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Anthropogenic litter in the SE Pacific: an overview of the problem and possible solutions *

Resíduos sólidos antropogênicos no Pacífico SE: uma revisão do problema e soluções possíveis

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ABSTRACT

Litter from anthropogenic sources is commonly observed on beaches in the SE Pacific. The composition of litter found on the shore suggests that most of it has passed relatively little time at sea, and has mostly local sources. In southern Chile, stray items from aquaculture installations comprise most of the garbage, whereas in central and northern Chile and in Peru, general household litter is most common. Abundances are highest in areas with intense human activities, i.e. harbors, cities, and aquaculture centers. Impacts on the marine life are commonly observed, but have not been systematically studied in the SE Pacific. Estimated costs of litter on local beaches are high, as underlined by the high costs of beach cleaning, especially during the annual tourist season. Current data suggest that beaches without regular cleaning activities accumulate large amounts of litter. Regulations are in place to avoid littering at sea and on beaches, but law enforcement is limited mainly because the governmental bodies in charge are understaffed. Therefore, the most viable option to reduce the amount of litter is to reduce its production in the first place, improve reuse and recycling, and enhance environmental awareness. Several governmental and non-governmental organisations develop education programs that incorporate environmental aspects. The geographic coverage of these programs should be expanded. Furthermore, there is a need for long-term programs that inform the public about the need to reduce the amounts of waste and increase reuse and recycling in all sectors of society.

Keywords: beach litter; anthropogenic marine debris; beach survey; volunteer participation; environmental education; plastics.

RESUMO

Resíduos de fontes antropogênicas são comumente observados nas praias do sudeste (SE) do Pacífico. A composição do lixo encontrado na costa sugere que a maioria deles passou relativamente pouco tempo no mar, e tem principalmente fontes locais. No sul do Chile, itens perdidos das instalações de aqüicultura compreendem a maioria do lixo, enquanto que na região central e norte do Chile e no Peru, materiais domésticos são mais comuns. Abundâncias são maiores em áreas com intensa atividade humana, isto é, portos, cidades e centros de aqüicultura. Impactos sobre a vida marinha são comumente observados, mas não têm sido sistematicamente estudados no Pacífico SE. Os custos estimados do lixo nas praias locais são elevados, com destaque para os altos custos de limpeza de praia, especialmente durante a estação turística anual. Os dados atuais sugerem que as praias sem atividades regulares de limpeza acumulam grandes quantidades de lixo. Foram implantados regulamentos para evitar

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o lançamento de lixo no mar e nas praias, mas a aplicação da lei é limitada, principalmente porque os órgãos governamentais responsáveis não possuem mão-de-obra suficiente. A opção mais viável para reduzir a quantidade de lixo é, em primeiro lugar, a redução da produção do lixo, além de melhorar a reutilização e reciclagem e aumentar a conscientização ambiental. Várias organizações governamentais e não-governamentais desenvolvem programas de educação que incorporaram aspectos ambientais. A cobertura geográfica destes programas deve ser ampliada. Além disso, há a necessidade de programas de longo prazo que informem o público sobre a necessidade de reduzir as quantidades de resíduos e aumentar a reutilização e a reciclagem em todos os segmentos da sociedade.

Palavras-chave: *lixo praial; lixo marinho antropogênico; monitoramento de praia; participação de voluntários, educação ambiental; plásticos.*

1. INTRODUCTION

Marine litter from anthropogenic sources is a common problem in many parts of the world (Katsanevakis, 2008; Barnes *et al.*, 2009; Criddle *et al.*, 2009; Ryan *et al.*, 2009). The coasts of the SE Pacific are no exception to this global pattern. Present data on the composition and distribution of floating marine litter along the shores of the SE Pacific suggest that these items have their origin mainly in local sources (Thiel *et al.*, 2003; Bravo *et al.*, 2009; Hinojosa & Thiel, 2009). This means that solutions to alleviate this problem should be sought mainly on the local level. In this contribution we explore the extent and causes of this problem, the ecological and economic impact, the legislative framework and possible solutions.

The coastal currents of the SE Pacific are driven by a system of major oceanic currents, namely the Equatorial Current (0ºS – 5ºS), Humboldt Current (5ºS – 40ºS) and the Magellan Current (45ºS – 55ºS). The latter two coastal currents originate in the West Wind Drift which meets the South American continent at about 40ºS to 45ºS. North of 40ºS the coastline is relatively straight, with a few large rivers between 35ºS and 40ºS, while south of 45ºS the coast is highly fragmented with deep channels and fjords, which receive freshwater input from rivers that are nourished from the extensive Patagonian ice fields. Due to the vicinity of the Andes Mountain range, most watersheds have comparatively limited extensions and distances between human population centers and the coasts are short, rarely exceeding 100 km. Rivers have been suggested as transport vectors of litter towards the coastal waters of the SE Pacific (Bravo *et al.*, 2009; Hinojosa *et al.*, in press).

Coastal upwelling within the Humboldt Current System brings nutrient-rich waters to the surface, which sustains very high primary production and huge populations of secondary consumers (fish, seabirds and marine mammals) (Thiel *et al.*, 2007). The rich fishing grounds along the SE Pacific generated intense fishing efforts since humans colonized the Americas (i.e. Sandweiss *et al.*, 2009). Consequently a large proportion of the human population of Ecuador, Peru and Chile lives along the coast, where they dedicate themselves to a wide diversity of fisheries and related activities. In many regions of the world, fisheries produce large amounts of anthropogenic litter (Dayton *et al.*, 1995; Hess *et al.*, 1999; Dameron *et al.*, 2007; Criddle *et al.*, 2009). Shipping activity along the SE Pacific is of minor intensity compared to that of the N Pacific, but is also believed to contribute to floating marine debris in coastal waters (Thiel *et al.*, 2003). Tourism is intense on some beaches, especially near the larger cities and in central Chile (Alvial & Reculé, 1999; Barragán *et al.*, 2005). Tourism activities can be a major source of litter on local beaches (e.g. Santos *et al.*, 2005; Bravo *et al.*, 2009).

The coasts of the SE Pacific have been considered as relatively pristine. For example, Castilla & Neill (2009) suggested that the comparatively low number of Non-Indigenous Species in the SE Pacific may partly be due to the limited intensity of human activities along the coasts. However, the majority of the population is living within the coastal zone, where insufficient treatment of sewage has been identified as a major problem (Barragán *et al.*, 2005). This contributes nutrients, contaminants, and anthropogenic debris to coastal waters. An oceanographic model by Martinez *et al.* (2009) suggests that most of the litter generated by human activities on the SE Pacific shores remains within the coastal zone. Due to the relatively high degradation resistance of most litter (e.g. Pegram & Andrady, 1989), it will persist for long time periods in the system, and it should be expected that the distribution of floating litter at sea and the densities of litter on local shores is mainly driven by the predominant wind and currents. These processes also determine the residence time of litter at the sea surface and the exposure risk for the marine biota. Knowing these risks can help design prevention and conservation plans.

2. COMPOSITION AND DISTRIBUTION OF ANTHROPOGENIC LITTER IN THE SE PACIFIC

The data presented here come from several sources including literature, unpublished reports, personal observations, NGO web sites and beach surveys. The types and quantities of litter previously had been examined on numerous beaches along the Chilean coast (Bravo *et al.*, 2009). Here we added new data for the Peruvian coast, which were obtained between July and September 2009 using the same method as described in Bravo *et al.* (2009). Briefly, a transect perpendicular to the shoreline was marked from the low tide line to the upper limit of the beach and divided in stations consisting of 9 m^{-2} squares. All litter inside the square was identified and counted. Along the Chilean coast, two studies examined the abundance and distribution of floating litter, one along the outer coast (Thiel *et al.*, 2003), and one in the interior fjords in southern Chile (Hinojosa & Thiel, 2009). The entire coast of the SE Pacific (~4ºS to ~56ºS) was subdivided into 6 zones, using the criteria outlined in Bravo *et al.* (2009) (Figure 1). This subdivision was done to explore local variations in composition, densities, potential sources and the fates of anthropogenic litter.

2.1 Composition of anthropogenic litter

A wide variety of litter items was registered on the beaches along the SE Pacific, and in accordance with the global trends reported by Derraik (2002), plastic items were always most ubiquitous (Figure 1). In addition to plastics, paper, wood, organic debris (shell pieces, algae, feathers, dead animals), metal and other items are found on the beaches. The proportion of the different types of litter varied between the different zones. In general, plastics comprised ~20% to 30% of the registered litter on the beaches of Peru and

Chile. In the zones C1 and C2 cigarette butts predominated (Figure 1). In the central region (C3) "other items" (mainly coal) were very common – this might be related to the large number of thermoelectric powerplants in the central region of Chile (Rovira, 2006). In Peru and in southern Chile (zones C4 and C5) metals, glass pieces, plastics and "other items" (mainly styrofoam) were more abundant (Figure 1). These differences in the composition of the litter are most likely due to the variation in beach use and/or the differences in litter input to the system (see below).

Plastic items were also more abundant among the floating litter registered along the SE Pacific coast (more than 80% of the floating litter were plastics, Figure 1). This pattern was consistent along the outer continental coast of Chile, but some differences were observed in the fjord region of southern Chile. Along the outer coast plastic bags were very common while styrofoam predominated in the interior sea of the Patagonian fjords, suggesting a local input of floating debris (Thiel *et al.*, 2003; Hinojosa & Thiel, 2009). Overall, plastics were more common among the floating litter at sea than among the litter found on local beaches. This suggests that floating litter is sorted at sea due to rapid degradation (paper) and sinking (glass and metal). The wide variety of litter and the large proportion of negatively buoyant items recorded on beaches could be due to the fact that a large part of the litter on beaches was not sorted by water, but rather directly deposited on the beaches. The floating plastics have a high floating potential and could be transported over large distances by ocean currents (see below).

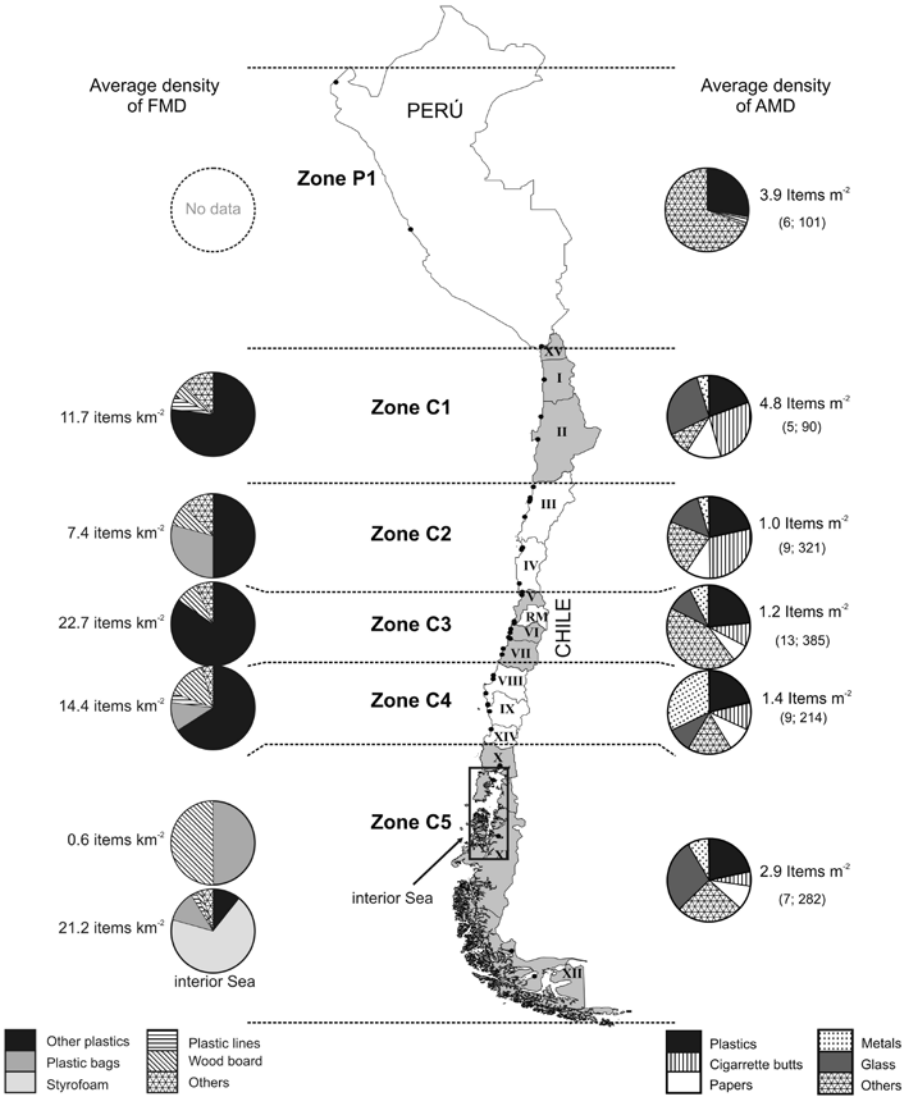

Figure 1. Proportions of different litter categories recorded at sea (left side) and on local beaches (right side) along the SE Pacific coast (data from Thiel et al. 2003, Bravo et al. 2009, Hinojosa & Thiel 2009, A. Pacheco unpublished data). Categories differ between sea and beach surveys, because certain items (paper, cigarette butts, metal, glass) either could not be recorded from ships or only occurred in very low abundances.

Figura 1. Proporções das diferentes categorias de lixo registradas no mar (lado esquerdo) e nas praias locais (lado direito) ao longo da costa do Pacífico SE (dados de Thiel et al. 2003; Bravo et al. 2009; Hinojosa & Thiel 2009; A. Pacheco - dados não publicados). As categorias diferem entre os registros do mar e das praias, porque certos itens (papel, pontas de cigarro, metal, vidro) não puderam ser observados a partir de navios ou só ocorreram em abundâncias muito baixas.

2.2 Abundances of beach and floating litter

In general the densities of litter along the beaches of the SE Pacific coast are moderate compared to the high abundances reported from other regions of the world (Bravo *et al.*, 2009). The average abundance of beached litter was ~2 items m^{-2} (Figure 2). Higher abundances (>2 items m^{-2}) were found in northern (zone P1 and C1) and southern areas (zone C5). The highest average abundance was found in Cantolao beach (10.5 items m^{-2}, zone P1), Antofagasta beaches (7.2 items m^{-2}, zone C1) and on Magellan beaches (3.1 items m^{-2}). Lower abundances were found in Punta Veleros, Peru (0.5 items m^{-2}) and in central areas (zone C2-C4) where most of the human population is concentrated (Figure 2). These differences could be due to varying attitudes of beach users, the intensity of beach use, or the frequency of cleaning activities (Bravo *et al.*, 2009).

Floating litter was found on all transects surveyed at sea, but densities in nearshore waters and in the Interior Sea of Chiloé were higher than in offshore waters. These densities reach similar levels as those in coastal seas of highly populated regions in the northern hemisphere (20 items km^{-2}, Thiel *et al.*, 2003; Thiel & Gutow, 2005). Especially high abundances were found in nearshore waters of zones C1 and C3 (Figure 3), with highest abundances (> 20 items km^{-2}) close to major port cities or near other major human activities (Figure 3). Lowest abundances of floating litter were found in the least populated regions in southern Chile (Figure 3). Globally, floating litter has been reported from all major oceans and coastal zones throughout the world (Coe & Rogers, 1997; Gregory & Andrady, 2003). In general, the highest abundances are found in waters at mid and low latitudes (Thiel & Gutow, 2005). In accordance with this trend, floating litter along the SE Pacific shows a similar pattern of lower abundances towards the south (Hinojosa & Thiel, 2009).

2.3 Sources of anthropogenic litter

Marine litter comes from several distinct land- and sea-based sources. It is difficult to estimate exactly how much litter enters the marine environment, but it has been suggested that up to 10% of the world plastic production ends up in the sea (Thompson, 2006). In Chile, 80% of the marine litter comes from land sources (Rovira, 2006). While the majority of household garbage is deposited in landfills, another large proportion is deposited in the environment. This litter from coastal cities and other human activities is transported to the sea during strong winds and rain. Tourism activities produce an additional input of litter on some local beaches - our observation of large proportions of non-buoyant litter on beaches along the SE Pacific confirms this

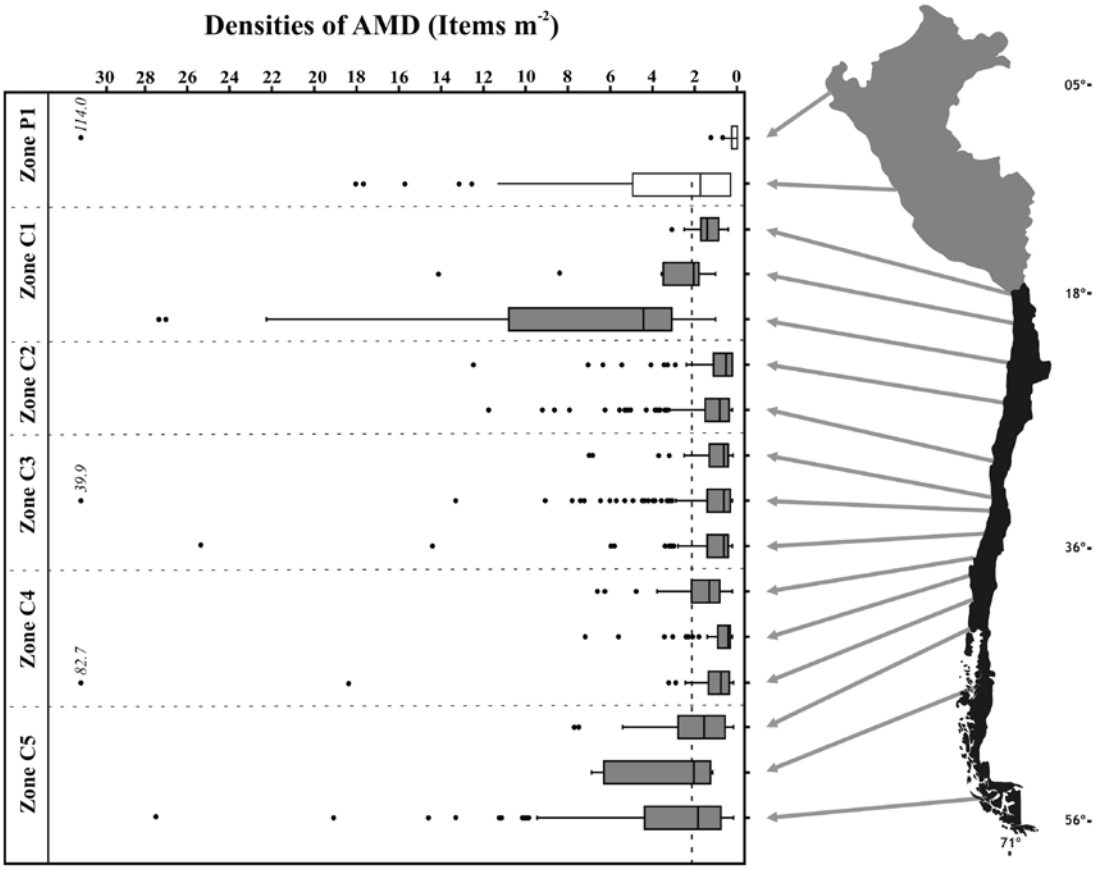

Figure 2. Average densities of anthropogenic litter on beaches along the coast of the SE Pacific (data from Bravo et al. 2009; A. Pacheco unpublished data).
Figura 2. Densidades médias de lixo antropogênico sobre as praias ao longo da costa do Pacífico SE (dados de Bravo et al. 2009; A. Pacheco - dados não publicados).

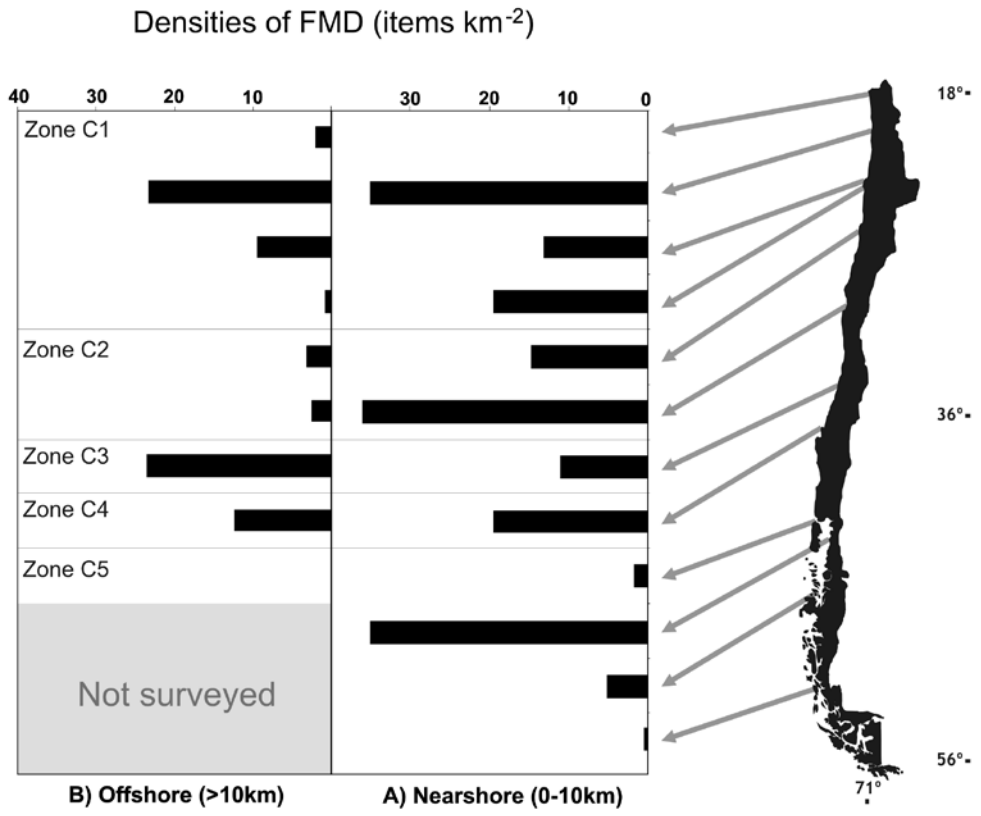

Figure 3. Average densities of floating litter in coastal and offshore waters along the Chilean coast (data from Thiel et al. 2003, Hinojosa & Thiel 2009).
Figura 3. Densidades médias de lixo flutuante nas águas costeiras e no mar ao longo da costa do Chile (dados de Thiel et al. 2003; Hinojosa & Thiel 2009).

suggestion (see above). In the particular case of Lima (Peru), a huge amount of the litter produced in the city goes to the landfill, which is being used for generating additional shore line. However, impacting waves erode the landfill and spread the litter in the sea and on local beaches. Another important source of litter along the SE Pacific is waste from sewage treatment plants. Untreated or only roughly treated sewage release large quantities of small litter into coastal waters. This problem has not been thoroughly examined and as such many coastal cities along the SE Pacific dump sewage without major treatment (Rovira, 2006).

Other important sources of anthropogenic litter are sea-based activities such as fishing, aquaculture and shipping (Hess *et al.*, 1999; Cunningham & Wilson, 2003; Fujieda & Sasaki, 2005; Criddle *et al.*, 2009). For example, the fact that most litter was found close to major shipping ports supports the idea that this litter comes from shipping or fishery activities (Thiel *et al.*, 2003). The composition of floating litter in the Interior Sea of Chiloé reveals aquaculture activities as the most likely sources (Hinojosa & Thiel, 2009). Despite the laws regulating littering in the environment, surveillance of compliance of the existing laws is relatively minimal in the countries of the SE Pacific (see below).

Anthropogenic litter could also be generated by natural catastrophes such as tsunamis, storms (e.g. during El Niño) and intense rains. During these events, many litter items are washed into the sea, and subsequently large amounts of this litter are deposited on the shore (see e.g. Cunningham & Wilson, 2003; Mallin & Corbett, 2006). For example, after the recent tsunami in southern-central Chile (27 February 2010) enormous quantities of litter appeared on local beaches (Figure 4d).

2.4 Fates of anthropogenic litter

Anthropogenic litter was found on all beaches and sea transects that were surveyed along SE Pacific coasts and plastic items usually were most abundant, especially at sea. Plastic items have a high floating potential and they are highly durable (10 to 1000 years). These properties imply that plastic items are accumulating in the marine environment (Ryan & Moloney, 1993; Gregory & Ryan, 1996; Barnes & Milner, 2005). Some studies suggest that floating plastics are accumulated and concentrated by ocean circulation in particular regions (for the NE Atlantic see Colton *et al.*, 1974; for the N-Pacific central gyre see Moore *et al.*, 2001). Additionally, along the coasts of the NE Atlantic a steady increase of plastic fragments and granules (plastic pellets) was observed during the past 40 years (Thompson *et al.*, 2004), generating an important impact on marine life (see below). This suggests a continuous breakdown of larger items and an increasing accumulation of plastic granules from plastic industries (Thompson, 2006).

The fates of anthropogenic litter in the SE Pacific are not well known. Litter may sink to the seafloor, be stranded on local beaches, or exit the system via currents. At present no information is available on litter on the seafloor of the SE

Figure 4. Litter on beaches in (A,B) Peru and (C,D) Chile.
Figura 4. Lixo nas praias do Peru (A, B) e do Chile (C, D).

Pacific coasts, but fishermen and scientists mention that they often find litter in benthic trawls (e.g. Figure 5). According to the oceanographic model by Martinez *et al.* (2009) most litter from nearshore waters of the SE Pacific remains in the coastal zone. Bourne & Clark (1984) also observed most floating litter in coastal fronts in nearshore waters and the farther offshore they went the fewer floating litter was observed. The predominant SW (i.e. onshore) winds along most of the SE Pacific most likely push a large proportion of the floating litter immediately towards local shores. Consequently, most floating litter in the SE Pacific may end up on local beaches after very short floating times. Here litter accumulates, with the highest abundances reported from beaches in Peru and northern and southern Chile (zones C1 and C5). In the central regions, where large amounts of floating litter are found in coastal waters (Figure 3), frequent beach cleaning may continuously remove litter from the beaches, thereby keeping the standing stock relatively low. Where plastic litter accumulates on the beaches, solar radiation may also contribute to degradation, and subsequent fragmentation. Fragmentation may be higher in northern Chile where solar radiation is intense, but at present, no data are available on the proportion of plastic fragments from beaches in Chile.

3. IMPACTS OF ANTHROPOGENIC LITTER IN THE SE PACIFIC

3.1 Ecological impacts

3.1.1 Seabirds and Marine Mammals

There are few data available concerning the impacts of litter on seabirds along the Peruvian and Chilean coast. Some observations suggest that negative effects such as mortality due to entanglement or ingestion of debris are common, as has been reported for other parts of the Pacific ocean (see e.g. Spear *et al.*, 1995). Birds entangled in plastic debris or fishing lines are commonly observed (Figure 6). Along the Chilean coast the most common species affected by fishing lines are oystercatchers (*Haematopus palliatus*), Peruvian pelicans

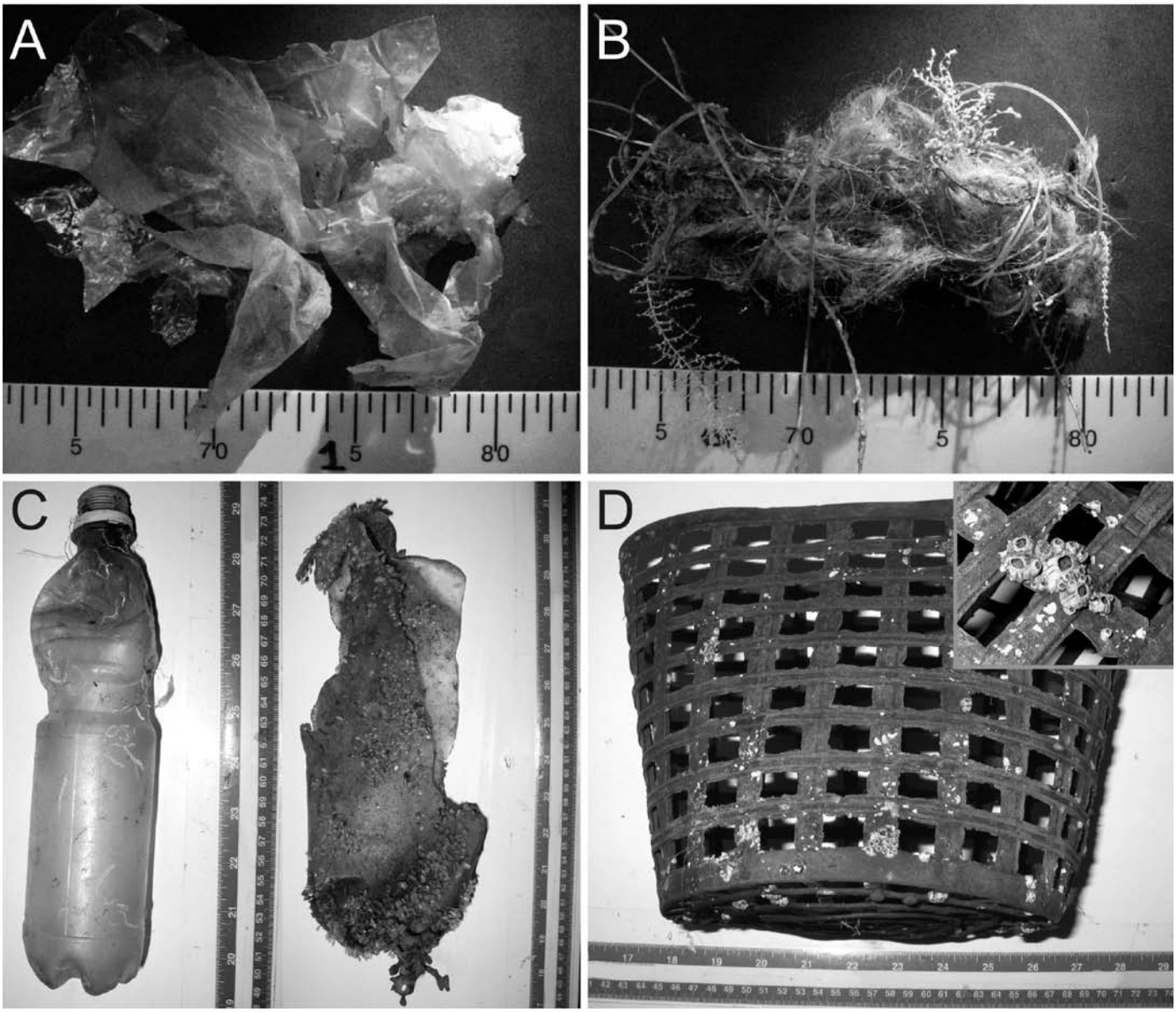

Figure 5. Anthropogenic litter from benthic trawls off the Chilean coast. (A) Fragments of plastic bags and (B) fishing line collected at ~500 m depth, off the Taitao Peninsula in southern Chile (45°55'S, 73°35'°W); images courtesy of Javier Sellanes. (C) Plastic bottles and (D) plastic cover of a wine jug collected at ~200 m depth off the coast of Coquimbo (30°09'S, 71°33'W); samples collected by Daniel Céspedes.

Figura 5. Lixo antropogénico oriundo de arrastos bentônicos ao largo da costa chilena. (A) Fragmentos de sacos de plástico e (B) linha de pesca coletados a aproximadamente 500 m de profundidade, ao largo da Península Taitao no sul do Chile (45 º 55'S, 73 º 35 'W º); imagens são cortesia de Javier Sellanes. (C) garrafas de plástico e (D) cobertura plástica de um garrafão de vinho coletadas na profundidade de ~ 200 m da costa de Coquimbo (30 º 09'S, 71 º 33'W), amostras coletadas por Daniel Céspedes.

(*Pelecanus thagus*), Peruvian boobies (*Sula variegata*), and Peruvian terns (*Sterna lorata*). In northern Chile discarded fishing lines also have been reported to cause the death of birds not directly associated with the marine environment, such as the Chilean flamingo (*Phoenicopterus chilensis*) and the Band-winged nightjar (*Caprimulgus longirostris*). In one case, a Chilean Flamingo was found trapped in a long line (commonly used in the fishery of the corvina, *Cilus gilberti*), with several hooks in its body. Lines and rope fragments discarded by aquaculture facilities affect mostly gulls (*Larus* spp.) and Neotropic cormorants (*Phalacrocorax brasilianus*).

As stated previously by Ivar do Sul & Costa (2007), there is no published information related to plastic litter ingested by seabirds along the coasts of Peru and Chile. Spear *et al.* (1995) mentioned that four species of Procellariiformes that breed in Chile are affected by floating litter, the Juan Fernandez petrel (*Pterodroma externa*), Kermadec petrel (*P. neglecta*), Stejneger's petrel (*P. longirostris*), and the Sooty shearwater (*Puffinus griseus*). Two of these species, the Juan Fernandez petrel and Stejneger's petrel, are endemic to Alejandro Selkirk Island and are critically endangered there due to introduced predators and other human

impacts. Quantitative data are available for two small petrel species from the coasts of Peru and Chile. Of 95 examined individuals of Markham's storm petrel (*Oceanodroma markhami*) from Peru, 3 individuals (3.1%) had small pieces of plastic and remains of aluminum paper in their stomachs (García-Godos *et al.*, 2002). A similar value is reported for the Peruvian diving petrel (*Pelecanoides garnotii*) breeding in Chile where the stomachs of 4 out of 103 birds (3.9%) contained plastics (Luna-Jorquera, unpublished data). These values are substantially lower than those reported for Great shearwater (*Puffinus gravis*), Sooty shearwater (*P. griseus*) and Manx shearwater (*P. puffinus*), collected in southern Brazil, where the percentages of stomachs with anthropogenic litter were 87% (n = 121 stomachs), 59% (n = 17), and 48% (n = 25), respectively (Petry *et al.*, 2008). Possibly, the low proportion of contaminated stomachs in petrels from the SE Pacific species is due to the relatively short residence times of floating plastics at sea (see above). Spear *et al.* (1995) suggested that a decrease in plastics in five Procellariiformes from the Tropical Pacific coincided with the enactment of international laws to reduce the amount of anthropogenic litter at sea (Annex V of MARPOL) in 1989, but no recent data are available.

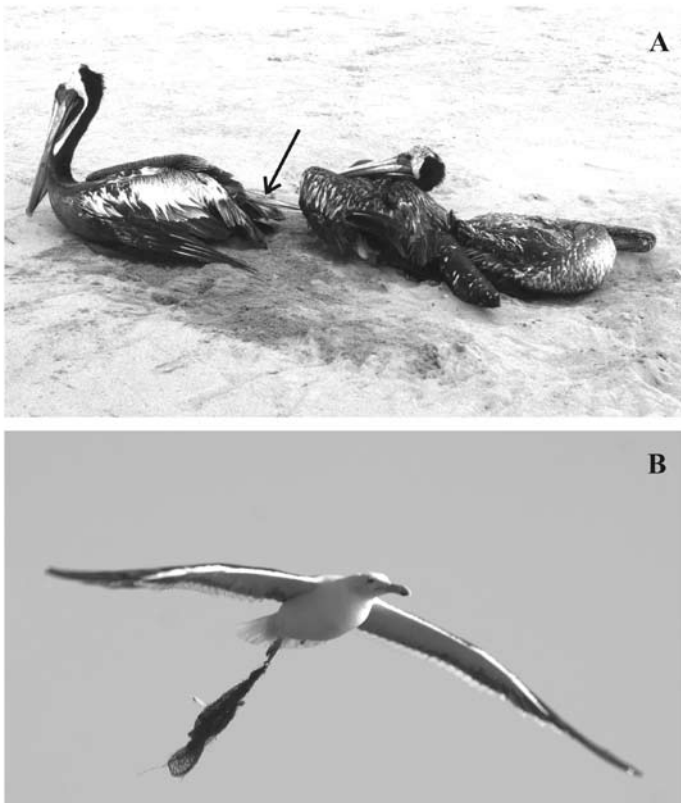

Figure 6. (A) Peruvian pelicans Pelecanus thagus entangled in fishing lines (arrow); Playa Ite in southern Peru; image courtesy of Carlos Zavalaga. (B) Kelp gull (Larus dominicanus) with mesh bag entangled around its leg; coast of San Antonio, Chile; image courtesy of Daniel González.

Figura 6. (A) pelicanos peruanos Pelecanus thagus enredados em linhas de pesca (seta); Praia Ite, no sul do Peru, cortesia da imagem de Carlos Zavalaga. (B) gaivotão (Larus dominicanus) com saco de rede enredado em torno de sua perna; costa de San Antonio, Chile; cortesia da imagem de Daniel González.

Upon revision of information concerning endemic or resident seabird species from Chile and Peru, it seems that most of them do not consume anthropogenic litter. In the stomachs of Guanay cormorants *Phalacrocorax bougainvillii* from Peru (Zavalaga & Paredes, 1999) and of Neotropic cormorants *P. brasilianus* from Chile (Luna-Jorquera, unpublished data), no evidence of plastic debris or other litter was found. The same holds true for the Humboldt penguin (*Spheniscus humboldti*) (Herling *et al.*, 2005) and the Peruvian booby (Ludynia *et al.*, 2010) studied in Chile. This coincides with observations by Bourne & Clark (1984) who reported that fish-eating seabirds ignore oceanic fronts with litter accumulations, while plankton-eating species (e.g. storm petrels) gather at these fronts where they might be at risk of consuming small plastic fragments. In the Kelp gull *Larus dominicanus*, items from landfills make up a high proportion (25% of 764 regurgitated pellets) of the diet (Ludynia *et al.*, 2005).

The available information for seabirds along the SE Pacific suggests that Procelariiformes consume more anthropogenic litter than other seabirds. This is partially in agreement with results by Spear *et al.* (1995) and Tourinho *et al.* (2010), but needs to be investigated in detail. As suggested by Thiel *et al.* (2003) and Martinez *et al.* (2009), most floating litter is concentrated in the coastal currents systems along the SE Pacific, where it is available for seabirds that breed on coastal islands. While foraging at sea many seabirds may not only come into contact with this litter but may also be directly affected by fishing activities due to drowning in nets (Simeone *et al.*, 1999; Brito, 2002; Schlatter *et al.*, 2010) or on longlines (Moreno *et al.*, 2006). In addition, most of the endemic seabirds from the Humboldt Current System face multiple threats from habitat degradation, invasive predators and human activities in the breeding colonies (Simeone *et al.*, 2003).

The problem of anthropogenic litter also is relevant on remote islands along the SE Pacific. The offshore island Lobos de Tierra (06°55.5'S; 80°42.4'W, 93 km off the Peruvian coast) is frequently used by fishermen, and a wide variety of anthropogenic litter (organic remains, plastic bottles, metal cans, rope, fishing lines, waterhoses and others) is commonly found on the island shores (Stucchi & Figueroa, 2006). In this zone, gulls have been observed using pieces of this litter for nest construction (Stucchi & Figueroa, 2006). In Chile, at Juan Fernandez Island it is common to find discarded fishing gear (Figure 7a), which causes serious problems for the endemic and endangered Juan Fernandez fur seal (*Arctocephalus philippi*) (Figure 7b). Entanglement of Juan Fernandez fur seals in derelict fishing nets had been previously observed in December 1983 (Luna-Jorquera, personal observation), and the problem continues to persist as of January 2004 (L. Osman personal communication). Potential impacts on population dynamics and reproductive success are not known at present but should be studied. For New Zealand fur seals, data from 1995 to 2005 show a total number of 185 individuals (average of 19 ± 0.2 per year) entangled in several types of anthropogenic litter (mainly trawl net and packing tape), of which 2.4% died (Boren *et al.*, 2006). Marine debris and entanglement is also contributing to the precarious population status of other pinniped species (e.g. Boland & Donohue, 2003). Considering the precarious conservation status of the Juan Fernandez fur seal it appears urgent to evaluate the rate at which entanglement occurs in this species and to define measures to reduce this problem.

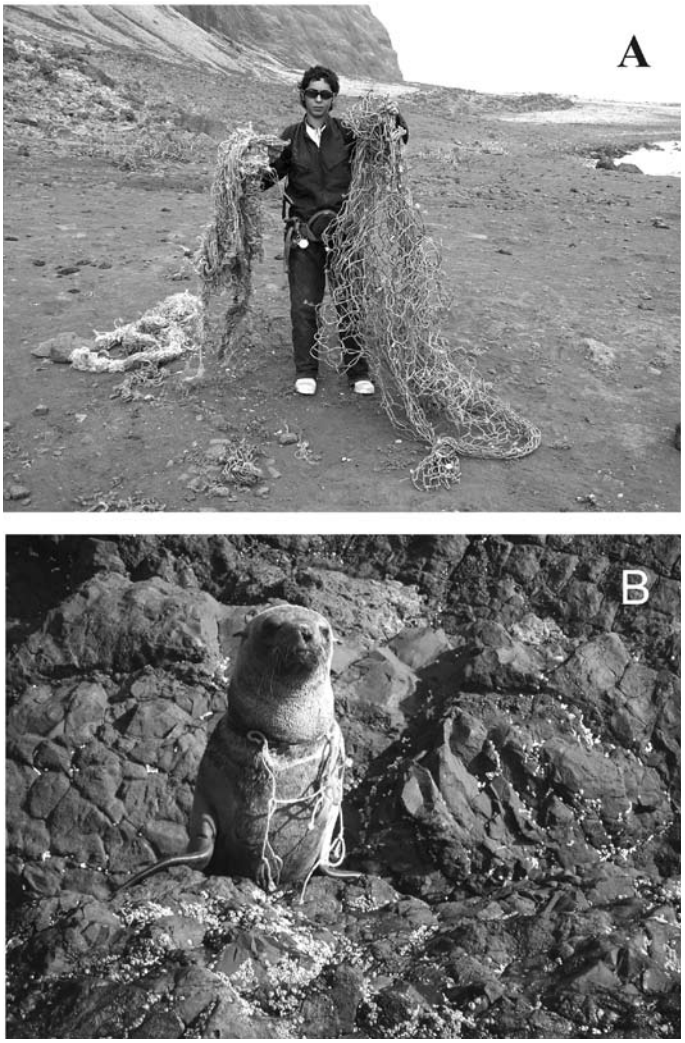

Figure 7. (A) Fishing nets on the shore of Isla Alejandro Selkirk (Chile) held up by photographer in March 2005. (B) Juan Fernandez fur seal Arctocephalus philippi entangled in fishing nets on Isla Robinson Crusoe (Chile) in January 2004; both images courtesy of Layla Osman.

Figura 7. Redes de pesca na costa da Ilha Alejandro Selkirk (Chile), sustentada pela fotógrafa em março de 2005. (B) Lobo marinho de Juan Fernandez Arctocephalus philippi emaranhado em redes de pesca na Ilha de Robinson Crusoe (Chile) em janeiro de 2004, ambas imagens são cortesia de Layla Osman.

Flórez-González *et al.* (2007) highlighted the importance of discarded fishing nets (i.e. gill nets, pelagic fish nets) as sources of accidental entanglement and mortality of adults and calves of humpback whales (*Megaptera novaeangliae*). This species approaches shallow coastal waters during their migration to breeding areas where they may encounter various types of floating litter. In the surroundings of Isla Lobos de Tierra (06°28'S; 80°50'W) in northern Peru, humpback whales have been observed interacting with the waste disposed by scallop fishermen (García-Godos, 2007). In southern Chile sperm whales, killer whales, and, to a minor extent, long-finned pilot whales interact with the toothfish fishery (Hucke-Gaete *et al.*, 2004). The authors reported only one case in which a sperm whale died entangled in a line, but since most incidents occur in the open ocean many may go undetected. Given that there is no information related to the effect of the discarded fishing gear (and other litter), it is urgent to determine the impacts of floating litter on marine mammals along the Peruvian and Chilean coast.

3.1.2 Sea turtles

Five species of marine turtles (*Dermochelys coriacea, Chelonia mydas agassizii*, *Lepidochelys olivacea*, *Eretmochelys imbricate* and *Caretta caretta*) are common along the SE Pacific. Even though these turtles are endangered and some are well known to suffer from ingestion of anthropogenic litter (see Mascarenhas *et al.*, 2004 for two species and Mrosovsky *et al.*, 2009 for a review from 1885 to 2007), there is very poor information about potential impacts of litter in the SE Pacific. An analysis of the stomach contents of 22 green turtles *Chelonia mydas* obtained from by-catch in Sechura Bay (05°20'S, 81°02'W; Peru) showed that plastic litter (26.67%) was a main component in the diet of this species (Santillan, 2008). In Antofagasta (Chile), different types of plastic have been recorded in the intestinal tract and feces of sea turtles maintained in a local wildlife rescue center (Silva *et al.*, 2007). Plastic consumption produces positive buoyancy and intestinal obstruction (Guerra-Correa *et al.*, 2007; Valenzuela *et al.*, 2008) causing high mortality rates of sea turtles in captivity (Silva *et al.*, 2007) and possibly also in the natural habitat. Considering that sea turtles are mainly omnivorous, anthropogenic litter represents a serious threat for their conservation. In addition, impacts caused by discarded fishing gear should be also evaluated – as an anecdotal example on 28 July 2009 one dead turtle (*Dermochelys coriacea*) was found entangled in a gill net in Mejillones Bay in northern Chile (23°S) (N. Piaget, personal communication).

3.1.3 Marine Invertebrates and algae

Small plastic fragments may be trapped by filter feeders on beaches, but the extent and impact of this problem is not known. Once stranded on the beach, water-filled containers, e.g. jars, cans or half-empty bottles can become mortal traps for beachhoppers (amphipods), which are unable to escape from the liquids. Litter accumulating on soft-bottoms may provide hard substrata for sessile organisms that otherwise would not be able to settle on the unstable soft substratum. The release of oil, paint and other toxic residues from broken containers may present another risk for invertebrates. An additional concern of the ever-increasing amounts of floating plastics is transport of non-indigenous species (e.g. Gregory, 1991; Winston *et al.*, 1997; Astudillo *et al.*, 2009).

3.2 Economic impacts

Litter in the environment causes a variety of economic impacts. Accumulations of litter on beaches may directly affect tourism activities (Ballance *et al.*, 2000). These include landscape deterioration, contamination of inland and coastal waters, vectors for invasive species, and direct costs for local communities that engage in beach cleaning activities. This problem is often caused by a lack of environmental awareness.

3.2.1 Industrial, Aquaculture and Fisheries activities

Anthropogenic litter may foul important submarine structures. Fish cages accumulate litter, which then needs to be removed. Similarly, industrial water intake pipes may be

fouled by litter. Finally, derelict lines and fishing nets may become entangled in ship propellers (Kirkley & McConnell, 1997), potentially with dramatic consequences for ship and crew.

3.2.2 Tourist activities

In the countries of the SE Pacific, it is the responsibility of city governments to collect, treat and dispose of garbage properly. This generates significant costs, especially during the annual tourist season, when the waste volume in coastal cities increases substantially. For example, in the principal tourist cities of the Region of Valparaiso (Chile) up to 25% more garbage is produced during the summer months than during the rest of the year (Diario el Mercurio de Valparaíso, 2010). In the small tourist city of Cartagena (approx. 17,000 inhabitants) about 50 tons of litter are collected daily on local beaches, where during summer weekends up to 700,000 non-paying visitors gather (Pontificia Universidad Católica de Chile Television). Collection of this gigantic amount of litter generates important costs for the local municipality, by far exceeding the available funds.

The costs associated with beach cleaning vary depending on the area covered, the number of tourists and the general features of the beach. For example, the city of La Serena (Chile) invested approximately US$ 375,000 for cleaning the local beach called San Pedro, which according to the local municipality has a high potential for future tourist activities. This beach section is 1 mile long and during the summer months cleaning is done daily by a 15 person crew and 3 times a week by machine. The overall costs also include landscaping, infrastructure (beach access, parking) and the installation of 50 garbage bins (Communications Department, City of La Serena). It is important to mention that the implementation of these beach cleaning services is only possible in areas with high tourist numbers where the income generated by tourists covers the costs for these services. Areas with little tourist activity are rarely cleaned on a regular basis and generally accumulate the garbage from local beach visitors and from the flotsam, as is currently the case on many beaches along the SE Pacific. This can be counterproductive because contaminated beaches repel tourists (e.g. Ballance *et al.*, 2000), which leads to a vicious cycle of less income from tourism and decreasing care for the local beaches (World Health Organization, 2003).

4. LEGISLATION

4.1 International treaties signed by the countries

Chile, Peru and Ecuador, as well as many other countries, have signed the MARPOL 73/78 treaty, wherein Annex V regulates the discharge of solid waste by ships. The implementation and compliance of this regulation depends on the maritime authority of each country. In Chile this falls under the responsibility of the "Dirección General del Territorio Marítimo y Marina Mercante" (DIRECTEMAR), in Perú the "Dirección General de Capitanías y Guardacostas" and in Ecuador the "Dirección General de la Marina Mercante y del Litoral". MARPOL only applies to ships but garbage and pollutants that originate on land or from other marine activities are covered by national laws.

4.2 National laws

In Chile, Peru and Ecuador, the treatment of household garbage is regulated by a diverse set of laws, codes, regulations and rules, under the responsibility of several ministries and public entities. In 1994 the Government of Chile created the National Commission for the Environment (CONAMA - Comisión Nacional del Medio Ambiente), which operates under the Law of General Environmental Rules (Ley sobre Bases Generales del Medio Ambiente). Within this framework CONAMA established in 2005 the Policy of Integral Solid Waste Management (PGIRS - Política de Gestión Integral de Residuos Sólidos). This policy is an interministerial agreement to reduce the amounts of solid waste, considering waste management from production, avoidance of garbage production, and, if this is not possible, treatment and eventual final deposition. Despite the national goals and the obvious benefits (generation of employment and of financial returns, extension of life-time of landfills), at present only in the capital (Santiago de Chile) and in some larger cities have integral waste management plans been established. CONAMA also participated in the development of the standards for submarine sewage outfalls that are common along the coasts of the SE-Pacific (Rovira, 2006), where they represent important sources of marine debris. In Chile, surveillance of these standards corresponds to the Superintendents of Health Services (Superintendencia de Servicios Sanitarios), DIRECTEMAR and the local health services. In Ecuador during the 1970s the Ecuadorian Institute of Sanitary Works (IEOs) became responsible for the solid waste management. In 1992 the first "Regulations for Solid Waste Management" were established and later amended in the year 2000. However, all these efforts did not have the expected results, mainly due to economic and administrative problems (Solid Waste Sectoral Analysis Ecuador, 2002). In Peru, after experiencing epidemiological problems, the General and Solid Waste Regulations, which supervise the entire path of solid waste from its initial generation to recycling and final disposal (Directorate of Environmental Health Peru, 2004), were created in 2004.

According to the Organic Constitutional Law of Municipalities (Ley Orgánica Constitucional de Municipalidades de Chile, first established in 1988), city governments are responsible for cleaning the cities and retrieval of household garbage. In the case of coastal cities this includes local beaches, and most communities have particular programs for beach cleaning (see above). In some regions, litter comes mainly from aquaculture activities (Hinojosa & Thiel, 2009). In response to this problem in 2002 the Chilean government strengthened the existing "Ley de Pesca y Acuicultura", by adding regulations that assign the responsibility to aquaculture centers to maintain adjacent areas litter-free. More recently (January 2008) the Supreme Decree (D.S. 86) was added, requiring aquaculture centers to use flotation systems that avoid the release of styrofoam fragments. While legislation is strong, surveillance of compliance is insufficient and often large accumulations of floating litter are found on beaches adjacent to aquaculture centers (Hinojosa & Thiel, 2009).

4.3 Control and fines

Among the various laws in Chile that regulate activities on the beaches, the codes of the Environment, Water and Health only contain general statements, which are difficult to interpret when defining the sanctions for littering. The principal monitoring organization is the Maritime Authority, which operates under the Regulations for the Control of Water Pollution (Reglamento para el Control de la Contaminación Acuática; DIRECTEMAR, 1994). These

regulations establish a system of prevention and surveillance for garbage and sewage dumping in all waters under national jurisdiction. The fines depend on the severity of the infractions and may reach up to US$3,000,000 (see the regulations established by DIRECTEMAR, 1994). The Peruvian law states that "pollution by dumping of any solid waste above the permissible limits causing damage to the environment, including its fauna and flora and hydrobiological resources, will be punished by imprisonment for not less than one nor more than three years" (Codigo Penal, Titulo XIII, Articulo 304).

The law that defines that the city governments are responsible for garbage collection and cleanliness of public places also empowers them to create their own regulations. For example, the small city of Mejillones (Chile) states in its "Environment and Public Health Ordinance" from 2004 that a person caught littering will be punished with fines ranging from US$70 to US$350. The control of compliance with this law corresponds to the local police and municipal inspectors. In this context a study in Ecuador reported several control mechanisms, where the main role is exercised directly by the municipalities. Another less-developed mechanism in their legislation mentions the "Social Role", which entitles individuals or groups of persons to report infractions of the law. However, all these mechanisms are underdeveloped and do not work fully due to "lack of institutional and financial capacity to fulfill, and because of ignorance of the general public" (Solid Waste Sectoral Analysis, Ecuador, 2002).

Examples from some coastal cities in Chile underline this last point. The northern town of Caldera (Chile) has an extensive coastline (more than 70 beaches along 170 km coastline), with approximately 15,000 inhabitants (Assistant Secretary of Community Development and Administration, Government of Chile). Records of the local police station indicate that during the period 2007 until February 2010, only one infraction concerning illegal dumping of garbage was recorded, where usually about 2000 other complaints are processed each year (Police Station Caldera, personal communication). According to officials, persecution of these cases is often casual in nature, without routine checks, and follow-up procedures usually occur only in response to external complaints. Similarly, in the town of Tongoy (Chile) the harbor master received a total of 65 official complaints in 2009, of which 2 were related to litter on the beach (Record Book, Harbor Master of Tongoy, Armada de Chile). In both cases the responsible person could not be identified and the cases were derived to the city government. The harbor master indicated that it is difficult to handle the problem of garbage on the beaches, because the authority can only apply a fine when the delinquents are caught in the act (Harbor Master of Tongoy, personal communication). Recognizing the low probability of detection and sanction, Sutinen (1997) emphasized that fines for littering should be very high in order to achieve compliance.

Clearly, in the countries along the SE Pacific, existing legislation defines certain legal aspects of the management of solid waste. However, these laws have many loopholes, which in combination with poor performance, lack of monitoring and weak enforcement of these laws, lead to a high degree of inefficiency (Solid Waste Sectoral Analysis, Ecuador, 2002). This underlines the need for multiple measures in order to improve the situation.

5. POSSIBLE SOLUTIONS

5.1 Incentives to avoid the generation of marine debris

At present, law enforcement along the coasts of the SE Pacific is very limited because many governmental organizations are understaffed and operate with insufficient budgets. While better regulations are desirable, such efforts would be futile without improved enforcement. The fact that most sources of litter are widely distributed over an extensive area makes surveillance extremely costly (Kirkley & McConnell, 1997). Thus, it might be more economical to avoid littering at sea and on the beaches at its source. This requires adequate infrastructure. For example, containers for different litter categories (recyclable and non-recyclable) need to be provisioned in sufficient number and easily accessible locations. Frequent retrieval of filled containers and surveillance of the surrounding areas is also required. The supervision of adequate disposal of waste in containers and the subsequent management and processing of the accumulated waste also produce high costs and therefore alternatives should be sought to reduce the amounts of litter in the first place.

One of the best strategies to avoid litter dumping in the marine environment appears to be a system of economic and social incentives. Initiatives to enhance environmental awareness are key in the efforts to reduce waste production. Social incentives for local communities (schools and neighborhoods) could promote programs of environmental education, e.g. fellowship programs for schoolchildren and private citizens who show exemplary services related to the reduction of the waste volume and the protection of the environment. Sutinen (1997) discussed social pressure (stigmatizing of delinquents) as another example of a social incentive.

Another important effort in this process is to encourage corporate responsibility of commercial beach users (e.g. aquaculture farms, fishing associations, commercial harbors). Additionally, the costs for adequate disposal of a product after its use could be incorporated in the sales price, which would encourage the use of reusable and recyclable products. Businesses with a high proportion of these products could be rewarded with a tax-reduction. Similarly, reusable bags could be promoted by special charges on plastic bags (several emerging economies, such as India and China, have established fines on plastic bags). In parallel, a reduction of waste production could be supported with recycling activities, which in turn can promote micro-businesses.

These programs could be developed under the framework of Clean Production Agreements (APL - Acuerdos de Producción Limpia), which, in the future, could also incorporate a certification process based on green seals. Within all these strategies, differences in economic status and litter production of the local population need to be taken into account. For example, in Chile a family of low socioeconomic levels generates a volume of garbage of 0.57 kg person^{-1} day^{-1}, whereas a high-income family generates 1.07 kg person^{-1} day^{-1} (CONAMA, 2005). Interestingly, in high-income communities the garbage is often directly transferred to landfills, and at present most recycling projects are located in poor communities, which recycle the garbage of the rich. A compensation system could be established for those communities where large amounts of garbage are recycled. These compensations could be transformed into incentives that foster an environmentally sound treatment of solid waste, including containers and processing facilities.

5.2 Recycling

Recycling has the potential to play a significant role in minimizing the amount of waste that is currently deposited in landfills. At present, many products cannot be recycled due to their physical and chemical properties. There is a need for efficient recollection and final disposal, which again produces high costs in form of recollection infrastructure and landfill maintenance. For this reason, recycling should be considered the ultimate goal, and reusable products and the avoidance of waste production should be encouraged.

A major goal of the Chilean government is to foster the innovative spirit of the future generations. Following the idea of reducing the production of waste in schools and other public and private entities, small funds could be established where schools could apply to acquire containers for collection and materials to transform waste into usable products (e.g. "wood" paper for fireplaces, toys, tire covers, water heating systems, etc.). Successful ideas could be rewarded with additional support to spread the idea to other schools or small companies in order to generate a small industry of recycling and reuse of waste. One example is the microenterprise RECIART (Ovalle Recyclers), a small recycling start-up in the town of Ovalle (Chile), which is funded through the Environmental Protection Fund CONAMA. Instead of poking through unsorted garbage, the participants of RECIART now collect cardboard that has been separated by the local population. By associating with recycling companies and local businesses they were able to double their monthly income and improve their working conditions. Another example is UPASOL (an association of parents and caretakers), which have supported the rehabilitation center for their disabled children through the collection and sale of recyclable materials. All these activities could be combined with promotion activities by popular figures in the media (actors or athletes), thereby creating wider public support for recycling activities.

In Chile, there are several larger companies engaged in the recovery of materials through recycling of glass, paper, aluminum, and PET 1. There are also many associations gathering recycling materials in order to generate funds for other tasks. Municipalities and charity centers act as storage centers for materials and collectors of materials. However, public participation and implementation of infrastructure is still very limited and only occurs in Chile's larger cities. It thus appears especially valuable to foster recycling programs in small coastal towns. Collection of recycling materials should begin in the households, but can also be extended to public places such as local beaches (Figure 8).

Figure 8. Recycling containers on beaches in Peru.
Figura 8. Lixeiras para lixo reciclável nas praias do Peru.

5.3 Strategic collaborations

Avoiding the production and dumping of garbage in the environment is one of the main goals of many communities, especially tourism-based seaside communities. This goal can be achieved by specific programs that include strategic associations between individuals, neighbourhood committees, government institutions, companies and local stores, media and non-governmental organisations (NGOs). In addition to improved infrastructure and surveillance, the government could discourage the use of plastic bags and foster reusable products. While some recycled products can have a high economic value, the collection, separation and processing of many materials (plastics, paper, metal) also generate high costs. Efficient recycling therefore may require initial subsidies by the government, which could be provided by competitive funds that encourage participation and innovation such as the Technical Cooperation Service (SERCOTEC – Servicio de Cooperación Técnica) and the Production Development Corporation (CORFO – Corporación de Fomento de la Producción) in Chile. Furthermore, the government could support recycling companies using tax breaks, for example, and offer special incentives to companies that involve local communities. This could be supported by the Solidarity and Social Investment Fund (FOSIS - Fondo de Solidaridad e Inversión Social) and by Development projects of City Governments (PROFO - Proyectos de Fomento de los Municipios). Neighbouring communities should also coordinate their efforts better to achieve higher economic efficiency in their recycling programs (Policy of Integrated Solid Waste Management, CONAMA).

A very good example of the formation of strategic alliances is the work done by the Peruvian NGO "Ecoplayas" (Table 1). This organization brings together local governments and private companies in regular cleaning campaigns on beaches along the Peruvian coast, motivating the participation of the local people through the exchange of valuable products (e.g. boat oil, clothes, groceries) for collected plastic debris. As a result, large amounts of plastic are regularly removed from the beach (Table 2). These campaigns are accompanied by informative talks about the importance of having a clean beach and the negative impacts of garbage on the environment. Similar activities conducted by other NGOs involve the participation of members of the local government and schoolchildren. Ecoplayas also hosts the "Ecoplayas Award", which is a contest where all members of different types of beach communities participate in a healthy competition in which the winner is the group with the cleanest, environmentally friendly and best conserved beach. The awarded community receives a governmental recognition for their efforts.

There are a number of NGOs dedicated to the conservation of the marine environment in general. Within their activities these NGOs also incorporate regular beach clean-ups and other events enhancing environmental awareness. For example

Table 1. Institutions working on issues related to anthropogenic marine debris (on beaches and at sea) in the SE Pacific. Among these institutions are non-governmental organizations (NGOs) as well as governmental organizations. NGOs mostly develop and conduct activities such as litter removal campaigns, environmental education programs and conservation of threatened species, while governmental organisations provide the regulatory framework for addressing the problem of anthropogenic marine debris.
Tabela 1. Instituições que trabalham em questões relacionadas com lixo marinho antropogênico (nas praias e no mar) no Pacífico SE. Entre essas instituições encontram-se organizações não-governamentais (ONGs), bem como órgãos governamentais. As ONGs desenvolvem e realizaram principalmente atividades como campanhas de remoção de lixo, programas de educação ambiental e de conservação de espécies ameaçadas, enquanto os órgãos governamentais fornecem a estrutura regulatória para lidar com o problema do lixo marinho antropogênico.

Name	Acronym	Country	Locality	Web site
Ecoplayas		Perú	Lima	ecoplayas.rcp.net.pe
Organización científica para conservación de animales acuáticos	ORCA	Perú	Lima	www.orca.org.pe
Áreas costeras y recursos marinos	ACOREMA	Perú	Pisco	www.acorema.org.pe
Asociación Peruana para la conservación de la naturaleza	APECO	Perú	Nacional	www.apeco.org.pe
ONG Vida		Perú	Lima	
Mundo Azul		Perú	Lima	www.mundoazul.org
Ministerio del Ambiente	MINAM	Perú	Nacional	www.minam.gob.pe/
Sistema Nacional de Áreas Protegidas	SINANPE	Perú	Nacional	www.areasprotegidasperu.com/sinanpe.htm
Instituto del Mar del Perú	IMARPE	Perú	Nacional	www.imarpe.pe
Policía Nacional del Perú Dirección de Turismo y Ecología	DIRTURE	Perú	Nacional	www.pnp.gob.pe/direcciones/dirture/inicio.html
Araqpacha-Lost-Olas Perú		Perú	Lima	araqpacha.org/
Dirección General de Territorio Marítimo y Marina Mercante	DIRECTEMAR	Chile	Nacional	www.directemar.cl
Comisión Nacional de Medio Ambiente	CONAMA	Chile	Nacional	www.conama.cl
Guías y Scout de Chile	AGSCH	Chile	Nacional	www.guiasyscoutschile.cl/index.php
Comité en Defensa de la Flora y la Fauna	CODEFF	Chile	Nacional	www.codeff.cl
Científicos de la Basura		Chile	Nacional	www.cientificosdelabasura.cl
Chile Surf		Chile	Nacional	www.chilesurf.cl
Festival de la Basura		Chile	Caldera	www.festivaldelabasura.cl
Acción Ecológica Borde Mar		Chile	Los Vilos	www.conama.cl/portal/1301/article-47655.html
Proplaya		Chile	La Ligua	proplaya.cl/
Chinchimen		Chile	Puchuncaví	www.chinchimen.org
Conservación Marina		Chile	Valdivia	www.conservacionmarina.cl
Unión de Padres y Amigos Solidarios	UPASOL	Chile	Vicuña	www.territoriochile.cl/1516/article-78002.html
Recicladores de Ovalle	RECIAR	Chile	Ovalle	
Centro de la Familia	CENFA	Chile	Santiago Viña del Mar Pto. Montt	www.cenfa.cl
ONG Casa de la Paz		Chile	Santiago	www.casadelapaz.cl
Canelo de Nos		Chile	Santiago	www.elcanelo.cl

Table 2. Data of marine debris collected during litter removal campaigns at several beaches on the Peruvian coast over the summer 2008. In decreasing order of abundance, the collected items were; plastic bottles, plastic bags, lids, plastic dishes and other plastic items (Ecoplayas original data).
Tabela 2. Dados de lixo marinho coletados durante as campanhas de remoção de lixo em várias praias na costa do Peru durante o verão de 2008. Em ordem decrescente de abundância, os itens coletados foram: garrafas plásticas, sacos de plástico, tampas, pratos de plástico e outros artigos de plástico (dados originais Ecoplayas).

Location-Beach	Date	N°-collector bag (50lt)	Weight kg (~each bag)	Total weight	N°- Items
Huacho/Centinela	02/08	66	7.5	495	7615
Barranca/Isla del Faraon	02/08	14	6	84	1292
Huarmey/Tuquillo	02/08	80	5	400	6153
Paracas/Yumaque	03/08	9	6	54	15891

Positions: Centinela (11º 03' 52.94"S; 77º 38' 05.58"W); Isla del Faraon (10º 48' 41.73"S; 77º 45' 03.91"W); Tuquillo (10º 03' 03.60"S; 78º 10' 34.75"W); Yumaque (13º 55' 07.86"S; 76º 16' 56.58"W).

the NGO Proplaya is formed by citizens who develop beach cleaning activities in central Chile, with support from public and private institutions (Table 1). Another organisation, Chinchimen, has been working for more than ten years for the protection of the coastal environment in the community of Puchuncavi (Chile) (Table 1). They, like many others, have started with a specific objective (protecting sea otters) and over the years embraced a more integral approach that includes all aspects of environmental protection, including avoidance and removal of marine debris on local beaches.

5.4 Environmental education

In Latin America a broad range of ecological challenges are linked to social problems. With the steady growth of the economies along the SE Pacific, however, it becomes increasingly evident that nature has limits and that sustainable development can only be achieved by integrating the ecological, sociocultural, economic and scientific-technological fields (Novo, 2006). The knowledge and environmental awareness of the local public is key to solving these challenges.

Pollution is an environmental problem that may be caused by social attitudes related to the current free market system (Huneeus, 2002). Many products do not only generate problems after their usage, but also contaminate the environment during their production. It is therefore especially important to inform people about the entire environmental history of a product in order for them to make educated choices during the acquisition of these items. Despite the increasing environmental awareness of the general public, certain problems such as litter in the environment continue to persist. One reason for this might be that occasional reports or singular events suggest that the situation is taken care of. However, keeping the environment clean requires recurrent action, just like getting dressed every morning. That is why education must find ways to reach the attention and willingness of the general public (García, 2002; den Brok *et al.*, 2006; Quintanilla & Adúriz-Bravo, 2006).

One way to reach the general public is the incorporation of environmental topics in science education (Fernández-Manzanal & Casal-Jiménez, 1995). Environmental education should be part of the daily curriculum in schools, colleges and universities. Using hands-on approaches like an experiment or a survey of a contaminated site, students generate knowledge that can become the basis for discussions and changes in habits (den Brok *et al.*, 2006; Quintanilla & Adúriz-Bravo, 2006). This might require didactic training of educators (Campanario, 2002), so that they can create a stimulating learning environment in the classroom (den Brok *et al.*, 2006). While the results of research activities can be important, such as uncovering sources of litter on local beaches (see example on stormdrains mentioned by Ryan *et al.*, 2009), the personal experience gained during these activities can even be more relevant (Quintanilla & Adúriz-Bravo, 2006). The experiences obtained from this newly generated knowledge often induce students to search for and develop practical solutions. Incorporating this constructivistic approach in schools and the workplace will help to resolve not only environmental problems, but also social and economic challenges.

In Chile, several initiatives to enhance environmental awareness and reduce the problem of waste production and littering in the environment are mediated by the National Policy on Education for Sustainable Development (CONAMA, 2009) and the Environmental Certification System of Educational Establishments (SNACE - Sistema Nacional de Certificación Ambiental de Establecimientos Educativos). SNACE is developed by the Minister of Education (MINEDUC) in collaboration with CONAMA. In coastal communities these programs are linked with the conservation of the coastal environment by workshops and environmental topics in the annual course schedule in local schools.

Between 1994 and 2004, the Chilean environmental protection fund of CONAMA has financed more than 100 projects to implement recycling and environmental education efforts in local communities. These projects have their origin in local organizations, such as schools or neighborhood committees, which strive to manage their solid waste and ideally recover materials that can be recycled. The national policy of education for sustainable development (Política Nacional de Educación para el Desarrollo Sustentable, EDS) aims to generate environmental awareness among citizens, private companies and governmental agencies. Within this framework, sustainability issues are incorporated in the educational curriculum. Current projects are mainly concerned with the management of household waste, but some initiatves also consider the problem of solid waste in public locations.

The Chilean education reform postulates that environmental education should not be a separate discipline or an extracurricular activity, but instead should be integrated across all courses (MINEDUC, 1998). In this context, issues such as sustainable development and environmental protection are among the key objectives of the CONAMA topic "People – Environment" (Policy of Integrated Solid Waste Management, CONAMA). This program is designed to help schoolchildren develop environmental awareness and promote the sustainable use of natural resources. Additional efforts have been made by diverse projects supported by the program EXPLORA of the National Commission of Science and Technology (CONICYT), which is oriented towards schoolkids of all educational levels. One example is the association *Cientificos de la Basura en las Playas*, founded in 2007 at the Universidad Católica del Norte (Table 1). This program, first developed in the cities of Coquimbo and La Serena, has now expanded to work with teachers and students from all over Chile (Bravo *et al.*, 2009). Students from coastal cities are encouraged to examine the problem of marine debris on their local beaches with a variety of innovative approaches (see www.cientificosdelabasura.cl). Ultimately this project aims at generating environmental awareness and encouraging students to develop solutions in their own school/community/home. Another project financed by the EXPLORA-CONICYT program is the NGO "Marine Conservation", which organized the First School Congress of Marine Sciences where more than 100 schoolchildren from basic and secondary schools from southern Chile presented their own scientific research on environmental conservation.

Despite their apparent benefits, environmental projects are sometimes confronted with unexpected opposition from the general public. For example, recycling projects may generate conflicts due to fear of pollution, noise or increasing truck traffic. Many of these problems develop because the community has not been sufficiently informed and involved in the planning of these projects. One major goal of environmental education should be to highlight the benefits of recycling projects and to raise public awareness about the problem of garbage in the environment. Overall, the general public in the countries along the SE Pacific has little knowledge about the problems and environmental hazards generated by garbage in the environment, and consequently many efforts to reduce the amounts of garbage have been met with indifference. Recycling programs have been developed by various entities (National Environmental Certification for Educational Establishments, CONAMA, MINEDUC, CONAF, UNESCO and the Chilean Association of Municipalities) but these are not always well communicated to the general public. A better regional, national and international coordination between different projects could substantially enhance their public impact.

Education programs should also be inserted within other environmental strategies. For example, marine protected areas (MPAs) represent a central point where visitors obtain information about the environment. Written and verbal communication about the negative impacts of marine litter helps to motivate people to keep their local beaches clean. In the marine reserve Paracas (Peru), leaflets with information about litter management are regularly distributed to visitors. This information campaign, which was initiated in the year 2000, led to a significant reduction of anthropogenic litter on the beaches throughout the reserve (Figure 9). This example highlights the importance of MPAs. Environmental education within these protected areas can have effects reaching far beyond the limits of the reserve by improving environmental awareness and promoting changes in attitude among visitors. At present very few MPAs exist along the coasts of the SE Pacific, and governmental agencies responsible for the establishment and maintenance of these areas (e.g. SERNAPESCA and CONAF in Chile) struggle due to lack of staff and financial support. However, the value of these protected areas in fostering environmental education can not be overestimated (see Figure 9).

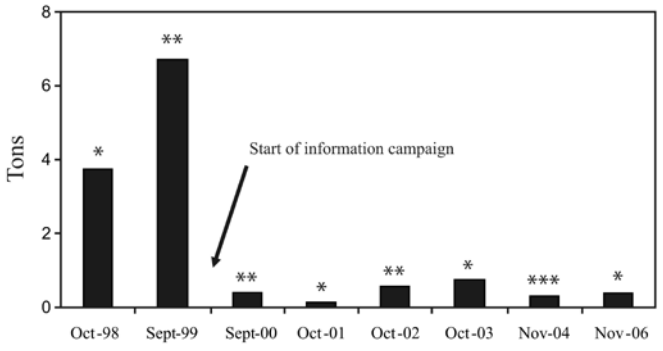

Figure 9. Total weight of litter collected during litter removal campaigns on different beaches inside the marine reserve of Paracas (Peru). Number of surveyed beaches are indicated with the following symbols: * = three, ** = five and *** = one (Ecoplayas Peru, original unpublished data).

*Figura 9. O peso total do lixo coletado durante as campanhas de remoção de lixo em praias dentro da reserva marinha de Paracas (Peru). Número de praias pesquisadas é indicado com os seguintes símbolos: * = três, ** = cinco e *** = um (dados originais não publicados de Ecoplayas Peru).*

Educational initiatives should be frequent and widespread so as to reach all levels of the society. While some strategies (e.g. establishment and maintenance of MPAs) require substantial financial support, many environmental activities can be done with minimal or no financial funds. For example, litter art can be made from the waste recollected on the beaches. Images from soda cans and bottles can be formed easily in the sand. This kind of action art has been used by professional artists (see e.g. http://www.haschult.de/trash.html; accessed 16 June 2010) and also by schoolchildren (Figure 10). The attitudes of teachers also play an important role in developing environmental awareness among their students. One of many examples is Mrs. Marta Navarro from the school Gigoux Byron in Caldera (Chile), who for more than 10 years has developed a technology workshop with approximately 30 schoolchildren every year. Her students use only garbage to develop toys, clothes, chair covers, and other things, thereby showing their care for the environment in a fun and constructive activity. In this same setting the entire school community (teachers, students and parents) participates in the production of compost and recycling paper, being one of the first schools in its region to obtain the environmental seal from SNACE. All these activities have received financial support through diverse public funds. This is just one of many examples highlighting the importance of environmental education for sustainability. There are diverse possibilities and with some imagination there are no limits to the activities that could be realized (Figure 10).

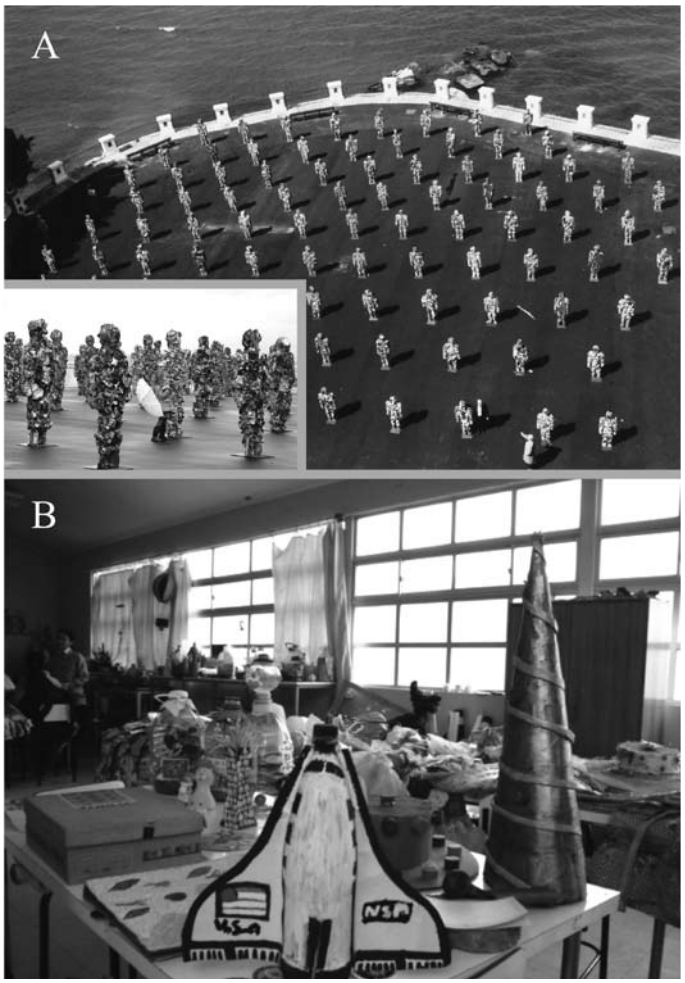

Figure 10. Innovative activities help raise public awareness for environmental problems such as litter in the sea. (A) Action art by HA Schult entitled Trash Man; images courtesy of HA Schult. (B) Art made from recycled materials created by schoolchildren from Caldera, Chile; image courtesy of Marta Navarro.
Figura 10. Atividades inovadoras ajudam a sensibilizar a opinião pública para os problemas ambientais, como lixo no mar. (A) Arte-ação de H. A. Schult intitulado Trash Man; imagens são cortesia de HA Schult. (B) Arte feita a partir de materiais reciclados criada por alunos de Caldera, Chile. Imagem é cortesia de Marta Navarro.

6. OUTLOOK

Anthropogenic litter is common in the marine environments along the SE Pacific. Present results suggest that most of this litter has local sources (e.g. Hinojosa & Thiel, 2009). Residence time at sea appears to be relatively short, since both coastal currents and predominant onshore winds transport most floating litter quickly to the beaches. Possibly the short residence times at the sea surface are responsible for the relatively low prevalence of plastics in the stomachs of pelagic seabirds, but this needs to be examined in more depths. Litter composition on beaches (with a high proportion of non-buoyant items) also indicates that a large proportion is directly deposited there by local beach users, most likely due to lackadaisical behavior. This local input of anthropogenic litter further underlines the need for local initiatives to combat this problem. One of the main problems appears to be more effective surveillance of compliance of existing rules. These controls (and fines where applicable) should go hand in hand with better environmental education, economic incentives, social pressure (moral suasion) and a functional infrastructure for litter recollection (see e.g. Sutinen, 1997). The problem of littering is also an opportunity – nobody likes litter in the environment, and once properly informed about the impacts (ecological, economic, aesthetical) most people will agree to measures to solve this problem. As is outlined above, there are a number of governmental and private initiatives, but these are often very dispersed and not well coordinated or disseminated. One approach to remediate this problem could be to assign a central institution that is responsible of coordinating activities on all levels (e.g. Criddle *et al.*, 2009). In addition to specific actions this institution should maintain a central website that connects the existing initiatives. This website could also organize the information so that visitors can quickly find recycling initiatives, innovative ideas, working guides, contact addresses.

Because the litter is primarily of local, land-based sources, the people of the SE Pacific have it in their control to reduce the litter input, i.e. they themselves are the sources as well as the solutions. It appears essential that initiatives reach all parts of the general public, starting with pre-school and extending to private households and companies. Given the fact that potential sources are spread over an extensive area, the problem of anthropogenic litter in the marine environment should be tackled at the sources. This requires an integral approach that incorporates all levels of the society (Liffmann *et al.*, 1997). Many promising initiatives have been developed but in order to produce the desired effects these need to be maintained over time. Environmental awareness and a change in attitude is a process that requires continuous and constructive re-enforcement, e.g. in the form of incentives, moral suasion and an effective compliance policy.

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