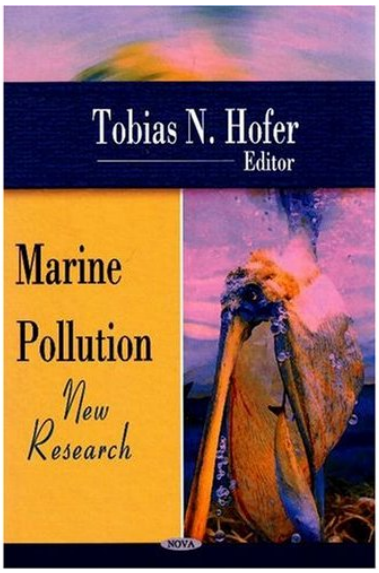

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PETROLEUM POLLUTION AND PENGUINS:

Marine Conservation Tools to Reduce the Problem.

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SUMMARY

Petroleum is one of the most common toxic substances released into the marine environment. Accidental pollution is spectacular and receives a lot of attention when the negative effect to the environment is dramatic. The impact of chronic petroleum pollution or small oil spills is often not sensational and hence has received less attention than it deserves. Seabirds are one of the most vulnerable groups of marine animals

affected by petroleum. Penguins are particularly vulnerable to petroleum spills because they swim low in the water, must surface regularly to breathe, do not fly, are less able to detect and avoid petroleum than other seabirds, and often encounter discharges of petroleum when they are at sea. Mortality of penguins from petroleum is a long term and large scale problem. Petroleum pollution has killed thousands of penguins in Africa, Australia and New Zealand, South America, and even Antarctica. The Southwest Atlantic, although not well known for petroleum pollution problems, is a chronic source of petroleum discharge. Magellanic penguins (*Spheniscus magellanicus*) are killed during their winter migration between Argentina, Uruguay and Brazil, when they encounter petroleum (Boersma et al. 1990, Gandini *et al.* 1994). To avoid severe negative impacts of petroleum on penguins and other marine species, planning and implementation strategies should concentrate on minimizing risk associated with petroleum discharge and development. New legislation combined with effective enforcement could reduce petroleum spills, minimize operational discharges from ships and from land-based sources and thereby, decrease the release of petroleum into the ocean. Reduced exposure and vulnerability to petroleum can be achieved through marine conservation tools, such as Marine Protected Areas or Marine Spatial Planning to minimize risk to wildlife. Conservation of marine biodiversity is an important value, but can protection be achieved with minimal impact on economic activity? This paper reviews how petroleum pollution has impacted populations of penguins. In addition, it suggests how marine management strategies could mitigate petroleum pollution harm to penguins, with particular emphasis on the Magellanic penguin populations in the SW Atlantic.

INTRODUCTION

The use of petroleum started to replace coal as a fuel in the beginning of the 20th century, and since the 1930s, increasing amounts of oil were transported by sea from producer to consumer nations (Underhill, 2007). Currently, petroleum is one of the most common toxic substances released into the marine environment, mainly through shipping and maritime activities (USNRC, 2003). Accidental pollution is often spectacular and receives public attention particularly when the negative effect to the environment is dramatic. During the 20th century, more than 200 oil tankers sank - many of these resulting in ecological disasters. However, chronic petroleum pollution (small scale but frequent oil discharges) accounts for most petroleum pollution in the ocean (USNRC, 2003), but since chronic pollution receive little media attention, the public perceives these oil spills as not as harmful (Hunt, 1987; Boersma *et al.*, 1995; Parrish and Boersma, 1995), but they can be far more damaging to wildlife and environment than one disaster.

There is no simple relationship between the amount of petroleum in the marine environment and the likely impact on the marine ecosystems. As summarized by the Australian Maritime Safety Authority (AMSA), among the important factors related to the impact of an oil spill on wildlife are: the spread of the oil slick, the type of oil spilled, its movement and weathering characteristics, the sensitivity of the regional environment, the timing of the incident (during seasonal breeding, bird migration), and the variety of species at the spill location (AMSA 2007)

Seabirds are one of the most vulnerable groups of marine animals affected by petroleum pollution (Clark, 1984; Dunnet, 1987; Piatt *et al.*, 1990). They have a high risk of coming in contact with petroleum because they spend much of their time at sea near the surface and on oil affected coastlines (Boersma 1986, AMSA, 2007). Sea birds are affected by petroleum in several ways: oiled feathers collapse and matt changing

their insulation properties and causing hypothermia, this can also cause the birds to lose buoyancy, thereby sink and drown because of increased weight or lack of air trapped in the feathers (AMSA, 2007). In addition, body weight decreases quickly as increased metabolism counteracts low body temperature (Culik et al 1991). Depending upon its form and chemistry, petroleum can cause severe irritation of the skin, ulceration of the eyes, skin, mouth, or nasal cavities, and poisoning or intoxication (AMSA, 2007). The stomach develops lesions and the immune system may be suppressed resulting in an increase in internal parasites (Gandini *et al.*, 1994). Even small amounts of petroleum lowered circulating hormones, increased corticosterone in females and suppressed breeding in Magellanic penguins (Fowler *et al.*, 1995).

Penguins are particularly vulnerable to oil spills because they swim low in the water, do not fly, and must surface often to breathe. Moreover, when petroleum is on the surface of the ocean penguins are probably unable to avoid being coated because they cannot detect it (Dann and Jessop 1991, Adams 1994, Gandini *et al.*, 1994, Goldsworthy et al., 2000).

Mortality of penguins from petroleum is a long term and large scale geographic issue. The problem is apparent where intense petroleum development and transportation overlaps with penguin distribution (Fig. 1). For decades petroleum pollution has killed thousands of penguins in Africa, Australia and New Zealand, South America and even Antarctica.

We review petroleum pollution impacts on penguins, highlighting the relevance of this conservation threat to penguin populations. Although African penguins (*Spheniscus demersus*) have been most affected by large spills, their populations have suffered from chronic petroleum pollution as well. In Australia and New Zealand, in constrast, the Little (blue) penguin (*Eudyptula minor*) is most common harmed by

chronic pollution. However, a large oil spill affected between 10000 and 20000 penguins in 1995 (Goldworthy et al. 2000).

Although the Southwest Atlantic has similar pollution problems as in Africa, they are not as well recognized. Chronic pollution has affected Magellanic penguin population for decades (Boersma 1987, Gandini *et al*. 1994, García-Borboroglu *et al*. 2006). Current trends in the economy of Argentina, Uruguay and Brazil indicate an exponential increase in oil industry development and in all maritime activities (OLADE/SIEE, 2000). We suggest that various marine conservation tools, such as fixed Marine Protected Areas, seasonal or moving Marine Corridors or Marine Spatial Planning could minimize risk to wildlife, and in particular reduce penguin mortality from petroleum pollution, thereby, contributing to the conservation of penguins and marine biodiversity.

CASE STUDIES

AFRICA. - Oiling of penguins is likely a common problem wherever tankers and penguins mix. The breeding distribution of African penguins in the southern cone of Africa overlaps with one of the world's major oil tanker routes (Fig. 1). The waterway off the coast of South Africa is one of the most heavily-traveled shipping areas in the world and a global hotspot for oil pollution (Nels and Whittington 2003). Petroleum is transported from the Middle East around the tip of South Africa to Europe. From 1968 until 1975 the Suez Canal was blocked by sunken ships and about 650 oil tankers traveled around Africa on their way from the Persian Gulf to Europe (Underhill, 2007). It is estimated that 350 million tons of crude oil, representing over 30 percent of world petroleum production, pass near or through these coastal waters each year. Thus, more than 5,000 tanker voyages per year travel through the breeding distribution area of

African penguins. On average, more than 20 large oil tankers are in transit nearby African penguin colonies every day (Africa Region-Indian Ocean Oil Spill Contingency Planning Project, 2007).

African penguin populations have been devastated by petroleum pollution resulting from both operational discharges, and a number of shipping accidents along the coast of South Africa. More than 80% of the global population breeds in two areas that lie within 50 km from a major shipping harbour and adjacent to the Cape shipping route, making the population extremely vulnerable to oiling (Nel *et al*. 2003) Population viability modeling showed that the African penguin was at substantial risk of extinction in the near future and that oil spills were among the greatest threats to the species' survival (Whittington *et al.*, 2000). Over the past 100 years, the African penguin population has declined dramatically. In 1910, there were about 1.4 million adult birds at Dassen Island. In the 1930's there were 570,000 pairs (Shannon and Crawford, 1999). In 2000 the population estimate was approximately 63,000 pairs (Hockey *et al*., 2005). Today, The World Conservation Union lists African penguins as Vulnerable with a population of only about 59,000 individuals (Ellis *et al.*, 2007). The African penguin population has dropped in the past few years by 40% (Koenig, 2007).

Since 1948, at least 13 major petroleum spills were identified to cause mortality to African penguins where at least 500 individuals were oiled (Underhill, 2007). Of these, five (38%) events were from ships that ran aground on islands or capes, three (23%) by ship sinking, another three by oil slicks of unknown origins, one by collision and the last one by a ruptured oil supply pipeline. The first serious petroleum incident took place in 1948, when the *Esso Wheeling* sank close to Dyer Island spilling an unknown amount of oil and killing one-third of the local penguin population (Underhill, 2007). The *Esso Essen* struck run aground in Cape Point, in April 1968, spilling

approximately 4000 tons of oil and affecting more than 1700 penguins. The ship was navigating only 5 km offshore at the time, when it should have been 16 km according to the prevailing legislation at that time (Underhill, 2007). Other remarkable incidents include the *Wafra* tanker that run aground near Cape Aghulas in 1971, spilling about 10 000 tons crude oil and affecting more than 1200 penguins; an unknown origin spill affecting 4000 penguins of Dassen Island in march 1972; and the *Oriental Pioneer* tanker that run aground at Struisbaai in July 1974, spilling 200 tons of fuel oil and oiling several thousand penguins.

The worst two major spills were the Apollo Sea in June 1994 and the Treasure in June 2000. When the bulk ore carrier *Apollo Sea* sank off Capetown, South Africa, spilling about 2,400 tons of heavy fuel oil that washed ashore at both Dassen and Robben Islands, 10,000 African penguins were oiled (IBRRC, 2005; Wolfaardt *et al.*, 2007; Underhill, 2007). Similarly when the *MV Treasure* sank near Capetown, South Africa, spilling 1,300 tons of bunker oil, 20,000 African penguins swam into oil, and another 19,500 penguins were moved 700 km from the spill site to prevent them from encountering petroleum (IBRRC, 2005; Underhill, 2007).

Large-scale rehabilitation efforts washed and released about 5,000 penguins in the Apollo Sea spill (Wolfaardt *et al.,* 2007) and 17,000 animals in the Treasure spill (Barham *et al.*, 2007). Simple deterministic population models indicate that the African penguin population is 19% larger than it would have been in the absence of rehabilitation efforts, suggesting that although demographic impacts of rehabilitating oiled penguins were initially modest, this activity is becoming increasingly important to conserve this species (Ryan 2003). Several studies have examined the extent to which African penguins that are oiled, recover and become part of the breeding population. Breeding success of penguins never oiled and penguins oiled in events other than the

Treasure spill were similar (61%). Penguins oiled in the Treasure spill, however had lower breeding success (43%) than penguins that were not oiled (Barham et al 2007a, 2007b). Rehabilitated penguins often lost their chicks when they were three quarters grown and pairs where both penguins had been oiled did more poorly than pairs where only one bird was oiled (Barham *et al*. 2007).

Apart from these spectacular spills, there is a chronic, ongoing problem of small spillages, which results in about 1000 oiled penguins being brought to rehabilitation centers each year (Parsons and Underhill, 2005; Underhill, 2007). Considering the conservation status of this species and the magnitude of the oil spills' impact, rehabilitation efforts may be a worthwhile conservation intervention (Barham *et al.*, 2007). However, only a small fraction of oiled penguins are found and brought to rehabilitation centers. Reducing the amount of petroleum released or the chance that penguins encounter the petroleum would benefit the entire populations, and therefore have a more significant conservation value.

AUSTRALIA and NEW ZEALAND. - Six penguin species breed in New Zealand. Two species are "endangered" according to the IUCN classification system: the erect-crested penguin, *Eudyptes sclateri*, and the yellow-eyed penguin, *Megadyptes antipodes.*

Little Penguins also breed across southern Australia and the islands of New Zealand, and it is estimated that their world breeding population is approximately 350-600,000 birds (Dann et al. 1996). Little Penguins are the most likely seabirds in southern Australia to come into contact with oil spills at sea (Dann, 1994, 1999). This species make up more than 90% of the 2996 oiled seabirds reported between 1980 and 1999 (Dann 1999). At least 21 major oil spills have occurred in or near Australian

waters since 1903, as well as several smaller offshore spills (AMSA, 2007). Residues and oily sludge from ship's bunker tanks killed or harmed up to 350 Little penguins (*Eudyptula minor*) yearly at Phillip Island, Australia (Revill and Healy, 1999). Colonies near oil terminals and ports are clearly most at risk as this is where most petroleum spills occur (Dann et al 1996). Little penguins are inshore foragers so are likely to encounter petroleum when it is discharged nearshore. Even minor diesel spills from recreational craft can kill little penguins. Particularly, in Melbourne's commercial ports and recreational harbors minor spills occur (Port Phillip Ecocentre, 2007).

To date, only relatively limited numbers of oil spills have apparently affected penguins in southern Australia, however the potential exists for oil spills to have major, even catastrophic, effects on their populations. Accidents involving large-scale spillage of petroleum or other toxic products from ships, boats and shore-based industrial complexes or trucks could have a major impact on little penguin colonies.

One event that affected higher numbers of penguins occurred at Portland in western Victoria, where forty percent of the birds breeding at a small colony (100 individuals) were killed in one oil spill in 1988 (Dann et al 1996).

On May 1990, an extensive oil slick was caused by the Arthur Phillip boat when it released illegally oil and an oily mixture. The slick was reported to extend for approximately 10 nm. and ultimately killed or seriously affected over 200 Little penguins (NZ Penguin net, 2007).

Australia`s largest on-shore oil spill took place in July 1995, when the Iron Baron ran aground at the mouth of the Tamar River in northern Tasmania releasing an estimated 325 tonnes of bunker fuel oil (North East Communigate, 2007, Goldworthy et al 2000). The most visible species was the little penguin, with 1894 oiled individuals being collected and treated for oiling. However, it was estimated that 19.6% of the birds

from the most affected colony were oiled and survived to come ashore (Goldworthy et al 2000). These authors believe that between 10000 and 20000 penguins were killed as a result of this relatively small volume spill.

In New Zealand, no scale oil spills involving oil tankers and affecting large numbers of penguins are reported, nevertheless many smaller spills occur. A massive spill occurred in Milford Sound, on February 2004 when up to 14,000 litres of diesel where spilled from a tank aboard a tourist launch. Although the sound is home to many species including penguins, local authorities say animals seem to have escaped harm (NZ Penguin net, 2007).

Spills of light fuel oil from sinking fishing boats and the emptying of engine-room bilges have oiled penguins around New Zealand. The urban-dwelling blue penguin is exposed sometimes to land-based oil spills when they nest in and around harbors or in industrial areas. Fledgling chicks and nest prospecting adults are at greatest risk because they explore more than breeding birds and spend more time at sea.

ANTARCTICA AND SUB-ANTARCTIC ISLANDS. - Eight penguin species occur in this region: Emperor (*Aptenodytes forsteri),* King (*Aptenodytes patagonicus*), Adelie *(Pygoscelis adeliae),* Chinstrap *(P. antarctica),* Gentoo (*P. papua*), Rockhopper, Macaroni (*Eudyptes chrysolopus*), and Royal penguins (*E. schlegeli*).

As human presence in the region increases, so does the risk of petroleum spills. Major oil spills are rare in the Antarctic. The first and still largest recorded spill in Antarctica took place in 1989 when the Bahia Paraiso, an Argentine ship ran aground and sank off the west coast of the Antarctic Peninsula near the Palmer research station, spilling 600,000 litres of marine diesel into the sea. The slick was over 100 square kilometers (BAS, 2007). The most affected seabird species was the Adelie penguin.

About 300 dead birds were counted, although this is probably an underestimate of the actual number killed because of the poor weather conditions which hampered an accurate survey (Antarctic Resource, 2007).

Another potential threat is posed by the increasing number of cruise boats that visit Antarctica each year. The MS Explorer, an adventure travel ship owned by a canadian company and registered in Liberia struck an iceberg and sank on November 2007. About 50,000 gallons of diesel, 6,300 gallons of lubricant and 260 gallons of gasoline were on board when the Explorer sank. Areas surrounding the mile-long spill site include breeding grounds for Adelie, Gentoo and Chinstrap penguins. The damage is unlikely to not be assessed in this remote location (USAToday 2007).

SOUTH AMERICA.-. Seven penguin species breed in South America. Magellanic, Galapagos (*Spheniscus mendiculus*), Humboldt (*S. humboldti*), King, Gentoo, Rockhopper, and Macaroni penguins.

In Argentina, several important oil spills impacted the Magellanic penguin population within their breeding distribution range in Patagonia, from Península Valdes (42º30´S, 64ºW) to Tierra del Fuego (54ºS, 66ºW). Specifically, an oil spill hit the coast in Bahia Bustamante, Central Patagonia, in 1981, an area that encompasses eight Magellanic penguin island colonies with an estimated population of 25,100 breeding pairs (García Borboroglu *et al.*, 2002). The number of penguins affected was not determined, but local residents found oiled penguins along many kilometers of coastline for several weeks (D. Pautaso, pers.com.), and layers of dried oil remain on the affected island colonies (Pers. obs). This major oil spill was not formally reported, the origin was not determined, and the impact on the ecosystem not assessed. The effects of this oil spill is evidenced in the high levels of contamination detected in this coastal sector

(Commendatore et al. 2000). In 1982, 500 oiled penguins were found along the beach of Punta Tombo, the main breeding continental colony (C. Passera, pers. comm.). In 1991, an oil spill of unknown origin killed approximately 17,000 Magellanic penguins in central Patagonia, Argentina (Boersma 2008). The number of penguins killed were estimated from walking and counting dead penguins on 256 km of coastline and calculating the expected number of dead penguins along the coast of Chubut Province. In 2006, an estimated number of 400 penguins were oiled due to an oil slick of unknown origin near Cabo Vírgenes in south Patagonia, Santa Cruz Province (NGS, 2007). Recently, in December 2007, an oil spill from the oil terminal occurred at Caleta Córdova, Chubut. At the area where the oil came ashore 300 penguins were collected for treatment and a preliminar estimation suggests that at least 1500 penguins were affected and returned to their colonies located at more than 100 km from the spill including one found at Punta Tombo in late December (Boersma per obs).

The commencement of petroleum exploration around the Malvinas/Falkland Islands represented a similar cause of mortality for breeding penguins. During a 5 month period of oil exploration around these islands in 1998, no less than three oil spills occurred, killing several hundred penguins (IPCWG, 2007).

Apart from big scale oil spills, it is recognized that chronic oil discharges in some sectors along the Patagonian coast result in low to moderate contamination (Commendatore et al. 2000). Impacts of oil spills on seabirds may be better documented than exposures to chronic discharge from ships, at terminals, or from oily ballast water. However, in the case of Argentina there are also long-term records documenting chronic oil pollution and its effects on penguins along the Chubut coast. Chronic oil pollution killed Magellanic penguins in Argentina (Jehl, 1974; 1975; Korschenewski, 1975; Jenkins, 1978; Perkins, 1983; Boersma, 1987; Knaus, 1990; Gandini *et al.*, 1994) and

more recently has been documented as a problem in Brazil (Petry and Fonseca, 2002; Petry *et al.*, 2004). Gandini *et al.* (1994) estimated over 40,000 Magellanic penguins (*Spheniscus magellanicus*) were killed each year by chronic oil pollution along the coast of Chubut Province, Argentina, from 1982 to 1991. This estimation was based on the number of oiled penguin carcasses found along the coast, but as the authors stated, carcasses disappear rapidly from the beaches and therefore this number is likely an underestimated. Moreover, many penguins might not be able to reach the coast once oiled further underestimating the impact of petroleum pollution.

Magellanic penguins migrate between Argentina and Brazil in the Atlantic Ocean on their winter migration, from March to September (Boersma et al. 1990). Satellite tracking of migrating penguins showed that they generally swim within a well defined highway less than a 100 km in width when they go northward or southward (Stokes *et al*., 1998, Boersma *et al*. unpublished data) (Fig. 2). During migration and over the winter, the Atlantic breeding population of Magellanic penguins congregate in a restricted marine area off the Buenos Aires Province of Argentina and Uruguayan coast (Penguinstudies 2007). This is a time of high risk for this species, because a single spill could affect and kill a big proportion of the population.

Their migration routes overlaps with heavy maritime traffic, harbors, petroleum development areas including oil terminals and oil platforms (Stokes *et al.*, 1998; Pütz *et al.*, 2000) and non-point source pollution from runoff from major cities. The location, nature and magnitude of the chronic oil pollution problem for Magellanic penguins along the southwest Atlantic coast in their wintering range, where little information is available, was recently assessed (García Borboroglu *et al*., 2006). The location of 25 rehabilitation centers for seabirds along the southwest Atlantic coastline from northern Brazil (Fortaleza, 3º46´S, 38º33´W) to central Argentina (San Antonio Oeste, 40º47'S,

64º47'W), covering approximately 8,200 km of coastline suggested chronic petroleum pollution is a serious, widespread problem. Interestingly, some of these centers have existed for more than 30 years, further indicating that petroleum discharge is a longstanding problem. Live penguins with petroleum were more common in northern Argentina and the total number of oiled penguins decreased from Argentina to Brazil with the lowest numbers found at the lower latitudes (Fig. 3, adapted from García-Borboroglu *et al.* 2006). Rehabilitation centers were generally clustered near ports, oil terminals and offshore platforms, the most likely point sources of marine oil pollution.

The number of oiled penguins found along the Atlantic coast of Argentina varied among years but there was a dramatic increase beginning in the mid 1990s coincident with exponential growth of oil exportations in Argentina (Garcia Borboroglu *et al*., 2006).

Penguins are brought to rehabilitation centers along the Southwest Atlantic coast every year during their nonbreeding season (winter) and the majority of them are contaminated with petroleum. What is surprising is that this problem has existed for decades from northern Argentina to Brazil and remains to be solved. The number of rehabilitation centers and the frequency of oiled penguins along the coast of the Buenos Aires Province, Argentina, suggest this is one of the main locations of petroleum pollution. Surprisingly, there are comparatively few petroleum industry activities in this area suggesting oil must be coming from other maritime activities. Lots of ships (mainly fishing, cargo, recreational and cruise boats), are found particularly in the proximity of the Buenos Aires, Mar del Plata, Bahía Blanca and Montevideo harbors, where discharges of untreated sewage, wastes, ballast water and marine litter are likely. Reports of petroleum spills near ports fishing or cargo ports are very frequent in Argentina (Prefectura Naval Argentina). Likewise, the highest

concentrations of hydrocarbons have been registered in ports adjacent to these areas (Esteves et al. 2003).

Petroleum pollution is likely contributing to the long-term decline at the world`s largest Magellanic penguin colony at Punta Tombo, Argentina, where active nests have declined over 20% since 1987 (Boersma 1997, 2008). The large number of adult penguins affected by chronic oil pollution in their wintering range suggests that this problem will have to be ameliorated before populations of Magellanic penguins rebound at their breeding colonies.

In the Pacific Ocean coast in South America there are also petroleum problems. A tanker ran aground spilling petroleum in the Galapagos Islands in January 2001, but fortunately the spill was in an area where penguins do not breed and are rare (IPCWG, 2007). The Galapagos penguins population is at high risk of extinction from an increased frequency of El Nino events (Boersma 1998, Vargas *et al*. in press).A spill in the western part of the archipelago in the heart of their breeding grounds could seriously damage the population.

Two recent spills affected penguins along the Chilean coast. In May 2004, a French flagged Tanker, the Berge Nice, collided with a tug-boat in Primera Angostura, Chile, an access point of the Magellan Strait. The collision resulted in a spill of bunker oil, oiling a 10 kilometer-long stretch of the northern coast of the big island of Tierra del Fuego and affecting an unknown number of Magellanic penguins (IBRRC, 2007). On November 1, 2005, the Eider, a Hong Kong-flagged cargo ship ran aground on the northern coast of Chile, near the city of Antofagasta. Over 7 km of Chilean coastline was impacted with heavy bunker fuel oiling Humboldt penguins (IBRRC, 2007).

UNDERSTANDING THE RISK

To avoid severe negative impacts on penguins and other marine species, planning and implementation strategies should concentrate on minimizing risk associated with petroleum. Risk could be defined as the probability of facing a loss or damage as a consequence of human activities or decisions. Risk is composed by four interlinked dimensions: hazardous potential, exposure, vulnerability and uncertainty (Natenzon, 1995; Natenzon *et al.*, 2003). *Hazardous potential* is the potential threat of any physical or natural phenomenon; *exposure* is related to the distribution or proximity to the danger of the valuables to be protected (beings or material trusts); *vulnerability* is the degree to which a system or unit (ecosystem, population, etc) is likely to experience harm due to exposure to perturbations or stresses, and it is linked to the system attributes and environmental factors that pose danger and foster recover. Finally, *uncertainty* is the unpredictable consequences of natural or human factors that can neither be predicted nor properly managed. A risk situation could become catastrophe depending of the intensity and interaction of these dimensions. Therefore, to minimize the risk it is imperative to reduce the magnitude of the dimensions involved.

Oil pollution problems with penguins are a clear case of an anthropogenic threat that can cause catastrophe. Hazardous potential depends on the nature and magnitude of the spill. Exposure is related to the spatial and temporal proximity of the birds to the petroleum. Vulnerability is associated with the intrinsic features of the species affected and to other environmental conditions that add to the situation affecting the general conditions of the population, such as the lack of food, additional mortality in fishing gears, habitat degradation, etc. The strategies to deal with the petroleum pollution risk should be concentrated on decreasing the three dimensions, as follows:

- *Hazardous potential*: Massive petroleum spills such as the ones produced by ship collisions, ship wrecks, oil platform accidents, and chronic spills like operational

discharges, ballast water dumping, should be avoided by creating new legislation combined with an effective enforcement of all available navigation and operational security measures. To reduce both operational discharges, and to prevent accidents, safeguards must be taken to ensure high standards of environmental protection are implemented. In case of an emergency, it is also essential to design contingency plans.

- *Exposure*: Penguin colonies or migratory routes cannot be moved, but tanker lanes, can be moved to avoid penguins. Tanker lanes can be placed to reduce collisions and, the installation of oil platforms at critical penguin breeding or migratory areas could be prohibited, to diminish penguin exposure to petroleum.
- *Vulnerability*: General environmental features influence vulnerability and must be considered in several dimensions and through a comprehensive approach. The challenges to minimize vulnerability are to prevent other threats to the species, such as overfishing, marine and terrestrial habitat degradation, and other types of contamination.

MARINE CONSERVATION TOOLS

Marine Protected Areas (MPAs), areas designated for special protection to enhance the management of marine resources, are effective tools to achieve multiple goals from an integrated and comprehensive perspective, such as conserving biodiversity, improving fishery management, protecting ecosystem integrity, providing educational and recreational opportunities, and establishing sites for scientific research (Kelleher 1999; NRC, 2001). In this sense, MPAs, if effectively managed, can reduce the three petroleum pollution problem risk dimensions mentioned. The size of an area to protect most penguin species during breeding or

migration, however, may be so large as to be politically impractical (Boersma and Parrish, 1998). For example, for the Magellanic penguins breeding in the South West Atlantic, an area of 100 km width and at least 5,000 km long would be needed to protect them during their migration. Considering that it is difficult to obtain social and or political acceptance even for the designation of small marine protected areas, other management tools likely to gain more acceptance should be considered.

A more targeted option is the implementation of seasonally **Protected Marine Migration Corridors**. Dispersal corridors are potentially powerful adjuncts to the use of reserves in biodiversity conservation (Lipcius *et al*., 2005). Their application is best suited to particular species for which dispersal is a key feature of their life cycle (Rosenberg *et al.*, 1997). Magellanic penguins are a good candidate for a seasonal protected area, with minimum disruption of other activities. During the non-breeding season, the penguins use predictable corridors along the Atlantic coast, staying within the exclusive economic zone (EEZ) of national jurisdiction of coastal countries. In this case, coordinated national actions could reduce mortality of penguins.

In this sense, Argentina, Uruguay, and Brazil could designate a **Seasonally-Protected Marine Migration Corridor** in the Southwest Atlantic, based on the penguin distribution during the winter migration. In this way, activities that harm penguins could be restricted or subjected to higher safety requirements. The corridor itself would be a stationary area comprising the entire strip of coastal waters (in the EEZ of each country) used by the penguins as they travel north in fall and south in the spring, and would include their wintering areas. Within the Corridor, a series of smaller areas, focused on where the majority of penguins are actually found in each month, could protect migrating penguins as they move to the north along the coast in fall (Chubut and Rio Negro Provinces in Argentina), in the wintering areas during

June-August (Buenos Aires Province in Argentina, and Uruguay), and then south again in the spring. The permanent corridor, with seasonally-appropriate protection zones, would provide predictability to human users of the area, allowing advance planning for human activities so as to avoid penguins.

Even when an area is finally created, it could take some time to see recommendations implemented. Therefore, some alternatives could be adopted to work towards conservation goals in the short term, to minimize the risk for penguins and for oceanic and coastal wildlife and habitats. In this respect, the hazardous potential and the exposure could be minimized through practical strategies focused directly on maritime and petroleum enterprises and / or governmental agencies. A good example of this is the regulation that required tanker lanes to be moved farther offshore along the Patagonian coast, Argentina, since 1997 (SAyDS 2007). Moreover, some strategies could come from the same private companies involved. An excellent example in Argentina of this approach is the agreement between the petroleum tanker companies separating geographically the routes of boats navigating southwards from the ones navigating northwards, which reduced the probability of accidents from boat collisions. Protection of both the EEZ and high-seas area could begin with voluntary pledges by industries (petroleum transport, certain types of industrial fishing) to mitigate threats to penguins. This has partly been the case in the Province of Chubut, Argentina where Magellanic penguins may benefit from the protected areas for spawning fish.

The more integrated and revolutionary marine conservation tool to address the petroleum pollution problem is **Marine Spatial Planning** (MSP). However, while MPAs are a more developed and embodied concept for the last decades, MSP is still just an idea even in developed countries (Gubbay, 2004). MSP can have a broader remit

than MPAs, by providing an overall framework for managing activities in the marine environment. MSP are a way to improve decision-making and deliver an integrated ecosystem-based approach to the management of marine activities, particularly where there are many demands for the use of marine resources and sea space (Gubbay, 2004). MSP includes an interlinked system of plans, policies and regulations of these resources and spaces with strategies that apply beyond the traditional MPAs boundaries. The ideal scenario is the designation of national or regionally representative networks of MPAs or similar tools set within the context of MSP. In the case of petroleum pollution risk, MSP should integrate plans and programs that regulate petroleum development and maritime transportation, to reduce both chronic or massive spill pollution, and zoning schemes with special temporal or spatial regulations considering the main breeding areas and migratory grounds.

Petroleum and penguins are a deadly mix.

Penguins only occur in the Southern Hemisphere where their breeding and migration grounds are mostly under the jurisdiction of developing countries, such as South Africa, Namibia, Argentina, Uruguay, Brazil, Chile, Peru, and Ecuador. However they also occur in developed countries like Australia and New Zealand. In these developed countries, the origin of most petroleum spills has been identified. They have strong laws and enforcement to prevent spills. In addition, the laws are coupled with effective litigation procedures, and in most cases, the companies that are responsible for spilling petroleum are identified, prosecuted and fined. On the other hand, in Africa and South America the origin of many petroleum spills, including some of the most harmful ones, remain unknown. In addition, law enforcement is ineffective and prosecution procedures are never-ending in a context where the judiciary is not always independent from political or economical powers (Spiller and Tommasi, 2007). As a result, the

companies that are responsible for the damage do not compensate for the harm inflicted. Added to these problems is the shortcoming that many petroleum tankers are governed not by the country whose waters they sail in, but by the country with whom the tanker is registered. Not surprisingly, tankers are often registered under countries with the lowest safety and environmental safeguards. They are often poorly maintained, and operated by crews that are untrained in emergency procedures (IPCWG, 2007).

An immediate response to petroleum pollution is rehabilitation of affected animals. Rehabilitating penguins is time-consuming and, costly, and may not be completely effective. Some rehabilitated African penguins, a decade after the spill still have lower reproductive success (Wolfaardt *et al.*, 2007). This has also been observed for little penguins where rehabilitated oiled birds and their offspring had also lower survival (Goldsworthy et al 2000, Giese et al 2000). Also, only a fraction of affected penguins are usually found and successfully rehabilitated, leaving the others to suffer a slow death by starvation or hypothermia. Conservation strategies that can reduce exposure of penguins to petroleum may be the most cost-effective, have the greatest long-term benefits for penguins, and will likely slow the decline of many species of penguins.

Penguins are important constituents of marine ecosystems in their top predator role, and they are good indicators of the oceanic and coastal ecosystem health. Many penguin species are also economically important because their breeding colonies are tourist attractions (Walker et al 2005, Boersma 2008). In addition, they are flagship charismatic species, creating public and political support to protect habitats and other species under the umbrella of their large marine habitat requirements.

Penguins are among the most conspicuous victims of petroleum pollution in the southern hemisphere oceans. Unfortunately, many species of penguins are becoming

more endangered and sadly the increasing anthropogenic sources of mortality appear to be an important driving factor in their decline. We should dedicate our very best efforts and wisdom to manage ourselves and the activities we carry out in our seas. We must improve our stewardship of the ocean.

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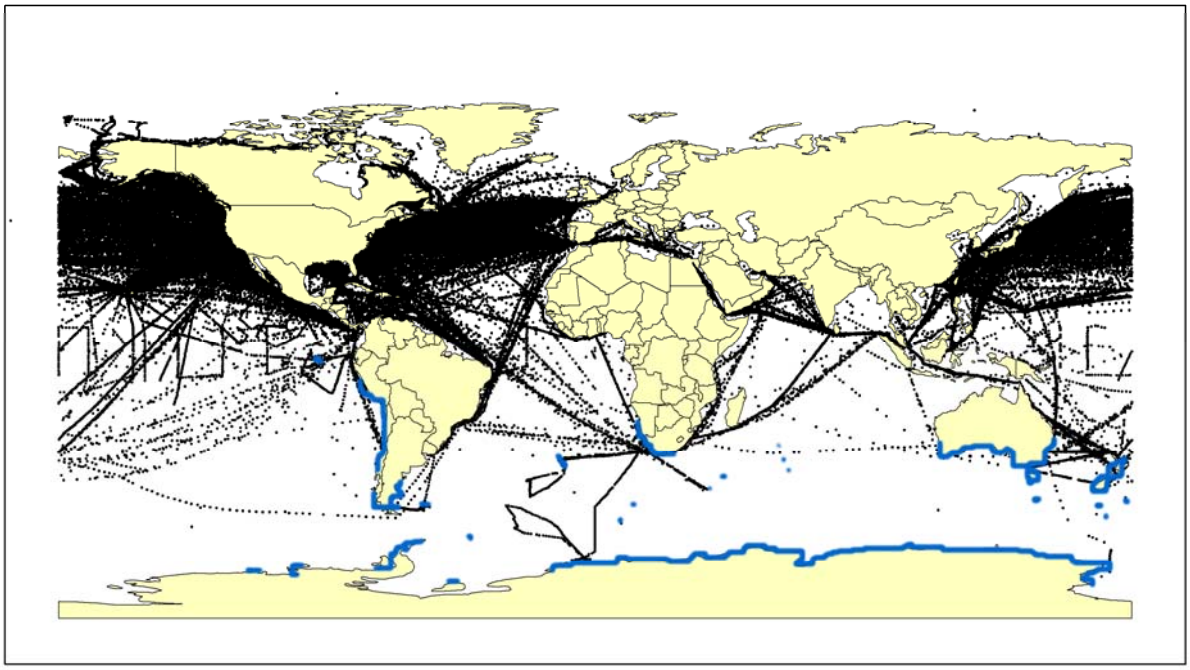
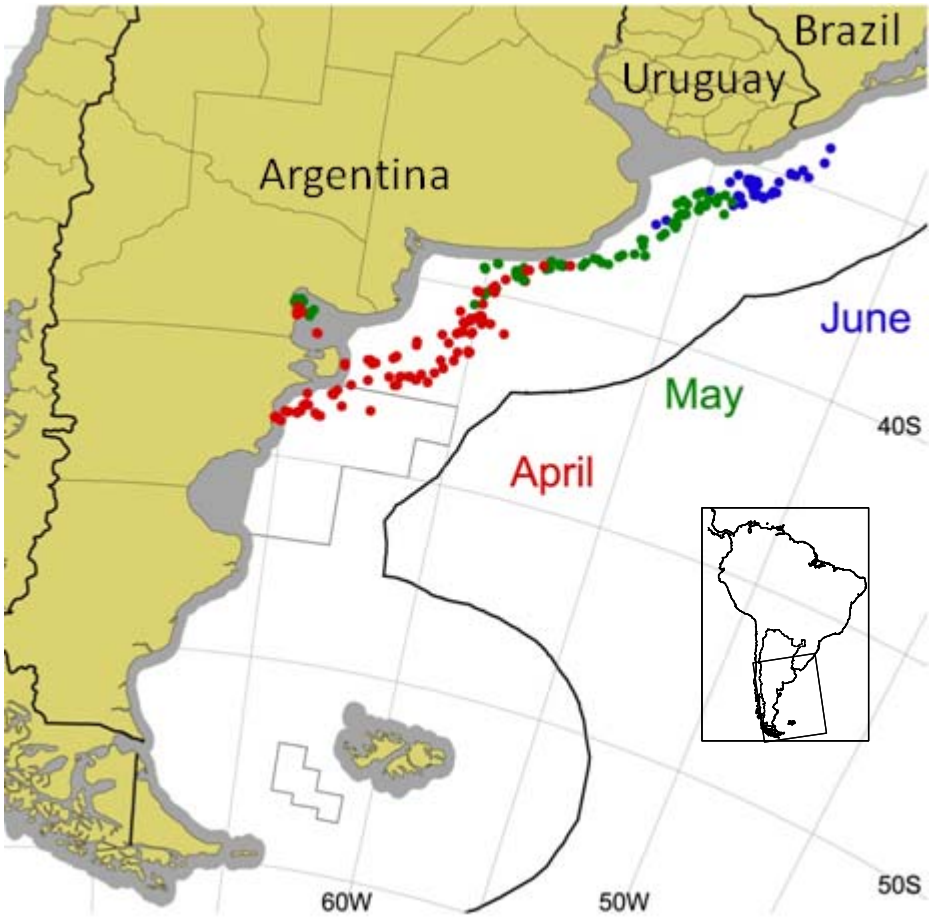
FIGURE CAPTIONS

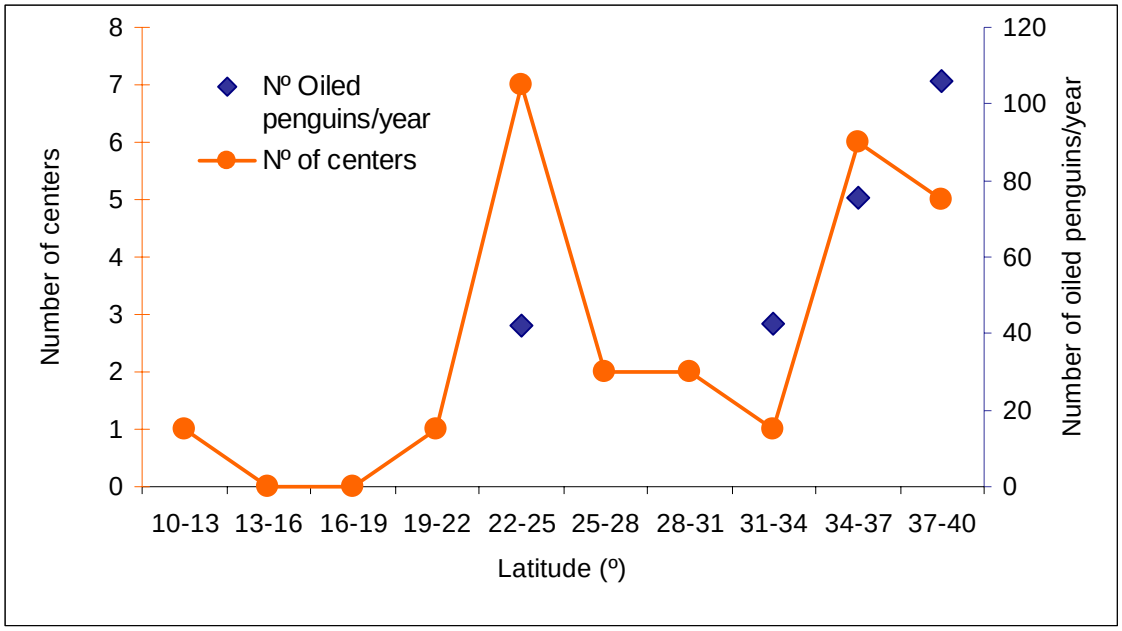
Figure 1. World map showing maritime traffic (black), and the distribution of penguin species (clear blue). Data sources: Base map from Environmental Systems Research Institute (ESRI). Maritime traffic downloaded from NOAA Physical Oceanography Division of AOML (SEAS BBXX December 2007). Penguin colony locations redrawn from Williams 1995.

Figure 2. Map of satellite telemetry locations of migrating penguins. A seasonal series of protected areas forming a seasonally protected Marine Migration Corridor could protect migrating penguins as they move to the north along the coast in fall (Chubut and Rio Negro Provinces in Argentina), in the wintering areas during June-August (Buenos Aires Province in Argentina, and Uruguay), and then south again in the spring. Data sources: Base map from Environmental Systems Research Institute (ESRI). Penguin migration locations redrawn from Stokes et al. 1998 and Boersma, unpublished data.

Figure 3. Number of oiled penguins counted per year and number of rehabilitation centers along the Atlantic coast of South America. X - Axis corresponds to geographic coordinates.




Brazil
Uruguay
Argentina
June
May
April
40S
50S
60W
50W


Number of centers
Number of oiled penguins/year
Nº Oiled penguins/year
Nº of centers
0
1
2
3
4
5
6
7
8
0
20
40
60
80
100
120
10-13
13-16
16-19
19-22
22-25
25-28
28-31
31-34
34-37
37-40
Latitude (º)