An Ecosystem Approach for Scientific Monitoring and Assessment of the The Laguna San Ignacio Wetlands Complex

Jorge Urbán R.
Autonomous University of Baja California Sur, La Paz, B.C.S., Mexico
E-mail: jurban@uabcs.mx

Steven L. Swartz
Cetacean Research Associates, Maryland, USA.
E-mail: kabloona15@comcast.net

Resumen Ejecutivo

Este es un intento de un Monitoreo Científico del Complejo de Laguna San Ignacio y sus humedales (LSIWC, por sus siglas en inglés) con un Enfoque Ecosistémico a través de un programa de monitoreo científico de largo plazo que proveerá de la información científica relevante necesaria para el manejo de los recursos de la laguna y contribuirá a solucionar preguntas y preocupaciones relacionadas con el desarrollo, el ecoturismo y en general con la sustentabilidad de LSIWC a través del tiempo. El estado del ***ecosistema*** lagunar será monitoreado rutinariamente midiendo una serie de parámetros físicos y biológicos claves o ***"indicadores ecológicos"*** que: (1) Proveerán de un índice de salud ecológica de la laguna y sus recursos marinos biológicos (p.e. ballenas, delfines, tortugas, algunos peces, bivalvos, aves, plancton, calidad del agua), y (2) Asegurarán en el largo plazo que la información científica sea utilizada para evaluar las tendencias de la vida marina que depende de la Laguna San Ignacio como su hábitat principal. El programa también será una plataforma de entrenamiento para que estudiantes de posgrado se experimenten en la investigación de campo de la conservación de la vida silvestre y aprendan las destrezas que les servirán cuando prosigan sus carreras en la conservación de la vida silvestre. El programa patrocinará talleres anuales donde se presentarán los hallazgos del programa a un grupo de avaluadores, administradores de los recursos de la laguna, inversionistas y público general, y considerará los resultados de la evaluación para mejorar el contenido del programa científico. El programa se asociará y coordinará sus actividades con otros grupos para investigar varios aspectos de LSIWC (p.e. Probatura-Noroeste).

Las actividades se diseñarán con base en investigaciones y monitoreos previos de algunas especies en la laguna (p. e. ballena gris), pero también iniciará líneas de investigación adicionales que complementarán los estudios que se están llevando a cabo incluyendo el establecimiento de valores de referencia de la calidad del agua de la laguna y de la producción primaria, así como prospecciones de mamíferos marinos diferentes a los de ballena gris (p. e. delfines y lobos marinos), tortugas marinas, aves marinas y aves acuáticas (p. e. monitoreo de los depredadores tope). En el largo plazo se espera que cada invierno se adicionen nuevos componentes científicos al programa para ampliar el alcance y duración de los estudios que constituirán el ***"enfoque ecosistémico"*** para estudiar esta área de vida silvestre tan particular y extenderla a las cuatro estaciones del año.

Executive Summary

It is the intent of the Ecosystem Approach for Scientific Monitoring for the Laguna San Ignacio Wetlands Complex (LSIWC) to establish a long-term sustained science based monitoring program that will provide scientific information relevant to lagoon resource management questions and concerns about development, ecotourism, and the sustainability of the LSIWC over time. The status of the lagoon ***ecosystem*** will be monitored routinely by measuring a suite of key physical and biological parameters or "***ecological indicators***" that will: (1) provide an index of the ecological health of the lagoon and its living marine resources (e.g., whales, dolphins, turtles, select finfish & shell fish, birds, plankton, water quality), and (2) ensure over the long term that scientific information is available to evaluate trends in the marine life that depend on Laguna San Ignacio as a primary habitat. The program will provide a training ground for graduate students to experience applied wildlife conservation field research and to learn the skills that will serve them should they pursue careers in wildlife conservation. The program will sponsor annual workshops to present the program findings to a group of peer reviewers, lagoon resource managers, stakeholders and the public, and take recommendations from the review to update the content of the science program. The program will form partnerships and coordinate its activities with other groups investigating various aspects of the LSIWC (e.g., Pronatura-Noroeste).

The program's activities will build upon previous research and monitoring of specific species (e.g., gray whales) in the lagoon, but also initiate additional areas of investigation that will complement ongoing studies including establishing baseline values for the lagoon's water quality and primary production, and surveys of marine mammals other than gray whales (i.e., dolphins and sealions), sea turtles, marine birds and waterfowl, (e.g., apex predator monitoring). In the long-term it is hoped that each winter additional scientific components will be added to the program to broaden the scope and duration of the studies that will make up the ***"ecosystem approach"*** for studying and monitoring this unique wildlife area, and expand into all four seasons.

Figure 1. Laguna San Ignacio and the surrounding Wetlands Complex looking northward from the entrance toward the islands in the northernmost portion of the lagoon.

Figure 2. Following its designation as a Marine Protected area under Mexican federal law, Laguna San Ignacio became the focal point for thousands of eco-tourists that come to view its unique marine wildlife each year.

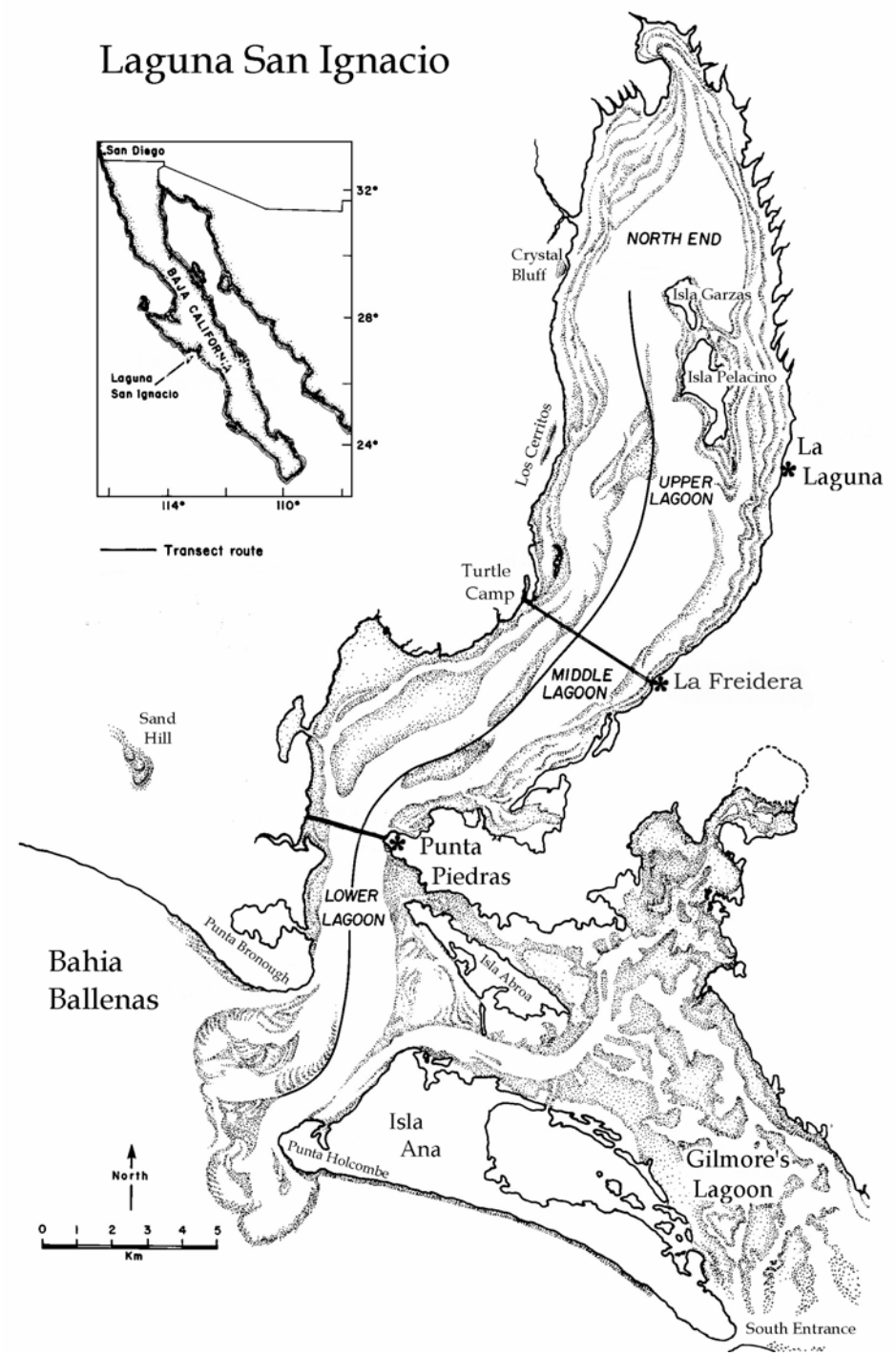

Figure 3. Chart of Laguna San Ignacio showing the deep water channels, shallow sand bars, mudflats and mangrove estuaries along its interior shores, and the vessel transect track (solid black line) used to count the number of gray whales in the lagoon during the winter.

An Ecosystem Approach for Scientific Monitoring and Assessment of the The Laguna San Ignacio Wetlands Complex

Vision, Mission, Goals, and Strategy

It is the ***Vision*** of the Laguna San Ignacio ecosystem science program to support the maintenance of a marine protected area that hosts sustained, low-impact, environmentally friendly eco-tourism and fishing operations for the economic and social benefit of the local communities, Mexico, and to benefit the wildlife that depend on this unique coastal marine ecosystem. Achieving this vision requires a scientific basis for management.

It is the ***Mission*** and long-term ***Goal*** of the Laguna San Ignacio ecosystem science program to develop and implement a multi-year, sustained ecosystem science program that would continue to provide wildlife and land managers and developers with information on the status and trends of the Laguna San Ignacio Wetlands Complex (LSIWC). Research and monitoring projects will provide information to address complex ecosystem issues at scales appropriate to management questions, and that recognize the natural and human-related mechanisms affecting the ecosystem. Such science based information is fundamental to evaluate development and conservation alternatives and options, and to assess the outcome of management and conservation measures implemented to determine if they achieve their intended purposes.

The ***Strategy*** for the Laguna San Ignacio ecosystem science program is to begins with pilot studies that build on the results of former and existing research and monitoring programs (*e.g.*, gray whale monitoring) and to expand those projects to include other biological and physical components of the ecosystem (*e.g.*, turtles, fisheries, whale-watching, water quality & productivity, *etc*.). The program will provide academic employment and training for graduate students interested in careers in wildlife conservation science. It will provide a forum for local fishermen, businesses, and residents to contribute their observations and information to the overall knowledge base for the lagoon and surrounding region. Research findings and information will be made available in published reports, at workshops and symposia, and on the Program's internet web-site.

Project Overview

Chronology of the Laguna San Ignacio Science Program

Dr. Steven L. Swartz and Ms. Mary Lou Jones conducted the first systematic studies of gray whales in Laguna San Ignacio from 1977-1982. In subsequent years other scientists that came to the lagoon included Bruce Mate and Jim Harvey who conducted early radio-tagging research, Jim Sumich and his students researched gray whale calf growth and energetic, and Marilyn Dahlheim conducted the first bioacoustics research. Little research was conducted between 1986 and 1995.Dr. Jorge Urbán R., his colleagues and students resumed abundance surveys for gray whales in 1996. Beginning in 2002, Swartz and Urbán collaborated to rescue and archive historic photographic identification data for gray whales, and developed the first Photo-ID Database for the Baja California lagoons. They began developing the "ecosystem science program concept" in 2005, and in 2006 proposed additional scientific investigations on other marine species and aspects of the lagoon ecosystem to complement research and monitoring of gray whales. In 2007 they joined forces with Chris Pesenti of Pro-Peninsula, to bring a social-economic component to the science program. Pro-Peninsula is a leading nonprofit organization that supports conservation activities throughout the Baja California peninsula to empower communities and organizations to protect and preserve their environment. The winter of 2008 will mark the second year of the "ecosystem science" program at Laguna San Ignacio.

Conservation Status

Laguna San Ignacio is the center of a unique marine ecosystem surrounded by, and part of the “Vizcaíno Biosphere Reserve” established by Mexican President de la Madrid in 1988. Previously, in 1979 then Mexican President José López Portillo declared Laguna San Ignacio a whale refuge and maritime tourist attraction zone. The lagoon is included in the UNESCO World Heritage Site: “Whale Sanctuary of El Vizcaíno.”

The "Laguna San Ignacio Wetlands Complex" (LSIWC) comprises 248-miles of wetlands coastline that includes intertidal mudflats, salt flats, sandy beaches and red-mangrove estuaries (Figs. 1-3). As one of the world's most biologically significant coastal sites (Wildcoast 2006), the lagoon is best known for the gray whales that congregate there each winter to breed and calve. However, it is also home to dolphin, sealions, sea turtles, commercially important fish and shellfish, and multitudes of migratory waterfowl, and shore birds. Protected species such as Osprey, sea turtles, Peregrine falcons, and desert iguanas are included in its fauna.

World wide attention was focused on Laguna San Ignacio in the late 1990s when it was targeted as the site for an industrial scale solar salt production facility; a project that would have significantly altered the lagoon ecosystem, perhaps irreversibly. Since the

defeat of that proposal, local residents, fishing co-operatives, and eco-tourism entrepreneurs have begun developing eco-tourism focusing on the winter-time abundance of gray whales. Today these companies annually host thousands of whale-watchers and eco-tourists from many countries. Through education and responsible management, they are striving to become stewards of the "ecosystem" and to maintain a balance between eco-tourism and the biological integrity of the lagoon as an alternative to industrial development of the area. As a hedge against future development threats, a consortium of environmental groups and local business organizations known as The San Ignacio Lagoon Alliance. Led by the non-profit organization Wildcoast (www.wildcoast.net), the Alliance has developed the "Conservation Plan for the Laguna San Ignacio Wetlands Complex" (Wildcoast 2006), and they have begun to purchase and/or economically secure the future development rights for the ejidos that control the wetlands surrounding the lagoon (Fig. 5).

Figure 4. White pelicans (*Pelecanus erythrorhynchos*) are one of the migratory bird species that utilize Laguna San Ignacio and its marine resources during the winter months.

The Ecosystem Science Program

The ecosystem science program at Laguna San Ignacio strives to promote social awareness and stakeholder participation in the conservation of this unique marine protected area, while promoting science based sustainable development alternatives, and local economic development that is in balance with the natural components of the region. The program is based on the fundamental concept that responsible stewardship of marine ecosystems and living marine resources requires a sound scientific basis to support environmental monitoring requirements, principles, needs, and sustainable use practices over the long-term.

Over time it is envisaged that this science program will become permanent activity in Laguna San Ignacio supported financially by the beneficiaries of the LSIWC, namely local governments, business interests, and stakeholders that have economic and social-cultural interests in sustaining a healthy lagoon ecosystem for generations.

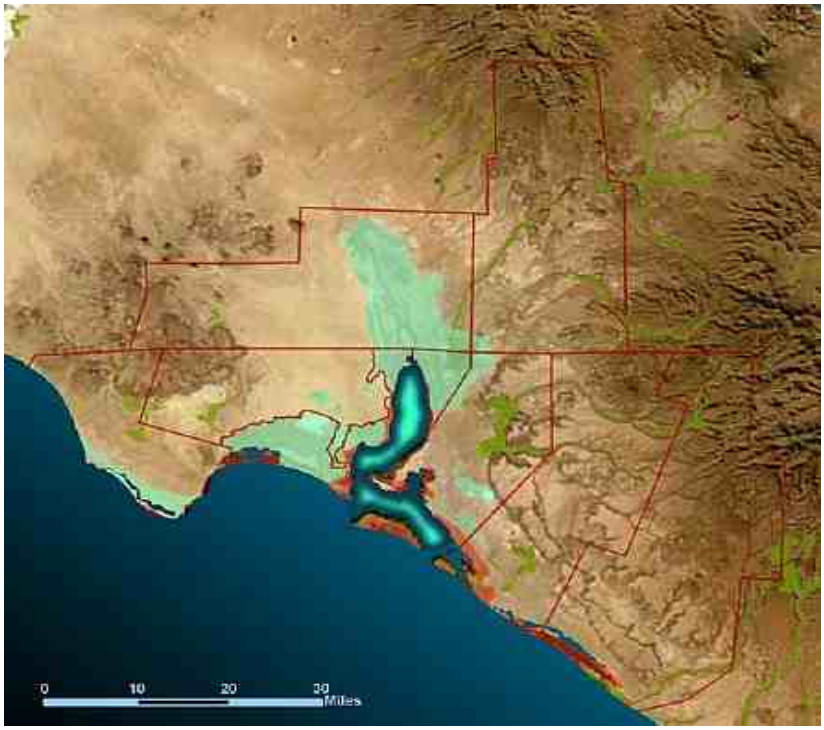

Figure 5. Laguna San Ignacio showing the Ejido boundaries (red lines) (from WildCoast 2006)

Ecosystem Approach to Research and Monitoring: Ecosystem monitoring focuses on a "*core suite of "indicator species and parameters"* that are measurable, and respond in ways that are indicative of the status of the ecosystem. Examples of indicator species include gray whales, bottlenose dolphin, sealions, sea turtles, marine birds and waterfowl, and the oceanographic parameters of the lagoon (e.g., water quality, temperature, salinity and primary productivity).

These "ecological indicators": (1) provide an index of the ecological health of the lagoon and its living marine resources (*e.g.*, whales, dolphins, turtles, select finfish & shell fish, birds, plankton, water quality), and (2) ensure over the long term that scientific information is available to evaluate trends in the marine life that depend on Laguna San Ignacio as a primary habitat. These data are analyzed in the context of larger scale environmental changes, trends and processes that affect the lagoon ecosystem to evaluate the contribution to observed changes attributable to human activities within the LSIWC and the contribution of natural external forces (*e.g.*, global climate change) and/or some combination of both.

It is hoped that each year additional scientific investigations will be added to the program to broaden its scope and expand the *"ecosystem approach"* for studying and monitoring this unique wildlife area. Over time, it is envisaged the program will include monitoring of a range of marine wildlife throughout the year - winter, spring, summer, and fall.

Figure 6. Gray whale breaching in Laguna San Ignacio.

An ecosystem approach to scientific monitoring: (1) Provides an "system-wide" context for interpretation of the trends of lagoon use by populations of living marine resources (*e.g*., declines in whale counts and migratory birds); (2) Contributes to an understanding of interactions and relationships between and among species and their physical habitats (*e.g.*, predator and prey dynamics, influence of water temperature and salinity on marine production, effects of climate change, or the combined effects of fishing, human development and whale-watching on the lagoon ecosystem); (3) and Generates scientific perspective that is more comprehensive than single species focused research and thus reduces uncertainty in scientific advice available to resource managers.

Figure 7. Red-mangrove (*Rhizophora mangle*) thrive along the shores of Laguna San Ignacio and provide habitat for marine birds like the Whimbrel (*Numenius phaeopus*) and the White Ibis *(Eudocimus albus*) as well as nurseries for many species of marine fish that populate the lagoon.

Program Review Workshops and Outreach: The ecosystem science program's content, findings, and conclusions are presented each year to a group of independent subject experts at peer review workshops held each fall (generally in September). These experts provide recommendations on the: (a) appropriateness of proposed monitoring methods; (b) adequacy of the planned monitoring effort; (c) reliability of survey and behavioral observation data; (d) appropriateness of statistical and other procedures used to analyze data; and (e) validity of the monitoring results and conclusions drawn from them. Representatives of the relevant regulatory agencies, affected industry, lagoon residents, and interested environmental organizations (i.e., stakeholders) are invited to participate in these workshops as observers. The workshop findings and recommendations are available through published reports and on the program's internet web-site. Investigators also conduct workshops and seminars at Laguna San Ignacio to provide information to the fishing cooperatives, eco-tourism operators, and local residents.

Figure 8. Dr. Jorge Urban discusses research findings during a workshop held for eco-tour operators, fishermen, and local residents at the Kuyima campground in Laguna San Ignacio on 24 February 2007.

Figure 9. Researchers from the Autonomous University of Baja California Sur (UABCS) launch the research vessel "Rhachianectes" at Laguna San Ignacio.

Research Facility at Laguna San Ignacio: In 2007 the Kuyima Eco-Turismo cooperative built a laboratory facility for the researchers and students to utilize while working at Laguna San Ignacio on their various research projects. The facility's electrical system is provided by re-newable, non-polluting, wind and solar generators. The system charges a bank of storage batteries that provide 12-volt DC and 110-volt AC electrical power for lights, computers, cameras, and battery chargers.

Figure 10. Marine Science Laboratory at the Kuyima Eco-Tursimo Campground 2007.

Collaborating Scientists and Student Researchers: The program provides graduate students academic support and opportunities to conduct marine research under the guidance of established research scientists. Project leaders and visiting scientists mentor students participating in applied wildlife conservation field research, and assist them to learn skills that will serve them in their careers as wildlife conservation scientists. As appropriate, the program forms partnerships and coordinates its activities with other groups investigating various aspects of the LSIWC (*e.g.*, Pronatura-Noroeste, Biosphere El Vizcanio). To date, research projects have included studies on gray whale seasonal abundance and distribution, individual whale identification and behavior, graywhale calf growth and development, survey of benthic invertebrate communities in the lagoon, marine acoustics from natural sources and from whale-watching and fishing boats, and basic oceanography and primary production of the lagoon. In 2008 projects on the extent and status of eel grass beds in the lagoon, and marine turtles and waterfowl that reside in the lagoon will be added to the science program.

Figure 11. The 2007 gray whale researchers and students (left to right): Sergio Gonzáles C., Steven L. Swartz, Mauricio Nájera C., Alejandro Gómez Gallardo U., Mariela Brito, and Benjamin Troyo V.

Principal Investigators

Jorge Urbán R., Ph.D., is a graduate and Professor of Marine Biology at the Autonomous University of Baja California Sur, La Paz, B.C.S., Mexico. He has led gray whale research in Baja since 1996. Dr. Urbán is widely published in the scientific literature on marine mammals and marine conservation. He serves on the IUCN Cetacean Specialist Group, the Scientific Committee of the International Whaling Commission, and is a founding member and past President of the Mexican Society for Marine Mammalogy (SOMEMMA). He currently teaches marine science and conducts research on large whales.

Steven L. Swartz, Ph.D., Maryland, USA is a graduate of the University of California at Santa Cruz and has researched gray whales in Baja California since 1977. He has published numerous books, scientific and popular articles on gray whales and their breeding lagoons in Baja California, served as a marine mammal and protected species researcher, consultant and scientific director for the Mexican government's Ministry for the Environment, Natural Resources, and Fisheries (SEMARNAP), the Ocean Conservancy, the U.S. Marine Mammal Commission, the U.S. National Marine Fisheries Service, and the International Whaling Commission. He currently conducts research on gray whales and on ecosystem approaches to marine science to support sustainable development and marine conservation.

Chris Pesenti, M.P.I.A., has worked with community-based conservation efforts throughout the Baja California peninsula for over 6 years as his role as Co-Director of Pro Peninsula. Chris also chairs the Board of Directors of *Vigilante de Bahía Magdalena* (Magdalena Baykeeper), a group whose development he has supported since its inception in 2005, and plays an active role in the Grupo Tortuguero sea turtle conservation network throughout Baja California.

Figure 12. Vast wetlands, salt marshes, and mangrove estuaries occur along Laguna San Ignacio's shores and represent some of the world's most productive coastal ecosystems.

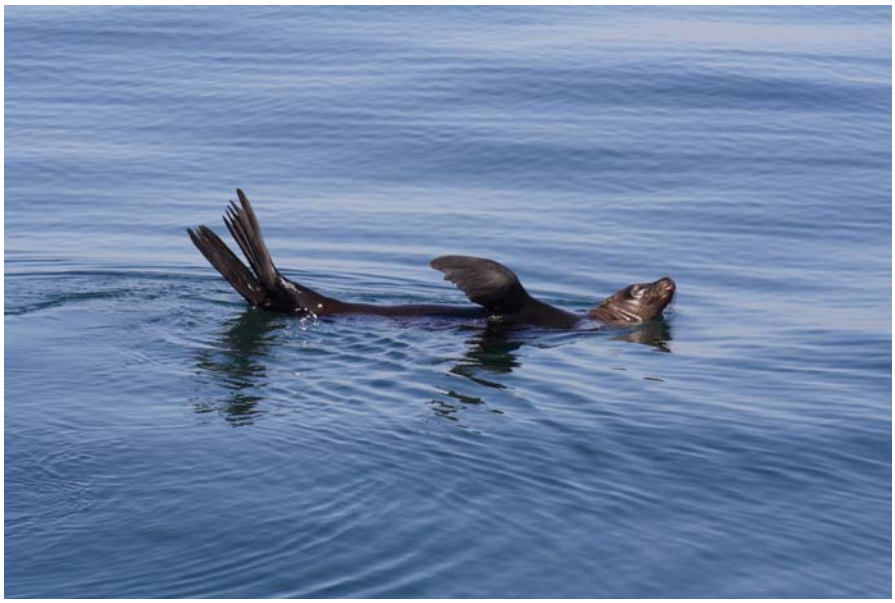

Figure 13. California sealions (Zalophus californianus) frequent the lagoon interior and haul-out on the ocean side of the barrier sand islands.

Background:
Laguna San Ignacio and Gray Whales in a Changing Ocean Environment

Gray Whales: Eastern North Pacific gray whales are the "charismatic mega-fauna" that attract thousands of whale-watchers to Laguna San Ignacio, Baja California Sur, Mexico each winter, and it is the gray whales that form the basis of a thriving eco-tourism industry in the coastal lagoon of San Ignacio along the Pacific coast of Baja California. Following their depletion from over harvesting by the whaling industry in the nineteenth century, the eastern North Pacific population of gray whales recovered from a few thousand whales (Reilly 1984) to an estimated 26,000 animals by the mid1990's. However, following a range-wide unusual mortality event in 1998-1999, the population declined and was estimated at approximately 18,000 in 2001 (Fig.14) (Rugh et al. 2005).

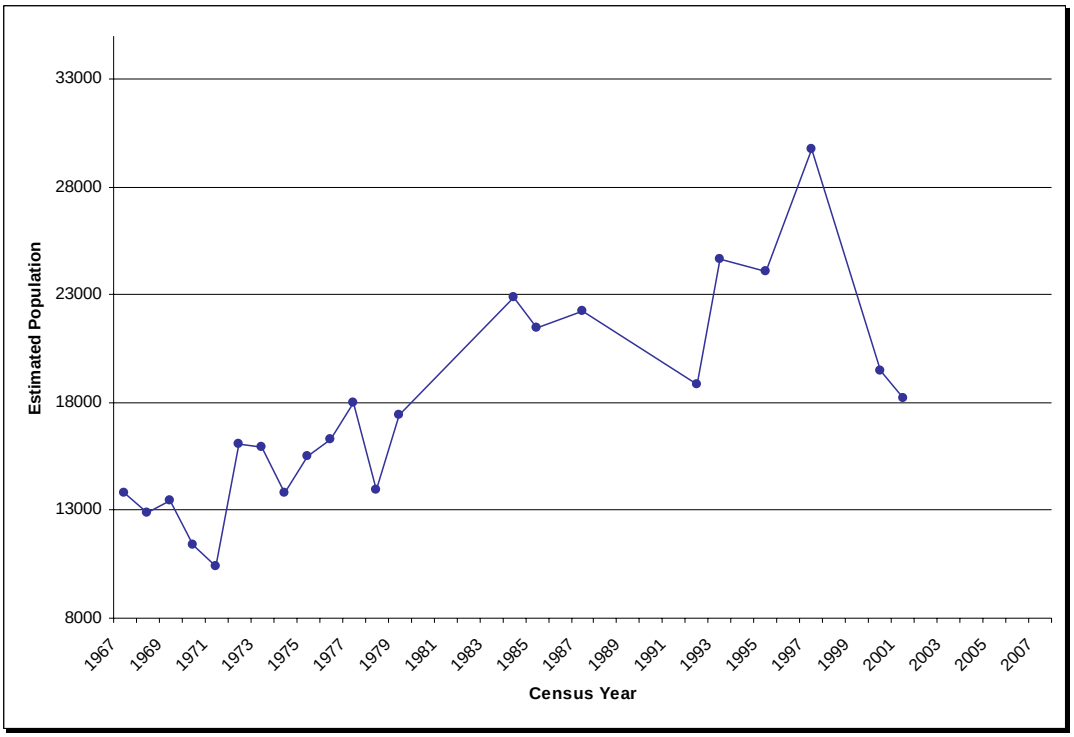

Figure 14. Estimates of the gray whales in the eastern North Pacific population based on visual census of the fall migration past the Granite Canyon, California observation station between 1967/1968 to 2001/2002 (from Rugh *et al.* 2005).

Eastern North Pacific gray whales were removed from the Endangered Species List in 1994, and as such, they represent a conservation success for a previously endangered species. However, with the gray whales' recovery and popularity come new challenges and potential threats from natural (*e.g.*, climate change) and human sources (*e.g.*, eco-tourism and development) (Wild Coast 2006).

Detecting and evaluating changes in the gray whales' use of their lagoon habitat and the persistence of other marine wildlife that utilize the lagoon and surrounding

wetlands requires an understanding of factors that affect these species both inside and outside of the LSIWC.

For example, from 1978 to 1982, approximately 300-400 adult gray whales were counted each February within Laguna San Ignacio compared to an average of 204 whales for the period 1996 to 2003, suggesting a 30% decrease in the use of this lagoon by the whales (Urban, *et al*., 2001) (Fig. 15, Table I). This declining trend in whale counts has continued through 2007 (Swartz *et al*. 2007). Unfortunately there are no data available on gray whale abundance in Laguna San Ignacio for the period from 1983 to 1995 to suggest likely causes of this decline. No field studies were conducted during those years, although levels of whale-watching tourism and commercial fishing continued to increase within the lagoon. While there is no direct explanation for the decrease in the use of the lagoon by the gray whales, the reduction in the size of the north eastern Pacific gray whale population, physical changes in the lagoon's characteristics, and increased levels of human activities within the lagoon may be contributing factors.

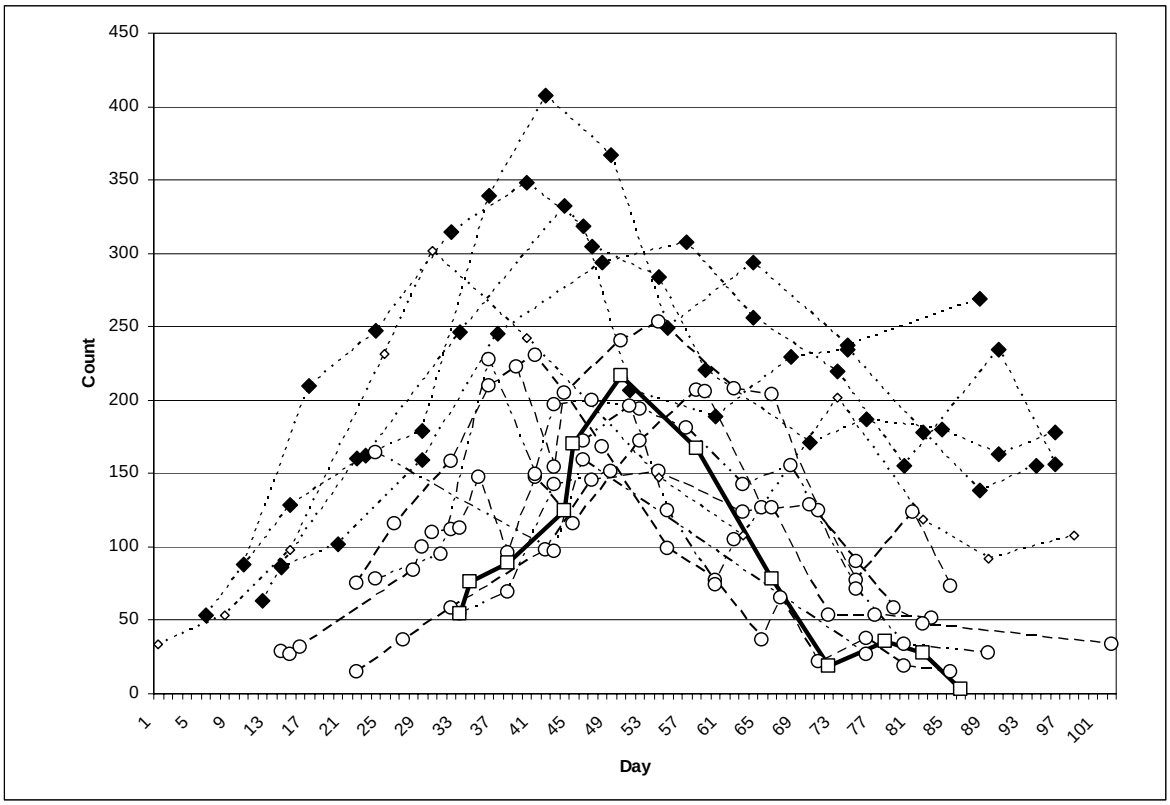

Figure 15. Number of adult whales counted in census surveys of Laguna San Ignacio during February peak season between 1978 and 2007. Black diamonds = 1978-1982 surveys; White circles = 1996-2006 surveys; White squares = 2007 survey counts. Day 1 = 4 January; day 102 = 15 April.

Table I. Maximum February survey counts and distribution of gray whales from 1982, 1996 and 2007.

Zone	Cow-calf pairs			Singles			Total Adult whales		
	14 Feb 82	2 Mar 96	22 Feb 07	14 Feb 82	2 Mar 96	22 Feb 07	14 Feb 82	2 Mar 96	22 Feb 07
Lower	15	33	10	187	84	126	202	117	136
Medium	15	31	5	52	25	60	67	56	65
Upper	107	28	5	31	6	11	138	34	16
TOTAL	137	92	20	207	115	197	407	207	217

External Environmental Change: Changes in the historical patterns of gray whales' use of Laguna San Ignacio likely reflect some combination of large scale changes in the north Pacific marine ecosystem that are affecting the entire whale population, and more local smaller scale environmental changes and human activities within the lagoon and its nearshore waters. As a result of these forces, gray whales appear to be responding to these changing environmental changes over several time and spatial scales.

The following discusses key environmental characteristics that appear to be changing and recent observations that appear to be indicative of the gray whales responses to those changes.

Prey resources: Gray whales from the eastern Pacific population historically fed primarily on benthic invertebrates organisms (*e.g.*, amphipods) in the Arctic (Grubemeyer 1989). During the summer months, large numbers of gray whales were previously found feeding on amphipods once in high densities on a region just north of the Bering Straits in areas such as the Chirikov Basin (Moore *et al.* 2003). These formerly rich feeding grounds now support less than 10% of their previous biomass and gray whales have been forced to range farther distances during the summer months and to feed on different prey (Grubemeyer *et al*. 2006, Moore *et al.* 2007). While we don't know the specific impacts this shift in diet and feeding grounds is affecting this population, there is evidence from recent observations of "skinny" whales that nutritional stress and possibly disease are operating to limit individual reproduction and population productivity.

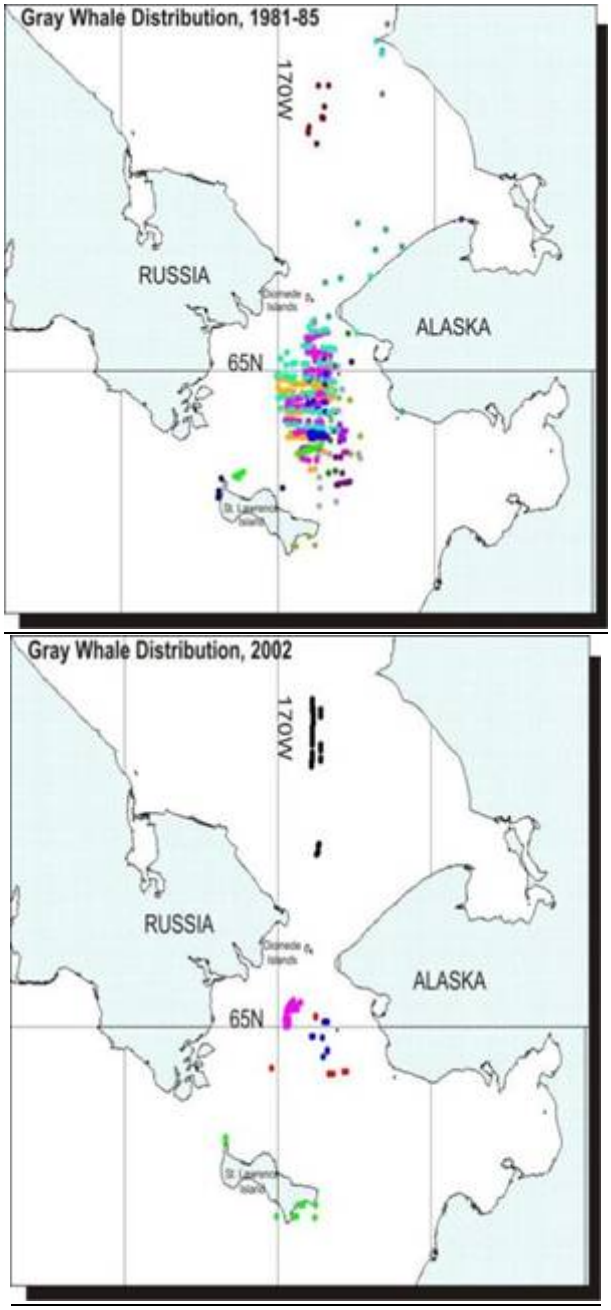

Figure 16 Top:. Sightings of gray whales on their primary Bering Sea feeding grounds between 1981 and 1985. Bottom:. Sightings of gray whales on their former feeding ground in 2002, indicating a significance decrease in the density of gray whales utilizing this area (from Moore 2003).

Calf production: There may be at least two factors impacting calf production in this population. Surveys of northbound calves conduction from the Piedras Blancas Light Station have fluctuated broadly over the 14 year survey period from 1994 to the present. Roughly 80% of this variability in calf production can be predicted based on the temporal and spatial distribution of seasonal ice in the Arctic. During heavy Arctic ice years females presumably have less time to feed, and the following year fewer calves are recruited into the population. Increased numbers of calves are seen following light ice years in the Arctic. While the short term variability can be explained by ice distribution, the overall calf production figures indicate that there have only been enough calves produced to replace normal adult mortality (if we assume it is somewhere between 5 and 6%) in 4 or the 14 years of survey effort since 1993. Photographic identification studies indicate that the two year calving intervals reported in the past for this population has now expanded to more than two years for many female whales. The drop in abundance in prey on historical feeding grounds and shifts to other prey are likely causal factors for lower number of calves produced each year and the increase in calving interval.

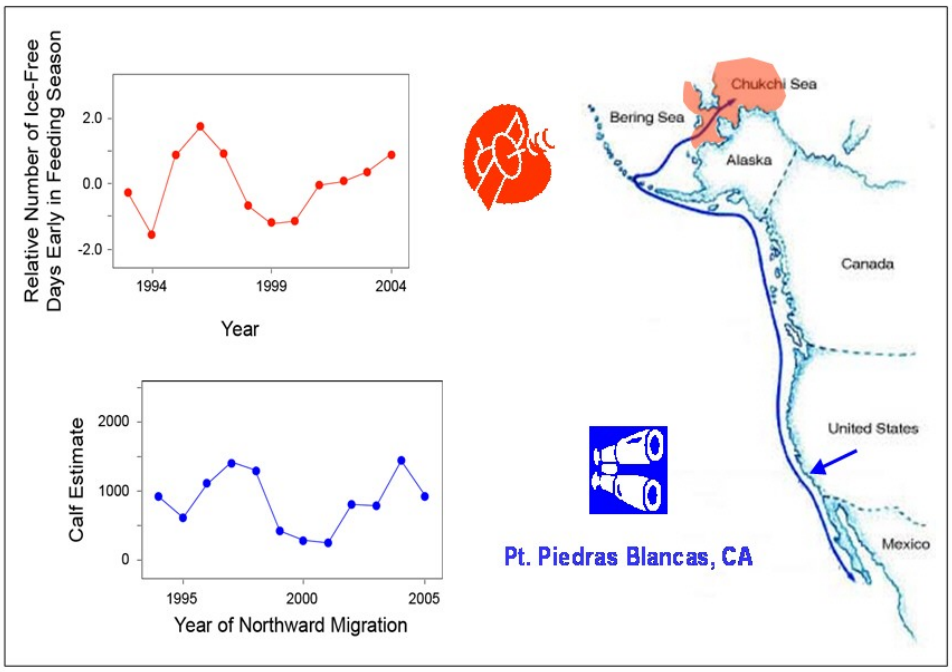

Figure 17. The relationship between Arctic ice cover on the gray whale feeding grounds and calf production the following year appear to be correlated.

Low gray whale calf counts in Laguna San Ignacio (Table I) and during their northward spring migration are especially troublesome, as they could indicate a reduction in the reproductive potential of the population. Low calf counts could be indicators that some gray whale females are unable to obtain sufficient energy resources to conceive, or if pregnant to bring calves successfully to term. Brownell and Weller (2002) suggest that in western north Pacific gray whales resource limitations may result in a three-year rather than the normal two-year reproductive cycle.

Health Assessment: Photographic data collected during the 2007 winter breeding and calving season in Laguna San Ignacio indicated that 11-13% of the whales photographed exhibited obvious signs of mal-nutrition and/or disease that has been termed evidence of the "skinny whale syndrome" (Weller et al. 2000) (Fig.18). While most gray whales observed within Laguna San Ignacio appeared to be normal, some individuals possessed noticeable "post cranial depression" and hump in the dorsal neck region of the body. Others were observed with protruding leading edges of their scapula, and concave rather than a convex profiles to their dorsal flank areas. The completion of the 2007 photographic identification data will allow the determination of the percent of gray whales observed that exhibited these characteristics, and an evaluation of how wide-spread these features are among those whales that frequented this breeding lagoon. Weller *et al*. (2000) and Brownell and Weller (2002) note that some "skinny" western North Pacific gray whales that were pregnant returned to their summer feeding areas with apparently healthy calves, suggesting that "skinnyness" may not be a fatal condition, but perhaps the result of diminished but a tolerable reduction I nutritional resources.

Figure 18.Top:and Bottom: Examples of a "skinny whales" observed in Laguna San Ignacio in 2007showing sub-dermal protrusion of the scapula and concavities around the blowholes and neck.

El Nino/La Nina events: The dramatic increase in observed mortality and drop in abundance during the late 1990s appear linked to a major environmental shifts in the North Pacific (Philander 1990) which began in 1998 (LeBoeuf et al. 2000, Urban *et al*. 2003), compounded by short term climate events. Most dramatic of these are shorter term ocean warming events know as the "El Nino Southern Oscillation" (ENSO) and ocean cooling of "La Nina" events (Dever and Winant 2002). ENSO events have occurred on 2 to 7 year periods and have had a variety of effects on feeding and reproduction in marine wildlife populations (Fiedler 2002), and on the gray whales' migration and survival (Urban, Gomez-Gallardo U, and Ludwig 2003).

A significant warming trend occurred in the North Pacific between 1997 and1998 Fig. 19). The following year began a two year period of unusually high mortality of gray whale calves and adults throughout their range, which was believed to be associated with lack of sufficient food (Le Boeuf et. al. 2000). Significant changes in the timing of the whales' occupation of its winter breeding lagoons and abundance in Baja California were associated with this mortality event (Urban, Gomez-Gallardo U, and Ludwig 2003).

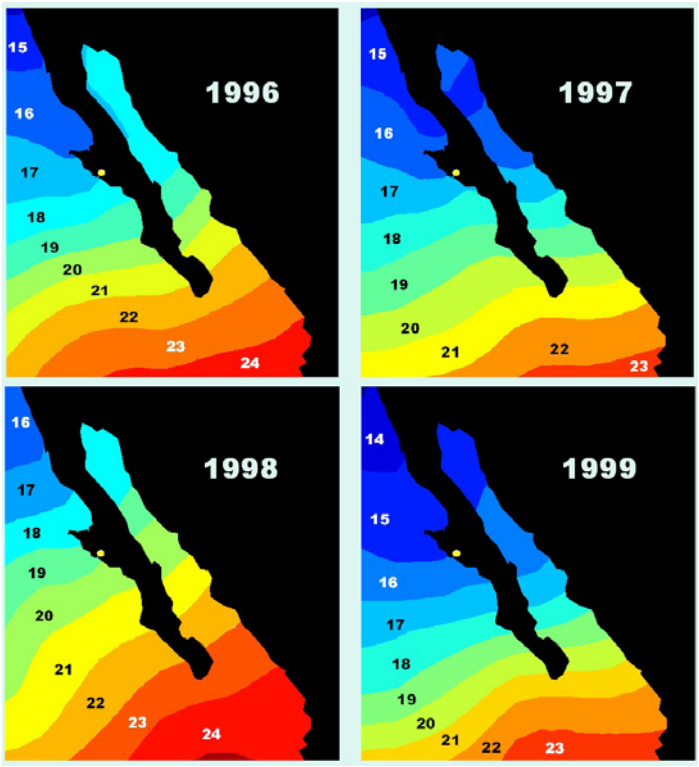

Figure 19. Pacific sea surface temperature differences during the 1996-1997 El Nino (top left and right) and 1998-1999 El Nino/La Nina events (bottom left and right).

The Future for Gray Whales: While eastern north Pacific gray whales appear to be responding and adapting to the impacts of short and long term climate factors and changing resource availability, their population appears to continue to decline from its peak abundance in the mid 1990s. Currently, there is no clear explanation for the apparent 30% drop in abundance between the1996/1997 and 2000/2001 censuses. It is not known how extensively the shift in prey is affecting population condition and contributing to the "skinny whales" observed in the breeding lagoons. We can't predict how continued ocean warming and prey shifting will impact reproduction and survival in this population over the long-term. Such resource limitation could reduce the ability of female gray whales to bring calves to term, and this could reduce overall production rates within the population.

Gray whales are unique among cetaceans and well suited for monitoring. They migrate close to shore each fall past Central and Southern California to their Baja California, Mexico breeding lagoons where they gather in significant numbers. These behaviors make them available for observation and monitoring. In addition, the long time series of annual abundance estimates from the census of the southbound fall migration, counts of calves during the spring northward migration, and counts of whales occupying the breeding lagoons in winter provide the frame work for examining the impacts of both long and short term environmental changes on the gray whale population. As such, gray whales are "sentinel" species that can inform on the health and status of the north Pacific ecosystem as well as themselves. The study of gray whales also provides opportunity for insight into large whale population dynamics, behavioral ecology, and the capacity of a mysticete species to explore disparate forage opportunities and respond to environmental changes.

Factors Operating within Laguna San Ignacio: Additional management Concerns

Human activities within Laguna San Ignacio represent another potential influence on the gray whale's use of this historical breeding and calving habitat. Because the gray whales' winter occupation is the basis of local eco-tourism, the whales' continued use of this marine protected is a concern for the local eco-tourism operators and the economic welfare of the local community.

Lagoon Fisheries: Commercial fisheries for fin-fish, lobster, and shellfish grew un-restrained in the 1970s and 1980s only to economically collapse in the 1990s with the depletion of the primary shell-fish species being harvested (Young 1999). During this period significant amounts of shellfish (i.e., Pacific calico scallops (*Argopecten circularis*), pismo clams (*Tivela stultorum*), hatchet clams (*Pinna spp. & Atrina spp.*), and other bivalves were commercially harvested from the lagoon's eel-grass beds (i.e., *Zostera marina*) and sand flats (Young, 1999). The removal of countless tons of bivalves from the lagoon is evidenced today by acres and acres of shell piles (middens) that liter the southern desert shore of the lagoon (Fig. 20). These filter feeding bi-valves excrete

nitrogen and phosphorous which are nutrients for marine plants from the smallest phytoplankton that form the basis of the marine food chain, to the macro-algae and marine grasses (Peterson and Heck, 1999; Ganter 2000). The removal of these suspension feeders also removed this source of nutrients from the lagoon's waters, nutrients utilized by the lagoon's marine plants.

Figure 20. Acres of scallop and other shellfish middens on the shores of Laguna San Ignacio are evidence of massive commercial catches in the recent past.

Before the bi-valve fisheries collapsed, the dominant marine plant in the lagoon was eel-grass. But today eel-grass density is noticeably reduced, along with reductions of Pacific black brant geese (*Branta bernicla*) (Fig.21) and surf scoters (*Melanitta perspicillata*) that migrate to the lagoon to feed on the eel-grass (Gantner 2000; S. Swartz; pers. observation). One can only wonder if the reduction in water-fowl is linked to the reduction in eelgrass, and that possibly linked to the reduction of the lagoon's bi-valve communities and the nutrients they provided.

Figure 21. Pacific black brant geese (Branta bernicla) frequent the lagoon during the winter and feed extensively on eel grass and other marine plants.

Whale-Watching Tourism: Perhaps the most noticeable human activity in the lagoon each winter is whale-watching tourism. Driven in part by the "Friendly Whale" phenomenon, the whale-watching tourism industry has grown in the lagoon since the mid-1980s and offer visitors a wildlife experience that is unique in the world (Fig. 22). Laguna San Ignacio now hosts five commercial whale-watching “camps” on its shores that operate from January through April each year. These programs strive to be examples of “sustainable eco-tourism” that strike a balance between human visitation and ecosystem conservation. Visitors receive educational information on the lagoon and on gray whales, and the number of whale-watching boats allowed on the lagoon at any one time is limited by permit.

Despite these positive attributes, the water-borne noise and disturbance associated with whale-watching must be considered with regard to the gray whales' continued use of the lagoon as a habitat necessary for breeding, giving birth to and rearing their calves at this critical time in their life-cycle. Like the commercial fisheries, eco-tourism operators are feeling competition for “whale resources” (Young 1999). There is an ongoing concern about the impact of whale-watching activities on the whales. Local tour-boat operators and lagoon resource managers struggle to address questions such as: what is the number of whale-watching excursions that can be tolerated by the whales?; what are the best approach methods and speeds that minimize disturbance to the whales?; and what constitutes harassment from whale-watching boats?

Figure 22. Most whale watchers come to Laguna San Ignacio and stay at shore based camps while others arrive on large vessels that enter the lagoon from the sea. The number of small whale-watching "pongas" allowed on the water is regulated by permit.

A coordinated management and permitting program for eco-tourism and other activities in the lagoon has maintained records of the number of whale-watching and fishing boats that operate in the lagoon since 1996. These records serve as the basis for assessing the potential impact of human activities on the lagoon and its wildlife. There is recognition that unmanaged growth of the eco-tourism industry in response to public demand and competition could over-stress the gray whales and cause them to abandon the lagoon, and diminish the lagoon habitat and the quality of the "wilderness experience" that is the foundation for the eco-tourism industry.

For the time being, through its collective cooperative management program, Laguna San Ignacio eco-tour operators are demonstrating to the world that planned and regulated eco-tourism can be self-sustaining, provide "low-impact" disturbance to the lagoon ecosystem, have tangible social and economic value to the local community, contribute to protection of environmental quality, and provides society with a unique wildlife experience through "hands-on" education.

Figure 23. Most eco-tourists are based out of camps located along the shores of Laguna San Ignacio, like this eco-camp on Rocky Point in the lower portion of the lagoon.

Figure 24. Gray whale calves are especially "friendly" to whale-watchers willing to rub their head and lips.

References Cited

Brownell, Rl. Jr. and D.W. Weller. 2002. Prolonged calving intervals in western gray whales: nutritional stress and pregnancy. Rep. Intl. Whal. Commission, SC/54/BRG12. 13 pp.

Dever, E.P. and C.D. Winant. 2002. The evolution and depth structure of shelf and slope temperatures and velocities during the 1997-1998 El Nino near Point Conception, California. Progress in Oceanography, Elsevier.

Fiedler, P.C. 2002. Environmental change in the eastern tropical Pacific Ocean: review of ENSO and decadal variability. Marine Ecology Progress Series, 244:265-283.

Gantner, B. 2000. Seagrass (Zostera spp.) as food for brent geese (Branta bernicla): an overview. Helgol Marine Research, Springer-Verlag and AWI, 54:63-70.

Grebmeier, J.M., H.M. Feder, and C.P. Mcroy. 1989. Pelagic benthic coupling on the shelf of the northern Bering and Chukchi Seas II: Benthic community structure. Marine Ecology Progress Series 51:253-268.

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L. McNutt. 2006. A major ecosystem shift in the Northern Bering Sea. Science 311:1461-1463.

Gutierrez de Velasco, G. and Winant, C.D. 2004. Wind- and density-driven circulation in a well mixed estuary. American Meterological Society, 34:1103-1116.

Jones, M.L. 1981. Lagoon bathymetry, benthic surveys, and productivity studies of Laguna San Ignacio, Baja California Sur, Mexico. Unpublished report for W. Wallace, Natural Science Department, San Diego State University, San Diego. 22 pp.

Jones, M.L. and S.L. Swartz. 1984. Demography and phenology of gray whales in evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico. Pp. 309-372 *In*: M.L. Jones, S.L. Swartz, and J.S. Leatherwood (eds.) *The gray whale, Eschrichtius robustus.* Academic Press, Inc., Orlando, Florida. 600 pp.

Le Boeuf, B.J., H. Perez-Cortez M., .J. Urban, B.R. Mate, and F. Ollervides U. 2000. High gray whale mortality and low recruitment in 1999: potential causes and implications. Journal of Cetacean Research and Management 2(2):85-99.

Moore, S.E., J.M. Grebmeier, and J.R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: Current conditions and retrospective summary. Canadian Journal of Zoology 81:734-742.

Moore, S.E., K.M. Wynne, J.C. Kinney, and J.M. Grebmeier. 2007. Gray whale occurrence and forage southeast of Kodiak, Island, Alaska. Marine Mammal Science 23:419-428.

Peterson, B.J. and K.L. Heck. 1999. The potential for suspension feeding bivalves to increase seagrass productivity. Journal of Experimental Marine Biology and Ecology, 240:37-52.

Philander, S.G.H. 1990. El Nino, La Nina and the Southern Oscillation. Academic Press, Orlando. 293 pp.

Reilly, S.B. 1984. Assessing gray whale abundance: a review. Pp. 203-223. *In*: M.L. Jones, S.L. Swartz, and J.S. Leatherwood (eds.) *The gray whale, Escherichia's robustus.* Academic Press, Inc., Orlando, Florida. 600 pp.

Rugh, D.J., R.C. Hobbs, J.A. Lerczak, and J.M. Breiwick. 2005. Estimates of abundance of the eastern North Pacific stock of gray whales (*Eschrichtius robustus*) 1997-2002. Journal of Cetacean Research and Management. 7(1):1-12.

Swartz, S.L., J.Urbán R., S.González C., A.Gómez-Gallardo U., B.Troyo V., M.Nájera C., and L. Rojas-Bracho. 2007. Preliminary report of the 2007 gray whale studies at Laguna San Ignacio, B.C.S., Mexico. Rep. Intl. Whal. Commn. SC/59/BRG39, 15 pp.

Urban, R., J., L. Rojas-Bracho, H. Perez-Cortes, A. Gomez-Gallardo, S. Swartz, and R.L. Brownell. 2001. A review of gray whales in their wintering grounds in Mexican waters. Report to International Whaling Commission, SC/BRG/16, 23pp.

Urban R., J., A. Gomez-Gallardo U., and S. Ludwig. 2003. Abundance and mortality of gray whales at Laguna San Ignacio, Mexico, during the 1997098 El Nino and 1989099 La Ninia. Geofisica Internacional, 42(3):439-446.

Young, E.H., 1999. Balancing conservation with development in small-scale fisheries: is ecotourism an empty promise? Human Ecology, 27(4):581-620.

Weller, D.W., B. Wursig, A.M. Burdin, S.H. Reeve and A.L. Bradford. 2000. Gray whales off Sakhalin Island, Russia: June-October 1999. A joint U.S. – Russian scientific investigation. Final contract report to Sakhalin Energy Investment Company, 69 pp. Available from Texas A&M University, Marine Mammal Research Program, Galveston TX 77551 U.S.A.

Wild Coast. 2006. Laguna San Ignacio Conservation Alliance: Conservation Plan 2006. Wild Coast, California. 24pp.