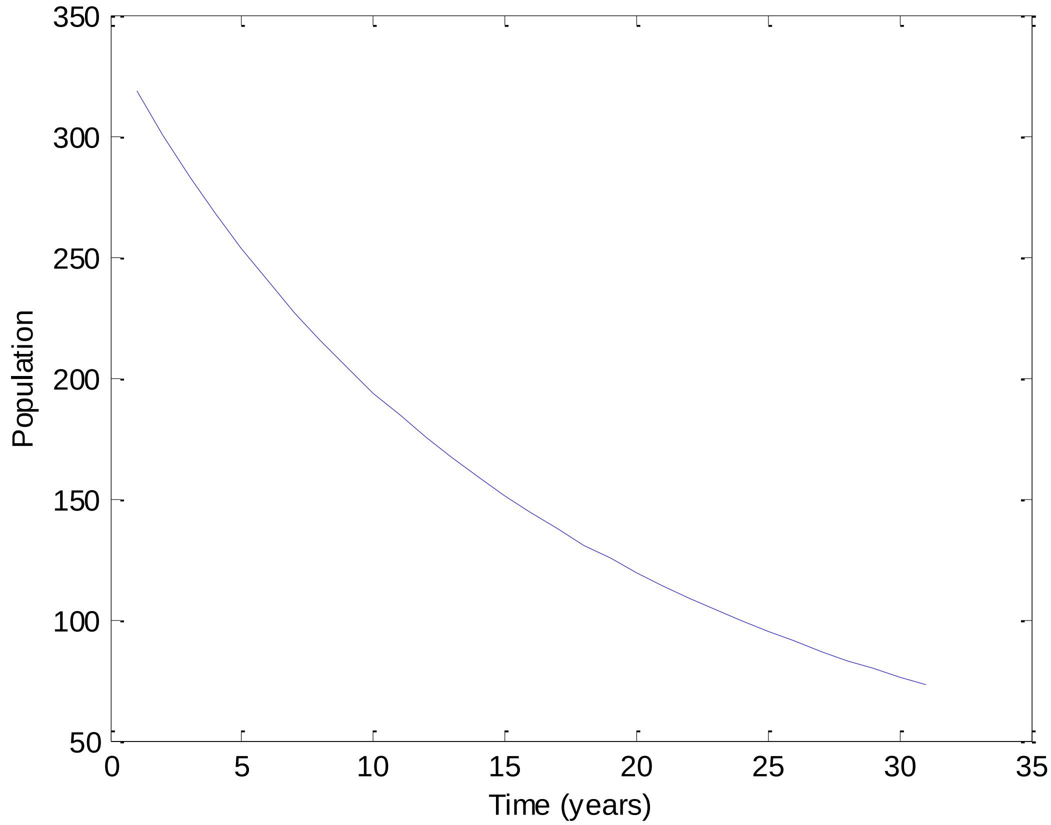

Figure 11. Predicted spinner dolphin population with effort set to maximum number of vessels seen per day. E = 10, N_1 = 1/2k = 318, r = 0.04, q = 0.23, v = 0.07, b = 0.52, h > rk/4.

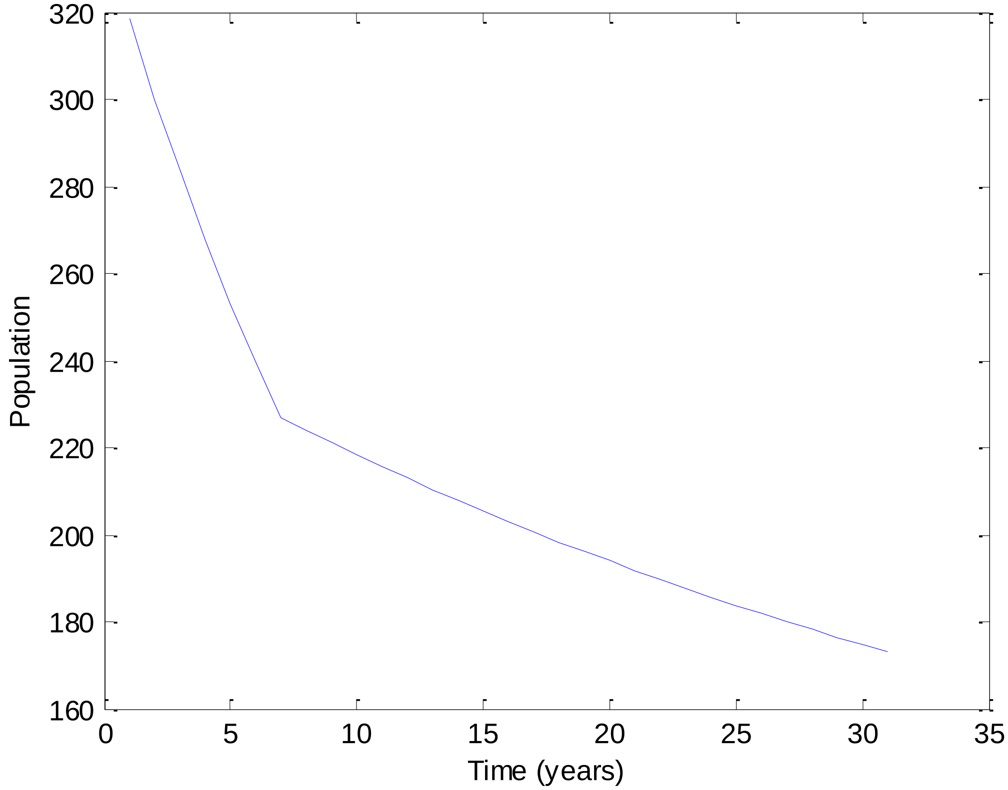

Figure 12. Predicted spinner dolphin population with previous effort set to maximum number of vessels seen per day (E = 10) and current effort restricted to average number of vessels seen per day (E = 5). $N_1 = 1/2k = 318$, r = 0.04, q = 0.23, v = 0.07, b = 0.52, h > rk/4.

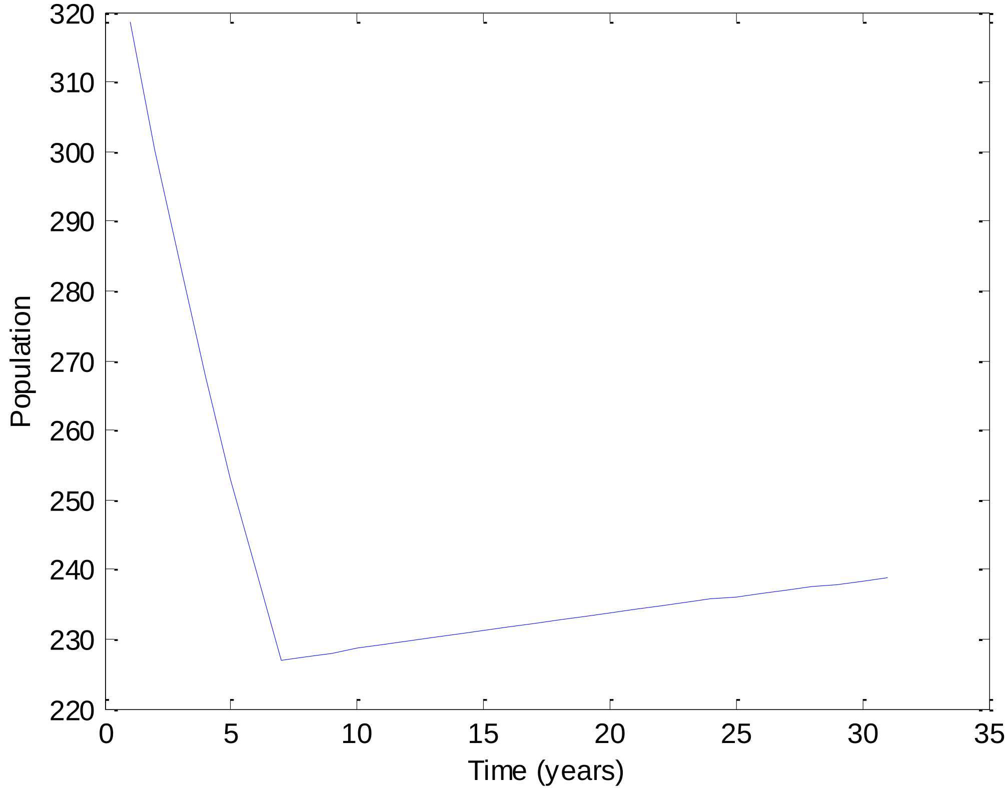

Figure 13. Predicted spinner dolphin population with previous effort set to maximum number of vessels sighted (E = 10) and current effort set to 3 vessels per day. $N_1 = 1/2k = 318$, $r = 0.04$, $q = 0.23$, $v = 0.07$, $b = 0.52$, $h < rk/4$.

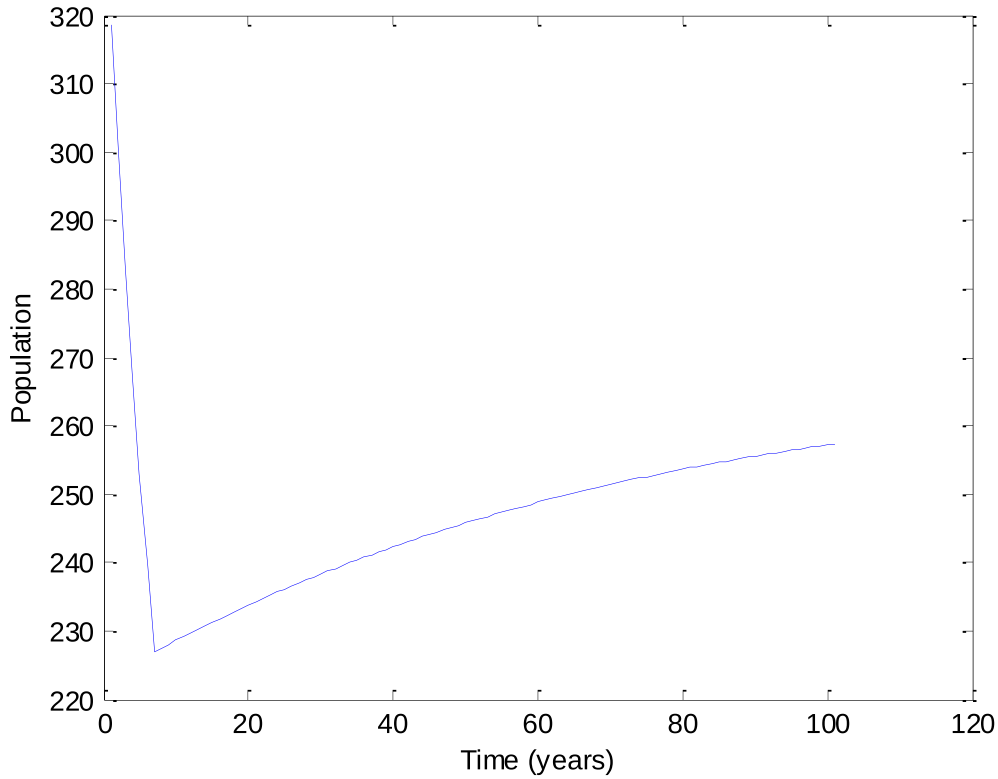

Figure 14. Predicted spinner dolphin population within 100 years of whale-watching with previous effort set to maximum number of vessels seen per day and current effort restricted to 3 vessels per day. $N_1 = 1/2k = 318$, $r = 0.04$, $q = 0.23$, $v = 0.07$, $b = 0.52$, $h < rk/4$.

Table 5. Predicted spinner dolphin population under conservative and non-conservative whale-watching effort in Bais, Philippines. Lambda λ is the derivative of growth rate with respect to population size, provided that harvest under whale-watching is less than the maximum sustainable yield ($h < rk/4$). K = 637, r = 0.04, q = 0.06, v = 0.25, b = 0.52.

		Population after restricted effort				
Initial open-access whale-watching effort (E)	Time (t *years*)	No effort restriction	Average vessels sighted (E = 5)	Recommended vessels (E = 3)	Harvest ($h < rk/4$)	Lambda (λ)
Total operating vessels (E = 16)	30	19	168	237	4.72	+/- 0.0204
	100	-	-	256	5.65	+/- 0.0134
Maximum vessels sighted (E = 10)	30	73	173	238	5.54	+/- 0.0144
	100	-	-	257	5.98	+/- 0.0099

4. Discussion

4.1 Overall Costs and Revenue

This was the first study to estimate the total annual costs and revenue from whale-watching operators in Bais, Philippines, and predict the spinner dolphin population from whale-watching exposure in the southern Tañon Strait. It provided data to locals for efficient, profitable and sustainable decisions in whale-watching operations. The study modeled alternative exploitation scenarios in which whale-watching effort was conservative and non-conservative.

The findings of this study indicated that operators exhibited differences in cost and revenue. The difference in revenue and cost between government and private vessels was especially notable. Vessels *Dolphin I* and *Dolphin II*, both of which were owned by the city of Bais, appeared to gain the most revenue as they booked the most trips of all operators. Scheduling, advanced training, amenities, and ticket price influence a tourist's decision on a particular whale-watching operator. Comparing all vessels, government vessels were trained in cetacean-safe boat approaches, accommodated the highest number of tourists and had a sink, shower, and head, of which other vessels did not possess. Also, it is possible that *Dolphin I* and *Dolphin II* book the most trips of all vessels because tourists were more informed about their availability. From a basic Google search, only the government vessels were stated to operate whale-watching although there were more private vessels available. As tourists were often recommended to contact the Bais City Tourism Office to schedule whale-watching trips, vessels owned by the government were often scheduled first. While *Dolphin I* and *Dolphin II* had the highest revenue, they also spent the most costs of all operators as their government staff received higher pay and their larger vessels required more fuel.

Of all cost types, total operating costs were the least spent; vessel *Vios* displayed the highest percentage of operating costs as it spent the most in fuel per year. Fuel consumption was higher for some operators because of less efficient engines, particularly for large vessels like *Vios*. In comparison, *Dolphin I* and *Dolphin II* had the least percentage of operating costs as their engines are more efficient and did not report opportunity costs of labor. Total fixed costs were the highest of all cost types as crews' wages cost more for operators than insurance, maintenance, permit fees or other fixed costs. Vessel *Unknown* displayed the highest percentage of fixed costs as their insurance costs were high. Vessels *Cristy I, Cristy II, Ezhra, Queen Mary*, and *Niko* displayed higher costs in capital as their initial vessel costs were high. Vessels *Dolly, Dolphin I* and *Dolphin II* also had initial high vessel costs, but their percentage of fixed costs were more than their overall capital due to larger wages.

Rather than displaying zero profit as an open-access industry, whale-watching in Bais exhibited negative profit. Some operators participate in other activities because whale-watching may not be fully support their livelihood. Fifty percent of operators reported opportunity costs of labor varying in the fishing, education and tourism industries. Vessel *Aroma* displayed the highest percentage of costs as its operator mainly functioned as a hotel; thus, their revenue from whale-watching was low.

As one can see from the sensitivity of profit to changes in discount rate, the selection of discount rate can have an impact on the discounted profit of businesses. Total annual profit from whale-watching in Bais was indirectly proportional to discount rate. As the discount rate increased, the investment of whale-watching became less valuable.

This happens because the higher the discount rate, the lower the initial investment needs to be in order to achieve the target yield. Private businesses, like most of the whale-watching operators, tend to discount at a higher rate in order to avoid high initial costs. Particularly in a developing country, high discounting may be the only affordable option. Moreover, whale-watching in Bais did not break even in the sensitivity analysis. Profit equal to zero was never reached and remained in negative values even when discount rate was set to one percent.

It is questionable whether whale-watching is a profitable business in the city of Bais. Operators may actually break even or gain profit from whale-watching if costs were misreported in the questionnaires. Operators possibly concealed that they had access to illegal fuel or paid lower wages to employees during the low season. Also, asset replacement could be required by authorities, such as lifejackets, however operators repurchased items to reduce spending. Also, memory failure, that is not having a precise memory of one's past behavior, possibly caused participants to over report data (Belli *et al*. 1999).

In addition, vessels may be used for other purposes, thus whale-watching practices may serve as a means to reduce fixed costs over an extended period. For instance, sport-fishing may be the primary operation of a vessel, however the vessel can reduce fuel costs by selling tickets to fish or whale-watch during one trip.

Hidden costs, such as asset values and increased effort, can explain why the whale-watching fleet persists in the face of economic losses. Operators possibly believe they are generating profit because they see immediate gains in revenue from trips and consider regularly scheduled payments into their budgeting such as fuel and wages. But other costs can go unnoticed; for example, capital costs can be miscalculated or ignored as they can be expensive assets that decrease in value over time.

Under open access, revenue becomes a stimulus for more capital and labor to enter the fleet, as seen in Bais with the increasing size of its whale-watching fleet and operators owning multiple vessels (Scott 1955). Operators work hard to detect cetaceans for the pleasure of potentially returning tourists, which leads to more effort and declines in harvest. As more vessels enter the fleet, less cetaceans inhabit the area. As a result, this requires vessels to increase their effort to detect cetaceans. Fleet capacity results from the investment choices made by individual operators (Clark 2010). If existing operators were to willingly reduce their whale-watching effort, additional operators are drawn into the open-access opportunity, with temporary economic gains. However, with limited entry, operators have less competition and can gain profit from limiting their effort in whale-watching.

4.2 Predicted Population

To develop economically and biologically sound whale-watching management guidelines, this study predicted the spinner dolphin population under whale-watching effort specifications. If Bais reduced effort in their whale-watching operations to five vessels per day (the average number of vessels seen whale-watching per day), the population continued to decrease throughout the period of whale-watching. However, if effort reduced to only three vessels per day, the spinner dolphin population increased to 80 percent of its initial population size. Although variable initial effort produced similar population models, the total number of known operating vessels was the more conservative parameter rather than the maximum number of vessels seen per day when modelling population dynamics under open-access whale-watching effort.

Stability analysis of lambda, the derivative of growth rate with respect to population size, indicated that lambda was positive after the population was exposed to 100 years of restricted whale-watching. A positive slope meant an increase in the population size, therefore an increase in the growth rate. As a result, the population moved away from equilibrium (i.e. away from extinction), as seen at year 30 and year 100 where $N < K/2$. By restricting effort, the population was allowed to recover from initial open-access whale-watching activities.

According to the theory of bionomic equilibrium, the whale-watching industry gains profit by reducing effort. As effort reduces and the population is allowed to grow from bionomic equilibrium to half its carrying capacity, the detectability of cetaceans grows with less effort and the operator pays less. But reduced effort is not likely with an open-access industry like that of Bais. When the maximum sustainable yield is harvested by an open-access industry, new operators enter the fleet thinking they can make individual profit (Suri 2008), as seen from the increase in whale-watching operators since the start of the business in Bais. Operators may rationally choose to deplete a cetacean population to a low level, even to extinction. For example, the economics of the whaling industry show that harvesting whales to extinction was most likely in the best interests of the whalers (Clark 2010). As an economic asset, whale stocks are unable to return more than about 2 – 5% per year, which is the average growth rate for whale populations. Harvesting the entire resource stock as quickly as possible is wise for an owner of the asset as it invests the profits in a more productive course. Investors are concerned with maximizing return; no one wants to invest in 5% earnings if investment opportunities are returning 10%. Slow-growth species competing in developing countries are particularly at risk of population decline as these countries tend to invest in fast growth opportunities. If marine mammals, forests, or grazing lands are unable to recover sufficiently, economically rational owners overexploit these resources (Clark 2010). This may further explain why our large, slow-growing charismatic animals, such as the tiger, elephant, and rhino, are on the verge of extinction.

If Bais continues to whale-watch at current effort levels, the spinner dolphin population decreases from the maximum sustainable yield. Through time, the population decreases as it is exposed to more vessels, causing effort to increase, and thus decreases profit for operators. Under current whale-watching effort, the spinner dolphin population was predicted to decrease by 94 percent in 25 years. The resilience of populations is due to ecological differences. When a population occupies an area where food availability is homogenous in time and space, dolphins move away from a disturbed area and do not travel far to continue activities. However, when the habitat contains patchy resources that are depleted, dolphins travel longer to resume activities after being temporarily displaced (Higham *et al.* 2014). Like spinner dolphins of the southern Tañon Strait, cetaceans residing year round in the same home range develop heterogeneity in space use such as for ease of prey capture. Active hotspots have disproportionate levels of whale-watching effort because of economic incentives. Thus, resident cetaceans are driven to use less suitable habitat to rest or feed in more risky areas (Higham *et al.* 2014).

4.3 Data Limitations

Long-term parameter estimates, such as abundance, life history, catchability, vessel exposure and unsuccessful reproduction, are needed of the spinner dolphin and other cetaceans of Bais, Philippines, to build more accurate population models. While the need for high-quality demographic data is clear, the means of getting them is not. Coastal environments and regions without adequate budgets for conservation have limits on survey design (Dalton 2003 and Aragones *et al.* 1997). To mimic the typical whale-watching route, data was collected on a platform of opportunity, in which the destination route could not be determined by the researcher. It was not possible to survey in a zig-zag line transect design, of which is usually used for cetacean surveys to ensure efficient coverage. Although vessel behavior was collected, the length of vessel-cetacean interaction time was not accurately obtained for thorough analysis. The decision to remain at a vessel-cetacean sighting was also not determined by the researcher. However, this study was an inexpensive method to detect areas of high density that were hotspots to whale-watching areas.

It is difficult to distinguish whether population variabilities are caused by whale-watching exposure, other anthropogenic, or natural effects (Suri 2008). Defining the threshold of harm is challenging as little is known about whether and when short-term responses turn into long-term biologically significant impacts on reproduction, physical condition, distribution, and habitat use (Bejder *et al.* 2006). The likelihood that vessel exposure causes population-level effects depends on the ability to alter life-history parameters on a proportion of a cetacean population exposed to whale-watching (Higham *et al.* 2014). Some populations are exposed to high levels of behavioral disturbance but seem to not be affected. Some populations are exposed to very low levels of disturbance and appear to cause serious shifts of population trajectory.

For simplicity of the model, several parameters were kept constant. For example, catchability was constant for each vessel and sightings were assumed to be non-repetitive. In reality, catchability is not always constant and may vary depending on available resources of the whale-watching fleet due to advancement in technology and whale-watching power through time (Suri 2008). The spatial distribution of spinner dolphins and whale-watching vessels were assumed to be homogeneous in this study. However, a variably distributed resource stock and effort are more representative (Suri 2008). Setting effort to the total number of operating vessels or maximum number of vessels seen per day assumed that vessels operate each day with equivalent capabilities. To increase whale-watching power, operators change to larger boats, add extra gear and navigation equipment. However, this gradual expansion of effort through technology, also known as effort creep, was not incorporated into the model. Maximum sustainable yield is not necessarily the most profitable exploitation of a resource. For a naturally fluctuating resource, annual harvest is unsustainable at low abundance levels. For competitive harvesting, regulation based only on MSY leads to overcapacity and near-zero profit.

Analysis was also limited when collecting data from human subjects. Data can be inconsistent or insufficient due to misinterpretation of questions.

4.4 Recommendations and Future Research

A limited entry is strongly recommended for whale-watching in Bais. To sustain the spinner dolphin population, a fixed number of whale-watching permits and trips per vessel must be awarded, in which all operators are on a rotating schedule that allows three vessels to whale-watch per day. Clearly defined legislation must have authority that revokes operator licenses (Higham *et al.* 2014). Economically, limited vessels rotating on a schedule allows an even distribution in ticket sales amongst private and government operators.

To increase the profit of whale-watching in Bais, marketing must be improved. Most private operators did not indicate spending costs in advertisement. If operators share costs in advertisement, their less expensive tickets and intimate setting on smaller vessels attract tourists. Utilizing Facebook, Yelp, or Foursquare particularly draws the younger and more educated generation that rely on online resources for their travels and make up majority of Bais' whale-watching audience. The addition of restroom facilities and sanitation maintenance fabricated from government spending make Canibol and Capiñahan Wharf more presentable and comfortable. Souvenir shops and snorkel gear rentals generate more profit to operators and locals as well. Raising ticket prices is an option as they are much less expensive than tickets sold at other whale-watching locations, however tickets must be affordable to Filipinos as they are the majority of Bais' tourists. Also, reducing the total time of trips in Bais, which are generally much longer than whale-watching trips in other locations, will also decrease fuel costs.

Forty-two percent of whale-watching vessels sighted during survey days exhibited invasive vessel behavior towards cetaceans. Tourist satisfaction levels are associated with increased likelihood of observing aerial displays or specific cetacean behavior. Hence, vessels do not only interact with cetaceans in their preferred habitat, but vessels also favor areas used for non-travelling dolphin activity states (Higham *et al.* 2014). Teaching non-invasive methods of whale-watching can be offered to known operators that exhibit patterns of disturbance. In addition, whale-watching vessels are recommended to operate only under supervision of trained and certified guides. Only 50% of the fishers interviewed in Bais City were familiar enough with marine mammals to be able to accurately describe them to species (Aragones *et al*. 2014).

For future research, prey availability and predation risk of the spinner dolphin population in the southern Tañon Strait can be researched for management action. Cetaceans are in areas that maximize energy intake and minimize energy output. As an environment becomes more harmful, cetaceans abandon prey-rich habitat to minimize mortality risks (Higham *et al.* 2014). If the population is spatially constrained, feeding on specific hotspots, then a spatial management plan of whale-watching is recommended. If the population is temporarily constrained (e.g. time-activity budgets driven by a daily cycle of prey availability), then a management plan must consider temporal variation and include time closures (Higham *et al.* 2014). Currently, there are time-out area closures for whale-watching in Australia, New Zealand, Greater Carribean and South Atlantic, and proposed areas in the Mediterranean and Black Sea. Photo-identification studies of the resident spinner dolphin population can provide more accurate parameters, such as abundance, vessel exposure, and unsuccessful reproduction, for the harvest logistic model. The quadratic equation can be applied to abundance counts to estimate vital rates of each stage class. Furthermore, total revenue and costs of each operator under limited entry restrictions can be calculated. To optimize the profit of whale-watching in Bais, ticket price variations can be evaluated.

4.5 Conclusions

This was the first study to predict the spinner dolphin population and estimate the total annual profit from whale-watching in Bais, Philippines. The model can be applied to other locations where whale-watching is developing. Failure to fully recognize that an economy is dependent on all types of capital, including natural resources, is the main reason for the persistent failure of economic systems. Therefore, it is crucial to have effective management in developing whale-watching regions that monitors cetacean populations and establishes thresholds of which are adaptive to change over time.

Overall, it is inevitable that common-property resources, such as cetaceans, are exploited unsustainably and resource destruction can lead to the collapse of societies. The current picture, in which most expert economists ignore resource conservation and in which most ecologists disregard economics, must yield to a science of resource management based on principles of bioeconomics. The practical application of bioeconomics is essential if the vision of sustainable development is actually enforced (Clark 2010).

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6. Appendix

Survey for whale-watching operators (Modified from Schowoerer 2007)

Consent Form for Participation in the Research Study Entitled
Optimal whale-watching for the Philippines:
A bioeconomic model of the spinner dolphin (Stenella longirostris)

IRB protocol #

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Site Information
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Dumaguete City Hall
Cmpd, Sta. Cataline St.
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What is the study about?
You are invited to participate in a research study. The goal of this study is determine the best amount of whale-watching to receive the highest income at maintained dolphin population levels.

Why are you asking me?
We are inviting you to participate because you are currently working with a whale-watching company. There will be between 5 and 10 participants in this research study.

What will I be doing if I agree to be in the study?
You will answer a 21 questionnaire about the whale-watching company. You will not be asked questions about your job position or opinion of the watching-company. You will choose to complete a vocal interview OR written survey. If you choose an interview, you will be interviewed by the researcher, Ms. Santos. You may take as much time as needed to complete the questionnaire. The questionnaire should take you no more than 1 hour to complete. If during the interview the researcher learns that you are not an English-speaking worker with the whale-watching company that makes you ineligible for the study, Ms. Santos will end the interview.

Is there any audio or video recording?
This research project will include audio recording of the interview. This audio recording will be available to be heard by the researcher, Ms. Allison Santos, personnel from the IRB, and the following committee members: Dr. Bernhard Riegl, Dr. David Kerstetter and Dr. Lemnuel Aragones. The recording will be transcribed by Ms. Allison Santos. Ms. Santos will conduct the interview in an area of your choice while transcribing the interviews to guard your privacy. The recording will be kept securely in Dr. Riegl's laboratory in a locked cabinet. The recording will be kept for 36 months from the end of the study. The recording will be destroyed after that time by shredding the tape. Because your voice will be potentially identifiable by anyone who hears the recording, your confidentiality for things you say on the recording cannot be guaranteed although the researcher will try to limit access to the tape as described in this paragraph.

What are the dangers to me?
Risks to you are minimal, meaning they are not thought to be greater than other risks you experience everyday. Being recorded means that confidentiality cannot be promised. Sharing the data about the whale-watching company may make you anxious or bring back unhappy memories. If this happens Ms. Santos will try to help you. If you have questions about the research, your research rights, or if you experience an injury because of the research please contact Ms. Santos at 1-949-584-6582. You may also contact the IRB at the numbers indicated above with questions about your research rights.

Are there any benefits to me for taking part in this research study?
There are no benefits to you for participating.

Will I get paid for being in the study? Will it cost me anything?
You will be paid 820 Philippine pesos (about $20 USD) if you complete 100% of the

questionnaire. If you complete at least 50% of the questionnaire, you will be paid 410 Philippine pesos. There are no costs to you for participating in this study.

How will you keep my information private?

The questionnaire will not ask you for any information that could be linked to you. The transcripts of the tapes will not have any information that could be linked to you. As mentioned, the tapes will be destroyed 36 months after the study ends. All information obtained in this study is strictly confidential unless disclosure is required by law. The IRB, regulatory agencies, or Dr. Bernhard Riegl may review research records.

What if I do not want to participate or I want to leave the study?

You have the right to leave this study at any time or refuse to participate. If you do decide to leave or you decide not to participate, you will not experience any penalty or loss of services you have a right to receive. If you choose to withdraw, any information collected about you **before** the date you leave the study will be kept in the research records for 36 months from the conclusion of the study but you may request that it not be used.

Other Considerations:

If the researchers learn anything which might change your mind about being involved, you will be told of this information.

Voluntary Consent by Participant:

By signing below, you indicate that

- this study has been explained to you
- you have read this document or it has been read to you
- your questions about this research study have been answered
- you have been told that you may ask the researchers any study related questions in the future or contact them in the event of a research-related injury
- you have been told that you may ask Institutional Review Board (IRB) personnel questions about your study rights
- you are entitled to a copy of this form after you have read and signed it
- you voluntarily agree to participate in the study entitled *Optimal whale-watching for the Philippines: A bioeconomic model of the spinner dolphin (Stenella longirostris)*

Participant's Signature: ___________________________ Date: ________________

Participant's Name: ______________________________ Date: ________________

Signature of Person Obtaining Consent: ______________________________

Date: ________________

A. General Information

1. Is the company privately owned? If yes, what proportion of the company is owned locally?
2. How long has the company operated in whale-watching?
3. How many trips, passengers and/or vessel hours did the whale-watching company have in the past 10 years? Please choose at least one category and complete for as many years as you can.

Year	Trips	Passengers	Vessel Hours
2012			
2011			
2010			
2009			
2008			
2007			
2006			
2005			
2004			
2003			

B. Whale-watching Vessels

1. Are the vessel(s) used for other operations (e.g. fishing)? If yes, what?
2. What percentage is used for whale-watching?
3. What are the capacities of the vessel(s) (number of passengers) and motors (horsepower)?
4. How many 2-stroke and 4-stroke engines does the company have?

C. Costs and Revenue

1. Please complete the table below about the employees in the whale-watching company.

	Salary			Number of employees	
Job Position	Wage	Length of employment	Total salary (pesos per year)	Local	Non-local
Manager					
Crew					
Maintenance					
Office					
Other					

2. Please complete the table below about the costs for the whale-watching company. Please select one type of cost that is applicable to the item.

			Choose one	
Item	Quantity	Item life (years)	Cost (pesos)	Annual cost (pesos per year)
Rent for land/building				
Advertisement				
Insurance				
Vehicles and trailers				

Boats				
Motors				
Fuel				
Life jackets				
Radios, first aid kit, etc.				
Boat maintenance				
Taxes, permits & other fees				
Other				

3. Please complete the table below about the trip lengths of the company's whale-watching season. Early/late season is when there are less whales and dolphins and peak season is when there are more whales and dolphins.

	Percent of total trips	Fuel (liters per trip)	Trip length (hours)
Early/late season			
Mid/peak season			
Other			

4. If the whale-watching company is co-operative/union, how is the remaining income shared or distributed, after costs are deducted? How much of the income contributed to the co-operative/union covers the costs?

5. Please complete the table below about the types of passengers and the proportion of the whale-watching trips that are these passengers.

	Walk-in	Group/bus	Agency	Cruise ship	Other (Please specify)	
Percent of trips						
Ticket Price						

6. Are the ticket prices different during early, mid, peak and late season, or for groups, senior citizens, students or children? If yes, what price(s)?

D. Whale-watching Permits

1. Who holds the whale-watching permit?
2. How long has the company had the permit?
3. How many flags come with the permit?
4. How does the company decide on who uses the flags on a certain day?
5. Are the flags rented or sold (temporarily or permanently)? If yes, how?

E. Whale-watching Training and Education

1. What are the minimum requirements for a hired captain?
2. Do the captain(s) and/or crewmen receive training? If yes, what does the training consist of (e.g. whale-watching boat approaches, boat safety) and who provides the training?
3. Is there a naturalist during the whale-watching trip that educates the passengers about whales and dolphins? If yes, what topics are discussed (ie. conservation, identification, behavior, distribution, etc.)?