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Assessment and rehabilitation of wildlife affected by an oil spill in Puerto Rico

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Abstract

On 7 January 1994, the barge *Morris J. Berman* spilled approximately 3.6 million liters of oil off Punta Escambrón in San Juan, Puerto Rico. This resulted in the contamination of extensive areas, impacting on natural resources along more than 48 km of Puerto Rico's north shore. Thousands of dead and live oiled organisms washed ashore. Dead wildlife were collected opportunistically, and examined for the presence of oil and identified. Live wildlife was cleaned and treated at a temporary triage facility. A total of 5687 organisms of over 152 species were collected, including cnidarians, annelids, crustaceans, molluscs, echinoderms, fishes, birds and sea turtles. Molluscs and echinoderms were noticeably more affected than other species. Four species classified as endangered or threatened were also affected. A significant impact was observed on the live specimens presented for medical treatment, including shore crabs, birds and sea turtles. Only 63% of these were successfully rehabilitated.

Keywords: Oil spill; Caribbean; Puerto Rico; Wildlife; Mortality; Rehabilitation

1. Introduction

On the morning of 7 January 1994, a barge carrying about 5.7 million liters of no. 6 diesel fuel oil grounded off Punta Escambrón in San Juan, Puerto Rico (18°28.3′N, 66°05.4′W) after the 365-m metal tow line from the tugboat *Emily S* broke in the middle of the night. The barge, identified as the *Morris J. Berman*, spilled approximately 3.6 million liters of bunker C oil while it was aground (Ross, 1994; Ornitz, 1996). This spill constituted the sixth major oil spill reported for Puerto Rico and the 11th for the Caribbean Sea since 1962 (Table 1).

The discharge of fuel oil from the barge resulted in the contamination of extensive natural resource areas. Initially, about 4.8 km of coastline and 68 km^2 of sea surface were affected (Ornitz, 1996). Areas affected in the vicinity of the spill consisted of coastal waters and/or lagoons with either gravel/boulder beaches, rip-rap and exposed rocky shores with high wave energy. The coral reef ecosystem the barge struck upon running aground was almost obliterated (Ornitz, 1996).

On 15 January, the barge was towed to an area located 37 km NNE of San Juan and sunk to a depth of 2 km to remove the constant heavy source of nearshore oiling that was damaging coastal resources and severely hampering cleaning efforts (Ross, 1994). In the weeks following, the extent of the impact on natural resources stretched along more than 48 km of shoreline, from Punta Boca Juana in Dorado to Punta Vacia Talega in Loíza, as oil patches, pancakes and sleeks traveled west parallel to shore. On 3 February 1994 oil from the *Morris J. Berman* impacted the beaches of Isabela and Aguadilla, on Puerto Rico's northwest coast.

Oil reached the shores of Isla Culebrita, an island east of Puerto Rico, on 10 January and 2 weeks later the shores of Isla Culebra, especially Playa Flamenco, in what was thought to be a related impact. The oil gradually impacted the north, northeast and southeast shores of Culebra, also east of Puerto Rico, affecting fish, sea shells, sea birds and sea turtles.

Three different types of oil were identified by the US Coast Guard (bunker oil, crude oil and lube oil), but no relation was found to the *Berman* spill through fingerprinting of the oil. These 'mystery spills' seem to have been due to illegal cleaning of barge tanks (T. Talhavest,

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Table 1
Major oil spills in the Caribbean between 1962 and 1994

Year	Locality	Vessel	Type of oil	Amount[a]	References
1962	Guánica and Bahía Sucia, Cabo Rojo, Puerto Rico	*Argea Prima*	crude	11.0	Díaz-Piferrer (1962); Klekowski et al. (1994)
1968	Off Bahía de San Juan, San Juan, Puerto Rico	*Ocean Eagle*	crude	1.0	Cerame Vivas (1969)
1968	Off Río Viejo, Panamá	*Witwater*	diesel and bunker C	3.2	Rutzler and Sterrer (1970)
1971	St. Croix, US Virgin Islands	*Santa Augusta*	crude	13.0	R.H. Boulon, pers. comm.
1973	Bahía Sucia, Cabo Rojo Puerto Rico	*Zoe Colocotroni*	crude	5.0	Nadeau and Berquist (1977); Page et al. (1979); Grady (1980–81); Gilfillan et al. (1981); Corredor et al. (1990); Redgwell (1992); Klekowski et al. (1994)
1977	Guayanilla, Puerto Rico	unidentified	Venezuelan crude	0.2	López (1979)
1978	Pasaje de San Juan, Fajardo, Puerto Rico	*Peck Slip*	bunker C	0.2	Gundlach et al. (1979); Getter et al. (1981)
1979	Off Tobago	*Atlantic Empress*	crude	158.0	Horn and Neal (1981)
1986	Bahía las Minas, Panamá	[b]	crude	8.0	Cubit et al. (1987)
1991	Off St. Kitts and Nevis	*Vista Bella*	bunker C	2.0	Corbin et al. (1993)
1994	El Escambrón, San Juan, Puerto Rico	*Morris J. Berman*	no. 6 fuel	3.6	Ross (1994); Ornitz (1996); McGehee et al. (1996); this paper
1994	Bahía de Guánica, Guánica, Puerto Rico	unidentified			this paper

[a] In millions of liters.
[b] No vessel was involved, but caused by a storage tank at Refinería Panamá, located 12 km NE of Colón.

Fish and Widlife Service, personal communication). Oil later impacted the beaches of Fajardo, Cayo Icacos, Cayo Diablo, Isla Palominito, Ceiba, Isla de Vieques, Naguabo, Humacao, Yabucoa and Maunabo, all on the eastern coast of Puerto Rico. Shores of Bahía de Guánica, on the south coast of Puerto Rico, were also found with oil between 22 March and 1 April 1994, affecting a number of birds. The source of this oil was not established, although on 14 May 1994, an oil spill occurred on the east shore of the bay, affecting the area of Guaypao in the village of Ensenada.

Biological resources in the immediate areas that were affected by the *Berman* spill and the other spills include sandy-intertidal invertebrate communities, rocky-intertidal invertebrate communities, and coastal and offshore communities of fish (some of commercial importance for artisan and recreational fishing and the aquarium trade). Endangered and protected marine mammals—such as the West Indian manatee (*Trichechus manatus*), numerous species of dolphins, humpback whales (*Megaptera novaeangliae*) and sperm whales (*Physeter macrocephalus*) are known to frequent or pass by in migration through the affected areas (Mignucci-Giannoni, 1989, 1998). The three known species of endangered sea turtles—green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*) and the leatherback turtle (*Dermochelys coriacea*)—are also found throughout, at times nesting in nearby beaches (B. Pinto-Rodríguez, Department of Natural and Environmental Resources, personal communication). A great number of marine and coastal birds (both resident and migratory) are found in the affected areas and inhabit nearby bays and lagoons, which are used as resting, feeding and nesting grounds. Some of the bird species are endangered or threatened and include: the royal tern (*Sterna maxima*), sandwich tern (*Sterna sandvicensis*), common tern (*Sterna hirundo*), roseate tern (*Sterna dougallii*), least tern (*Sterna antillarum*), brown pelican (*Pelecanus occidentalis*), magnificent frigatebird (*Fregata magnificens*), Audubon shearwater (*Puffinus lherminieri*), Caribbean coot (*Fulica caribaea*), white-cheeked pintail (*Anas bahamensis*), osprey (*Pandion haliatus*) and the peregrine falcon (*Falco peregrinus*) (Raffaele, 1989; J.E. Saliva, Fish and Wildlife Service, personal communication).

Although the grounding site and its vicinities are not normally considered areas of high ecological value, biological resources residing in these areas were severely affected. Areas considered of high ecological value are

Table 2
Wildlife species affected by the barge *Morris J. Berman* spill in Puerto Rico and collected by the Caribbean Stranding Network, including seven phyla, 15 taxon groupings, 152 species and 5687 organisms

Taxon	Phylum/species	Common name	No. organisms collected
	Porifera (30)		
Actiniaria	–	unidentified sponge	25
Gorgonacea	*Haliclona echinoformis*	sponge	5
	Cnidaria (23)		
Anthozoa (23)			
Actiniaria		unidentified anemone	16
Gorgonacea	*Gorgonia* spp.	unidentified seafan	5
	Eunicea sp.	sea rod	1
Scyphozoa (1)	–	unidentified jellyfish	1
	Annelida (11)		
Polychaeta (11)		unidentified sea worms	11
	Arthropoda–Crustacea (557)		
Malacostraca (557)			
Stomatopoda	*Gonodactylus oerstedii*	swollen claw squilla	1
	Lysiosquilla spp.	mantis shrimp	2
	Squilla empusa	common mantis shrimp	1
Decapoda		unidentified shrimp	3
	Apherasa jurinei	–	3
	Goniopsis cruentata	spotted mangrove crab	2
Canceridae	*Cancer* spp.	cancer crab	2
Coenobitoidea	*Coenobita clypeatus*	land hermit crab	1
	–	unidentified hermit crab	18
Palinuridae	*Panulirus argus*	spiny lobster	5
Grapsidae	*Grapsus grapsus*	sally lightfoot	425
	Pachygrapsus transversus	mottled shore crab	26
	Percnon gibbesi	urchin crab	1
	Plagusia depressa	flattened crab	18
	Sesarma curacaoense	curacao marsh crab	19
Hippidae	*Emerita* spp.	Atlantic mole crab	3
Majidae	*Macrocoeloma crispinosum*	sponge spider crab	5
	Mithrax spinosissimus	spiny spider crab	3
Ocypodidae	*Ocypode quadrata*	ghost crab	7
Portunidae	*Arenaeus cribarius*	speckled crab	5
	Callinectes ornatus	ornate blue crab	1
	Callinectes sapidus	blue crab	4
	Portunus spinimanus	spinyhand crab	1
Xanthidae	*Panopeus herbstii*	common mud crab	1
	Mollusca (1439)		
		unidentified mollusc	13
Cirripedia (1)			
Thoracica	*Lepas* sp.	stalked barnacle	1
Gastropoda (622)			
		unidentified gastropod	81
	–	unidentified shell	139
	–	unidentified snail and whelk	29
Archaeogastropoda, Fissurellidae	*Diodora cayenesis*	Cayenne keyhole limpet	8
	Fissurella barbadensis	Barbados keyhole limpet	1
	Fissurella nodosa	knobby keyhole limpet	13
	Fissurella spp.	limpet	3
Trochidae	*Cittarium pica*	West Indian top shell	29
	Tegula fasciata	colorful top shell	2
Turbinidae	*Astraea caelata*	carved star shell	90
	Astraea tecta	imbricated star shell	4
	Astraea tuber	green star shell	12
	Turbo castanea	chestnut turban	2
Neritidae	*Nerita* spp.	nerite	22
	Nerita fulgurans	Antillean nerite	4
	Nerita peloronta	bleeding tooth	4

(Table continued overleaf)

Table 2—*(Continued)*

Taxon	Phylum/species	Common name	No. organisms collected
	Nerita tessellata	checkered nerite	46
	Nerita versicolor	fourtooth nerite	6
	Puperita pupa	zebra nerite	1
Mesogastropoda, Littorinacea	*Littorina* spp.	periwinkle	104
	Littorina ziczac	zebra periwinkle	1
	Tectarius muricatus	beaded periwinkle	1
Turritellidae	*Vermicularia spirata*	West Indian worm shell	1
Planaxidae	*Planaxis lineatus*	dwarf atlantic planaxis	1
Cassididae	*Phalium granulatum*	Scotch bonnet	16
Neogastropoda, Muricacea	*Purpura panda*	widemouth purpura	1
Tectibranchia, Aplysiidae	*Aplysia dactylorela*	sea-hare	1
Pelecypoda (112)			
Eulamellibranchia		unidentified clam	12
Fillibranchia, Arcidae	*Anadara notabilis*	eared ark	1
Mytilidae	–	unidentified mussel	71
	Brachidontes exustus	scorched mussel	27
Pinnidae	*Atrina* sp.	penshell	1
Amphineura (685)			
Chitonida	–	unidentified chiton	133
Mopaliida	*Ceratozona squalida*	eastern surf chiton	29
Ischnochitonidae	*Ischnochiton* spp.	chiton	3
Chitonidae	*Acanthopleura granulata*	fuzzy chiton	11
	Chiton spp.	chiton	3
	Chiton marmoratus	marbled chiton	57
	Chiton squamosus	squamous chiton	29
	Chiton tuberculatus	West Indian green chiton	420
Cephalopoda (6)			
Octopoda	–	unidentified octopus	5
	Octopus vulgaris	common Atlantic octopus	1
	Echinodermata (3303)		
Stelleroidea (40)			
Ophiurida	*Ophiocoma echinata*	spiny brittle star	5
	Ophioderma spp.	brittle star	8
	Ophionereis reticulata	reticulated brittle star	23
	Opicnida scabriuscula	lubated brittle star	4
Echinoidea (3228)			
	–	unidentified sea urchin	1484
Cidaroida	*Eucidaris tribuloides*	slatepencil urchin	1
Diadematoida	*Diadema antillarum*	longspin urchin	1
Arbacioidea	*Arbacia punctulata*	Atlantic purple urchin	31
Temnopleuroida	*Tripneustes ventricosus*	sea egg	37
	Lytechinus variegatus	variagated urchin	5
Echinoida	*Echinometra lucunter*	rock-boring urchin	1663
Spatangoida	*Meoma ventricosa*	West Indian sea biscuit	1
	Moira atropos	mud heart urchin	5
Holothuroidea (35)			
Aspidochirotida	*Holothuria* spp.	unidentified sea cucumber	35
	Chordata (324)		
Pisces Osteichthyes (294)			
Teleosti	–	unidentified fish	48
Acanthuridae	*Acanthurus bahianus*	ocean surgeon	12
	Acanthurus chirurgus	doctorfish	3
	Acanthurus coeruleus	blue tang	5
Apogonidae	*Apogon maculatus*	flamefish	7
Aulostimidae	*Aulostomus maculatus*	trumpetfish	4
Belonidae	*Platybelone argalus*	keeled needlefish	2
	Strongylura notata	Atlantic needlefish	2
Blennidae	*Ophioblennius atlanticus*	redlip blenny	5
	Parablennius marmoreus	seaweed blenny	1
Carangidae	*Selar crumenophthalmus*	bigeye scad	9

Table 2—(*Continued*)

Taxon	Phylum/species	Common name	No. organisms collected
Chaetodontidae	*Chaetodon striatus*	banded butterflyfish	6
Congridae	–	unidentified eel	2
Fistulariidae	*Fistularia tabacaria*	bluespotted cornetfish	1
Gerreidae	*Eucinostomus argenteus*	sportfin mojarra	1
	Gerres cinereus	yellowfin mojarra	1
Gobiesocidae	*Arcos macrophthalmus*	tadpole clingfish	4
Haemulidae	*Anisotremus virginicus*	porkfish	1
	Haemulon chrysargyreum	smallmouth grunt	5
	Haemulon flavolineatum	French gunt	2
Hemiramphidae	*Hemiramphus brasiliensis*	ballyhoo	1
Holocentridae	*Holocentrus* spp.	unidentified squirrelfish	4
	Holocentrus ascensionis	longjaw squirrelfish	13
	Holocentrus coruscus	reef squirrelfish	1
	Holocentrus rufus	squirrelfish	2
	Holocentrus vexillarius	dusky squirrelfish	13
	Myripristis jacobus	blackbar soldierfish	10
	Plectrypops retrospinis	cardinal soldierfish	7
Labridae	*Lachnolaimus maximus*	hogfish	2
Lutjanidae	*Lutjanus cyanopterus*	cubera snapper	1
	Lutjanus griseus	gray snapper	4
	Lutjanus mahogoni	mahogany snapper	2
Monacanthidae	*Aluterus punctatus*	speckled worm eel	1
	Cantherhines pullus	orangespot file fish	2
Mullidae	*Mulloides martinicus*	yellow goatfish	2
Muraenidae	*Enchelycore nigricans*	viper moray	1
Ophidiidae	*Lepophidium* spp.	cusk eel	2
Pempheridae	*Pempheris schomburgki*	glassy sweeper	1
Pomacanthidae	*Pomacanthus arcuatus*	gray angelfish	1
	Pomacanthus paru	French angelfish	1
	Pomacentrus fuscus	dusky damselfish	29
	Pomacentrus variabilis	cocoa damselfish	12
	Chromis cyaneus	blue chromis	1
	Microspathodon chrysurus	yellowtail damselfish	1
	Abudefduf saxatilis	sergeant major	9
Priacanthidae	*Priacanthus arenatus*	bigeye	2
Scaridae	*Scarus vetula*	queen parrotfish	13
	Sparisoma aurofrenatum	redband parrotfish	1
	Sparisoma chrysopterum	redtail parrotfish	1
	Sparisoma rubripinne	yellowtail parrotfish	5
	Sparisoma viride	spotlight parrotfish	14
Scorpaenidae	*Scorpaena plumieri*	spotted scorpionfish	1
	Scorpaenodes caribbaeus	reef scorpionfish	1
	Sebastes melanops	rockfish	1
Serranidae	*Epinephelus adscensionis*	rockhind	2
	Epinephelus morio	red grouper	1
	Epinephelus spp.	grouper	2
Sparidae	*Calamus bajonado*	jolthead porgy	2
Synodontidae	*Synodus foetens*	inshore lizardfish	1
Tetraodontidae	*Canthigaster rostrata*	sharpnose puffer	1
	Sphoeroides spp.	pufferfish	2
Reptilia (2)			
Testudines, Chelonidae	*Chelonia mydas*	green turtle	2
Aves (28)			
Charadriiformes, Laridae	*Sterna sandvicensis*	sandwich tern	2
Scolopacidae	*Calidris* sp.	sandpiper	1
Ciconiiformes, Ardeidae	*Nycticorax violaceus*	yellow-crowned night heron	1
Columbiformes, Columbidae	*Columba livia*	rock dove	6
Coraciiformes, Alcedinidae	*Ceryle alcyon*	belted kingfisher	1
Pelecaniformes, Pelecanidae	*Pelecanus occidentalis*	brown pelican	4
Sulidae	*Sula leucogaster*	brown booby	12
Procellariformes, Procellariidae	*Puffinus lherminieri*	Audubon's shearwater	1

found nearby, including the shores of the Piñones State Forest, and these were later affected after the sinking of the barge. The other areas affected by oil, although not necessarily from the *Morris J. Berman*, are also of ecological value. Thousands of marine organisms came ashore the days following the grounding and sinking of the barge, the majority beaching already dead. Live oiled animals were also reported on shore or floating in coastal waters, including crabs, birds and sea turtles.

As part of the Wildlife Recovery and Rehabilitation Units of the Local Spill Response Plan for Puerto Rico and the Virgin Islands (US Coast Guard, 1993), the Caribbean Stranding Network (CSN) was deputized by Puerto Rico's Department of Natural and Environmental Resources (DNER) to document damages to biological resources and to avert damages to live wildlife, oiled or intoxicated from the spill. This paper reports on the latter efforts.

2. Materials and methods

2.1. Study area

The north shoreline of Puerto Rico impacted by the *Berman* spill was divided by the US Coast Guard (USCG) and the National Oceanic and Atmospheric Administration (NOAA) (Ross, 1994) into 18 zones between the Rio Grande de Loíza and Punta Borinquen in Aguadilla (Fig. 1). Officially, these zones constituted the study area, but as the response phase developed, oil-affected wildlife was recovered from numerous other localities, including Isla Culebra, Isla de Vieques, the west, east and south coasts of Puerto Rico.

2.2. Source of data

Affected wildlife was obtained or collected opportunistically under permits issued by the DNER to the CSN (permits DRN9409 and DRN9410). Initially, animals which washed ashore or were found floating at the surface were collected by authorized beach clean-up crews, USCG personnel, DNER Vigilantes and biologists or CSN beach-patrol volunteers. Combined CSN and DNER shore-searches were conducted during the first week of the spill, particularly covering zones 1–5, 7–8, and 12–13. Other areas were searched for affected wildlife as part of USCG and DNER documentation or were collected opportunistically when found by beach clean-up crews. On a number of occasions, private citizens called regarding the finding of oiled wildlife, and some brought them to a provisional triage (emergency) facility. No dive searches were conducted to collect oil-affected organisms. By its nature, most of the opportunistic data presented here are non-random and biased in a variety of ways, mainly by observational chance and effort. Therefore, numerical conclusions must be treated with caution. However, since this is the only available information, it serves as a general assessment of the wildlife affected by the oil spill.

2.3. Computer data base system

A data base management system was custom-formatted to file information on the occurrences of each species in the study area. The alpha-level data collected from each case were: (1) date and time when found; (2) taxon and species; (3) locality; (4) time brought in; (5) condition; (6) initial treatment or disposition; and (7) chain of command. Each case was assigned a four-digit catalog number or a CSN serial number (NEPAV000 for birds or NEPCH000 for sea turtles). Additional information, medical procedures, and specific husbandry protocols for animals in rehabilitation were also documented and entered in a computerized data base system.

2.4. Salvage, examination and necropsy protocols

Dead wildlife brought to the triage facility were initially examined for the presence of oil by examining surface areas, appendages, gills or nares, and mouth-parts.

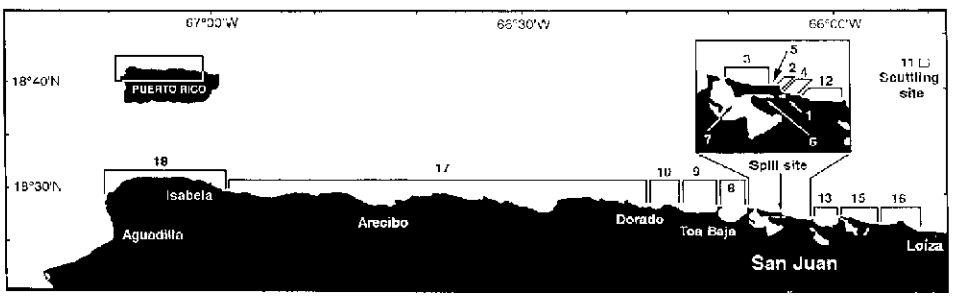

Fig. 1. Reference map of demarcated shoreline zones used by the US Coast Guard and the National Oceanic and Atmospheric Administration for the *Morris J. Berman* spill in Puerto Rico.

following adaptations of protocols by Meyer and Barclay (1990). Each animal was preliminary identified by taxon, but if species identification was possible at the time, it was noted as such. Organisms were then stored by placing them in zip-lock bags, each labeled with alpha-level data. Bagged organisms were frozen in a locked chest freezer as vouchers. Dead birds were examined using the protocols of Gullet (1987) and US Fish and Wildlife Service (FWS, 1977), and additionally tagged with FWS "Evidence Seizure Tag" and placed under the custody of a FWS Law Enforcement Officer, for necropsy referral to the FWS National Wildlife Health Center in Wisconsin.

2.5. *Rescue and rehabilitation protocols*

A temporary triage facility was established to admit and treat oiled and injured wildlife. Bird rehabilitation followed protocols detailed by International Bird Rescue Research Center (1978). Treated birds and sea turtles in stable condition were referred to the CSN Rehabilitation Facility at Isla Magueyes (Department of Marine Sciences, University of Puerto Rico, La Parguera).

Upon admittance to the triage facility, where initial information was documented using the salvage protocol (see above), live wildlife were rapidly assessed in a first station (preliminary examination station), noting signs of stress, degree of oiling, and general condition of the animal. The animal's nares and mouth were examined for the presence of oil. As each case varied as to degree of oiling, species being treated, stress, and general condition, treatment was based on these parameters. After the initial assessment, animals were dosed with olive oil dependent on the weight of the animal (olive oil helps coat the gastro-intestinal lining and reportedly provides relief from some of the toxic effects of oil), and a non-steroid antibiotic was placed on the cornea of both eyes just prior to cleaning.

If animals appeared to be highly stressed, they were immediately placed in a dark box with air holes on a heating pad, to reduce transport stress prior to treatment. If animals were considered to be in good physical condition and relatively stable, they were sent to the second station (cleaning station) for bathing. Olive oil was also used as a solvent to assist in the breakup of the oil, by placing it on a towel and massaging it into the plumage, carapace or skin of the animal. Simple Green (dilution rate 1:10) or BioSolve (dilution rate 1:10) were used as mild detergents to clean animals in luke-warm water-filled tubs. Birds were held by the wings and turtles were held by the edge of the carapace, as their bodies were immersed in the solution. The solution was pressed into the feathers or skin, and gently massaged. In birds, massaging the feathers was done with the lay of the plumage. Care was taken not to roughly handle the feathers of birds as waterproofing is a function of the feathers' arrangement and integrity. When the cleaning solution was dirty, it was exchanged. The heads of animals were carefully cleaned with a soft cloth so as to not be immersed.

Animals were then sent to a third station for rinsing and drying. Drying was accomplished by forced air heat (household hair blower) and absorbent toweling. This was to prevent excessive chilling due to evaporative cooling. If animals appeared to be unduly stressed during cleaning, they were rinsed, blotted dry and immediately placed in a warm heated box to recover. Cleaning was then repeated 24–48 h later dependent on the animals' health status.

Animals were medically reassessed daily. If fluid therapy was indicated, it was administered in addition to any other prescribed medication. If animals were considered to be in a very poor condition and had extreme low probabilities of survival, euthanasia was conducted.

Birds in rehabilitation were initially housed in an intensive-care isolation area in a warm and quiet large box (34 to 40°C, via low setting heating pad), and visually monitored hourly by the animal care staff. The boxes were made of cardboard, with air holes on the sides and the top flaps taped open to allow maximum circulation. The boxes were lined with both flat and 'balled' newspaper, to help cushion the feet and legs of birds, and provide some insulation from possible drafts. The tops of boxes were covered with a draped towel. If animals appeared to be forcefully panting or prostrated, the heating pad was removed. The heating pad was placed only half way under the box to allow animals to move from the heated side to the non-heated side if it desired to. The box was well ventilated to limit excess inhalation of toxic oil still on birds.

When the birds' prognosis was found to be improving, they were housed outdoors in 1-m^3 chicken-wire cages for the remainder of the rehabilitation period. In general, one bird was housed per cage. Sea turtles in rehabilitation were placed in a 2.5-m-round, 0.75-m-deep concrete pool with a sea-water flow-through system. Stabilized animals were comprehensively cleaned with BioSolve solution on a rotating basis, every 48 h, weather permitting. Animals were not bathed if the day was overcast or rainy. This bathing schedule was maintained until all physical signs of oil were removed.

Feeding was implemented when the animal was stabilized by hand-feeding small sardines or a fish gruel mixture, depending on the species. Fish gruel consisted generally of: (1) two to three small sardines; (2) 30 ml of lactated Ringer's solution; (3) half a pill of Mazuri 1/2 lb bird multi-vitamin pill (once a day); and (4) sufficient water to puree the mixture to a soupy texture. The gruel was force-fed using a lubricated stomach tube and a 60-cc syringe.

Precise records were kept by the CSN animal care staff on each animal. When animals were given a clean bill of health by the veterinarian, the animals were prepared for release. In the case of birds, animals were placed in a flying cage with ample space to allow them time (about 2 weeks) to waterproof their plumage, exercise and feed on their own. At the end of this period, birds and sea turtles were tagged. Animals were then taken to a safe area for release. Release sites were contingent on species, and on tranquil and clean (from oil) areas that would provide the animal with a natural reintroduction into the wild.

3. Results and discussion

3.1. Occurrence and mortality assessment

A total of 5687 oil-affected organisms were collected in the study area between 7 January and 24 February 1994. Affected organisms collected included sponges, anemones, sea worms, crustaceans, molluscs, sea stars, sea urchins, fish, birds, and sea turtles.

Temporal statistics of wildlife affected by the *Berman* spill were not uniform. About 85% of all animals were collected during the first week, with 82% occurring in the first 4 days after the grounding of the barge. Fourteen per cent of all organisms recorded were collected during the second week of the emergency. A significant increase in the trend of organisms collected was observed during the day and the following day the barge was towed offshore. Only 1% of all organisms were collected during the remaining weeks of the emergency, most of them birds.

Wildlife species affected by the *Berman* spill and collected are outlined in Table 2. Over 152 species and 15 taxon groupings, were collected, including the following phyla: Porifera (sponges, 0.5%), Cnidaria (anemones and corals, 0.4%), Annelida (worms, 0.2%), Arthropoda Crustacea (crustaceans, 9.8%), Mollusca (molluscs, 25.3%), Echinodermata (sea stars and sea urchins, 58.1%), and Chordata (vertebrates, 5.7%).

Within phyla, some species were more affected than others. In the Crustacea, the sally lightfoot crab (*Grapsus grapsus*) was noticeably the most affected by the oil. Of the Mollusca, periwinkles (*Littorina* spp.) and common West Indian chitons (*Chiton tuberculatus*) were most affected. In the Echinodermata, undoubtedly, rock-boring urchins (*Echinometra lucunter*), and in comparison to all other species of other phyla, was the species most affected. Occurrences of affected rock-boring urchins constituted 29% of all records. The effect of the *Berman* spill on the intertidal invertebrates is consistent with that found in the *Zoe Colocotroni* spill of 1973 off Cabo Rojo, and the *Peck Slip* spill of 1978 off Fajardo (Gundlach et al., 1979; Redgwell, 1992).

Some taxa did not show high mortality in particular species, but rather a great diversity in the overall number of species affected by the spill. This was clearly seen in fish (60 species), crustaceans (22 species), and gastropods (24 species), due to the type of habitats the barge impacted when it came aground. One species of sea turtle and eight species of birds were directly affected by the *Berman* spill. Of all species of birds, the brown booby (*Sula leucogaster*) was the most affected. This is contrary to what Norton (1988) predicted in his review of densities and abundance of Pelecaniformes in Puerto Rico, in which he suggested that brown pelicans would be the most vulnerable species to the effect of oil spills. Considering both the *Berman* and Guánica spills, there were seven times more brown boobies found affected from oil exposure than brown pelicans.

Species classified as endangered or threatened were also affected by the spill. Two endangered green turtles, and one endangered sandwich tern were directly affected by oil from the *Morris J. Berman*. Four threatened brown pelicans were also affected, one of them dying. An Audubon shearwater, a species considered very endangered, was found dead from oil at Jobos Beach in Aguadilla.

Other endangered or threatened marine wildlife were reported either affected or near oil patches, but were not collected as part of recovery efforts, either because they were not weak enough to warrant capture or the reports were not verified. About 15 brown pelicans were observed in Laguna Torrecilla (zone 14) with varying degrees of oil in their feathers and bodies. These birds were not collected due to logistical reasons and none were later reported distressed or lethargic, or were found dead. A bottlenose dolphin (*Tursiops truncatus*) with oil on its back was sighted off one of the piers of Bahía de San Juan (zone 6), but later no dolphins were reported stranded during the emergency period. A year after the oil spill, on 14 February 1995, a 262-cm male bottlenose dolphin was recovered dead within the Bahía de San Juan at Isla de Cabras (Toa Baja), and upon internal examination, its stomach was found with streaks of oil imbedded in the lumen (Mignucci-Giannoni, 1996). During the spill event, manatees were observed on more than two occasions from the air off zone 3 at the mouth of the Bahía de San Juan near oil slicks. A humpback whale was also reported offshore near oil patches close to the scuttling site (zone 11).

Nineteen organisms affected by oil, not necessarily attributable to the *Berman* spill, but occurring during the emergency, were collected during the process of this study. Seventeen brown boobies, one endangered green turtle and two endangered hawksbill turtles were collected. One of the brown boobies died in Isla Culebra, and its death was attributed to intoxication with oil. A brown pelican and a hawksbill turtle hatchling were also found dead during January in Isla Culebra, but there

was no evidence to link their death to the oil spill. As a reference, wildlife species affected by oil and collected during the Bahía de Guánica spill included two clapper rails (*Rallus longirostris*) and two yellow-crowned night herons (*Nycticorax violaceus*).

Affected wildlife was collected from all zones in the study area, except zones 5, 9, 14 and 16. Most organisms were collected from zones 1 (Laguna del Condado and Puente Dos Hermanos), 2 (El Escambrón and Caribe Hilton) and 4 (Condado). Oil-affected birds were found in zones 2, 4, 6 (Cuerpo de Ingenieros, Club Náutico, and Villa Pesquera La Coal), 7 (Punta Salinas), 10 (Toa Alta), 11 (15 miles offshore), 12 (Santurce and AcuaExpreso), and 18 (Jobos Beach and Shacks Beach). Oiled sea turtles were found in zones 4 and 13 (Punta Las Marías). Other localities where oil-affected wildlife was collected during the *Berman* spill time lapse included Cabo Rojo, Fajardo, Guánica, Humacao, Isla de Culebra, Isla de Vieques, Luquillo, Maunabo, Mayagüez and Yabucoa. However, the occurrence of affected wildlife in these areas was not necessarily attributable to the *Berman* spill.

3.2. Rescue and rehabilitation

The *Berman* spill had a significant impact on the live specimens presented for medical treatment. About 400 shore crabs (mostly sally lightfoot crabs) were treated and released. Between 7 January and 20 May 1994, a total of 48 oiled birds (eight species, including brown pelican, yellow-crowned night heron, brown booby, sandwich tern, Audubon shearwater, rock dove [*Columba livia*], belted kingfisher [*Ceryle alcyon*], and sandpiper [*Calidris* sp.]), and five oiled green turtles were admitted for treatment (Table 3). Of these, 28 birds and two sea turtles were cases attributable to the *Berman* spill. The others were affected by oil from other spills.

Of all *Berman* spill live animals ($n = 30$), 19 were successfully rehabilitated and released, nine expired during rehabilitation, and two were rescued, but arrived dead to the facility. Of animals in other spills, five were successfully rehabilitated and released, 15 expired during rehabilitation, one was euthanized, and four were rescued but arrived dead to the facility. In general terms and considering all spills, oiled animals needed an average 35.6 days in treatment, with a maximum rehabilitation time of 118 days (the last oiled bird in rehabilitation was released on 6 June 1994). Animals which did not survive, expired on average before 9.5 days of treatment. The maximum time in rehabilitation before an animal expired was 36 days. *Berman* spill animals brought in for rehabilitation needed on average 29.4 days in treatment, with a maximum rehabilitation time of 72 days. Animals which did not survive, expired, on average, before the eighth day of treatment. The maximum time in rehabilitation before an animal expired was 31 days. Of all species rehabilitated, brown boobies required the highest average time in rehabilitation (57.4 days), followed by rock doves (23.2 days), green turtles (18 days) and brown pelicans (12.6 days).

Survival rates for oiled birds and sea turtles brought in for rehabilitation varied depending on the species treated (Table 3). Rock doves and sea turtles had the highest chances of survival, with over 80% probabilities, followed by brown pelicans with a 75% chance

Table 3
Summary of rescue and rehabilitation efforts on oil-affected vertebrates in Puerto Rico during 1994

Species	No. of individuals	Oiling (%)	Treatment	Cleaning agent[a]	Survival rate (%)
Morris J. Berman *oil spill*					
Chelonia mydas	2	12–20	cleaned and flushed	OO, BS	100
Calidris spp.	1	40	none	–	0[c]
Ceryle alcyon	1	100	cleaned and flushed	SG	0
Columba livia	6	12–90	cleaned and flushed	OO, BS, SG	83
Nycticorax violaceus	1	95	cleaned and flushed	OO, BS	0
Pelecanus occidentalis	4	5–20	cleaned and flushed	OO, BS, SG	75
Puffinus therminieri	1	90	none	–	0[c]
Sterna sandvicensis	1	12	cleaned and flushed	OO, BS	100
Sula leucogaster	12	20–100	cleaned and flushed[b]	OO, BS	58
Other oil spills in 1994					
Chelonia mydas	1	40	cleaned	OO	0
Eretmochelys imbricata	2	25	cleaned and flushed	OO, BS	50
Nycticorax violaceus	2	20–100	cleaned and flushed	OO, BS	0
Rallus longirostris	2	100	cleaned and flushed	OO, BS	0
Sula leucogaster	16	20–100	cleaned and flushed[b]	OO, BS	25

[a] OO, olive oil; BS, BioSolve; SG, Simple Green.
[b] Some animals required to be hydrated with lactated Ringer's and treatment with antibiotics.
[c] Rescued, but arrived dead at rehabilitation facility.

of survival. Oiled brown boobies exhibited on average a 38% survival rate, and a 58% survival rate if *Berman* spill boobies are considered separately. This was probably due to a pronounced prevalence for secondary respiratory complications. The extent of oil coverage on the birds and turtles ranged from light (spotty/patches) to extensive, where the animal body was saturated completely, including inside the mouth. The overall analysis indicated that the degree of oil saturation did not appear to play a key role in survival. Some birds that were extensively saturated were successfully rehabilitated and eventually released, while others with a lesser degree of saturation expired. In general, considering all spills and all species, oiled animals brought in for rehabilitation showed a 44% probability of survival. No comparisons can be made regarding rehabilitation of oiled animals in Puerto Rico with previous oil spills in the area, as this is the first time this effort has been conducted in Puerto Rico, and as far as it can be ascertained from the literature, also in the Caribbean.

4. Conclusions

It took 114 days, 15 Puerto Rican and Federal agencies, 1.5 million man-hours, over 1000 workers, and over 87 million dollars to clean-up and assess the overall damage of the oil from the *Morris J. Berman* (Ornitz, 1996). The three company owners of the barge were found guilty of criminal negligence based on the Oil Pollution Act of 1990, and felony convictions were imposed on one of the managers of the barge company as well as on the Captain and First Mate of the *Emily S*, for violations of the Clean Water Act. The Federal District Court in Puerto Rico imposed a fine of 75 million dollars to the companies, plus over half a million dollars in legal fees (the fine imposed by the court on the landmark *Zoe Colocotroni* case in 1973, for clean-up costs and environmental harm, was about 6.2 million dollars [Redgwell, 1992]).

The latter statistics are small compared to the significant and long-term impact the *Berman* spill had on the biological resources of the San Juan, Cataño and Carolina area. Wildlife in other areas of the island were also affected, especially birds on the northwest, northeast, east and southwest coasts. A minimum of 5268 organisms washed-ashore between 7 January and 24 February 1994 or were found dead from intoxication or suffocation as the oil spill covered organisms in the rocky-intertidal and sandy-intertidal shores. Sixty-two per cent of these deaths were of echinoderms (sea urchins, sea stars), while 27% were of molluscs (sea shells, chitons). Eleven oiled marine birds died. Thirteen other deaths (11 birds, 2 sea turtles) related to oil occurred during the *Berman* spill time lapse, but were not attributable to the *Berman* spill. The spill also had a significant impact on the live specimens presented to the CSN for medical treatment. Only 63% of the 30 birds (eight species) and sea turtles (one species) presented for treatment were able to be successfully rehabilitated.

Some species were more affected than others, with sally lightfoot crabs, periwinkles, common West Indian chitons and rock-boring urchins, being the most affected by the spill. The brown booby was the bird species most severely affected. Due to a variety of reasons, including search efforts, condition of the affected wildlife, etc., the species and organisms catalogued represented only a small percentage of those truly impacted and those which died as consequence of the *Berman* spill. As a comparison, the number of invertebrates affected from the *Zoe Colocotroni* spill was estimated to be in the region of 92,109,720 (Redgwell, 1992). Without a doubt, thousands more marine invertebrates and fish died offshore as a consequence of the *Berman* spill, but were not recovered. The present assessment does not even include benthic communities of coral, sponges, seagrass, algae, etc. (partially conduced by McGehee et al., 1996), which were and probably continue to be heavily affected. In addition, there were many birds, for example, that were not collected and probably died offshore as a direct result of exposure to the oil, or direct or indirect intoxication with oil from the spill. The status of these populations, both invertebrate and marine birds, should be further studied to truly assess the long-term impact of the *Morris J. Berman* spill on the Puerto Rican marine biota.

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