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A simple Bird Sensitivity to Oil Index as a management tool in coastal and marine areas subject to oil spills when few biological information is available

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ABSTRACT

This study sought to develop a simple index for ranking birds' environmental sensitivity to oil in which birds are used as biological indicators. The study area consisted of both the Santos Estuarine System (SES), and the Laje de Santos Marine State Park (LSMSP), located in Southeastern Brazil. Information on the bird species and their feeding and nesting behaviors were obtained from the literature and were the basis of the sensitivity index created. The SES had a higher number of species, but only about 30% were found to be highly sensitive. The LSMSP presented a much lower number of species, but all of them were considered to be highly sensitive to oil. Due to its simplicity, this index can be employed worldwide as a decision-making tool that may be integrated into other management tools, particularly when robust information on the biology of birds is lacking.

1. Introduction

Oil spills have been recurrent worldwide and have caused varying degrees of damage to marine and coastal ecosystems (Gundlach and Hayes, 1978). In the vicinities of potential sources of oil, such as ports, refineries, vessel routes, oil terminals, and oil rigs, both marine organisms and their habitats are permanently at risk of being affected by oil spills (Gundlach and Hayes, 1978). When marine and coastal environments are subjected to oil spills, environmental recovery may be slow. According to reports on affected mangrove forests, recovery may takes years or even decades (Burns et al., 1993, 1994; Kingston, 2002; Santos et al., 2012). In an attempt to establish guidelines for quick and successful responses to oil spills, the National Oceanic and Atmospheric Administration (NOAA) developed Environmental Sensitivity Index (ESI) maps. These maps include shoreline classifications according to sensitivity to oil. The ESI itself was first proposed by Gundlach and Hayes (1978). It classifies coastal environments into different environmental sensitivity categories based on physical and geomorphological characteristics such as slope, wave exposure, and grain size. This classification was expanded by the NOAA to include biological and socioeconomic characteristics of the shoreline environments in addition to the physical parameters (NOAA, 2002). Information on sensitivity to oil is required if priority protection efforts are to be established; it is also essential when choosing the most appropriate response strategy during oil spill emergencies.

Emergency response measures should be carefully outlined in a contingency plan in order to minimize the impacts of oil on coastal and marine environments (Romero and Abessa, 2014). A contingency plan usually provides information on hazard identification, vulnerability analysis, risk assessment, and response actions. An oil spill contingency plan should present three sections: (1) a strategy section; (2) an action and operations section; and (3) a data directory containing all relevant maps, resource lists, and data sheets required to support an oil spill response effort and to allow the response to be carried out according to an agreed-upon strategy (IPIECA, 2000). A good contingency plan provides a prompt response to an oil spill.

Birds are highly vulnerable to oil spills; however, the sensitivity of a given species depends on a number of characteristics, from species behavior to biology (King and Sanger, 1979; Wiens et al., 1984; Burger, 1993; Speich et al., 1991; Williams et al., 1994; Wiens and Parker, 1995; Begg et al., 1997). When a bird is oiled, it essentially may be affected by two types of impacts: physical impacts and/or toxic impacts (IPIECA, 2016; Kennish, 1992; NOAA, 2002). Physical impacts are generally caused by heavy oils, which cover the animal and remove the waterproofing of their feathers, resulting in a loss of insulation and buoyancy (Kennedy, 1970; Peakall et al. 1982; Fry and Lowenstine, 1985; Islan and Tanaka, 2004). Toxic effects are largely caused by light oils, especially when spills are confined to limited areas. These oils have

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more soluble and volatile components that may be directly absorbed via dermal contact, through the inhalation of hydrocarbon saturated vapors, or through the ingestion of contaminated food or water, all of which may cause a range of sublethal effects (Clark and Brown, 1977) such as liver damage and a decrease in the number of viable eggs (Grau et al., 1977; IPIECA, 2016; NOAA, 2002; Velando et al., 2007). Furthermore, these effects can increase mortality rates, and the aggregate effect of these consequences may produce negative alterations at the population level or the community level (GESAMP, 1980).

The mortality of oiled birds is a clearly visible impact of oil spills. Due to their position on the food chain, birds have been considered suitable indicators of the health and conservation statuses of ecosystems (Grant, 1991; Koskimies, 1979). Some marine and coastal birds establish breeding colonies, which have a substantial influence on local patterns of marine nutrient cycling and energy flows (Golovkin, 1968; Tuck, 1961). Birds tend to occur in highly productive ecosystems and may consume 22% to 27% of the annual production of small fishes (Wiens and Scott, 1975). Both the relative abundance and the presence of different groups of birds in the environment are thought to be important tools in environmental monitoring studies. The conservation statuses of ecosystems can be measured by factors such as changes in behavior, alterations to the size and/or structure of populations or communities, and amounts of biomass (Koskimies, 1979). Estimating birds' sensitivity to oil is therefore very important for providing information on the risks that oil spills create for this taxonomic group (Begg et al., 1997) and for the ecosystem as a whole. King and Sanger (1979) suggest that the establishment of a sensitivity index for birds could be a useful management tool with a range of applications. These authors proposed the first sensitivity index for birds: the Oil Vulnerability Index (King and Sanger, 1979). Later, Speich et al. (1991) developed a bird sensitivity index known as the Bird Oil Index and applied it to Puget Sound, a coastal area located in Washington State in the US. The US Coast Guard incorporated this index into oil spill response maps. The Bird Oil Index created by Speich et al. (1991) considers a range of information on bird behavior, population characteristics, and seasonal occurrences in the region. Other indices were further proposed (Anker-Nilssen, 1987; Begg et al., 1997; Camphuysen, 1989; Camphuysen and Leopold, 1998; Tasker and Pienkowski, 1987; Webb et al., 1995; Wiese and Ryan, 2003; Williams et al., 1994), but they basically represented adaptations of those indices established by King and Sanger (1979) and/or Speich et al. (1991). However, all of the detailed information necessary to calculate those indices may not always be accessible, especially in megadiverse areas, such as the coasts of tropical and subtropical regions. A lack of information may therefore hinder the use of this index and consequent coastal classification. In the current study, we provide a simple index for ranking environmental sensitivity to oil using birds as indicators, and apply it to two sites with different environmental and biological characteristics in order to assess its functionality. We have established a sensitivity ranking that considers the ecological niches occupied by all of the species identified, and we have created a set of symbols to represent the different levels of sensitivity on ESI maps.

2. Materials and methods

2.1. Description of study area

The study area is located on the central coast of São Paulo State in Southeastern Brazil (Fig. 1). It includes the Santos Estuarine System (SES) and the Laje de Santos Marine State Park (LSMSP). The SES is approximately 160 km^2 in size and includes two main estuarine channels (the Santos Channel and São Vicente Channel), a major bay (the Santos Bay), and a series of small inlets, creeks, and estuarine islands. The coastal ecosystems in this region are dominated by mangrove swamps and salt marshes, as well as by rocky reefs, sand and mud flats, sheltered and semi-sheltered sandy beaches, and other types of habitats. This area experiences intense anthropic influence, including the presence of a major industrial complex (including a major oil refinery, a large steel plant and several fertilizer and petrochemical plants), urban areas, and the Port of Santos, the largest port in Latin America. Due to these factors, part of the studied area is considered to be highly polluted (Abessa et al., 2008; Lamparelli et al., 2001). The LSMSP (24°19′S, 46°11′W) is located approximately 42 km from the coast and is formed by a main rocky islet and some rocky shores and reefs. The LSMSP is the only marine state park in São Paulo and is considered a hot spot for marine biodiversity. This islet is inhabited primarily by coastal and pelagic seabirds (Campos et al., 2004).

2.2. Determining bird sensitivity

Information on the birds of the study sites was obtained from the literature, including technical briefs, books, scientific papers, and academic reports containing information on different species, and, if possible, their distribution within the region. The survey was initially focused on collecting data on which bird species inhabit or occur in the SES and the LSMSP. The species found were then divided according to groups accepted by the National Oceanic and Atmospheric Administration, or the NOAA (2002) and the Brazilian Ministry of the Environment, or the MMA (2004): gulls/terns, pelagic birds, diving birds, waterfowls, wading birds, shorebirds, raptors, passerine birds, and non-passerine birds.

The purpose of the index is to classify different bird species according to their sensitivity to oil in the case of a hypothetical oil spill. Thus, the Bird Sensitivity to Oil Index (BSOI) was defined qualitatively based on the nesting and feeding behaviors of the birds found in the study area. These aspects were selected because they indicate the type and intensity of the contact of the birds with the oil spread on the water surface, after and oil spill. The information on the birds was obtained from such books as *The Avis Brasilis - Field Guide to the Birds of Brazil* and *The Handbook of the Birds of the World* (Hoyo et al., 1992; Sigrist, 2009) and other publications. Feeding behavior was defined according to the intensity of the species' contact with water: “no contact with water” (low sensitivity), “contact with surface water” (moderate sensitivity), and “diving” (high sensitivity). Nesting behavior was defined according to the distance between the respective species' nests and water. The classes established for nesting behavior were “no contact with water” (low sensitivity), “nest near water” (moderate sensitivity), and “nest in water/flooded area” (high sensitivity). The low, moderate, and high sensitivity levels for feeding and nesting behaviors were then crossed in a qualitative table in order to generate the Bird Sensitivity to Oil Index (Table 1).

The “Slight Sensitivity” category is applied to species that do not experience any contact with water during nesting or feeding behaviors. The “Moderate Sensitivity” category reflects species which nest near water or experience contact with surface water when feeding. Species that nest near water and experience contact with surface water during feeding were classified as having “Severe Sensitivity.” The Highest BSOI category, “Extreme Sensitivity”, is applied to species that dive or/and nest in water or in flooded areas.

2.3. Creating symbols for the Bird Sensitivity to Oil Index

In order to integrate the BSOI into ESI maps so that they may be of use in the oil spill response planning process, we developed a set of images to represent the different bird sensitivity categories. This study used the bird point symbols created by the NOAA (2002), which are the same symbols used to represent biological resources in Brazilian protocols (MMA, 2004). A small colored circle is placed above the bird point symbols used to represent each group of species, and the categories are indicated by different colors: blue represents Slight Sensitivity, yellow represents Moderate Sensitivity, orange represents Severe Sensitivity, and red represents Extreme Sensitivity (Fig. 2).