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Does the marine macrobenthic community recover after an oil spill? 10 years since the Nissos Amorgos disaster in Venezuelan Gulf, Caribbean Sea

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Abstract

In 1997, 25.000 barrels of petroleum were spilled along 40 Km of marine beaches in Venezuela Gulf, an area where we carried out, two years before, benthonic macro invertebrates (BMI) inventories. In order to monitor the ecosystem "recovery", we repeated inventories five (2003) and 10 years (2008) later. Before the spill (1996), the BMI community was constituted by 75 species: 30 gastropod mollusks (GM), 28 bivalve mollusks (BM), 11 annelids (A) and 6 crustaceans (C). After five years this community structure became 27 GM, 26 BM, 5 A and 3 C. Although biodiversity only decreased 16.7% (14 species), the composition changed: out of the 75 BMI before the spill, only reappeared 31% (11 BM, 7 GM, 3 A and 2 C). After 10 years, the BMI biodiversity increased by a factor of 1.5 (113 species) respect to 1996. Community structure changed to 48 BM, 36 GM, 14 C and 13 A, plus 2 new echinoderm species. Out of these 113 species only 38 were original species (OPS) before the oil spill (16 BM, 15 GM, 3 C and 2 A). Therefore, 51% of the OPS remained without returning. Our results contradict the classic statement about marine ecosystem recovery affected by oil spills, i.e. *to return to its "original condition" are required 2-5 years*. Indeed, this investigation indicates that recovery of Caño Sagua BMI community may take, at least, one more decade. But, will the BMI return to their original condition? The probability is extremely low. The most likely scenario will be, at a time difficult to estimate today, a new assemblage of BMI species in equilibrium, with a mixture of OPS and new ones. These results means that, in terms of the original ecosystem condition, the BMI community of Caño Sagua beach, never will recover since its trophic structure never will be the same.

Keyword: oil spill, macroinvertebrates, benthos, recovery, trophic structure, Venezuela Gulf, marine ecosystem.

¿Se recupera la comunidad macrobentónica después de un derrame petrolero? A 10 años del desastre del Nissos Amorgos en el Golfo de Venezuela, Mar Caribe

Resumen

En 1997, 25.000 barriles de petróleo fueron derramados a lo largo de 40 Km de playas marinas en el Golfo de Venezuela, una zona donde dos años antes se habían realizado inventarios de macroinvertebrados bentónicos (BMI). Con el objetivo de monitorear la recuperación del ecosistema se repitieron los mismos inventarios a los cinco (2003) y 10 años (2008). Antes del derrame la comunidad de BMI estuvo constituida por 75 especies: 30 moluscos gasterópodos (GM), 28 moluscos bivalvos (BM), 11 anélidos (A) y 6 crustáceos (C). Después de cinco años la estructura de la comunidad cambió a 27 GM, 26 BM, 5 A y 3 C. Aunque la biodiversidad solo se redujo en 16.7% (14 especies), la composición cambió ya que de 75 BMI antes del derrame, solo reaparecieron el 31% (11 BM, 7 GM, 3 C y 2 A). Después de 10 años, la biodiversidad de BMI aumentó en una proporción de 1.5 (113 especies). La estructura de la comunidad cambió a 48 BM, 36 GM, 14 C y 13 A, más 2 especies nuevas de equinodermos. De las 113 especies, solo 38 eran especies originales (OPS) desde antes del derrame de petróleo (16 BM, 15 GM, 3 C y 2 A). Por lo tanto, 51% de las OPS se mantuvieron sin regresar. Los resultados obtenidos contradicen la clásica afirmación acerca de la recuperación de ecosistemas marinos afectados por derrames de petróleo, i.e. *para regresar a la "condición original" son necesarios de 2 a 5 años*. En efecto, esta investigación indica que la recuperación de la comunidad de BMI de Caño Sagua se pudiera llevar, al menos, una década más. Pero, ¿volverán los BMI a su condición original? La probabilidad es extremadamente baja. El escenario más probable será, en una cantidad de tiempo difícil de precisar hoy, volver a una nueva estructura de BMI especies en equilibrio, con una mezcla de OPS y otras nuevas. Estos resultados significan que, en relación a la condición ecológica original, la comunidad de BMI de la playa de Caño Sagua no se recuperará debido a que su estructura trófica nunca será la misma.

Palabras claves: Derrame de petróleo, macroinvertebrados, bentos, recuperación, estructura trófica, Golfo de Venezuela, ecosistema marino.

Introduction

Since the last three decades of the XX century, mankind observed a huge amount of petroleum spills in the world aquatic environments, product of exploration, exploitation and international trade exportation of this mineral at worldwide level (1). Also, we witnessed the highest quantity of oil spilled into oceans peaked between 1974 and 1979 when there was an average of 78.8 spills/year (1). Despite the exploitation and transport of petroleum has not diminished, it has been observed a reduction of the number of spills, due to the enforcement of new restrictions and regulations. Thus, between 2010 and 2017 the yearly average of oil spill decreased to 6.8 spills/year, but huge oil spills still occur, such as the Deepwater Horizon oil spill, which released 4.9 million barrels of oil covering more than 1700 Km of shores (2). The presence of petroleum in nature constitutes a threat for all organisms, and especially for aquatic ones that live in those environments where have been occurred most of the largest oil spills in our whole history (3).

According to several authors (4-6) most marine ecosystems exposed to huge quantities of raw petroleum that have been studied, require between 2 and 5 years for their recovery. However, this concept of "recovery" is based essentially on the re-colonization of the affected areas, without previous knowledge of which species were there present and even less whether or not, the previous trophic structure has changed. Even nowadays, there are authors applying the same concept (7-9) without considerations about the kind of habitat being affected, the guilt structure and the persistence of oil inside the substrate affected. Thus, conclusions about the recovery time of an ecosystem affected by oil spills are based on misguided premises and supported, most the time, only on post impact studies (10-13).

Venezuela, the thirst largest oil producer country of the world until 2002, was the site for massive oil spills and they are still occurring (14). In effect, a 25.000-barrel oil spill happened in Venezuela Gulf in 1997. This spill covered 40 Km of marine coast, killing every aquatic invertebrate between the low and high tide lines (15). Because two years before (1994-1996), we performed a two years biodiversity inventory of benthonic macroinvertebrates (BMI) along the same area, an invaluable opportunity rose to measure the direct impact of this oil spill, starting from ecological pristine conditions. Thus, we not only made estimation of the number of species affected and the quantify of the total mortality of these organisms but also, and more important, we also make projections, in real time, of how many years this ecosystem could take to totally recover. This opportunity was also important because Caño Sagua beach is a tropical high energy sandy beach, one of the few where an oil spill has happened and where an exceptionally high diverse macroinvertebrate benthonic fauna was known before it (15).

The macroinvertebrate fauna (organisms retained by 500mm mesh sieve) of sandy beaches is important because of their size and its ecological role as relevant preys to higher trophic levels (16). This macrofauna have some adaptations that remark its trophic role: 1) planktonic larval development able to be disperse; 2) one or more years of generation times; 3) iteroparous reproduction and continuous growth; 4) feeding on a broad range of particles size; and 5) most of them motile (17). This assemblage is normally formed by bivalve mollusks, decapod crustaceans, polychaetes, amphipods, and isopods, with low number of species, no more than 20. However, in Caño Sagua beach the macroinvertebrate fauna is four times that number with an uncommonly high number of gastropods mollusks.

In the present article we aim to answer the following questions: How did the spill of petroleum affect the biodiversity of BMI of the marine coast of Caño Sagua beach, located at the southwestern of the Venezuela Gulf? How many species disappeared? How much time the BMI community will take to recover? It has been enough 10 years? In addition, we explore the concept of "recovery" looking for the best way to define, to in ecological terms, what this term really means.

Material and methods

The present study was carried out in the beach Caño Sagua, located to 80 Km. of the city of Maracaibo, in the Southwestern area of the Gulf of Venezuela (Fig. 1). This coastline was the main zone affected by the Nissos Amorgos Tanker oil spill. This entire coastal zone, 40 Km of a tropical high energy sandy beach, has a broad intertidal flat (100 m between high and low tide borders) which uncovers twice every to 24 hours. The supra tidal area plus the intertidal one, were covered by a thick layer of petroleum which was estimated in 15.000 barrels (15). It was calculated that 9.000 barrels, covered the bottom of the subtidal zone at least for a year. After, there was neither other measurement of this oil cover nor any monitoring of the evolution of the disintegration of petroleum remains.

Before of the oil spill (1994-1995), six months after the oil spill and them at 5 (2003) and 10 years (2007), we proceeded to carry on a yearlong biodiversity inventory following the sampling methodology with transect and quadrant, the same that was used for the before spill inventory (15). This consisted on tracing a perpendicular 100 m transect to the beach beginning at the low tide line. Along the transect, each 10 m, three samples were collected (replicates) perpendicular to it, each separated by two meters. Each sample was pull out with an Ekman grab, collecting 0.01 m^2 (approximately 2 pounds of sand) and placed in plastic bags.

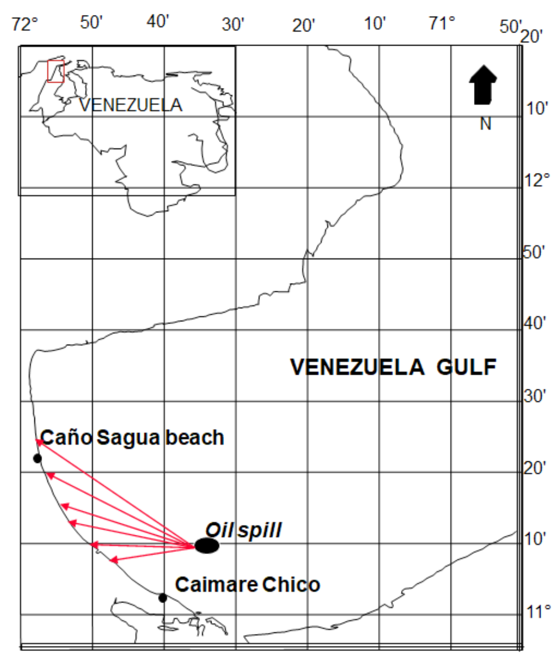

Figure 1. Geographic location of the Nissos Amorgos oil spill along the southwestern coast of Venezuela Gulf. Arrows indicate the course of oil spread.

The collected sediment samples, were transported by car to the laboratory where they were sieved through a series of nets (180 microns up to 2 mm). The organisms retained by the different sieves were sorted with forceps, separated by Fila and later on identified to the lowest taxonomy category (39-43). All organisms were fixed in 10% formalin and preserved 24 hours later in a 70% buffered ethanol solution.

The BMI data used and discussed in this paper were collected, processed and analyzed by the methodology above described during 1994-1995 (two year before the oil spill), 2002-2003 (five years after the oil spill) and 2007-2008 (10 years after the oil spill). The discussion only will employ the list of species (Biodiversity level 1) that were found during a standardized year of intensive collection that gather 360 individual samples, to support the premise that "recovery" from an oil spill cannot be state using increases of absolute abundances and ecological diversity indexes. We intentionally did this because it has been demonstrated that the extreme variation of organisms abundance and density in space and time, which appear to be real, does not allow to separate background variation from impact changes (18-20). Thus, we just want to proof that after ten year, the species arrangement of the macroinvertebrate fauna has not showed up to the original, pristine composition.

Results

Out of 75 BMI species quantified before the oil spill, 58 were mollusks (30 gastropods, 28 bivalves), 11 annelids and six crustaceans (Fig. 2, Table 1). Six months after the oil spill a brief sampling was done but no living organisms were found. The process to collect coastal oiled sediments, oil contaminated debris and meteorized solid mass of petroleum took almost a year (1998) but because 9000 oil barrels sunk close to the coast, they generated a continuous flow of oil fractions at least for one more year. Beaches along the 40 Km affected were open to tourist two year after (2000) but patches of sand-oil were seeming until late 2001. By the time of the first formal biodiversity survey, five year after the oil spill, no meteorized solid masses were seen. At this time, BMI community became structured by 61 species (27 gastropods, 26 bivalves, 5 annelids and 3 crustaceans) (Fig. 3, Table 2) (15). The fact that after five year the number of species of the BMI community were still below the initial amount (75 vs 61) clearly indicated that the impact of the oil spill has not finished yet. Notwithstanding, in term of number of species, there was a reduction of 14 species (19%), the composition changed completely. If we consider the species that were initially (Table 1), only 11 bivalves, 7 gastropods, 3 crustaceans and 2 annelids came back in five years (Table 2). We can infer that the return to the original species arrangement still remain at 31% (23 species out of the original 75). In other words, 69% of the original species have not came back.

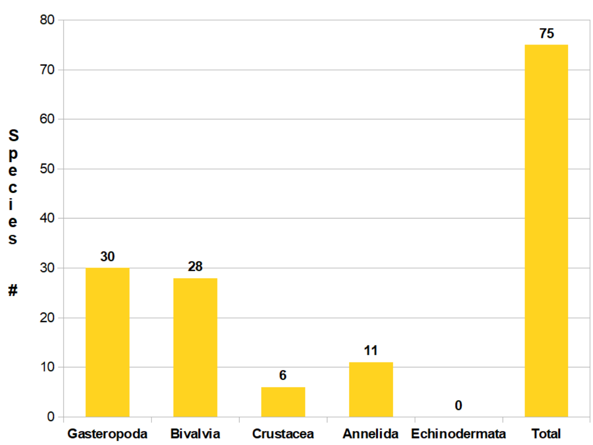

Figure 2. Macrobenthic Invertebrate fauna of Caño Sagua beach before the Nissos Amorgos oil spill (1994-1995)

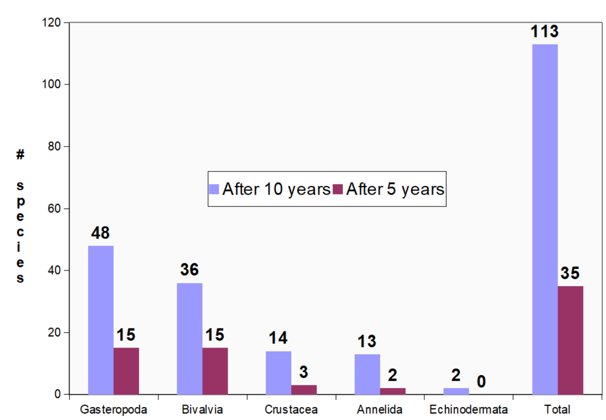

Figure 3. Macrobenthic Invertebrate fauna of Caño Sagua beach, after five (2003) and 10 years (2008), of the Nissos Amorgos oil spill

Table 1.- Species list of benthonic macroinvertebrates of Caño Sagua beach before the Nissos Amorgos oil spill (1996).

Bivalves	Gasteropods	Crustacean	Annelids
Anadara brasiliana	*Alaba incerta*	*Emerita brasiliensis*	*Hemipodus sp.*
Anadara floridana	*Anachis sp.*	*Excirollana braziliensis*	*Leanira sp.*
Brachidontes sp.	*Antigona sp.*	*Lepidopa sp.*	*Lumbrineris sp.*
Chione cancellata	*Bittium sp.*	*Liljeborgia sp.*	*Malacocerus sp.*
Codakia orbicularis	*Cerithiopsis latum*	*Ogyrides alphaerostris*	Pilargidae sp. 1
Codakia orbiculata	*Cirsotrema dalli*	*Penaeus sp*	Pisionidens sp.1
Codakia pectinella	*Cochliolepis parasitica*		Polychaet sp 1
Crasinella lunulata	*Cresseis acicula*		Polychaet sp sp 2
Crassostrea rhizophorae	*Diastoma varium*		Polychaet sp 3
Cyrtopleura costata	*Diodora sp.*		Polychaet sp 4
Diplodonta sp.	*Epitonium frielei*		*Spio sp*
Donax denticulatus	*E. novangliae*		
Donax striatus	*E. turritellarum*		
Ervilia concentrica	*Eulima bifasciata*		

Gemma purpurea *Macoma breviformis* *Mulinia lateralis* *Mytilus sp.* *Petricola pholadiformis* *Pholas campechiensis* *Pitar dione* *Pteria sp.* *Rangia cuneata* *Strigilla pisiformis* *Tellina exilis* *Tellina radiata* *Tivela mactroides* *Transennella cubaniana*	*Fontigens turritella* *Marginella sp.* *Melongena melongena* *Microdochus floridanus* *Mitrella nitens* *Natica canrena* *Odostomia sp* *Olivella minuta* *Petaloconchus erectus* *Pseudomalaxis nobilis* *Serpulorbis sp.* *Solariella obscura* *Teinostoma sp.* *Truncatella sp.* *Turbonilla sp.* *Vitrinella sp.*		
28	**30**	**6**	**11**

Table 2.- Species list of benthonic macroinvertebrates of Caño Sagua beach five year after the Nissos Amorgos oil spill (2002). In bold are the original species since 1996

Bivalvia	Gasteropoda	Crustacean	Annelida
Anadara ovalis *Anadara sp.* ***Chione cancellata*** *Chione granullata* *Circulus multistriatus* ***Crassostrea rhizophorae*** *Crassotrea virginica* ***Cyrtopleura costata*** ***Donax denticulatus*** ***Donax striatus*** *Heliacus bisulcatus* *Mitrella nitens* *Mulinia lateralis* ***Mytilus sp.*** *Nuculana acuta* ***Pitar dione*** ***Pteria sp.*** *Strigilla carnaria* ***Strigilla pisiformis*** *Tellina provina* ***Tivela mactroides*** *Crassinella martinicensis* *Gouldia cerina* *Pecten sp* ***Brachidontes modiolus*** *Corbula sp.*	***Alaba incerta*** *Alvania arpa* Anachis obesa. ***Antigona sp.*** *Antipoda sp* ***Bittium varium*** *C. costata* *Cerithiella whiteavessis* *Cerithiopsis emersoni* *Ciclostremiscus trilix* *Epitonium candeanum* *E. foliacercostatum* *Heliacus sp* *Hidrobia sp* *Hyalina sp* *Marginella sp.* ***Natica canrena*** *Natica menkeana* ***Odostomia laevigata*** ***Olivella minuta*** *Petaloconchus irregularis* *S. decussatta* *Thais sp* *Tricolia adamsi* *Truncatella caribaensis.* ***Turbonilla sp.*** *Zebina browniana*	***Liljeborgia sp.*** ***Emerita brasiliensis*** ***Excirollana braziliensis***	*Capitella capitata* ***Malacocerus sp*** **Pilargiidae** ***Pisionidens sp 1*** *Serpulloides decussata*
26	**27**	**3**	**5**

The results 10 years after the oil spill shows a more dramatic panorama in term of the BMI community structure. First of all, there was a huge increase of the number of species. The BMI community reached almost twice of the number of species before the oil spill (75 vs 113; Fig. 4, Table 3). These 113 species were 48 gastropods, 36 bivalves, 14 crustaceans, 13 annelids and a new taxonomic group, very uncommon in these high energy sandy beaches, echinoderms, with two species.

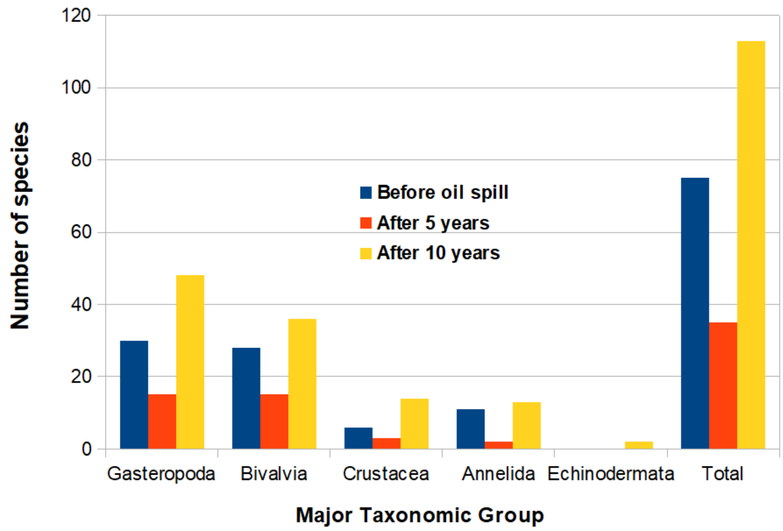

Figure 4. Comparison of Macrobenthic Invertebrate fauna of Caño Sagua beach, before (1996), after five (2003) and 10 years (2008), of the Nissos Amorgos oil spill.

Table 3.- Species list of benthonic macroinvertebrates of Caño Sagua beach ten year after the Nissos Amorgos oil spill (2007). In bold are the original species since 1996.

Bivalve	Gasteropods	Crustacean	Annelida	Echinoderms
Americardia guppyi	***Alaba incerta***	Amphipod sp 1	Aphroditidae sp 1	*Sea urchin sp 1*
Anadara notabilis	***Anachis mangelioides***	Copepod harpacticoide	*Capitela capitata*	Ophiuroidea sp 1
Anadara ovalis	*Arene cruentata*	Brachyura crab sp 1	Gliceridae sp 1	
Anadara transversa	*Assiminea succinea*	Caprellidae sp 1	*Heteromastus sp*	
Arca imbrincata	*Caecum antillarum*	***Emerita brasiliensis***	***Lumbrineris sp***	
Brachiodontes exustus	*Caecum imbrincatum*	***Excirolana braziliensis***	Onuphidae sp 1	
Corbulla contracta	*Circulus multistriatus*	Haustoriidae sp 1	Orbiniidae sp 1	
Crassinella lunulata	*Crepidula convexa*	*Mithrax sp1*	Polichaeta sp 1	
Crassostrea rizhophorae	*Cyclostremicus pentagonus*	***Ogyrides alphaerostris***	Polichaeta sp 2	
Cyrtopleura costata	Cyclostremicus sp 1	*Parguristes puncticeps*	Polichaeta sp 3	
Diplodonta notata	Cyclostremicus sp 2	Processidae sp 1 (shrimp)	Sigalionidae sp 1	
Donax denticulatus	*Cyclostrema cancellatum*	Tanaidacean sp 1	**Spio sp 1**	
Donax striatus	*Cylichna auberi*	Tanaidacean sp 2	*Sygambra sp 1*	
Ervilia concentrica	*Diastoma varium*	Tanaidacean sp 3		
Gemma purpurea	***Diodora sp 1***			

Lucina muricata	*Epitonium albidum*			
Macoma constricta	*Epitonium candeanum*			
Mactrellona alta	*Epitonium foliaceicostum*			
Martesia sp 1	***Epitonium novangliae***			
Mulinia lateralis	*Epitonium turritellulum*			
Musculus lateralis	***Eulima bifasciata***			
Mytella sp 1	Gastropod sp 1			
Mytilopsis dominguensis	Gastropod sp 2			
Nuculana acuta	Gastropod sp 3			
Periploma sp 1	*Haminoea succinea*			
Pholas campechensis	*Hidrobia sp 1*			
Pitar dione	*Ithycithara lanceolata*			
Pteria sp. 1	*Litiopa melanostoma*			
Semele nuculoides	*Marissa cornuarietis*			
Sphenia antillensis	*Melanella sp 1*			
Strigilla pisiformis	*Melongena corona*			
Tellina sp.1	***Microdochus floridanus***			
Tivela mactroides	***Mitrela nitens***			
Trachycardium muricatum	***Natica carenna***			
Trachycardium sp1	***Odostomia laevigata***			
Transenella cubaniana	*Olivella dealbata*			
	Olivella minuta			
	Olivella petiolita			
	Parviturboides interruptus			
	Petaloconchus erectus			
	Polinices sp 1			
	Pseudomalaxis nobilis			
	Retusa candei			
	Serpulorbis decussata			
	Tricolia adamsi			
	Turbonilla sp1			
	Turritella variegata			
	Vitrinella sp 1			
36	**48**	**14**	**13**	**2**

This apparent "recovery", as a function of number of species, masks the true alteration of the original condition of the aquatic ecosystem in Caño Sagua beach. If it is compared the community of BMI before the spill and 10 years later, in terms of the species that originally were present, it is observed that the community changed. After 10 years only 16 bivalves, 15 gastropods, three crustaceans and two annelids of the original species, have returned. These 38 species, representing a 51%, what indicates is that in the last five years (2003-2007) the original BMI fauna of Caño Sagua recovered only 20% (51 less 31), a mean of 4% annually. Still, 49 % of the species that used to live in Caño Sagua beach before the spill of petroleum, remain missing.

In addition, as a consequence of the missing species, an immense quantity of opportunists species (66 species, Table 3) move into Caño Sagua beach ecosystem to compete for a place (i.e. a niche). These niches were left empty by the species that disappeared.

Discussion

Coastal invertebrates' studies on the effects of oil spills, on different bottom-dwelling invertebrate groups, have to a large extent been based on data where there is not direct comparisons between pre-spill and post-spill. In effect, there are many reports that used toxicity tests laboratory experiments to proof, whether or not, chemical derived from petroleum (and their concentrations), may affect (death) organism living within the areas covered by the spills (21). Other studies used field or laboratory microcosms containing oiled sediments to verify how the spill could affect the growth rate of larval stages, juveniles and adults, and then extrapolate the results comparing, less oiled, most oiled as well as unexposed sediments/organisms, correlating oil concentration and growth rates (22-23). Other researchers, use comparisons of the fauna in affected sediments by the spill versus sediments in other zones no affected and, with the assumption, that these last zones are "pre-spill ones" (24-26). All above examples, of an incorrect way to estimate oil spill impacts, what have created is an unprecedented confusion and wrong expectations when mankind has had to deal with the destruction of our environment, in the present case, our oceans. We want to believe that no matter what we do, always nature will return to the former equilibrium, which nature achieved in thousands or millions of years, in a few of years. Due to this, not only we have an incorrect estimation of how many years will be necessary, but also that the arrangement, the trophic structure and the ecological equilibrium, never more will be the same. Examples of the above false expectation abundance such as the recovery, in six years, of Korean coasts after a 10.900 ton of crude oil from the Hebei Spirit (27) (see 4-6 for similar or lower times).

An additional mistake when analyzing oil spill is to compare different habitats and different organisms. There is no way to contrast oil spill in salt marshes, wetlands, mangroves, estuaries, marine coastal habitat and coral reef. Each of these "environment" has different attributes, physico-chemical features, and biota. An example of a huge oil spill that affected all those habitats is the Deepwater Horizon mega oil spill (28) and where there are, separate formally, oil impact studies in each of these environment/habitats (29-33).

In relation with the present article, it is important to point out that the Nissos Amorgos oil spill occurred in a high energy sandy marine beach, under tropical conditions, which is very unusual. Most oil spill that has taken place in sandy beaches, were in subtropical or temperate zones. Effectively, in a recent revision (34, see Table 1) is remarked that only 17 oil spills, that were documented, occurred in coastal sandy shores between 1973 and 2016. Although our literature review found some more articles, it is important to note that any of them coincide with our study. In fact, seven studies were done only with meiofauna (invertebrates size between 45 microns and 1 mm), two with both meiofauna and macroinvertebrate fauna, but in temperate zones (Spain and United Kingdom). From the resting six studies, three documented the oil spill impact only over the macrofaunal amphipods community; one in subtropical (Sidney, Australia), the second one in temperate latitudes (Paranagua Bay, Brazil), and the third in tropical conditions (Puerto Rico) but it did not include other important macrofaunal organisms and it was concentrated on sandy sediments within mangroves. Thus, the last three studies, notwithstanding reported the oil spill impact over important macrofaunal components (crustacean, annelids and mollusks), two of them occurred in temperate conditions (Alaska, US and Campeche, Mexico). So, from the 17 oil impact studies mentioned, only one (35) came about in very similar condition as our in Caño Sagua beach, but only included amphipods and crabs because no other organisms were found.

The above discussion about oil spill impact studies developed in sandy beaches had the only objective to re-emphasize the relevance of the present paper for the Caribbean region and tropical ecosystems in general. Recent articles (36-37) have emphasized the potentially dangerous situation of the whole Caribbean region where more than 30 oil spills occurred during the 70s, plus "countless mundane releases of petroleum from ships and shoreline facilities" (36). This enclosed sea is ranked as having one of the most intense maritime traffic in the world (37) and, at the same time, it is the supports of many critical habitats functioning as a large marine ecosystem (38). In most cases, all these accidents affected coral reef, mangroves and their flora and fauna. But it is clear that high energy sandy beaches are potential targets in future decades.

Now, are our results unexpected? No really. Several studies have shown that, after an oil spill impacts, the fauna that reappear follows a two steps pattern (34). First, it is the disaster phase where everything alive is destroy. When “recovery” begins, a second phase take place where species which were present before the spill, start to appear. Then comes a phase that is characteristically evidenced by the arrival of new species that do not existed before the oil spill. These new species are considered as “opportunistic” (34-36). The reason of their generic names is obvious, as they get the chance to occupy niches that were left empty by the species killed by the oil spill. We saw clearly these three phases as a sequence in our 12 years study, presented in the above lines.

As we stated at the beginning of this article, the results obtained contradict the classic statements about the ecosystem recovery time after an oil spill: *to return to its original condition as function of diversity and abundance of the present species, between two and five years are necessary* (4-6). On the contrary, the present data indicates that the ecosystem of Caño Sagua beach, studied through the changes in the community of BMI, would take more than two decades in returning to the original species composition. This time, is at least between 6 and 15 times longer than those mentioned in the scientific literature reviewed in the present article. Indeed, this study demonstrates that 10 years after the impact of the oil spill, only have returned 38 species, 15 of them in the last 5 years (2003-2007). If we project these numbers (a gross rate of 10 species every 5 years) the BMI community of Caño Sagua should return to its original condition in 20 more years. These years, added to the 10 already lapsed, tell us about of a total time of 30 year for the recovery.

Now, to finish this discussion let us take another side of the “recovery concept”. Taking into account what we have seen, can we affirm that the BMI community of Caño Sagua can return to its original structure? We must begin, conceiving that this recovery only could happen in a hypothetical situation where the niches left vacant, can be re-colonized by the same species that existed before the oil spill. Indeed, the results indicate that after 10 years there are 76 new species competing for approximately 35 niches (75 in 1996 less 35 in 2003). In other words, approximately two new species, are already competing versus an old one that has not returned yet in 10 years. Is it likely that this event may happen? Definitely the answer is no. Everything indicates that, in terms of the original condition of the ecosystem, Caño Sagua beach will never recover. This is the paradox and the take-home message that this investigation contributes. Many studies that have investigated the effect of oil spill, at some point, have used the phrase “the ecosystem is showing sign of recovery” or other similar (5-8). However, we can state that the impacts taken place against the nature by mankind are likely irreversible. The thousands or millions of years that nature has taken in developing stable ecosystems and their trophic nets cannot recover in just some decades after the imbalance introduced by man. As an alternative, nature will look for to reach a new balanced, in equilibrium stage, with a similar number of species to the original ones, but with a mixture of old and new species. This means that the trophic net never will be the same.

Although the knowledge about the effects of major oil spills on marine and coastal ecosystems has improved considerably in last decades, there are still critical research needed for questions that remain unresolved or are poorly understood. One key point at this respect is that we need to leave the approach of using non-impacted areas biodiversity, abundances and ecological indexes, to obtain likely numbers for oil impact of unknown results. Bases lines studies and regular inventories in areas, zones or habitat that are potential target for oil spill must be the strategy in order to be prepared for the future (34).

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