Understanding the Economic Benefits and Costs of Controlling Marine Debris in the APEC Region

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Glossary

ANZECC	Australia and New Zealand Environment and Conservation Council
APEC	Asia-Pacific Economic Cooperation
COBSEA	Coordinating Body on the Seas of East Asia
DAFF	Department of Agriculture, Fisheries and Forestry, Australia
DEWHA	Department of the Environment, Water and Heritage, Australia
DFAT	Department of Foreign Affairs and Trade, Australia
DFG	Derelict fishing gear
FAO	Food and Agricultural Organisation of the United Nations
GDP	Gross domestic product
GRP	Gross regional product
GSP	Gross state product
GT	Gross tonnage
HKSAR	Hong Kong Special Administrative Region
HKD	Hong Kong dollars
ICC	International Coastal Cleanup (Ocean Conservancy)
IUA	International Underwriting Association of London
IUMI	International Union of Marine Insurers
MARPOL	Marine Convention for Pollution at Sea
MB	Marginal benefit
MBI	Market-based instrument
MC	Marginal cost
MDC	Marginal damage costs
MOMAF	Ministry of Fisheries and Marine Affairs (Republic of Korea)
MOU	Memorandum of Understanding
MR	Marginal revenue
MRC	Marine Resource Conservation

MRCWG	Marine Resource Conservation Working Group
NOAA	National Oceans and Atmospheric Administration
NOEP	National Ocean Economics Program
NGO	Non-government organisation
NOWPAP	North West Pacific Action Plan
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
P&I	Protection and indemnity – marine insurance
SMMI	Sunderland Mutual Marine Insurance
ToR	Terms of Reference
UNEP	United Nations Environment Program
US$	United States dollars

Executive summary

Increasing levels of debris in the world's seas and oceans is having a major economic impact.

In 2008, marine debris was estimated to have directly cost the 21 Asia-Pacific Economic Cooperation (APEC) member economies approximately US$ 1.265 billion.

Fishing, transportation, tourism and insurance industries suffered along with governments and communities.

Controlling marine debris is a challenge shared by all APEC economies. In 2007 the APEC Marine Resource Conservation Working Group (MRCWG) approved a study to:

> *improve awareness amongst governments, communities and industry within the APEC region of the economic implications of marine debris and provide guidance and practical advice for governments, communities and industry within APEC economies on targeting resources to mitigate the impacts of marine debris and adopting economic instruments (and non-economic incentives where relevant) for preventing the incidence of marine debris.*

This report documents the findings of that study. It focuses on the situation of the APEC member economies, but also refers to relevant data, methods and experiences from non-APEC economies. The report is designed to assist the understanding of the economic costs and benefits of controlling marine debris and empower governments, industries and the community to take action.

Marine debris, also known as marine litter, marine garbage and ocean debris, is defined in this report as, *any manufactured or processed solid waste material that enters the marine environment from any source whether on land or at sea*.

Research suggests that 6.4 million tonnes of debris reach the world's oceans each year, and that around eight million items enter the sea every day. Plastics consistently comprise 60 to 80% of total debris recorded. Levels and rates of debris input are increasing despite measures to control the problem.

Globally, as much as 80% of marine debris entering the ocean each year is thought to come from land-based sources, with the remainder arising from shipping and other maritime sources.

Marine debris is an avoidable cost. Preventing debris entering water courses will therefore reduce the economic impact, including clean-up costs. Simple debris stock-flow models confirm that intercepting debris early in the marine debris cycle, prior to dilution at sea, can reduce the damage cost.

Preventative measures such as boom devices placed across rivers and estuaries can be effective and have positive cost-benefit ratios. However, further information on costs and benefits of such devices, plus the development of new devices is urgently needed for dissemination and uptake across APEC economies.

In many cases improved marine debris outcomes could come from improved land debris control, hence the need for a joint land and marine agency approach.

As part of its study, the MRCWG consultants examined literature to identify different economic instruments that could be applied in controlling marine debris. There are limitations on the applicability of some market-based instruments (MBIs) to marine debris control as marine debris is a non-point-source pollutant. The following MBIs are recommended as being most suited to controlling marine debris:

- deposit-refund systems
- user and administrative charges, and
- sales taxes and cost sharing.

Some measures have to be implemented on land, to prevent debris entering the sea and require cooperation with land agencies. Cost sharing shows promise for national and international situations where collective action can allow the clean up marine debris to proceed. Under a cost sharing agreement the cost is divided between adjacent economies under a previously agreed formula.

The consultants contacted each APEC economy regarding the costs, benefits and economic incentives in controlling marine debris. This report highlights six of the case studies from that process and includes: Hong Kong Special Administrative Region (HKSAR); the economies adjacent to the Yellow Sea—China, Korea, Japan; the west coast of the United States of America, Alaska and Hawaii; Peru; the east coast United States of America; and Indonesia. The MRCWG held three workshops to raise awareness of incorporating costs and benefits into the control of marine debris.

The case studies show signs of some technical and policy innovation in the face of increasing marine debris and derelict fishing gear issues. However there are only a minimal amount of economic data used in the marine debris control process and the report makes several recommendations to enhance this deficiency.

Measures to control and prevent debris need to be implemented by governments and the private sector. Given the nature of the marine debris problem a larger effort needs to be applied by the APEC economies to prevent debris entering the sea, including the use of market based instruments, replacing plastic packaging with paper and the implementation of litter traps in river and estuarine areas.

Marine debris damages marine industries, but is also an economic cost to society and the environment. All bodies working to control marine debris need to identify expenditure, assess the most effective use of funds and communicate and cooperate more effectively with each other to control and lower levels of marine debris in the APEC region.

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PART 1. Introduction

This report responds to a call for improved understanding of the 'harmful effects and costs of marine debris'[1] and the need to identify control and prevention measures and incentives for use by the 21 APEC economies[2]. The report focuses on experiences within the Asia Pacific region, however data limitations mean that on occasions non-APEC economy data examples are used if they contribute to the project objective.

The report seeks to:

1. enhance the understanding of the economic costs and benefits of controlling marine debris

2. fill a significant gap in literature, and

3. provide information necessary for decision making in managing the problem.

Much of the literature on marine debris examines the prevalence and forms of marine debris, but little mention is made of the costs that are imposed on society by marine debris. The effectiveness of control measures is usually examined from a technical point of view and the economic benefits of removing marine debris are often assumed, but not normally measured.

We propose that many of the benefit-cost decisions about the control of marine debris are happening intuitively, but may not be the best use of limited resources when alternatives are considered. There are also occasions when regulatory approaches to control can be substituted by economic instruments. These approaches to the marine debris problem are in their infancy.

The introduction outlines the terms of reference for the MRCWG study that underpins this report and describes the sources, types and fate of marine debris.

1.1 Aims and objectives

The aims and objectives of the study were to:

> *improve awareness amongst governments, communities and industry within the APEC region of the economic implications of marine debris and provide guidance and practical advice for governments, communities and industry within APEC economies on targeting resources to mitigate the impacts of marine debris and adopting economic instruments (and non-economic incentives where relevant) for preventing the incidence of marine debris.*

[1] Part Ib., paragraph ix of the APEC Bali Plan of Action 2005

[2] The 21 APEC economies are Australia; Brunei Darussalam; Canada; Chile; People's Republic of China; Hong Kong, China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; The Republic of the Philippines; The Russian Federation; Singapore; Chinese Taipei; Thailand; The United States; and Viet Nam.

The Request for Proposals required a consultant to address the following Terms of Reference (ToR):

1. Compile existing data on the direct and (where possible) indirect economic impacts of land and marine-sourced marine debris on communities, governments and selected industries (fishing, shipping and transport, tourism, insurance) in the APEC region.

2. Using available data, develop an economic-based model to estimate the costs and benefits of controlling marine debris for communities, governments and selected industries (fisheries, shipping and transport, tourism, insurance) in the APEC region.

3. Identify economic incentives and other measures (where appropriate) that are targeted at policy makers, managers and/or marine-based industries within the APEC region to:

    a. limit or prevent the incidence of marine debris, and

    b. direct available resources to effective mitigation of the impacts of marine debris.

4. Disseminate project results through an agreed outreach program to governments, relevant industries and the public in the APEC region and project partners, highlighting the benefits and costs of controlling marine debris and appropriate measures for limiting these costs in the future.

1.2 Definition of marine debris

The definition of marine debris for the purpose of this project is:

> *marine litter, marine garbage and ocean debris, is defined as any manufactured or processed solid waste material that enters the marine environment from any source whether on land or at sea* (APEC MRCWG).

The term marine debris is used in the text and includes marine litter, which may refer to domestically produced beach litter only (Cheshire *et al*. 2009).

1.3 Sources, types and the fate of marine debris in the APEC region

While there are no certain statistics, it is estimated that worldwide approximately 6.4 million tonnes of debris reach the ocean each year and that around eight million items enter the sea every day (UNEP 2005). Cheshire *et al*. (2009) consider this a low estimate, and although it is based on a comprehensive assessment, it is now quite dated (National Academy of Sciences 1975). In the APEC region the information on marine debris is limited and is most available in the more industrialised economies. Plastics are the most prevalent debris items and consistently comprise 60 to 80% of total debris recorded in marine debris surveys (Derraik 2002). It is generally agreed that both the current levels and the rates of input are increasing (eg, Ryan and Maloney 1993; Barnes 2002; Derraik 2002) in spite of measures targeted at controlling the problem (Williams *et al*. 2005; National Academy of Sciences 2008). It is estimated that globally as much as 80% of marine debris entering the ocean each year comes from land-based sources, with the remainder arising from shipping and other maritime sources (UNEP 2005). This percentage varies in different locations and with the effectiveness of debris emission regulations on land and at sea. Derelict fishing gear is a major part of fishing boat sourced marine debris. On reaching the ocean it is estimated that 15% of marine debris floats on the sea surface, 15% remains in the water column and 70% rests on the seabed (UNEP 2005).

Debris may enter the sea directly (either deliberately or accidentally), or be indirectly transported to the ocean via rivers, sewers, stormwater drains or wind (UNEP 2005).

The natural capacity of the ocean to decompose inorganic marine debris is not well understood, or readily measurable. Paper and cardboard can decompose, but plastics break down into smaller pieces and tend to be long lasting with residual damage to the marine environment. Replacing plastics with paper may reduce overall residual marine debris.

Box 1. Economic issues in the control of marine debris

Figure 1 is a conceptualised diagram that can help explain the economic issues in the control of marine debris. In the diagram there are four points (1, 2, 3, 4) at which the economies of intervention for marine debris can be measured and compared. The details of each point are given below:

1. The debris entering the sea from land and sea sources can be measured and the volume reduced through prevention and control measures.

2. The stock of marine debris in the ocean may be estimated using ambient debris levels and the various types of damage costs it inflicts can be measured.

3. The cost of reducing the stock of debris by various types of removal measures can be measured.

4. The rate of decomposition can be changed by having decomposable debris, through substituting plastic with paper.

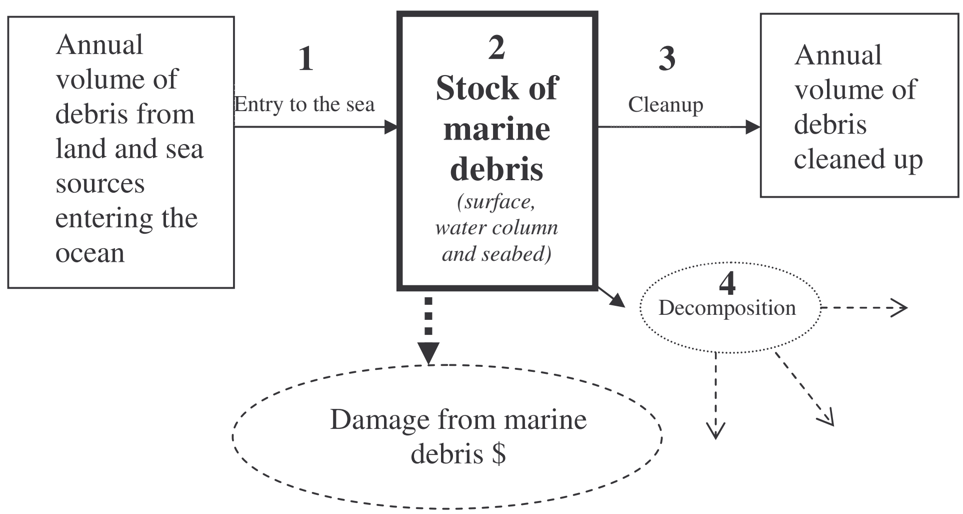

Figure 1: A conceptualisation of the sources, stock and fate of debris in the marine debris cycle (not to scale).

If the volume of debris entering the oceans is more than the volume cleaned up, there will be cumulative growth in the residual stock of marine debris. The stock of marine debris at time (t) can be represented by the following equation:

Stock (t) = Stock (t-1) + Volume of debris entering the sea (t-1) - Volume cleaned up (t-1) - Volume decomposed in the environment (t-1)

The equation describing the process in Figure 1 shows that the stock at time t, is related to the amount of debris entering the sea after preventative measures in time (t-1), less the volume of debris decomposing and the volume cleaned up in (t-1).

1.3.1 Sources and composition of marine debris

Developing marine debris prevention and clean-up initiatives first requires an understanding of where marine debris comes from. Land-based activities are recognised as a major contributor to marine debris particularly in populated areas (Slater 1994). It is estimated that as much as 80% of marine debris entering the ocean each year comes from land-based sources. These include municipal landfills, public littering, discharges of sewage and stormwater, industrial activities, ports and marinas, construction and coastal tourism. Debris originating from land-based activities includes medical waste, stormwater debris, sewage and associated waste,[3] landfill debris and litter. A fuller description of each of these is presented in Appendix 1.

Ocean-based sources of debris include merchant shipping, ferries and cruise liners, commercial fishing vessels, military and research vessels, recreational boating, offshore oil and gas platforms, and aquaculture facilities (UNEP 2005). Ocean-based debris, or land-based debris originating from ocean-based activities, includes recreational fishing and boating waste, commercial fishing waste, waste from shipping or ocean-going vessels and legal and illegal discharge at sea. In many nations military vessels are exempted from debris regulation (Cheshire *et al*. 2009). A fuller description of each of these is presented in Appendix 1.

1.3.2 Types of marine debris

Industrialised society generates solid wastes in many forms, as goods are transported, sold by retailers and used by consumers. Some of the waste finds its way to the oceans where it ends up as marine debris. Debris is ubiquitous in the world's oceans, and is now recognised as one of the most insidious pollution issues facing our oceans (Sheavly 2005a). Over the past 50 years, the nature of disposed waste has changed and organic materials, which once comprised the majority of discarded wastes, have largely been replaced by synthetic materials which are durable and may persist in the environment for many years (Sheavly 2005b; Allsopp *et al*. 2006). In addition, many synthetic materials are buoyant and can be transported over large distances, impacting on environments a long way from their point of origin.

Estimates suggest that on average, 13,000 pieces of debris are floating on every square kilometre of ocean surface (UNEP 2005). Despite efforts made across regional, national and international scales the problem of debris continues to increase (Uneputty and Evans 1997b; UNEP 2005).

There are a wide variety of items that become debris in the ocean. According to Fanshawe and Everand (2002) the main types of debris found in the ocean are as follows:

- plastics (fragments, sheets, bags, containers)
- polystyrene (cups, packaging, buoys)
- rubber (gloves, boots, tyres)
- wood (construction timbers, pallets)

[3] Under the definition of marine debris, sewage is generally not considered marine debris although they may be in association with each other.

- metals (beverage cans, oil drums, aerosol containers)
- sanitary or sewage-related items (condoms, tampons)
- paper and cardboard
- cloth (clothing, furnishings, shoes)
- glass (bottles, light bulbs)
- pottery/ceramic, and
- munitions (phosphorous flares).

Of all the debris types listed above, plastics consistently comprise 60 to 80% of total debris recorded in marine debris surveys (Allsopp *et al*. 2006). Plastics have become extremely important in modern society, and usage has greatly increased over the past three decades (Derraik 2002). Plastic production in the US increased from 2.9 million tonnes in 1960 to 47.9 million tonnes in 1985 (Robards *et al*. 1997). Plastics are lightweight, strong, durable and cheap to produce (Derraik 2002), and it is these properties that make plastic such an issue in the marine environment. Plastics pose a great threat to marine systems as once released into the ocean they do not degrade and may persist in the environment for many years. In addition, many plastics are buoyant, and therefore can be travel great distances.

Figure 2: A plastic bottle, discarded ropes and twines, typical of beach debris found in many economies in the APEC region. (Photograph: A. McIlgorm).

Table 1a indicates the frequency and relative percentages of marine debris collected in the APEC Region economies in the 2007 International Coastal Cleanup (ICC) day.

Table 1a: The different marine debris sectors in the International Coastal Cleanup day results in 14 APEC economies[4] (Source: ICC 2008).

Marine debris activity sector	Frequency	Percentage of total by number (%)
Shoreline and recreational activities	3,388,742	55.5
Ocean/waterway activities	360,408	5.9
Smoking-related activities	2,179.870	35.7
Dumping Activities	132,775	2.2
Medical/personal hygiene	45,463	0.7
Total number of items	***6,107,258***	***100***

Shoreline and recreational activities generate over 3.38 million items of debris and smoking-related debris generates 2.18 million items. These exceed the number for dumping activities, but a further breakdown of the items in the dumping activities category (shown in Table 1b) suggests that many of the items in this category are probably heavy.

Table 1b: A further breakdown of the most frequent items collected in the 14 APEC economies participating in the International Coastal Cleanup day 2007[5] (Source: ICC 2008).

Shoreline and recreational activities	Frequency	Ocean/Waterway activities	Frequency	Smoking-Related activities	Frequency
Food wrapper/containers	599,833	Rope	92,863	Cigarettes/filters	1,907,717
Caps/Lids	550,961	Fishing line	58,071	Cigar tips	169,629
Bags	443,064	Plastic sheet /tarps	50,422	Tobacco packs/wraps	70,041
Beverage bottles plastic	378,535	Strapping bands	29,421	Cigarette lighters	32,483
Beverage bottles glass	311,074	Bait containers /packaging	26,222	**Total**	**2,179,870**
Cups, plates	288,953	Buoys/Floats	22,835	**Dumping activities**	
Beverage cans	272,092	Bleach/Cleaner bottles	18,570	Building materials	78,064
Straws/Stirrers	228,800	Fishing lures/lights	15,612	Batteries	20,679
Clothing/Shoes	83,989	Oil/Lube bottles	14,520	Car/Car parts	13,803
Pull tabs	74,978	Fishing nets	9,773	Tires	12,610
Balloons	55,098	Crab/Lobster/Fish traps	6,344	Appliances	6,342
Toys	52,230	Light bulbs/tubes	6,039	55-Gallon drums	1,277
Six-Pack holders	28,419	Pallets	5,836	**Total**	**132,775**
Shotgun shells	20,716	Crates	3,947	**Medical/Pers. Hygiene**	45,643
Total	**3,388,742**	**Total**	**360,408**	**Total**	**45,463**
				Totals	**6,107,258**

[4] The economies were Australia; Canada; China; Hong Kong, China; Indonesia; Japan; Korea; Malaysia; Mexico; New Zealand; Peru; The Philippines; Thailand; and the United States of America.

[5] Note the total data for the 14 APEC economies reflects a greater number of ICC program participants from the United States than in other nations with fewer participants likely over representing the US results.

The prevalence of plastics can be seen in shoreline and recreational activities. In the ocean and waterways debris categories, ropes, fishing lines and plastic sheets are most frequent, but are followed by a range of ancillary categories of commercial fishing items. Smoking-related items are frequently encountered in all APEC economy beach cleanups. Though low in number, building materials, batteries and car parts make a significant contribution to the volume of debris (ICC 2008).

Derelict fishing gear is another type of marine debris. It enters oceans either accidentally during the course of normal operations (eg, storms or through entanglement on reefs), or through deliberate dumping (Kiessling 2003). Most modern fishing gear is constructed of synthetic materials and is relatively inexpensive. Therefore, there may be an economic incentive for fishermen to discard gear rather than spend time in repairing old or damaged gear (Kiessling 2003). Derelict fishing gear causes severe problems through entangling larger fauna such as seals and turtles, and through damaging sensitive habitats. In addition, it can pose a navigational hazard or cause damage to vessels through collision, or fouling of water intakes and propellers.

1.3.3 The fate of marine debris

Around 70% of debris entering the sea sinks to the seabed while 15% floats on the sea surface. Another 15% remains in the water column (UNEP 2005).

1.3.3.1 Floating debris

Floating debris generally comprises plastic bags, plastic items and woody debris, and it may be transported by currents and winds over great distances before sinking or being cast ashore. Marine organisms such as seals, birds and turtles can become entangled in, or ingest floating debris. In addition, floating debris poses a risk to vessels which may be damaged through collisions with larger debris (such as cargo containers and oil drums), or by having ropes and nets foul propellers and water intakes leading to engine damage.

In more remote locations, floating debris from commercial fishing operations is often washed ashore and may cause significant problems to local wildlife (Johnson 1989; Kiessling 2003). In addition, a large volume of litter from land-based sources remains on beaches, and in coastal habitats. General litter (eg, cigarette butts, paper, food wrappings) often makes up most of the items in beach clean ups (Sheavly 2005b). Debris on beaches and shorelines poses problems to wildlife and local tourism, and potentially presents a hazard to the health of beach goers (Wagner 1989). Loss of amenity on beaches and in shallow coastal habitats can cause significant economic impacts.

1.3.3.2 Seabed debris

Studies of seabed debris have revealed that heavier types of debris may sink when discarded and come to rest on the seabed or become incorporated into soft sediments (Moore and Allen 2000). Debris on the seabed is very often derelict fishing gear, metal, cans and plastics, mainly from vessels and fishing activity (Moore and Allen 2000; Lee *et al*. 2006). In a study of seabed debris by Chiappone *et al*. (2002), 90% of debris encountered in the Florida Keys was derelict fishing gear. Debris on the seabed poses a threat to sensitive habitats such as coral reefs which can be damaged by fishing gear and other forms of debris (Chiappone *et al*. 2005). *Guidelines for Monitoring Marine Litter on the Beaches and Shorelines of the*

Northwest Pacific Region have been prepared by the North West Pacific Action Plan forum (NOWPAP 2007a and b).

1.3.3.3 Wildlife marine habitats and ecosystems

Marine debris also has an impact on wildlife, marine habitats and ecosystems. The ecological impacts of marine debris have been extensively studied in all but the deep oceans. These impacts include injury and death of wildlife through entanglement and ingestion, the destruction of fragile habitats such as coral reefs, and the potential spread of invasive species. Estimates suggest that as many as 40,000 Northern Fur Seals may be killed in the Bering Sea annually through entanglement in plastic debris (Derraik 2002).

While marine debris damages environmental amenity, it also has direct economic impacts. For example, the death of marine animals from ingesting or becoming entangled in debris is a loss of natural capital. Habitats such as coral reefs can also be damaged by physical abrasion, being covered or being negatively impacted by chemical residues. Derelict fishing gear can become entangled on corals, and can abrade the delicate skeleton.

Plastic debris probably has most impact on the marine environment. Plastics enter the marine environment as, for example, waste plastic bottles or containers, and they gradually deteriorate over years and decades to become pieces and eventually small plastic fragments. These can be ingested by marine mammals, birds, fish and benthic life and remain in the animals.

Marine debris can also be part of the introduction of invasive species. Any floating object in the ocean is capable of distributing species into non-native habitats. Dispersal of invasive species has been greatly increased by the introduction of large quantities of floating plastic which can act as ‘rafts’. The presence of invasive species can have devastating ecological consequences to local marine communities, and Barnes (2002) suggests that biological invasions pose one of the greatest threats to marine biodiversity. In addition, the cost of cleaning or removing invasive species and the potential loss of fisheries can have serious economic consequences for coastal human communities.

1.3.3.4 Ghost fishing and derelict fishing gear

Lost fishing nets, such as gill nets, can ‘ghost fish’, continuing to trap fish until they have settled and become ineffective. They do not readily break down and can entangle wildlife and rocky habitat such as reefs including corals. Worldwide, at least 267 vertebrate species have been affected by becoming entangled in derelict fishing gear or plastic packaging, or through the ingestion of plastic debris (Laist 1987; Laist 1997). This includes 86% of all sea turtle species, 44% of all sea bird species and 43% of all marine mammal species. It is likely that this is an underestimate of the number of species affected by debris, as many would die and sink or are consumed by predators before being observed (Derraik 2002). During periods of wave action, debris can cause corals to break. If left in place for long periods, debris can be incorporated into the reef structure (Donohue *et al*. 2001).

Costs of disposing of fishing gear can be high, so fishing gear is sometimes dumped as a low-cost disposal method (Pooley 2000). Proper disposal can be encouraged by providing low-cost reception facilities and this would also lower the amount and impact of debris.

PART 2. Compiling the existing economic impacts on communities, governments and selected industries in the APEC region

Compile existing data on the direct and (where possible) indirect economic impacts of land- and marine-sourced marine debris on communities, governments and selected industries (fishing, shipping and transport, tourism, insurance) in the APEC region

2.1 Method

The economic impacts of marine debris are generally seen in either marine debris reports, or are noted by industries. The marine debris and associated grey literature was examined for economic or financial examples of impacts from marine debris on communities, government and industries in APEC economies. Other marine industry publications were researched for references to economic impacts from marine debris in the APEC economies.

The current study concentrates on the 21 APEC member countries on the Pacific Rim. The MRCWG used its nominated contacts to seek information on the economic impacts of marine debris in each APEC economy.

We also cite information from other regions when it can add to the objectives of this study and fill gaps in the information provided by the APEC economy respondents. The industries impacted by marine debris include secondary industries like vessel insurance. Several of the largest global shipping underwriters were contacted regarding the impacts of marine debris on shipping and fishing and hence on marine insurance.

Other sources such as the International Coastal Cleanup data (Ocean Conservancy 2008) and data on the fishing industry were also obtained.

2.2 Results

The methods chosen to identify information on the economic impacts in industries included literature searches, contact with APEC nominated representatives, and industry enquiries. Appendix 2 summarises the economies contacted and their responses. The nine replies from economy representatives indicated that economic data on marine debris is available in five of those nine economies. Information on the economic costs of various types of damage caused by marine debris is limited, or may not be held centrally by government. The low number of responses limited the data available to the consultants.

The study identified that much of the information on the economic impacts of marine debris is not held by central government, and is not recorded by industry, as there is no statutory or industry obligation to do so. Data on the economic impacts is often held by local and state governments and is not generally gathered nationally. Some of the economic impact information is gathered by non-government organisations (NGOs).

There is also a lack of land agencies issuing economic impact data as it essentially a measure of pollution, even though this is the data required to estimate the economic cost of debris prevention. They were also some references in the literature that enabled fishery production data to be utilised to scope the potential cost of marine debris damage across the APEC economies.

2.2.1 The marine economy

Marine debris may potentially have a negative impact both on the economies of industries using the oceans and on the economic values of the ocean itself. The value of the marine economy has been investigated by several projects (NOEP 2000; McIlgorm 2004) and these studies indicate the economic value being generated by activities associated with the oceans.

In the APEC region the marine economy is typically between 2% and 4% of total Gross Domestic Product (GDP) for economies such as the United States, Canada, Australia and New Zealand (McIlgorm 2004; NOEP 2005; New Zealand statistics 2006). The industry sectors contributing to GDP in the marine economy are reported in Box 2. Fisheries, shipping and marine tourism industry sectors are most impacted by marine debris.

Box 2: The agreed APEC list of industry categories in the marine economy (McIlgorm 2004):

1. Oil and Gas (minerals)
2. Fisheries / Aquaculture (living resources including sea plants)
3. Shipping (transport and shipbuilding)
4. Defence / Government (government services)
5. Marine Construction (coastal defences and restoration)
6. Marine Tourism (leisure services)
7. Manufacturing (equipment, medicines, etc)
8. Marine Services (mapping, surveying, consulting)
9. Marine Research and Education

The total APEC GDP in December 2008 was US$29,329 billion at current prices (Department of Foreign Affairs and Trade (DFAT) 2008). Of this total for all economies, the value of the marine economy across APEC economies is approximately 3% of total GDP[6] (McIlgorm 2004)—a sum of US$879 billion at 2008 price levels. Within this, the total APEC GDP for the fishing, shipping and marine tourism sectors is estimated at 48% of the marine economy or US$421.9 billion (McIlgorm 2004).[7] It is this US$421.9 billion of GDP generated by marine industries that is vulnerable to being impacted by poor control of marine debris in the APEC region.

Takehama (1990) estimates that damage from marine debris in Japan is 0.3% of the annual gross value of the fishing industry catch. If we apply this observed percentage to the value of

[6] This assumes the marine economy as a percentage of total GDP is as the US, Australian, Canadian and New Zealand studies. The marine economy contribution in other less industrialised and coastal island economies will like exceed this, but has not been measured.
[7] This is an average of the percentages of the total marine economy for these sectors in Australia, Canada, New Zealand and United States.

different sectors in the marine economy,[8] we can estimate that damage from marine debris across the APEC region for the fishing, shipping and tourism industries is US$1.265 billion annually. The next section uses different data to compare with this estimate.

Table 2: The GDP of the APEC marine economy sectors in 2008 terms with the GDP of debris-impacted sectors and damage estimates for those sectors (DFAT 2008; McIlgorm 2004; Takehama 1990).

Sector of the Marine Economy	**Percentage of the Marine economy** (Aus, Canada, NZ and US)	**Sector GDP in APEC at 2008 price levels (billions USD)**	**The GDP of Debris Impacted Sectors (billions USD)**	**The estimated value of damage from marine debris in the APEC region (billions USD)**
i. **Oil and Gas** (minerals)	26.5%	233.31	n/a	n/a
ii. **Fisheries** / **Aquaculture** (living resources)	13.8%	121.48	121.48	0.364
iii. S**hipping** (transport and shipbuilding)	10.6%	93.14	93.14	0.279
iv. **Defence** / **Government** (government services)	17.0%	149.27	n/a	n/a
v. **Marine Construction** (coastal defences/ restoration)	3.6%	31.51	n/a	n/a
vi. **Marine Tourism** (leisure services)	23.6%	207.33	207.33	0.622
vii. **Manufacturing** (equipment, medicines, etc)	4.1%	35.78	n/a	n/a
viii. **Marine Services** (mapping, surveying, consulting)	0.4%	3.52	n/a	n/a
ix. **Marine Research and Education**	0.4%	3.52	n/a	n/a
Total	**100%**	**879.00**	**421.95**	**1.265**
Key - n/a not applicable.				

These values do not account for non-market value estimates of beaches or marine animals. These non-market values are partially expressed in the value added by tourists visiting the coast and ocean, therefore contributing to the marine economy. The marine economy data illustrates the economic contribution from the marine sector of the economy to decision makers at the political level.

2.2.2 Direct, indirect and non-market economic impacts of marine debris

Economic costs are lost benefits to society. The economic impacts of marine debris can be measured by the diminished opportunities to exploit the marine environment for pleasure or profit (Faris and Hart 1994).

Impacts can have either direct or indirect costs. The different categories of economic costs in the marine debris are as follows:

- **Direct economic costs:** those costs which arise from damage to an industry or to an economic activity, for example the costs of vessel downtime due to marine debris entanglement on a vessel propeller. These costs are readily measured.

- **Indirect economic impacts:** those costs which arise indirectly, for example from marine life ingesting plastic waste and contaminating the food chain, therefore impacting on fish and even humans. These costs are not so easily measured.

[8] There are no equivalent data for shipping and marine tourism. Takehama's observation is a guide to the dimension of damage, giving a point estimate with high error boundaries. Caution should be taken in using these data for more than indicating the dimensions of marine debris damage. In the literature single references to damage, anecdotal information and insurance contacts align with these estimates.

- **Non-market values:** those costs which arise when marine debris compromises non-market values such as scenic values, or the values placed on the marine environment, or marine activities by people who do not necessarily access them. Marine debris is of concern to the community and there can be a willingness to pay, even on the part of non-users, to have the beaches cleaned (Faris and Hart 1994). For example, the levels and value of recreational activities in the marine environment are reduced by marine debris. Beach goers finding a variety of marine wastes on beaches will reduce their visits, or length of stay, with losses to tourism in the local economy. Measuring such non-market losses is not straightforward, as visitors may travel to another beach that has no marine debris, and it is the relative loss between beach sites that determines the loss of economic value.

When seeking to remedy the marine debris problem costs of prevention and cleanup should be considered. Prevention can involve waste management schemes, technical intervention and regulations. The costs of cleanup include expenditures to remediate coastlines, beaches and ports impacted by marine debris.

Values can also be measured for non-market impacts such as the impacts of plastics on marine animals. This would require specific non-market valuation studies of the costs of harm to and reduction of populations of various marine species.

2.2.3 Categories and costs of damage

An overview of the categories of damage by marine debris is reported in Table 3. Fishing vessels, leisure craft, commercial shipping, tourism, and wildlife and the marine ecosystem are all impacted by marine debris and damaged to some degree.

2.2.3.1 Fishing industry

The fishing industry is particularly impacted by marine debris (Hall 2000; Takehama 1990). There have been several studies of the marine debris damage to fishing boats in the APEC region. In Japan, Takehama (1990) estimated the cost of damage to fishing vessels caused by marine debris, based on insurance statistics available through the Japanese fishing insurance system. Such damage includes accidents, collisions with debris, entanglement of floating objects with propeller blades and clogging of water intakes for engine cooling systems. Losses in 1985 across all fishing vessels less than 1,000 gross tonnage (GT) were ¥6.6 billion. Takehama estimates that the annual vessel damage of ¥6.6 billion is 0.3% of total national fishery revenue in Japan.

Table 3: Different types of debris damage and cost estimates in different APEC economies (* notes non -APEC economies).

Category	Type of damage/loss	Type of debris	APEC Economy	Estimated cost	Source
FISHING	Damage to fishing boats	Drifting objects	Japan	¥ 6.6 billion	Takehama (1990)
	Loss of fisheries production	Nets "ghost fishing"	US	Loss of $250m in lobsters UNEP	(Raaymakers 2007)
	Loss of fishing gear and down time	Entanglement with derelict fishing gear	CDA	$10m for retrieval of nets	(Slater 1994)
	Damage to leisure boats	Entanglement of propellers	US	$792m	(Ofiara and Seneca 2006)
	Human injury/fatality/rescue costs	Rescues due to debris	UK*	£440 000/yr	Fanshawe (2002)
SHIPPING	Damage to ships		Korea	Vessel loss of 292 lives	Cho (2005)
	Damage to intake line for cooling	Plastic ingested to intake lines for cooling	UK*	>£100 000	Fanshawe (2002)
COASTLINE/ TOURISM	Loss of amenity to beaches and reefs	Plastics, fishing and general debris	US	US$1-28m/yr	(Ofiara and Seneca 2006)
WILDLIFE and MARINE ECOSYSTEM	Loss of environmental amenity, death of animals, Coral reef habitat damage	Plastics, fishing nets	Unknown	Recovery /animal rescue - costs unknown	(Fanshawe and Everand 2002)

Takehama also found that in analysis of the frequency of fishing boat accidents, 'drifting objects' was the largest single category at 10%—double that of any other cause. Vessels in the 5 to 20 GT size class had highest frequency of accidents with drifting objects, engine cooling systems and entanglement of foreign material in propellers. Generally the frequency of these accidents was less in larger vessels as they work offshore. Vessels below 5 GT have relatively fewer accidents which may reflect use of outboards, close attention by drivers avoiding marine debris, and less fishing at night than larger fishing vessels.

Takehama (1990) noted that fishing vessels damage is 0.3% of the value of the Japanese fish catch. Table 4 presents the value of the fish catch for 21 APEC economies for 2006. From this we use the 0.3% value of fish catch to impute the value of fishing boat damage in the APEC region. It is found that for a total catch value of US$89.4 billion by APEC economies in 2006 the imputed cost of damage to vessels is US$268.2 million across the APEC region. This is an estimate made from fishery data, provided as a best available estimate of the scale of damage to fishing vessels from marine debris across the APEC region.

Table 4: The value of fish production in APEC economies in 2006 with the imputed estimate of damage from marine debris (FAO 2007; Takehama 1990).

Economy 2006	Value of fish production USD million	Imputed value of marine debris damage USD million	Economy 2006	Value of fish production USD million	Imputed value of marine debris damage USD million
Australia	1,873	5.6	New Zealand	983	2.9
Brunei Darussalam	31	0.1	Papua New Guinea	135	0.4
Canada	5,524	16.6	Peru	1,803	5.4
Chile	3,815	11.4	The Philippines	521	1.6
China	13,338	40.0	Russian Federation	3,576	10.7
China, Hong Kong	2,452	7.4	Singapore	1,153	3.5
Indonesia	2,162	6.5	Chinese Taipei	2,023	6.1
Japan	15,715	47.1	Thailand	6,818	20.5
Korea	3,817	11.5	United States of America	17,589	52.8
Malaysia	1,221	3.7	Viet Nam	3,644	10.9
Mexico	1,183	3.5	**Grand total**	**89,385**	**268.2**

The value of damage to the APEC fish sector of US$268.2 million is less than the estimate in Table 2 of US$364 million. The APEC categories are a wider interpretation than just the value of fish catch and this accounts for most of the difference.

2.2.3.2 Transportation industry

Marine debris is known to be a hazard to marine vessels in various ways. Floating containers are a navigational hazard to coastal and ocean shipping, and derelict fishing gear and ropes may represent a threat to fishing and smaller vessels. Entanglement with ropes has on occasions led to propeller damage and sinking of vessels via stern tube damage causing an influx of sea water.

The literature on vessel damage from marine debris is disparate and was examined in the hope of being able to estimate the annual damage to marine boats and ships from marine debris. It became apparent that insurance underwriters' data tend to record only 'total loss' of vessels, whereas much of the marine debris damage incurred by vessels is less severe, but nonetheless disruptive to operations and requires maintenance expenditure; for example, ingestion of plastics into engine cooling water intakes or recreational craft having propellers fouled and needing to be towed back to port or hiring a diver. The value of debris damage to shipping is reported in Table 2 and is US$279 million per annum.

In Korea, Cho (2005) identified that marine debris was involved in 9% of all Korean shipping accidents in the 1996–98 period. Of the 204 accidents, 111 were operational delay and 56 were propeller damage. The highest fatality was associated with the 110 GT Ferry M/V Soe-Hae in 1993. The vessel capsized and sank with 292 deaths. The Korean Maritime Accident Investigation Agency reported that fishing ropes around the shafts and propellers and over loading were the causes of the accident (Cho 2005).

The shipping industry is regulated by MARPOL 73/78 *International Convention for the Prevention of Pollution from Ships* (MARPOL 1973). Annex V: Prevention of Pollution by Garbage from Ships came into force in 1988 and it prohibits the discharge of all plastics into the ocean from ships. This includes items such as plastic fishing lines and nets, synthetic ropes, plastic bags, as well as items such as food waste and any floating garbage within specified distances from land (Table 5). Annex V also requires that ports and terminals provide adequate waste reception facilities. All ships over four GT are required to have a waste management strategy, including for incineration and compaction.

Table 5: Summary of MARPOL Annex V regulations regarding dumping of waste at sea.

Waste type	All ships	Offshore platforms
Plastics—includes synthetic ropes and fishing nets and plastic bags	Disposal prohibited	Disposal prohibited
Floating dunnage, lining and packing materials	>25 nm from shore	Disposal prohibited
Paper, rags, glass, metal etc. comminuted or ground	>12 nm from shore	Disposal prohibited
Food waste not comminuted or ground	>3 nm from shore	Disposal prohibited
Food waste comminuted or ground	>12 nm from shore	>12 nm from shore

The following APEC economies are not signatories of MARPOL: Hong Kong, China, Chinese Taipei and Thailand.

The costs from meeting the requirements of MARPOL have been borne by shipping companies. There is no data available on the benefits arising from these measures. Some vessels do not appear to comply and to cite a vessel for illegally discharging garbage or plastics into the seas an individual must witness the event and report, or provide sound evidence, that such a discharge occurred. Many pollution violations go unreported or are never fully pursued due to lack of evidence. This is a weakness of the regulatory approach. However Shealvy (2005b) considers that 'without a doubt, MARPOL has helped to reduce the amount of trash on the beaches and oceans of the world'.

2.2.3.3 Tourism industry

Studies in the APEC region have shown the value of the marine economy and the marine tourism sector in particular (NOEP 2005; McIlgorm 2004). Table 2 shows that 23.6% of the value of the marine economy (US$207.3 billion) is the GDP attributable to the marine tourism industry in the APEC region. It is estimated that damage by marine debris to the tourism sector in APEC is US$622 million (see Table 2).

Marine debris such as ropes, plastics and derelict fishing gear can end up on the seabed, on beaches and along the coastline. This negatively impacts the aesthetic values of the coastline and beaches for marine tourism visitors and residents. This can translate into a reduction in the amenity value of beaches for tourists and may mean that tourists will be less willing to pay to go to a tourist location.

The perceived loss of amenity can cause consumers to move to other beaches and coastal areas with a loss of expenditure to the region. The economic loss to the whole economy considers the relative change in values by consumers using a substitute beach. Marine debris is a concern for municipalities when tourists go elsewhere, manifesting as a loss in the local economy (if not the national economy).

On an international scale, tourists may chose between holiday locations in different countries on perceptions of aesthetic coastal values. An anecdotal example known to the report authors is of a tourist who did not intend to return to a holiday resort site in an APEC economy because ‘on entering the water the sea was full of marine debris’ (pers. comm. Dr Lindstrom).

The importance of tourism expenditure in many economies may provide the private sector with an incentive to contribute to keeping the beaches clean. Given the importance of marine tourism to many national economies, national governments should also see beach litter and marine debris in the sea as prejudicing their marine tourism industries.

2.2.3.4 Damage to leisure craft

Marine debris also has an impact on leisure boats, causing loss of operational time. Johnson (2000) relates one case:

> *This twin screw motor yacht caught a line during a routine trip for fuel. It wrecked propeller shafts, stern gear and flexible couplings on both engines. It was out of operation for a significant part of a busy charter season. Drifting while disabled or having to go overboard with a knife to wrestle with a rope can have tragic consequences…*

Data on the economic impacts of marine debris on small vessels in the APEC is limited. There are data on small boat safety in most APEC economies, but little economic information. There are over 13 million registered recreational vessels in the United States as reported by the US Coast guard national survey of small boat safety (SRA 2003). No data on damage was available.

We know from the previously presented data on the marine economy and marine tourism that leisure craft are part of the marine tourism category. Therefore the damage by marine debris to the leisure boat industry is some unknown fraction of the US$622 million of damage estimated earlier in the tourism sector.

2.2.3.5 Insurance industry

One aspect the current study investigated was the impact of marine debris on the insurance industry. Given the prevalence of ropes and plastics that can impede vessels' functions we approached the insurance industry for their perspective, starting with fishing vessels.

Fishing vessel insurance

Contact was made with Sunderland Mutual Marine Insurance (SMMI), one of the largest insurers of fishing vessels in the APEC region. They confirmed that fishing vessels were known to be impacted by marine debris, but the insurance claims data does not specifically identify any interaction with marine debris as the cause, with flooding or sinking being recorded. Again, claims are made by vessels that have collided with some object at sea and many times, while a floating container is suspected, the fishing vessel remains unaware of the exact nature of the item. Entanglement of vessels in ropes and fishing nets is the most frequently identified interference from marine debris. On some occasions those ropes may be those of the fisher's own vessel. Plastic bags are also cited in claims where engines have overheated due to blocked inlets (Pers. comm., Michael Gristwood, SMMI).

While marine debris is a cause of damage to fishing vessels, the insurance industry appears not to be able to estimate the extent. They indicate that marine debris contributes to many vessel claims and that the insurers regarded it as part of the risk of insuring fishing vessels.

Shipping insurance

For large ships the project made contact with the International Union of Marine Insurance (IUMI) Zurich, which underwrites US$20.3 billion of premiums annually. On asking about the impacts of marine debris on insurance claims, senior representatives indicated that:

> *... it is difficult to obtain such data. We produce statistics by claim type such as grounding, fire, engine failure etc., and to a certain degree have some information on what caused the accident, but it is not so detailed that I could tell which accidents might be due to marine debris. Neither do I know of any other source giving that type of information. The leading insurer or claims handler on an individual claim will probably have that type of information in his claim file, but I don't know of any source where this would be compiled for statistical purposes* (Astrid Seltmann and Fritz Stabinger pers. comm.).

The project also made contact with the International Underwriting Association of London (IUA) which stated:

> *Sixty per cent of marine hull cover is written in Europe and Asia and 22% in the Asia Pacific and 18% in North America. Lloyds and IUA account for 20%"* (Taylor 2007). The IUA view was that *marine debris is not seen as a significant contributor to hull losses although containers in the sea are known to cause hull damage, but not on a scale that is significant. Underwriters investigate claims thoroughly and the results tend to remain in their files unless it is extracted on a market basis because of a growing problem* (P. Taylor pers. comm.).

There was general agreement among insurers that fishing vessels are more prone to marine debris impacts than large ships. Fishing vessels are seen as an unattractive insurance risk for large shipping companies and they tend to be covered by specialist mutual insurers such as Shipowner protection and indemnity clubs (P&I clubs). Insurers of fishing vessels may be more open than insurers of larger ships to considering the impacts of marine debris on fishing vessel insurance.

2.2.4 Summary of industry impacts

In summary, the best available estimates of direct damage from marine debris are from two sources. From data on the marine economy, the damage from marine debris on the fishing, shipping and marine tourism sectors has a damage value of US$1.265 billion per annum in the APEC region. The marine debris damage is estimated as US$364 million to the fishing industry, US$279 million to shipping and US$622 million to marine tourism. Using APEC fishing catch values data, an estimate of damage of US$268.2 million was made for the fishing industry.

We would consider the estimates to be reconcilable, the gap being represented by the marine economy estimate including marine tourism, usually a larger segment of the marine economy than shipping, and also small vessel activity. As a scoping figure estimated on best available information, the total direct damage from marine debris to industries in the APEC region is US$1.265 billion per annum in the APEC region. As previously discussed this does not include indirect costs and impacts on non-market values.

2.3 Conclusions and recommendations

The study found there are a range of direct, indirect and non-market economic impacts of marine debris on government, communities and the fishing, transportation, tourism and insurance industries. From the information supplied, six case studies in APEC economies were prepared.

Economic data on the damage caused by marine debris needs to be collected by industry and government so as to help control the impacts of marine debris. At the coastal level all across the APEC region, municipal authorities and harbours spend funds cleaning up debris. This sum needs to be determined, so as to make clear how much marine debris clean up costs society. The effectiveness of expenditure can then be increased through larger scale cooperative national or regional initiatives.

The total APEC GDP in December 2008 was US$29 329 billion at current prices (DFAT 2008). The value of the APEC marine economy, as reported in a previous APEC Marine Resource Conservation (MRC) study, is approximately 3% of total GDP, a sum of US$879 billion at 2008 price levels. Within this, the total APEC GDP for the fishing, shipping and marine tourism sectors is estimated at 48% of the marine economy, US$421.9 billion. It is this US$421.9 billion of GDP generated by marine industries that is vulnerable to being impacted by poor control of marine debris in the APEC region.

From data on the marine economy and debris damage estimates from Japan, the damage from marine debris on the fishing, shipping, and marine tourism sectors is estimated to have a damage value of US$1.265 billion in the APEC region. The marine debris damage is estimated as US$364 million to the fishing industry, US$279 million to shipping and US$622 million to marine tourism. Japanese fishing studies indicate that, within the shipping industry, marine debris has a greater impact on small vessels than on large ones.

Using a different data set of fishing catch values in the APEC region, an estimate of damage of US$268.2 million was made for the fishing industry. This supports the previous estimates made from aggregate marine economy data.

The study makes the following recommendations on targeted application of economic measures to address marine debris by APEC economies:

- **Recommendation 1:** APEC economies prioritise the inclusion of measures to prevent debris from land-based sources entering the sea in new and amended marine and coastal sectoral and integrated policies and management plans. This action would require joint action between marine agencies and municipal and government authorities in charge of land waste to work together on reducing land debris and hence marine debris.

- **Recommendation 2:** APEC economies establish and implement an information system and guidelines for monitoring the national cost of cleaning up marine debris involving data from national, state and municipal government levels. Industry could also contribute information to this system, including data on the costs of damage from marine debris. This information would enable a more effective allocation of resources to be made nationally on debris issues.

- **Recommendation 3:** Industries within the APEC economies should consider the use of paper and biodegradable packaging materials in place of plastic materials to reduce the load of debris entering the marine environment.

♦ PART 3. An economic-based model to estimate the costs and benefits of controlling marine debris for communities, governments and industries in the APEC region

Using available data, develop an economic-based model to estimate the costs and benefits of controlling marine debris for communities, governments and selected industries (fisheries, shipping and transport, tourism, insurance) in the APEC region.

3.1 Method

In this section, two economic modelling approaches to analysing the economic benefits and costs of controlling marine debris are used. Both approaches use the conceptual model of the debris cycle in Figure 1, to illustrate the costs and benefits of intervention at alternative points of the debris cycle.

The first approach compares the marginal costs and marginal benefits from altering the level of prevention and clean up considering the stock levels of debris. This approach has not previously been applied to the understanding of marine debris. The second approach uses benefit-cost analysis to compare the net benefits of different options for controlling marine debris.

3.2 Results

3.2.1 The costs of control

The total annual costs of prevention or clean up of marine debris increase with the amount of prevention or clean up activity being undertaken. The cost of a sustained reduction in the stock of debris by one unit, either through a sustained program of prevention, or of clean up activity, is referred to as the marginal cost[9] (MC).

The marginal cost of prevention or clean up increases with the level of activity. As more and more debris is prevented from joining the stock, the cost of preventing the addition of another unit of debris to the stock rises; and as the stock of debris declines, and debris becomes more inaccessible or harder to locate, the cost of cleaning up an extra unit of debris also rises.

A cost effective program of reducing the stock of marine debris would strike a balance between the levels of prevention and clean up activities which equated their marginal costs. Such a balance would ensure that an extra dollar of program expenditure would have the same impact on the stock of debris irrespective of whether the dollar was allocated to prevention or to clean up activity.

In these circumstances the marginal cost of debris stock reduction can be referred to without specifying the method of stock reduction employed. Figure 3 indicates the expected relationship between the marginal cost of stock reduction and the stock of debris. It indicates that the marginal cost of stock reduction is lower in the presence of a large marine debris stock. As the stock of marine debris reduces, the cost of further reductions through increased levels of prevention and clean up is likely to rise. It is also worth noting that because marine

[9] The additional cost of prevention or clean up of one additional tonne of debris.

debris is diverse in nature, these conceptualised relationships will vary with different debris types. For example the marginal cost per tonne of retrieving deep sea derelict fishing gear would be represented by a higher schedule than for the marginal cost of cleaning coastal marine debris.

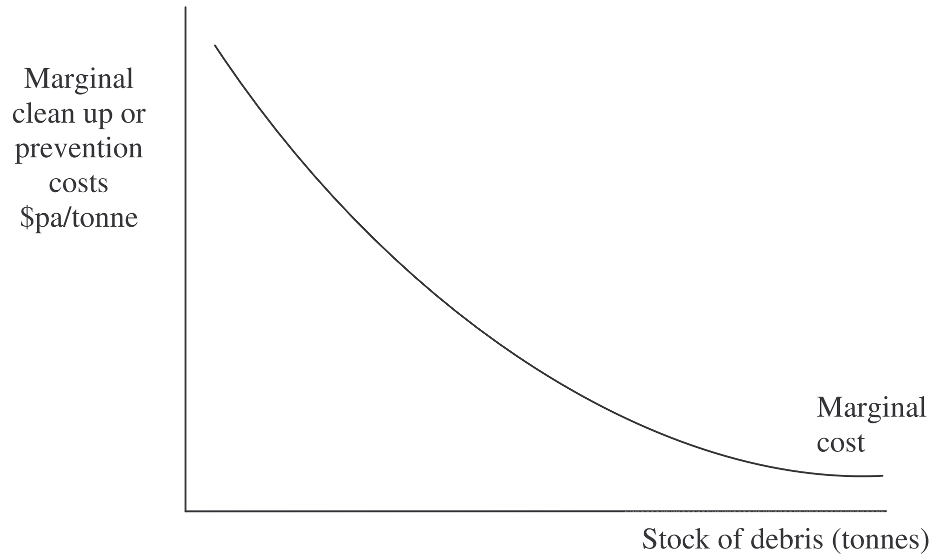

Figure 3: The marginal cost of prevention and clean up.

What level of stock of marine debris is efficient from an economic point of view? The relationship between marginal cost and the level of the stock suggests that preventing or removing marine debris so as to reduce the stock level towards zero would involve successively higher marginal costs. Totally clean seas would cost a great deal to achieve, and annual expenditure to this end would need to be balanced against the annual benefits from maintaining a lower stock of debris.

3.2.1.1 The benefits of controlling marine debris

The benefits of controlling marine debris are measured as the reduction in the annual damage costs attributable to the stock of marine debris. This is due to the avoided cost nature of marine debris.

The relationship between the total annual damage cost and the size of the stock of marine debris is illustrated in Figure 4, and the marginal damage cost is illustrated in Figure 5. Figure 4 shows that the total annual cost of damage is highest when the stock of marine debris is high. However, the total damage cost function is rising at an increasing rate. At stock level 'X', the marginal damage cost (MDC) is the change in the total damage cost as a result of one extra unit of debris being added to the stock. Figure 5 illustrates the marginal cost of damage as a function of debris stock size. This figure indicates that, as the stock of marine debris increases, the annual damage cost imposed by each unit of debris added to the stock becomes steadily higher.

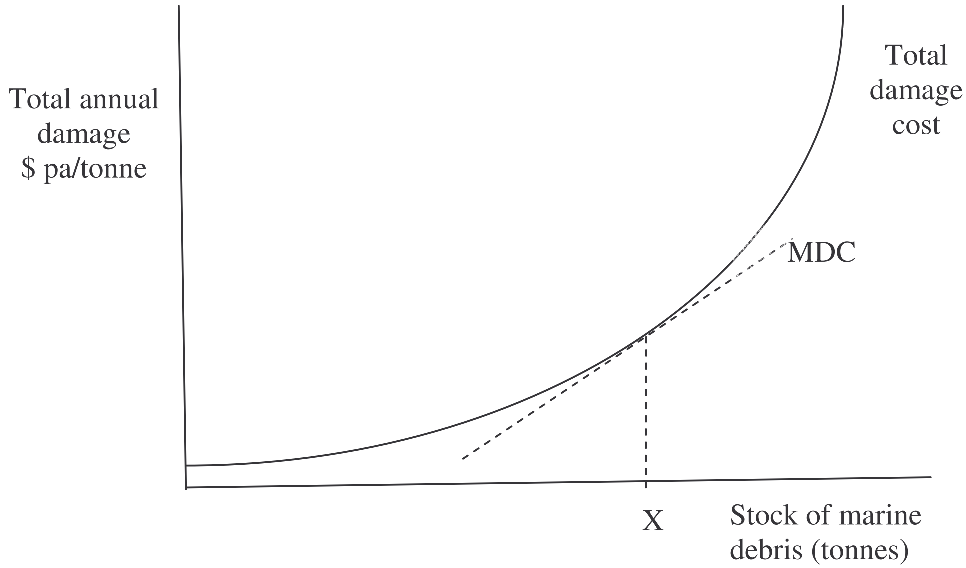

Figure 4: The annual total damage cost caused by the stock of marine debris.

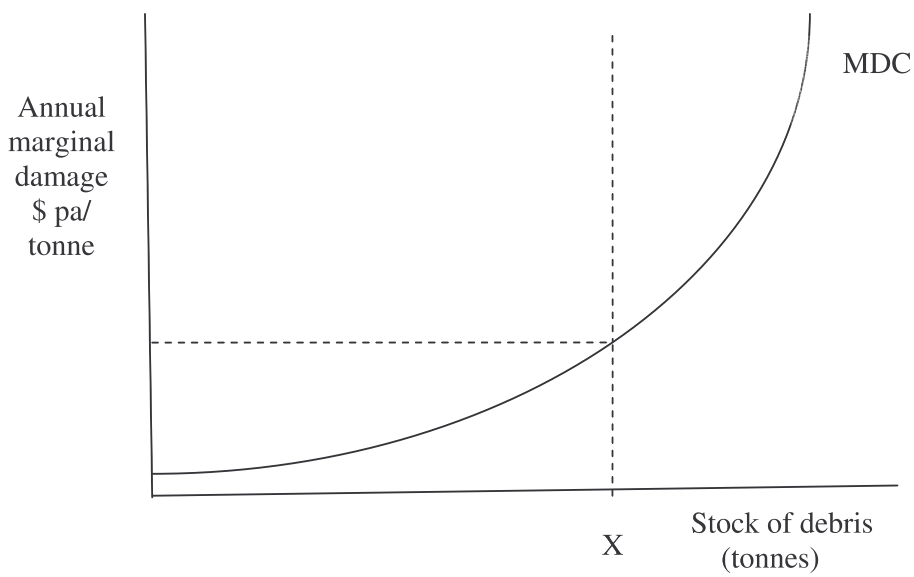

Figure 5: Annual marginal damage cost of marine debris.

3.2.1.2 The optimal volume of marine debris

The two relationships (annual marginal cost of prevention/clean up and annual marginal damage) previously identified, are the two key control and economic decision making relationships for policy makers. In Figure 5 marginal damage rises as the stock of debris increases. Since the marginal benefit of prevention/clean up is the avoided marginal damage cost, the marginal benefit of prevention/clean up falls as the stock of marine debris falls. Figure 6 combines the marginal benefit and marginal cost functions and indicates the optimal sustained level of marine debris at stock level 'Q*'.

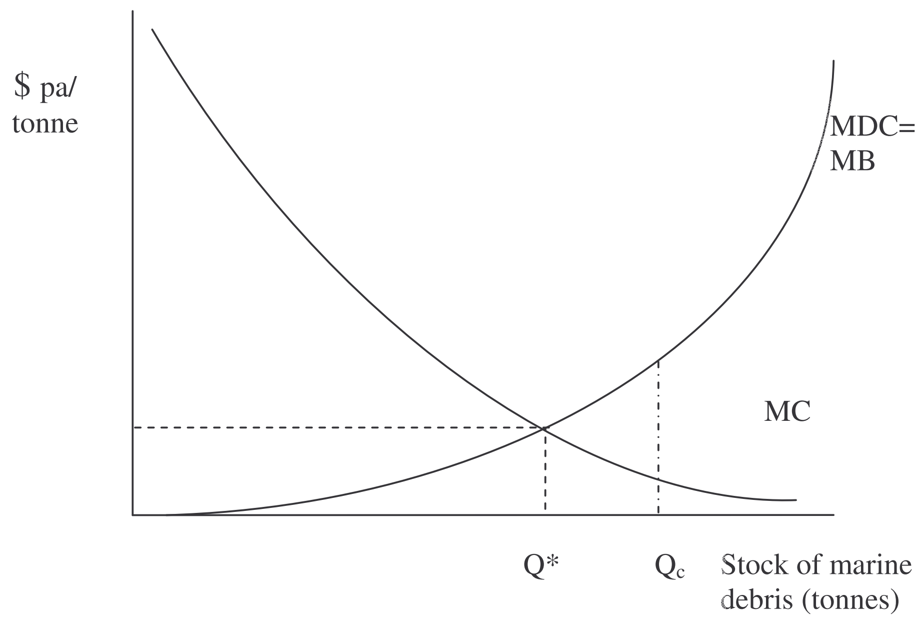

Figure 6: Optimal stock of marine debris showing marginal cost (MC) and marginal benefit (MB).

It would not pay to reduce the marine debris stock below this level because the extra annual cost of the prevention/clean up measures required to reduce the stock by an extra unit would be higher than the additional annual benefit (avoided damage cost) generated by the additional debris control measures.

It is likely that ‘Q_c’ illustrates the initial level of the marine debris stock (relative to the optimal level) in the APEC region. Here, at ‘Q_c’, the annual marginal cost of clean up/prevention required to reduce the stock of debris by one unit is less than the annual marginal benefit of the reduction in the debris stock (the extra damage prevented). The stock of debris should be reduced to ‘Q*’, at which level marginal benefit equals marginal cost of prevention/clean-up.

To the left of ‘Q*’ in Figure 6, the marginal clean up or prevention costs exceed the marginal damage cost and a larger marine debris stock is economically efficient under this framework. The model is indicating that, given the costs and benefits described, it is unlikely that zero marine debris will ever be an efficient objective from an economic viewpoint. However, containing the marine debris stock at an optimal level is a realistic goal which efficiently uses resources. Without highly detailed modelling, we are unable to specify the optimum marine debris stock level. However, a simple example to illustrate the issue is given in relation to Figure 7.

Figure 7: An ecotourism vessel in Nha Trang Harbour, Viet Nam (Photograph: A. McIlgorm) .

The photograph in Figure 7 shows up to seven pieces of marine debris of different sizes. Is this more or less than the economic optimum? Taking some pieces away would involve general debris clean up of the harbour with a marginal cost, but there would also be a marginal benefit by reducing the level of debris and therefore, damage. In practice the marginal damage is measured approximately ‘by eye’ (see the Hong Kong case study at Appendix 4). A proposal to clean all the debris in the harbour would have a high marginal cost and may exceed the marginal benefit. It is likely that the optimum economic level of marine debris would leave some debris, given the high marginal cost of cleaning the last unit of debris. This is one reason we should not put debris into pristine marine areas. There will be a very high cost to remediate the environment back to a pristine standard. The economically optimal standard will have some debris.

3.2.1.3 Economic decisions and the control of marine debris

Often the economics of marine debris control is over simplified to an assessment of finding the lowest clean up cost per tonne. The economic decision to intervene with clean up action is often made from necessity with little consideration of alternatives.

In the longer term it is desirable to compare the benefits from spending additional funds on prevention. This will take cooperation on a wider area or national scale. The stock flow approach indicates that when the total stock of marine debris is low, then a local approach may be adequate, but this will become more expensive and more inefficient as global debris stock grows. For example in Hawaii,

> *... in 2006, the project transitioned from a large-scale clean up aimed at removing historical accumulations of debris to a maintenance mode effort aimed at keeping pace with annual accumulations. We have since learned that our maintenance mode effort is not keeping up with annual accumulation (estimated at 52 metric tons per year), and that remains a gap* (Seema Balwani, NOAA).

The two control variables for economists and policy makers to use in reducing the stock of marine debris are ***prevention*** and ***clean up***. Two principles are recommended:

1. in any control program the marginal costs and marginal benefits of spending resources on prevention and clean up, should be compared, and

2. annual clean-up and prevention activities should be carried to the point at which their marginal costs are equalised.

For example, suppose a small coastal local authority has to find an additional $10,000 per annum to be spent on marine debris stock reduction. The short-term response is to spend the funds on clean up. This cannot continue each year and links with national debris prevention initiatives need to be made. A strategy of contributing additional funds with many other local authorities to increase debris prevention in an adjacent polluting city estuary, may reduce the marine debris load coming down the coast giving several communities additional clean up costs. The example suggests that at times one marginal dollar spent on debris prevention on the land/sea may yield marginal savings of greater than one dollar when clean up costs are considered. This would represent an economy that could be gained by greater prevention. The link between sources and deposits of marine debris is important in assessing the economics of alternative interventions.

3.2.1.4 Economic costs and benefits and the control of marine debris

The cost of cleaning up marine debris is important in developing economic strategies for controlling marine debris. Marine debris is not a uniform waste product and the cost of clean up varies with the type of debris, the location and the methods used. Clean up costs are expressed in dollars per cubic metre, dollars per kilometre of coast or beach, or preferably dollars per tonne. In this section we wish to derive an average clean-up cost per tonne for use in generating APEC economy estimates.

Clean up cost data estimates in the APEC region range from $100/tonne under volunteer labour (Hwang and Ko 2007) to $25,000/tonne for derelict fishing gear (Raaymakers 2007). Cho (2005) and (Hwang and Ko 2007) report an average clean-up cost of US$1,300 per tonne over a six-year period. These values are confirmed by data from outside the APEC region.

Outside of the APEC region, Kalaydjian *et al*. (2006) report 11 sites along the French coast as having between 400 kg and 4.0 tonnes of debris per kilometre of shoreline, the highest density being in the Mediterranean. The cost of mechanical cleaning up was estimated at €4000 per kilometre or €1000–10,000 per tonne in 2003 (US$1,140–$11,400). Manual collection is twice the cost of mechanical clean up (Kalaydjian *et al*. 2006).

From available cost information, the average cost of clean up in the APEC region for typical shoreline clean up is approximately US$1,500 per tonne in 2007 terms. This is likely an under-estimate for urbanised areas in developed countries and an over-estimate for less developed countries.

3.2.2 Benefit-cost analysis

Benefit-cost analysis is a technique for undertaking an economic appraisal of a proposed project or program. Any expenditures on scarce resources, whether of a capital or recurring nature, involve an opportunity cost—the value of the goods and services which the scarce resources could have produced in alternative uses. The benefit-cost analysis compares the value of the output of the project with the value of output which the resources involved could have produced in their alternative uses. Benefit-cost analysis relates to economic and environmental impacts analyses.

First, an economic impact analysis measures the effects of undertaking a project on GDP or gross regional product (GRP). All expenditures have an impact on economic activity (GDP or GRP) through the market system and the associated multiplier effect, but these expenditures should not be confused with net benefits.

An example presented by Kirkley and McConnell (1997) illustrates this point. Suppose that beach 'A', which involves $50 in travel cost per visit, is closed because of marine debris; consumers now switch to visiting beach 'B' which offers identical recreational benefits, although it is further from the city and involves a $55 travel cost. The cost of the marine debris is the extra $5 per beach visit, whereas the economic impact may well be zero: the original $50 travel expenditures—on fuel, food, accommodation—continue and the extra $5 expenditure is diverted from some other part of consumers' budgets.

An environmental impact statement is a detailed analysis of the physical effects of the proposed project or program. Examples of these effects include changes in pollution levels, habitat extent, and wildlife populations, expressed in physical units such as percentage of dissolved oxygen, hectares, or biomass. While measured in physical units, these changes affect economic welfare and should be included in the benefit-cost appraisal in terms of dollar costs or benefits, an issue which will be discussed further.

3.2.2.1 Benefit-cost analysis and marine debris

An economic appraisal reveals whether the value of the benefits of a proposed project or program exceeds the opportunity cost. In other words, it indicates whether allocating resources to the project generates more value, in terms of the project output, than the value the additional goods and services the resources would have produced in their alternative uses. The appraisal can also contribute to the design of the proposed project; to maximise the net value of the project or program its various elements should be extended to the point at which marginal benefit equals marginal cost, but not beyond that. This point has already been illustrated by Figure 6.

In calculating the MC and MB for comparison, the inclusion of non-market and other values in the analysis must be addressed. A pragmatic approach in a world where little such comparison is undertaken is to start with market costs and see where the optimum level is. The inclusion of more non-market values will increase the marginal benefit and give an analysis with a lower target debris stock level.

A benefit-cost analysis of a program of reducing marine debris starts by identifying the benefits and costs. The benefits consist of 'avoided costs'—the reduction in costs imposed by marine debris which will occur as a result of the reduction in the volume of marine debris achieved by the program. Such cost reductions include lower costs to shipping, fisheries, and recreationists (such as preventing the extra $5 travel cost identified in the beach example described above) as well as more general environmental costs associated with damage to coastal ecosystems.

Some of the costs of prevention or removal of marine debris can be measured by market prices. For example, an expansion of refuse collection and storage facilities may involve improved stormwater disposal systems, more landfill sites, and storage facilities on vessels and at docks, while removal of debris will involve labour and equipment. These costs of the program, consisting of the opportunity costs of the scarce resources involved, are generally measured by the market value of the resources allocated to the program. In some situations resources may be over-priced (eg, otherwise unemployed labour) or under-priced (eg, carbon-emitting fuels) by the market, and will need to be shadow-priced in the program appraisal.

Other costs are not directly measured by the market although market prices may allow an indirect measure to be generated. Less readily measured by market prices are the adjustment costs faced by consumers when, for example, they substitute reusable bags for plastic grocery bags.

Having identified the types of benefits and costs involved, a benefit-cost analysis of a program of marine debris removal would proceed to value these in dollar terms. Some outputs or inputs would be valued at market prices, some would be valued at market prices adjusted for those imperfections which drive a wedge between market price and marginal benefit or marginal cost, and some would be valued using non-market valuation techniques based on revealed or stated preference approaches.

The summary measure of the performance of the program is the present value of the net benefit stream, where net benefits are expressed in dollars, but measured in the ways described above. If the net present value is positive, adopting the program will increase economic welfare, in the sense that the gains associated with the program exceed the losses that would be imposed. In principle the gainers could compensate the losers and still remain better off. This criterion of welfare gain is known as the Kaldor-Hicks criterion and it is the basis of recommendations based on program appraisal by means of benefit-cost analysis.

3.2.2.2 A hypothetical example of distributional issues impacting on marine debris mitigation

A conceptualised model of marine debris circulation among three economies, A, B and C, is shown in Figure 8. The ocean circulation distributes the stock of marine debris among the three economies as well as in the high seas. It is often assumed in policy that each economy will compare its costs and benefits independent of other economies, which may be true in a case where there is little ocean water movement as any interactions are reciprocal. In Figure 8 the prevailing tides and currents means the amount of marine debris deposited in each economy is different, as indicated by the shaded area on each island economy.

In Figure 8 the prevailing ocean circulation leads to less marine debris being deposited on the shores of economies A and C, and more in economy B. This represents a net transfer of marine debris from economies C and A, to B. Given that the deposited debris comes via the stock in the ocean which is in common, unequal deposits from the common stock can cause potential inequity issues between economies, and can lead to slower and more costly policy development.

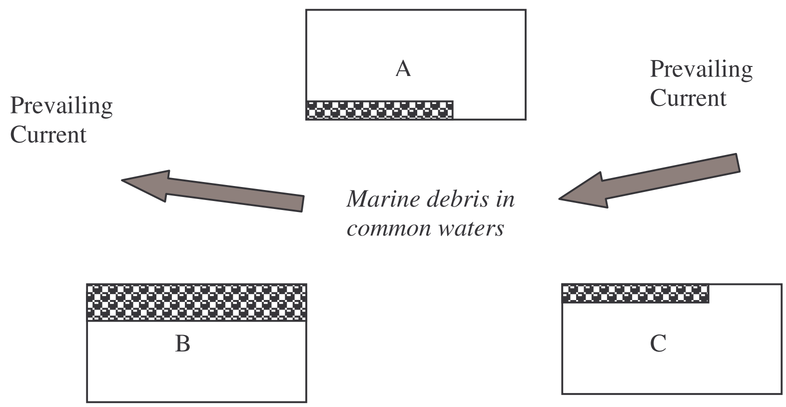

Figure 8: Marine debris held in common waters between three adjacent marine island economies with prevailing ocean circulation (shaded arrows) which impacts the level of marine debris deposited from the ocean (shaded areas) in each economy. The shaded rectangle in each island economy represents the level of debris experienced by each economy.

If economies A, B and C each engage in debris control measures, with their associated costs, they will each benefit in the form of reduced damage costs. However, because of the prevailing ocean currents, the benefits may not be in proportion to the costs incurred. For example, the following table of hypothetical data shows the distribution of benefits (reduced damage costs) and costs (control costs) of a proposed marine debris reduction program involving the three economies.

Table 6: Distribution of benefits and costs of marine debris control.

Economy	Control costs	Reduced damage costs (benefits)	Benefits net of costs
A	300 (0)	250 (10)	-50 (+10)
B	200 (200)	260 (210)	+60 (+10)
C	150 (150)	160 (140)	+10 (-10)
Total	650 (350)	670 (360)	+20 (+10)

It can be seen from the values (unbracketed) in Table 6 that it is not in economy A's interests to participate because the benefits it receives are lower than the costs it incurs. If A does not participate, but economies B and C were to go ahead with their own debris control measures, the total benefits and costs of the amended program would be lower and might be distributed as shown by the values reported in brackets in the table. Now it can be seen from the bracketed values that it is not in economy C's interests to participate. If economy C drops out of the program there will be a further reduction in benefits to economy B which may lead to economy B dropping out as well. As a result, a series of measures which are to the general good of the three economies are not undertaken because of self-interest and the distribution of program benefits and costs. Self-interest can be expected to endure, but the distribution of benefits and costs can be altered by a cooperative program involving inter-economy transfers so that it is in all economies' interests to participate. This example underlines the importance of estimating and reporting the distribution of benefits and costs among participants when evaluating a proposed marine debris control program.

The practical implications of this example are that cost-sharing agreements between economies to reduce marine debris levels will require significant negotiation where tidal patterns and water movements are complex. The hypothetical data in Table 6 also shows that in some circumstances it may seem irrational to work together. These difficulties in allocating clean up costs between economies reinforce the view that each economy should reduce their marine debris at source by national prevention programs.

3.3 Conclusions and recommendations

Two economic models were used referencing the conceptual model of the debris cycle in Figure 1. The first approach compares the marginal costs and marginal benefits from altering the level of prevention and clean up, considering the stock levels of debris. The second approach uses the benefit-cost analysis to compare the net benefits of different options to control marine debris.

In the first model the stock-flow lifecycle is used to analyse the marginal costs and marginal benefits of the debris control problem. Two principles for debris control are proposed: *In any control program the marginal costs and marginal benefits of spending resources on prevention and clean up should be compared (this prevents wasting resources); and the annual clean-up and prevention activities should be carried out to the point at which their marginal costs are equalised.*

Generally, as an avoidable cost, the cost of marine debris clean up is greater than the cost of prevention. Debris entering the sea can be limited by technical boom devices across rivers and estuaries. The collation of information about the costs and benefits of such devices is prioritised. The model assumes all debris has a similar rate of decomposition. Replacing plastics with paper will reduce the marginal damage cost and reduce the amount of residual marine debris.

The second approach is cost-benefit analysis. Actual clean-up costs were obtained, though the costs of prevention are less available, possibly residing in land-based government or waste management agencies. For a given project program the net benefits are appraised. The study contacted APEC economies for examples of the costs and benefits in marine debris control policy and these six case studies are presented in Appendix 3. These case studies showed signs of innovation, in the face of increasing marine debris and derelict fishing gear issues, but there is usually only a minimal amount of economic data available for use in the control process.

To illustrate how benefit-cost analysis can assist marine debris clean up operations in waters held jointly by three states, a hypothetical case is shown that illustrates that while cost sharing of clean-up operations is advocated for potential cost savings, its effectiveness may be reduced by different incentives accruing to each of the participating economies.

- **Recommendation 4:** Information on the impacts of marine debris on the non-market values of the marine environment is limited and requires site-specific studies in APEC economies.

- **Recommendation 5:** APEC economies should attempt to record weight or volume units of measurement from any marine debris prevention and clean up cost data to calculate the cost per tonne, or cost per cubic metres m^3.

- **Recommendation 6:** APEC economies should introduce arrangements for return of debris and fishing gear into harbour waste reception facilities at ports, including low cost recycling arrangements or disposal for old fishing nets and fishing gear.

- **Recommendation 7:** MRCWG should liaise with appropriate representatives from the insurance industry to encourage them to collect data on accidents and incidents caused by marine debris.

PART 4. Identify economic incentives and other measures that are targeted at policy makers to prevent or mitigate the impacts of marine debris

Identify economic incentives and other measures (where appropriate) that are targeted at policy makers, managers and/or-marine based industries within the APEC region to:

a. *limit or prevent the incidence of marine debris, and*

b. *direct available resources to effective mitigation of the impacts of marine debris.*

4.1 Methods

Marine debris has normally been controlled by regulations. Alternative control measures for controlling marine debris were sought. Each economy was contacted regarding their experience in regulating marine debris and alternative approaches. Case studies which involved the measurement of the costs and benefits of controlling marine debris were requested from APEC member economies.

Use of economic incentives in controlling marine debris is a new development. The natural resource and other literature was investigated to identify different economic instruments and how these could apply in controlling marine debris.

4.2 Results

The economic incentives to control marine debris come from the fact that debris is avoidable, and therefore damage and clean up costs can be reduced. Stopping debris entering the marine environment has a double cost saving. Economic instruments can be part of the measures to control marine debris, being potentially most effective in addressing prevention of debris. Much of this marine impacting activity requires policy changes on land.

4.2.1 Economic responses to marine debris impacts

There are different approaches to controlling environmental issues. These involve regulation (authority), market instruments (exchange), community (persuasion) (Stavins 2003; Martin 2006), management measures, and imposition of technical and operational procedures.

4.2.1.1 Regulation and marine debris

Regulation has been the favoured approach of governments in reducing marine litter due to the public good and common property nature of the debris in the sea. In the last two decades market instruments have been introduced to environment and resource management planning, problems and policy responses (Martin 2006). Some market instruments have been used in controlling marine debris, although there is limited literature on this method. The community has been encouraged to be involved in public beach clean-ups by NGOs. The literature suggests that in addition to a core of regulation, there is a range of diverse policy tools that can assist the control of marine debris as reported in Table 7. Few of these have had explicit economic content and are presented to give context to the use of market-based instruments.

A step-wise policy development process is recommended by Hoagland and Kite Powell (1997):

1. disposal standards (prohibitions on littering)
2. provision of disposal facilities
3. tax/subsidy programs
4. moral persuasion
5. education programs
6. beach clean ups, and
7. research.

The need is also to prevent and minimise marine debris creation.

4.2.1.2 Economic instruments

Using economic instruments to control marine debris has received relatively little attention, possibly due to the avoidable cost nature of the issue which may lend itself to regulation, rather than the remedial use of economic instruments. In many areas of policy, market-based instruments (MBIs) are developed to use the market mechanism to create incentives and disincentives to bring about more positive environmental outcomes. ‘MBIs allow any level of pollution clean up to be realised at the lowest overall cost to society’ (Stavins 2003).

‘Most applications of MBIs have been at the input or emission point of regulatory intervention, although few have focussed on ambient concentrations’ (Stavins 2003). Wide-based source pollutants are more difficult to address due to the disconnect between the pollutant and the source or sources. Marine debris is impacted by this non-point-source issue.

MBIs can be categorised as charge systems, tradable permits, market friction reductions and government subsidy reductions (Stavins 2003). Different types of MBIs used in general environmental policy are shown in Table 8.

Table 7: Summary of the types of debris from each of the major land- and ocean-based sources, and options for control (references as stated).

Source of debris	Types of debris	Control mechanism	Source
Discharges of stormwater	General litter, paper, plastics, construction material, woody debris	Litter traps to prevent litter entry at outfalls or use floating fences	(McKay and Marshall 1993; Cho 2005)
		Waste facilities (including facilities for the collection of recyclable material) on streets and beaches	(McKay and Marshall 1993; Topping 2000; Gordon 2006)
		Education	(Gordon 2006)
Municipal landfills	General litter, paper, plastics	Better designed land-fills	(Topping 2000)
		Update regulations for land-fills to include controls to minimise debris release	(Gordon 2006)
		Address littering caused during transport of litter	(Gordon 2006)
Industrial activities	Resin pellets, oil drums	Reduce discharges of raw materials through increased enforcement of stormwater regulations	(Gordon 2006)
		Encourage the substitution of packaging materials	(Slater 1994; Gordon 2006)
		Encourage commercial waste audits to reduce waste	(Topping 2000)
Coastal tourism	General litter, food waste, food packaging, cigarette butts, plastic toys	Beach/reef clean up	(Topping 2000; Sheavly 2007)
		Provision of waste facilities (eg, bins on public beaches)	(McKay and Marshall 1993; Hall 2000; Topping 2000; Gordon 2006)
		Install litter traps on waterways known to contribute to beach debris	(McKay and Marshall 1993)
		Education and tourist information notices	(Hall 2000; Gordon 2006)
		Local authorities define litter management standards for beaches	(Hall 2000)
		Increase enforcement of anti-littering laws	(Gordon 2006)

Commercial fishing vessels	Derelict fishing gear (nets, lines etc), floats, buoys, general litter, buckets, rope,	Education	(Kiessling 2003; Allsopp *et al*. 2006)
		Law enforcement	(Allsopp *et al*. 2006)
		Biodegradable gear (eg, pots with sections that will break down, plastic-free bait boxes)	(Slater 1994)
		Incorporate debris management requirements into fisheries management plans	(Kiessling 2003)
		Ensure adequate waste reception facilities in ports and marinas	(Recht and Lasseigne 1989; Gordon 2006)
		Retrieval of gear at sea (as clean up)	(Cho 2005)
		Provide incentives to fishermen to retrieve gear or return damaged gear to port	(Kiessling 2003; Cho 2005; Raaymakers 2007)
		Mandatory reporting/logging of lost gear	(Kiessling 2003; Brown and Macfadyen 2007)
		Mandatory tagging or coding of gear to allow identification of source	(Kiessling 2003)
		Attachment of tracking devices to gear	(Brown and Macfadyen 2007)
		Recycling of nets	(Recht and Lasseigne 1989)
Merchant shipping, ferries & cruise liners	General litter, food waste	Ensure adequate waste reception facilities in ports	(ANZECC 2003; Gordon 2006)
Recreational boating	Fishing debris (nets, line, lead etc.) General litter	Ensure adequate waste reception and recycling facilities in areas used by recreational boaters	(Gordon 2006)
		Introduce waste minimisation strategies into boating curriculum	(Gordon 2006)

Table 8: Different types of market-based instruments (Stavins 2003; Department of Agriculture, Fisheries and Forestry (DAFF) 2008).

Category and instrument	Brief explanation of general principle
Charge systems	**Assign a price to desired environmental outcomes**
Effluent charges	Payment of fees to pollute
Deposits-refund systems	Repay a deposit for items returned
User and administrative charges	Product disposal and municipal costs
Auction or tender	Of a right to create pollution
Tax incentives/differentiation	Tax rebates for collection or waste prevention
Sales taxes	To restrict use of inputs and generate revenue
Insurance premium taxes	Oil tankers asked to take additional insurance
Tradable permit system	**Deciding on a quantity limit**
Create a right	A right for trading a pollution quantity
Cap and trade	A limit on pollution forcing trade
Credit programs	Use of environmental credits
Offsets	Alternative areas used to meet quota obligations
Reduce market friction	**Improve how markets function**
Market creation /conservation agreements	Creation of voluntary exchange systems to reduce pollution
Levering private investment	May be elements with private sector benefits
Liability rules and risk	Firms consider the damage from their actions
Product differentiation	Market premium for eco-labelled products?
Revolving funds	Buying capital areas to protect
Government subsidies	**May be used to address environmental problems**
Reducing government subsidies	Can be reduced to provide an efficiency gain

There are a range of economic instruments that have not generally been applied to marine debris policy. Their use to control marine debris will be examined later in the report.

4.2.1.3 Community

The community role in marine debris policy comes from the widespread impact of debris once it enters the sea, eventually falling on many coastlines and beaches. While regional municipal government often have responsibility for coastal clean up, the available resources leave ambient levels of debris that over time have attracted the attention of community groups. The collective action of community groups including non-government organisations is a feature of the APEC countries being assisted by many international initiatives.

Programs established by the Ocean Conservancy such as International Coastal Cleanup (ICC) (www.coastalcleanup.org) involved 100 countries and 5.9 million participants in 2004. With the beach clean up also came data recording via an international data card for recording debris. Other special days such as World Environment day and Clean Up the World day (www.cleanuptheworld.org) also led to beach clean ups by the community. Table 9a shows the effort of communities in the ICC day 2007 in 19 APEC economies.

Table 9a: The participation and quantity of rubbish removed and area cleaned, on land and underwater, in the ICC day 2007 (Source: ICC 2007).

APEC Economy*	Land			Underwater			Total		
	People	Kgs	Kms	People	Kgs	Kms	People	Kgs	Kms
Australia	190	1,922	2,186	260	579	161	450	2,501	2,347
Canada	28,708	100,173	5,058	429	6,125	33	29,137	106,298	5,091
China	232	432	23		-	-	232	432	23
Hong Kong, China	396	495	1	58	175	56	454	670	57
Indonesia	179	796	14	117	552	23	296	1,348	37
Japan	15,930	34,056	46	520	3,219	2	16,450	37,275	48
Korea, Republic of	4,361	107,301	27	311	6,556	1	4,672	113,857	28
Malaysia	710	1,678	1,701	289	1,404	17	999	3,082	1,718
Mexico	7,842	76,773	1,805	168	5,752	45	8,010	82,525	1,850
New Zealand	35	426	3	55	178	43	90	604	47
Peru	2,500	4,659	4	2,500	4,659	4	5,000	9,318	8
Philippines	50,526	114,079	350	721	3,182	51	51,247	117,261	400
Russia	32	45	0	32	45	0	64	89	1
Singapore	3,032	10,132	27	50	27	5	3,082	10,159	32
Chinese Taipei	193	1,281	732	98	810	91	291	2,092	823
Thailand	3,186	7,184	2,297	319	3,322	126	3,505	10,506	2,422
United States	187,454	1,772,513	15,712	2,742	22,751	559	190,196	1,795,264	16,271
Vietnam	16	22	11	16	22	11	32	44	23
Totals	**305,522**	**2,233,968**	**29,998**	**8,685**	**59,358**	**1,228**	**314,207**	**2,293,326**	**31,226**

* No entry for Brunei Darussalam, Chile, Papua New Guinea

The contribution of NGOs is clearly seen in each of the APEC economies. This can be valued on the basis of the imputed value of a volunteer day multiplied by a shadow price for a day's volunteer's labour. For example, for the 314 207 persons volunteering one day this has a value of US$15.71 million @ US$50 per day, a value of US$31.42million @ US$100 per day, and a value of US$47.13 million @ US$150 per day as reported in Table 9b. Given there was 2284 tonnes of debris collected, this had an average clean-up value per tonne of between US$6879 and US$20 636 per tonne, depending on assumptions.

Table 9b: The value of total volunteer days and the average cost of clean up per tonne at three shadow labour rates using the ICC day 2007 data in the APEC region (ICC 2007).

Category	Labour value 1	Labour value 2	Labour value 3
Persons/Volunteer days	314,207	314,207	314,207
Inputed $ per day of labour	$ 50	$ 100	$ 150
Total value of labour	15,710,350	31,420,700	47,131,050
Tonnes of debris collected	2,284	2,284	2,284
Average cost per tonne	$ 6,879	$ 13,758	$ 20,636

The commitment of many people in cleaning debris from beaches on a volunteer basis is a significant contribution to the removal and containment of marine debris. The cost of collection by NGO volunteers has a monetary value, even though zero rated by the volunteers. It is important that data is collected on volunteers and time used in clean up, so that this policy alternative is properly costed by policy makers. In the APEC region, as Table 9b indicates, on International Coastal Cleanup day the shadow value of labour was likely US$31.42 million. This is a large contribution to the region's clean-up expenses.

The community also produces some alternative approaches to marine debris control. Topping (2000) suggests from the Canadian experience that,

> *The majority of marine debris is released as a result of human behaviour—such as littering or dumping—behaviour which has been historically accepted in many communities. Community-based initiatives are often the most effective means to address environmental issues, including marine debris, but require support to build and maintain networks and have access to sound science. It requires a set of strategies for behavioural change.*

Other community policy alternatives call on moral suasion and designing policies that reduce the cost of 'doing the right thing'. For example, garbage pick up facilities can be designed and located in a way that increases the amount of garbage collected.

Some of the Asian experience points to a need for increased community understanding and awareness of marine debris issues (Ohkura and Kojima 2006). Education is also a significant way to improve behaviour in the long term and Japanese schools have involvement in programs. Japanese and Korean experience points to prompt information sharing on marine debris which can make government and non-government clean up response much more effective (Tanaka 2006; Jung 2007).

4.2.1.4 Enforcement

A major problem identified in the potential application of many regulatory marine debris policies, is their dependence on enforcement. Table 10 reports an overview of different areas where marine debris is found, the responsible enforcement agency and a ranking of enforcement capacity to address marine debris issues.

Enforcement at sea tends to be costly, and while technical advances linking debris items to their sources can raise the effectiveness of enforcement in some situations, marine debris monitoring would require high levels of observer coverage. The cost of enforcement is an economic cost of any regime and may differ between debris control methods.

Table 10: Areas where marine debris is found, the responsible enforcement agency and a rating of enforcement capacity.

Location of debris	Responsibility	Enforcement capacity	Comment on enforcement
Urban landfill	Municipal authority	High -by land authorities	Land legislation can be applied
Harbour (internal waters)	Port authority	High -by Port authority	Port legislation can be applied
Urban coastline	Municipal authority/rural councils	Lower - by land authorities	Lower in rural coastal areas
Tourist coastline	Tourism venture/ rural council	Low	Private beach resort may clean debris
Residual coastline	Rural town councils	Low	Rural communities are recipients of debris
Inshore of 3 or 12 miles	National responsibility	Low	Coastal patrols may intercept vessels
Outside of 12 nmiles in EEZ	National responsibility	Very low	Occasional vessel interception
Outside EEZ	International conventions	Negligible	Require record keeping but are 'self enforced' at sea

4.2.2 How can economic instruments add to current marine debris controls?

There have been few MBIs that have been used directly to control marine debris. The existing instruments tend to be applied in the management of land debris. The potential of each market-based instrument to be involved in the control of marine debris was examined for their potential to control marine debris. Some measures are recommended, others are recommended as secondary instruments that could be part of a mature system and finally some instruments were not felt to be appropriate for the control of marine debris.

1. **Recommended:** Deposit-refund systems, user and administrative charges, sales taxes and cost sharing.

Deposits-refund systems A deposit system on drinks containers can have a refund condition to minimise the loss of containers to debris. Deposit systems can also ensure 100% recycling while reducing marine pollution. This also transfers the cost of reducing litter to the drinks manufacturer. This could be implemented to prevent marine debris.

User and administrative charges Municipal waste can be charged at a fixed amount, or on a 'pay-as-you-throw' system, where users pay in proportion to the volume of their waste and the environmental damage. Product disposal can have special charges for car tyre recycling and car battery disposal (Martin and Verbeek 2006). This system can reduce the generation of debris that may ultimately have become marine debris. Implementing systems where new charges apply for disposal of municipal debris requires education, fines and enforcement to detect non compliance problems.

Sales taxes Sales taxes can be applied to products with environmentally damaging contents (ozone depleting chemicals etc). Taxes on plastic bottles and plastic containers could reduce the use of plastic, and force innovation in alternative cardboard packaging. For shipping, implementing payment of a fee at port for vessel rubbish reception, whether it is used or not, may ensure use of the reception facilities. Plastic bags and alternatives have a sales tax applied in Denmark, the proceeds going to the general budget (Stavins 2003). A tax or ban on plastic bottles was proposed by Kirkley and McConnell (1997) with paper being substituted where possible. Sales taxes on other disposable items commonly found in marine debris could be considered (plastic containers, aerosols etc). These are readily implemented by government and can reduce marine debris.

Cost sharing Cost sharing agreements are made between parties to divide the total cost of a future course of action into proportions to be paid where a municipality and a port authority agree to divide the costs of debris clean up equally, or by some other agreed percentage, for the coming year. In the international arena three neighbouring countries could negotiate cost sharing the total costs of a joint remedial program. (Ha *et al.* 2006) The cost sharing agreement can enable a single joint clean up operation to take place at less total cost than three individual programs.

2. **Recommended as a secondary design feature in more mature systems**: Credit programs, offsets, levering private investment, liability rules and risk, product differentiation, market creation/conservation agreements, reducing government subsidies, and tax incentives/differentiation.

Credit programs In a mature environmental or marine debris control scheme, government can give credits for environmentally beneficial behaviour. Marine debris prevention could be included in such a scheme.

Offsets An offset is a positive environmental action on an alternative location that counterbalances the environmentally degrading issue at a given environmental site. The offset action can be contracted to another party to perform. Total environmental outcomes can be achieved at lower cost than by on-site mitigation. For example, a city has been identified as the source of 500 tonnes of marine debris arriving annually on the coastline of local coastal towns, who seek reimbursement for the clean up cost from the polluting city. The city could offer to spend funds to prevent 1000 tonnes of debris per annum entering the water course in the city. This may well be a more effective use of funds.

Levering private investment Cleaning up marine debris may also create commercially attractive benefits to private investors (beaches and tourism) able to gain from a differentiated product, such as a clean beach.

Liability rules and risk In industries with insurance and risk, such as shipping and fishing, the adoption of industry practices to reduce the risk of damage from marine debris can reduce insurance premiums.

Product differentiation Differentiating a product can alter incentives. A marine tourist resort may advertise a clean ‘no marine debris resort area’. This can provide a commercial premium, and maintain and improve visitation rates.

Market creation/conservation agreements These are voluntary legally binding agreements with industry to keep pollutants as agreeable levels (DAFF 2008). A port authority may enter such an agreement with government in respect of acceptable levels of marine debris, as a condition of operating the port.

Reducing government subsidies Subsidies from government can promote inefficiency and environmentally unsound practices (Stavins 2003). Most governments pay for cleaning up marine debris and effectively subsidise those creating it, but also meet the gap caused by market failure associated with marine debris. The intervention of government through subsidised clean up needs to be reduced, with more emphasis being put on government assisting the prevention of debris to reduce the clean up requirement.

Tax incentives/differentiation Tax deductions for the prevention of debris or rebates for returned debris, could be considered by government. It is possible to investigate higher taxation for items that cannot be recycled and subsidies for those that can be (Laist and Liffmann, 2005).

3. **Not recommended**: controlling marine debris through tradable permits and cap and trade systems and effluent charges. These are of less applicability to the APEC economies due to implementation issues.

Tradable permit* and *cap and trade systems Permits to release a quantity of debris, that is, the cap, are created to be a tradable right that could be purchased by emitters. However marine debris is generally a non point source pollutant, as opposed to, for example, a large chemical factory or power station. If applied to marine debris, a total quantity of marine debris, the cap, would be set. Trading would ensure efficiency in allocation of the marine debris right, providing the cap is enforced. The funds raised could be used for remediation. Tradable permits and cap and trade systems are not applicable to most marine debris situations. While the idea of being able to cap and subsequently reduce marine debris is appealing, the fundamental identification of those generating marine debris makes this approach problematic in most situations.

Effluent charges Charges can be applied at the point of waste generation, or entry to the watercourse, if the debris is attributable to a specific source. Charges can be either fixed or preferably related to the volume of debris. The 'polluter pays principle' creates an incentive to reduce the discharge of debris, but may increase illegal dumping also (Stavin 2003). It has long been accepted that an external cost, or market failure, can be corrected by applying a tax that will internalise the external costs on to the polluter (Pigou 1920). The taxation approach is, however, less applicable to controlling marine debris due to the difficulty in identifying point source polluters generating marine debris.

4.2.2.1 Discussion

The use of MBIs for control of marine debris is a new development and overlaps with some economic policies in use on land to control waste. Stavins (2003) does not consider marine debris but, from other pollution examples given, there appear to be two key issues policy makers should be aware of in trying to apply market-based policy instruments:

Firstly, if a pollutant can be regulated at a point source by input or emission interventions, before it receives a great degree of mixing in the environment, it is suited to MBIs. Secondly, intervention in the marine environment may be 'focused on ambient concentrations, at a minimum.

Marine debris does not generally meet the point source criterion. However the second criterion assesses the density of marine debris by area or volume, and is a usual criterion for commencing clean ups. For example the use of a technical boom device on rivers can gather debris for removal before going into the ocean (Nam and Jung 2005).

Regulatory approaches to control marine debris have been popular as the governance system is used to make rules restricting marine debris pollution. Such rules have low transaction costs as people mostly comply. Community approaches to clean ups often come from the voluntary non government organisation sector and getting people to work cooperatively in clean up of marine debris involves high transaction costs.

MBIs for marine debris are in their infancy and need to be tested. MBIs are envisaged for a range of environmental problems but,

…this should not leave the impression that market-based instruments have replaced, or have come anywhere close to replacing, the conventional, command-and-control approach to environmental protection (Stavins 2003).

We propose that some MBIs can play a selective role in the control of marine debris, given the context of the control problem. They have potential gains in the prevention of land generated debris. Trials are required to compare MBIs with the benefits from alternatives, such as a preventative river boom. In some cases MBIs may not be economically viable for the implementing authority, but may have external benefits though reducing avoidable costs in the whole economy. MBIs could also be evaluated with regulatory and community alternatives.

4.2.3 The benefits and costs of alternative marine debris policies

Due to the 'avoided cost' nature of the marine debris, benefits accrue when the level of marine debris reduces. A program to clean up marine debris has an operational cost which can be measured, but the measurement of the benefit from the program would require a specific market and non-market valuation exercise.

We propose that the economic decision for the policy maker is given by a comparison of the marginal costs and marginal benefits at the point where policy makers make decisions and with the information available to them. Marginal benefits/marginal costs comparisons were examined in Figure 6 illustrating that if marginal benefits exceed marginal costs then the policy step should be applied—the stock of debris reducing. Economics uses the marginal approach to set the direction of policy action. For example if the marginal benefit exceeds the marginal costs, then the clean up can proceed and it will reduce the stock of debris, the objective being to keep the stock of debris at the optimal level. In the Hong Kong Harbour case study at Appendix 3, the funds spent on clean up, the marginal cost, are being compared to the cleanliness index of the harbour, a proxy measure of the marginal benefit.

So where should APEC debris managers look for the most effective return on scarce resources when addressing the control of marine debris? The preference would be to follow initiatives where the marginal benefits exceed the marginal costs or which have potentially positive benefit-cost ratios. Given the lack of empirical data, the benefit/cost estimates in the following sections should be treated with caution.[10] The approach follows Figure 6 and we examine generation/prevention, ambient stock levels and clean up.

4.2.3.1 Prevention

Prevention addresses sources of debris generation and the different approaches with estimated benefit and costs as reported in Table 11a.

Table 11a: The estimated benefits, costs and likely benefit-cost ratios of different type of marine debris prevention measures

Type of policy	Benefits	Costs	Benefit/cost ratio estimate
Regulation of waste	Reduces waste	More enforcement cost	Positive, reducing
MBIs—waste charges (if polluter is evident)	Reduced volume of waste and revenue generated	Administrative and enforcement costs	Positive
MBIs—deposit refund system	Less bottles or plastic containers	Administering the scheme and recycling	Positive/marginal *TBC
Regulation/MBIs Prohibition/sales tax on plastic bags	Less plastic bags as problem from landfill, revenue from sales tax	Alternative types of bag	Positive
Technical devices—booms, waste traps preventing debris entering sea	Gathers and concentrates floating debris for removal	Significant construction, and maintenance costs	Positive ? TBC*
Regulation via industries (shipping and fishing)	Rules to bring back marine debris to port for disposal	Cost to ship of waste management and carriage	Positive, reducing
Community-conservation agreements	Debris levels are reduced	Industry bears costs of not dumping debris	Positive/marginal

Key: *TBC–to be confirmed

4.2.3.2 Reducing the marine debris stock level

Once debris is in the inshore, offshore and ocean arena, the main monitoring tool is the ambient level of the marine debris stock and whether there are 'hot spots' where litter gathers. Similarly the flux, or turnover of debris after removal, can be measured at a given site to

[10] The benefit /cost ratio in Table 11a and Table 11b is to be interpreted as a marginal benefit for a marginal cost, when at a given starting point. This will enable policy direction to be determined, but the extent of the policy, requires a fuller specific benefit cost study. For example if a beach resort area finds that several popular beaches have high debris levels, then the MB exceeds the MC of clean up and the beach cleaning is initiated.

indicate the local abundance debris. Knowledge of stock levels and marine debris deposits is important if governments decide to 'go fishing' to clean up marine debris aggregations.

4.2.3.3 Clean up

The benefits and costs of clean-up policies are shown in Table 11b.

Table 11b: The estimated benefits, costs and benefit-cost ratios of different types of marine debris clean-up measures.

Type of policy	Benefits	Costs	Benefit/cost ratio
MBI-product differentiation private leverage	Tourists respond to cleaner beach bringing more revenue	Cost of cleaning the beach of debris	Positive *(depending on the value of the beach)*
Fishers paid by government to clean up debris	Cleaner marine environment	Cost to pay fishers, plus government administration costs	Marginal/Loss
Subsidy—fishers given subsidised recycling for old fishing gear	Fishing reefs cleaned, environment improved	Costs for fishers of retrieving old gear	Marginal/Loss *(depends on the level of damage)*

4.2.3.4 Discussion on prevention and clean up costs and benefits

From the limited information it appears the benefit-cost ratios for clean up are not as great as those for prevention. This is driven by the avoided cost nature of the problem, and the high costs of cleaning up dispersed marine debris. However, both prevention and clean-up measures are required for control. The stock of ocean debris could take many years to reduce by either clean up or prevention alone. In some cases clean up may only mitigate debris accumulating locally.

Currently, clean-up decisions are driven by the immediate perceived benefit from cleaning an area, relative to the cost of clean up. The economic approach, with more data, would evaluate the extent of clean up relative to alternative use of funds for preventative measures. There are also alternative ways to provide the actual clean-up services in order to reduce costs.

The removal of derelict fishing gear has led to some government agencies paying fishers to clean up fishing debris (see the Korean and Hawaiian case studies at Appendix 3). The Korean example indicates that the cost of the payment to fishers to collect rubbish on a volume basis, is much less than the cost of the government agency for the same task. It may be more efficient for fishers to be paid to remove fishing gear. This would have to be reconciled with the current approach which imposes penalties and polices activities.

The study has introduced the need to be aware of the stock of debris in the oceans. As the debris stock levels reduce it is expected that the marginal benefit of retrieving debris will decrease and the marginal cost of collecting more diverse debris will increase.

4.3 Conclusions and recommendations

The use of economic incentives to control waste practices on land is gaining momentum and is now being extended to the control of marine debris. However, in many cases improved land debris control practices would also benefit the marine environment. Linkages in management measures and between these issues need to be strengthened, as does establishing collaborative relationships between the different institutions with management and legislative authorities.

There are some limitations on the applicability of market-based instruments to marine debris control. As marine debris is a non-point-source pollutant, some instruments such as effluent charges are not automatically feasible.

After evaluation the following market-based instruments are recommended as being most suited to controlling marine debris:

- deposits-refund systems
- user and administrative charge, and
- sales taxes and cost sharing.

Some of these would have to be implemented on land to prevent debris entering the sea and require cooperation with land agencies.

A second set of instruments have design features to augment debris control programs and could be considered, including:

- credit programs
- offsets
- levering private investment
- liability rules and risk
- product differentiation
- market creation-conservation agreements
- reducing government subsidies, and
- tax incentives-differentiation.

These could be used in different APEC economies as part of designed solutions to control marine debris.

Thirdly, the following are not recommended for controlling marine debris at this point due to a range of implementation issues: tradable permits, cap and trade systems and effluent charges. Although effluent charges follow the polluter pays principle, marine debris is a non point source pollutant, making the polluter difficult to identify.

The implementation of market-based instruments to control marine debris involves an overlap with initiatives by land-based agencies to control debris on land. These common interests should be developed through joint programs developing market-based instruments.

- **Recommendation 8:** APEC MRCWG to undertake two case studies exploring the design and implementation of market-based instruments to reduce marine debris involving land and marine agencies in APEC economies. These case studies could explore deposit-refund system and a sales tax on plastic bags and plastic bottles at a site where changes in marine debris can be easily assessed.

- **Recommendation 9:** APEC MRCWG to undertake a case study involving several adjacent APEC economies, examining the feasibility of cost sharing of clean up, and how it can benefit each economy.

- **Recommendation 10:** APEC economies to encourage municipal authorities to work jointly with the private sector to share the costs of beach clean up, ie, where private sector tourism enterprises clearly benefit from clean beaches in tourist resorts.

PART 5. Disseminate the results through an outreach program highlighting the costs and benefits of controlling marine debris

Disseminate project results through an agreed outreach program to governments, relevant industries and the public in the APEC region and project partners, highlighting the benefits and costs of controlling marine debris and appropriate measures for limiting these costs in the future.

5.1 Method

This study included an outreach phase which was intended to take the draft results of the study into the field to workshop with participants in different APEC economies. The preliminary results of the project formed the basis for instruction and feedback from those involved in the control of marine debris.

The first workshop was held in Indonesia in August 2008 and was followed by a presentation at the Second Coordinating Body on the Seas of East Asia (COBSEA) Marine Litter Workshop, held 18-20 September 2008 in Pattaya, Thailand. A final workshop will be held at the World Ocean Conference in Manado, Indonesia, in May 2009.

The outreach method was to expose relevant policy makers to the need to take account of the economic costs and benefits of controlling marine debris in the APEC region. Each outreach had a range of participants, with differing perspectives on the costs and benefits of controlling marine debris.

5.2 Results

This study includes an outreach component to share the current report findings with interested parties in APEC economies and to explore the economic incentives and approaches to prevent marine debris.

The first workshop was in Indonesia in August 2008 and was followed by presenting at the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) maritime litter forum in Thailand in November 2008. It is intended to conduct a final workshop at the World Ocean Conference in Manado, Indonesia, in May 2009.

The outreach program worked with Indonesia, the host APEC economy, to run a National APEC MRC workshop on the Control of Marine Debris. This was held in Jakarta, on 14 and 15 August 2008. The workshop was focused around a challenge statement:

> *The 'Understanding the economic benefits and costs of controlling marine debris in the APEC region' report finds APEC economies could reduce the economic impacts of marine debris by introducing economic incentives and a more integrated policy approach with land sources and the use of additional policy instruments.*

The workshop was intended for staff involved with marine debris policy at the national, provincial and municipal levels of government, in departments such as the environmental protection authority and waste disposal, ports, marine safety, shipping, fishing/aquaculture, land planning and tourism. It was also intended for industry associations such as those in the shipping, fishing and marine tourism sectors.

A workshop report is at Appendix 3.

The workshop was appreciated by the participants. They indicated that the workshop would give the economic benefits and costs of controlling marine debris more profile in Indonesia. They also indicated that the uptake of the project results would be best if discussed and actioned by several different government departments. The participants were keen to have a larger outreach based on controlling the marine debris in Jakarta Bay.

Part of the outreach that participants identified with was the case study material (Appendix 3). One of the expectations of participants was that APEC economies could share the information on the effectiveness of debris barriers and control programs more effectively.

5.3 Conclusions and recommendations

The outreach method was to meet with various policy makers from industry, government and the community involved in the management of marine debris in APEC economies in a workshop setting.

From materials presented and discussed the participants developed an understanding of the economics of controlling marine debris. In Indonesia they were interested in the economics of technical devices to prevent litter and in solving the difficulties facing Jakarta with marine debris, and the link to general debris issues faced by the municipal authorities. Participants also identified the lack of a coordinated approach across all agencies and industries suggesting a more coordinated approach between land and marine agencies.

The workshop was appreciated by the participants and would give the economic benefits and costs of controlling marine debris more profile in Indonesia. They also indicated that the uptake of the project results would be best if discussed and actioned by several different government departments. The participants were keen to have a larger outreach workshop based on controlling the marine debris in Jakarta Bay.

- ♦ **Recommendation 11:** APEC MRCWG to consider a follow up project that explores technical effectiveness and operational costs of litter devices, such as litter traps and river and harbour booms, to make information and experience in technical controls for marine debris available to many communities in the APEC economies.

- ♦ **Recommendation 12:** APEC MRCWG to identify major urban marine debris ‘hot spots’, by area or issue, that may benefit from targeted marine debris control workshops and prioritise funding for delivery.

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PART 7: Appendices

Appendix 1: Sources of marine debris

A1.1 Land-based sources of debris and composition

A1.1.1 Discharges of stormwater

The main land-based contributor of marine debris in California is urban stormwater run-off which may transport large volumes of waste to the ocean (Gordon 2006). During heavy rain events stormwater drains direct water to discharge points which are typically on the shoreline or in rivers and estuaries. Waste in watershed or catchment areas may be swept to the ocean. Debris in this context comes largely from public littering and poor waste management in urban areas. The mishandling of waste materials (eg, food wrappings, plastic bottles etc) by the general public is the foundation of the marine debris issue in the US (Sheavly 2005b).

A1.1.2 Sewer overflows

Sewers generally carry both sewage and stormwater to waste water processing and treatment facilities. During an effective treatment process, most solid waste is removed and disposed of appropriately. However in periods of heavy rainfall the capacity of treatment facilities may be compromised by high flows, resulting in an excess volume (of sewage and stormwater) which may be discharged, untreated, directly to rivers or the ocean, carrying with it any solid material (ANZECC 1995; Allsopp *et al.* 2006). Indeed, according to Nollkaemper (1994), waste from sewer overflows is one of the most significant land-based sources of marine debris in the United States.

A1.1.3 Municipal landfills

Municipal landfills and garbage dumps that are located in coastal areas in Australia contribute to marine debris, although the extent to which they contribute is unknown (ANZECC 1996a). Any debris that escapes from land-fills may enter the marine environment through run-off into adjacent rivers and estuaries. It is generally thought that the main debris items from landfills are light plastic bags, sheeting and paper which can be dispersed by wind (ANZECC 1996a). In addition, debris may be lost to the environment during the collection and transport of waste, and through the illegal dumping of domestic and industrial waste into rivers and estuaries (Sheavly 2005a; Allsopp *et al*. 2006).

A1.1.4 Industrial activities

Industrial products can become marine debris if disposed of incorrectly or lost during transport. One of the most important types of industrial debris is the small resin pellets (2–6 mm diameter) that are used in the manufacture of plastics. Gregory (1998) reported that plastic pellets reached densities as high as 100,000 per metre of coast in New Zealand. While some pellets float, many sink and are incorporated into sediments. They have been reported in most of the world's oceans, including small, remote countries that are not industrialised, such as Tonga (Gregory 1999; Derraik 2002; Allsopp *et al*. 2006).

A1.1.5 Coastal tourism

Litter generated by populations living in coastal areas can contribute a large amount of debris to the ocean. Tourists may add to coastal debris by depositing items such as cigarette butts, food packaging, glass and plastic bottles which are often the most numerous debris items recorded in Australian beach clean ups (ANZECC 1996a).

A1.1.6 Ports and marinas

Debris from ports and marinas can arise from poor packaging processes and not having adequate port facilities for garbage. Where reception facilities for vessels are inadequate, dumping of garbage into the ocean may occur.

A1.2 Ocean-based sources of debris

All ocean-going vessels and platforms are potential sources of debris. It is estimated that in Australian waters, 6,447 tonnes of debris enters the ocean from ocean-based sources each year (ANZECC 1996b). Annex V to the International Convention for the Prevention of Pollution from Ships (MARPOL), came into force in 1988 and prohibits the discharge of all plastics into the ocean from ships. This includes items such as plastic fishing lines and nets, synthetic ropes, plastic bags, food waste and any floating garbage within specified distances from land. Annex V also requires that ports and terminals provide waste reception facilities.

A1.2.1 Commercial fishing vessels

Debris that arises from commercial fishing vessels poses a significant threat to global marine ecosystems. Derelict or lost fishing gear causes numerous problems including the entanglement of wildlife, ‘ghost fishing’, and possible damage to sensitive coastal habitats, and presents a hazard to vessels. The most problematic types of debris are derelict nets, ropes and traps. In addition, large quantities of plastic packaging and general waste may be disposed of at sea (Jones 1994; Jones 1995). Estimates of DFG from commercial fishing vessels are varied, but there may be as much as 135,000 tonnes of fishing gear discarded globally each year (Merrell 1984).

Derelict fishing gear is a significant type of marine debris, with lost nets and traps potentially persisting for years (Laist 1995). For example, it has been estimated that:

- US$250 million of marketable lobsters are lost each year from the United States because of the loss of traps (Raaymakers 2007).
- as much as 7,000km of drift nets were lost each year in the North Pacific fisheries (Bullimore *et al*. 2000)
- as many as 135,000 tonnes of fishing gear are lost worldwide each year Jones (1995). Slater (1994) reported that some 8000 nets are lost each year in Canada. Many traps and pots are lost from commercial vessels each year, and
- 7,000 to 31,600 pots are lost each year in the North American Bristol Bay king crab (*Paralithodes camtschaticus*) fishery (Bullimore *et al*. 2000).

A1.2.2 Merchant shipping, ferries and cruise liners

Debris from shipping is generally in the form of food packaging and general waste. While accurate data is difficult to obtain, estimates suggest that 2-3.5kg of waste is generated per person per day (ANZECC 1996b; Gregory 1998). Therefore vessels with a large number of people on board can potentially produce large amounts of garbage (ANZECC 1996a). Garbage from vessels may be accidentally or deliberately discharged into the ocean. While the dumping of garbage at sea is regulated under MARPOL Annex V, it requires adequate port reception facilities to handle waste generated at sea.

In addition to the general waste produced on ships, cargo containers from container vessels can be lost during periods of rough weather. These may float for long periods of time before sinking, posing a navigational hazard to other vessels, or may burst open and release their contents which can be washed ashore (ANZECC 1996a).

A1.2.3 Recreational boating and fishing

Estimates of recreational vessels suggest that there are approximately 7.3 million recreational vessels in the United States alone (Committee on Shipborne Wastes 2000). These have the capacity to produce debris from items such as plastic fishing line, nets, buoys and floats, and beverage containers and plastic bags. While recreational fishing and boating produces a small amount of garbage per person per day, the large numbers of recreational vessels means that they will be a significant part of coast and beach litter, often leaving monofilament and plastic bait bags. This will vary between the APEC economies in relation to their recreational pursuits.

A1.2.4 Offshore oil and gas platforms

Offshore operations on oil platforms produce large amounts of debris. In addition to general garbage, other debris items such as hard-hats, gloves, large storage drums and survey materials may be deliberately or accidentally discarded into the ocean (Allsopp *et al*. 2006).

Appendix 2: Marine debris project responses from APEC economies

Replies from nine economy representatives led to further investigation of data on marine debris. The replies also indicated that economic data on marine debris is available in five of the nine economies. From the information supplied, six case studies in APEC economies were prepared.

Australia (MRCWG contact responded and provided economic data) There was a limited amount of data available from Australia reflecting the non-economic approach often taken to marine debris studies. Several anecdotal examples of damage to animals and habitat were available, but only a limited amount of numerical costs data. Contact with local government suggested clean up cost data probably resides within coastal councils but there is no requirement to report it. Some anecdotal data on the cost of damage and clean up was available for derelict fishing gear.

Canada (MRCWG contact responded but provided no economic data) The ecological impacts of marine debris on birds and mammals have received some attention in the economy of Canada although a wide range of government and non-government initiatives to address the problem have been implemented (Topping 2000), few economic data exist. The economic impact of marine debris in Canada largely appears to affect commercial fishermen through catches being contaminated or through gear loss. Slater (1994) reported that whole fish catches were being discarded because they are contaminated with glass debris. Furthermore, Slater (1994) reported that some 8,000 nets are lost each year in Canada; the estimated cost of retrieving these nets is CAN$10 million.

China (no response from MRCWG contact) There are very limited data available for the economy of China. No marine debris density estimates have been published and the only economic information comes from conference papers. For instance Fan (2005) suggested that, during 2004, fisheries losses due to pollution was approximately 900 million Yuan (US$120 million). However, the contribution of marine debris to this figure is unknown.

Hong Kong, China (economic data provided by MRCWG contact) See Appendix 3 case studies.

Indonesia (MRCWG contact responded but provided no economic data) While there are several published estimates of densities of debris on beaches in Indonesia (Willoughby 1986; Evans *et al*. 1995; Uneputty and Evans 1997a; Uneputty and Evans 1997b; Willoughby *et al*. 1997), there are limited data concerning the economic impact of marine debris from the economy of Indonesia (Indraningsih 2007). The most important study of the economics of marine debris was conducted by Nash (1992), who investigated the direct and indirect impacts of debris on subsistence fishermen. Nash reported that in Yotefa Bay (20 km from Jayapura, Irian Jaya province), debris directly impacted fishermen by decreasing yield, mainly because individuals needed to use second-choice gear as their primary gear became fouled by debris (eg, using hook and line gear because drifting debris would interfere with gill-net operation). Indirectly, floating debris caused fishermen to move to less polluted areas, where there was not as high an incidence of gear fouling.

Japan (MRCWG contact responded but provided no economic data) There is limited data concerning the economic impact of marine debris to the economy of Japan. Japan is exposed to a large amount of marine debris with approximately 100,000 tonnes of debris collected from Japanese shores each year between 1994–2005 (Adachi 2006). Yagi and Otsuka (1989) reported that, in 1987, debris was cleaned (seashores cleaned using manpower, cleaning fishing grounds using trawl nets and divers to clean rocky sub-tidal areas) from 137 areas around Japan at a total cost of US$73 million. In addition to the costs associated with cleaning beaches, marine debris (largely plastics) is the leading cause of vessel engine damage in Japan. Insurance companies estimate US$50 million has been awarded as a result of repairs for damage incurred by debris.

Korea (MRCWG contact responded but provided no economic data) See case studies at Appendix 3.

Sung (2005) suggests that the cost of processing marine debris may be as high as ¥50,000a tonne, and that nation-wide, processing costs may be as high as ¥5–10 billion. Furthermore, Chun (2005) reported the Korean government had spent approximately US$0.3m between 1999–2005 on data collection. Overall, the Korean government invested US$51 million won in their marine debris project between 1995 and 2005.

From 2000, the Korean government implemented a marine debris management strategy for which they committed an estimated US$20m. This strategy included surveys of debris loads, the collection and treatment of debris and the construction of a vessel for collecting debris at sea. As part of this program, the Korean government instigated a ‘buy back’ program in which the government purchased marine debris returned by fishermen. The government paid fishermen US$6/60L of debris returned (Nam and Jung 2005). In 2005, the Korean government purchased a total of 3076 tons of debris from fishermen at a cost of US$1 842 million won. In addition, they spent a further US$7,965 million won collecting 5352 tons of debris from the ocean floor.

Since 2000, a further US$28 million has been committed to implement a three-phase management system which includes the construction of base and practical technologies such as containment booms, recovery vessels, and re-cycling and incineration facilities.

Mexico (no response from MRCWG contact) There are no data concerning the economic impact of marine debris available for the economy of Mexico. In one small, informal study, 58 beach-goers were interviewed and 49 said they would use beaches more frequently if they were cleaned; many said they would be happy to pay a user fee to ensure beaches were cleaned (Silva-Iniguez and Fischer 2003).

Papua New Guinea (no response from MRCWG contact) There are no data concerning the economic impact of marine debris available for the economy of Papua New Guinea.

Papua New Guinea is a member of the International Coastal Clean up (Centre for Marine Conservation 1999), and in 2001 around 138km of coastline was cleaned by volunteers. More than 549,750kg of debris was cleaned (Pacific Magazine 2002). In 1999, more than US$50,000 was raised for clean up operations (Centre for Marine Conservation 1999).

The Philippines (no response from MRCWG contact) There are no data concerning the economic impact of marine debris available for the economy of The Philippines (Laciste 2007).

There are no systematic data collection activities in The Philippines although it is a member of the International Coastal Clean up, and some debris data are collected during clean up days (Laciste 2007).

Singapore (MRCWG contact responded but provided no economic data)

There are no data concerning the economic impact of marine debris available for the economy of Singapore. Singapore's Maritime and Port Authority carry out daily maintenance flotsam clean up in port waters. In addition, daily inspections of port waters are undertaken and pro-active clean up actions are taken if required. The associated costs of these activities include deploying retrieval craft and personnel on a daily basis (Yuhua Li, pers. comm.).

The United States (economic data provided by MRCWG contact) There are many data concerning the economic impact of marine debris for the economy of the United States. See case studies section. In the most significant debris-related incident, beaches along the Jersey shore were affected by a serious pollution event in 1998. This event was estimated to have cost the New York economy US$1 billion (Ofiara and Brown 1999).

The economic impact of derelict fishing gear is high in the United States. It has been estimated that US$250 million of marketable lobsters are lost each year from the United States (Raaymakers 2007). The cost of retrieving derelict fishing gear in Puget Sound has been estimated from data collected over a number of years by Natural Resource Consultants (2007). These authors estimated the cost of retrieving nets at $4,960 per acre of net removed. Furthermore, the cost of retrieving fishing taps and pots was $193 per trap. Moreover, these authors estimated the economic benefits of retrieving derelict fishing gear, and calculated that the value of catch saved from derelict fishing gear was $248 per year for traps, and $6,285 per net, and thus the cost-benefit ratio was positive (ie, the benefit was more than the cost).

The cost of retrieving derelict fishing gear from the North-West Hawaiian Islands has been estimated at US$25,000 per ton (Raaymakers 2007). Between 2001 and 2005, the multi-agency removal program had funding between US$2-3 million. After this, the debris collection program was changed to a maintenance program and the allocation was reduced in 2006 to US$500,000 per year. It appears; however, that this level of funding is not adequate to keep pace with annual accumulation rates (S. Balawi, pers. comm.).

Viet Nam (MRCWG contact responded but provided no economic data) There are no data concerning the economic impact of marine debris available for the economy of Viet Nam.

Appendix 3: Extracts from the report of the APEC MRCWG outreach workshop, Jakarta, Indonesia

National APEC MRC Workshop on Controlling Marine Debris, Jakarta

The participants were from a range of government environmental and municipal departments as well as NGOs and private sector port authorities. Each of these agencies has involvement with marine debris. There was a range of degrees of involvement of agencies in the management of marine debris.

Appendix Figure 1: Some of the 18 registered participants at the MRCWG workshop in Jakarta, August 2008.

Participants' expectations

The expectations of the workshop participants were varied and covered the following:

- The latest information from other institutions on their contributions to dealing with marine debris and also information from the rest of the world/APEC to be used in environmental protection programs in Indonesia (comment by several participants).
- Information on technical litter traps, intercepting surface and bottom marine debris and the efforts on land to stop marine debris occurring (comment by several participants).
- How to manage marine debris? (comment by several participants).
- Environmental information on how to deal with the environmental issues caused by marine debris.
- That there will be an effort to increase community awareness to manage the waste through ecosystem understanding approach and to create integrated marine debris management.

The two-day program is presented below in Appendix Table 1.

Appendix Table 1: The workshop program for the APEC workshop

Day 1	**THURSDAY 14 AUGUST, 2008**
08.30 - 09.00	Registration
09.00 - 09.15	**Welcome Remarks** *Chairman of Agency for Marine and Fisheries Research*
09.15 - 09.30	**Workshop introduction** *Prof. A. McIlgorm, Consultant to provide overview of challenge statement*
09.30 - 10.15	**Outline of involvement in marine debris** *Each Participant summary (5 minutes each)*
10.15 - 10.30	**Morning Tea**
10.30 - 11.30	**Outline of involvement in marine debris** *Each Participant summary (5 minutes each)*
11.30 - 12.00	**Discussion on and comparison with each agencies role and brief - gaps identified**
12.00 - 13.00	**Lunch Break**
13.00 - 14.00	**Presentation of a summary of the APEC document overview** *Prof. A. McIlgorm*
14.00 - 15.00	**Policies to control marine debris** *Prof. A. McIlgorm, Consultant will provide overview*
15.00 - 15.15	**Afternoon Tea**
15.15 - 16.15	**Case study A** *Prof. A. McIlgorm, This will present the problems faced by municipal councils and harbour authorities in controlling marine debris*
18.30 -	**Dinner**
Day 2	**FRIDAY 15 AUGUST, 2008**

09.00 - 09.30	**Policies to control marine debris** *Prof. A. McIlgorm, Discussion of Day 1*
09.30 - 10.15	**Discussion of Case study A** *This will present the problems faced by municipal councils and harbour authorities in controlling marine debris*
10.15 - 10.30	**Morning Tea**
10.30 - 11.00	**Case study B** *This will outline the problems face in controlling by discarded fishing gear in several areas of the APEC region*
11.00 - 12. 00	**The costs and benefits of marine debris control** *Prof. A. McIlgorm, The costs and benefits of controlling marine debris will be presented*
12.00 - 13.00	**Lunch Break**
13.00 - 14.00	**Discussion and comparison of control policy options** *Consultants will have a summarised schedule of policy options for discussion*
14.00 - 15.00	**Overcoming impediments to implementation** *Consultants to discuss approaches and all to explore utility*
15.00 - 15.15	**Afternoon Tea**
15.15 - 16.00	**Close of Day 2** *End of Workshop*

The damage and economic costs of marine debris in Jakarta

Is the current level of marine debris causing damage?

1) Jakarta has 13 rivers exiting into the sea. Three of these rivers exit into the largest commercial shipping port, Tanjung Priok. The port authority has a set of nets and screens to trap debris from the river. Each day 40m^3 of debris is taken from the traps using an excavator and carted away to land fill. The Port Authority pays for the clean up.

2) Within the port area the Tanjung Priok Port Authority also have specifically designed cleaning barge vessels straining debris within the port area.

3) One participant tells of taking a small outboard vessel on a 30km journey to the Thousand Islands north of Jakarta Bay and having to stop two to three times to untangle the outboard propeller taking an additional one hour of time.

4) Another participant showed photographs of marine debris as a high proportion of fish catch spoiling fish quality in west Java provincial waters. Lack of litter traps in local rivers is cited.

5) A hotel resort property developer visited the Thousand Islands 30km north of Jakarta to examine locating a new international tourist resort. All the attributes check out, apart from excessive marine debris on the beaches and waterways that would be essential to the viability of a beach holiday experience. The project did not proceed.

6) A national park is 35km away and has an influx of marine debris covering some habitats.

What is the economic loss to Indonesia?

The participants agreed that the damage from marine debris could be avoided by improved waste practices at all levels. Two key principles were noted:

- Marine debris impacts are **"avoidable costs"** (litter has to be picked up at a cost, reduce litter, reduce the cost).

- Marine debris impacts the economy through **lost opportunities.** Some participants felt that marine debris limits future development opportunities.

Examples of economic costs, avoidable costs and lost opportunities.

These can be seen clearly from the items 1-5 above.

(1) The Port Authority is left with little option but to bear the cost of trapping and removal of $40m^3$ debris per day from the river/port interface. This includes excavator use, trucks for transport and disposal fees. Labour charges for up to five people. A high private cost per annum for cleaning municipal waste.

(2) The Port Authority has to purchase a specifically designed barge for marine debris collection and hire staff and take waste away. These are costs borne by the Port Authority.

(3) All small boat users in the Jakarta to Thousand Islands area have to waste one hour of time and risk damage to their boats from marine debris. This is a substantial cost annually for all boat users.

(4) Pictures of fish catch on the coast adjacent to Jakarta show that marine debris is exceeding the amount of fish in the catch. There are also health issues in sorting the catch and with the fish being damaged. This reflects the sub-surface litter which generally exceeds the volume of the surface litter volume. This also implies that fish habitat has been covered or fouled and must be having potential productivity impacts.

(5) The high level of marine debris dissuades investors from putting millions of US dollars of potential capital investment into marine tourism in the Jakarta region. This loss is also in perpetuity, inhibiting economic growth of the marine tourism sector. Jakarta can expect to earn less income from marine tourism than other major regional cities, until it reduces the marine debris load substantially. Indonesian citizens also loose on the welfare benefits of having a clean inshore area where it is possible to relax.

In summary, the level of marine debris in the Jakarta region is at chronic levels and is costing Indonesia significant economic losses in its national economy. Jakarta region may also be forgoing the current and future economic opportunities available through marine tourism.

Discussion as part of the conclusion of the workshop—day 2

What are the main impediments to controlling marine debris in Indonesia? And how can they be overcome? The participants made the following points.

- Cultural impediments. These can be improved by education at all levels.
- Communication between agencies is needed and then with NGOs and community groups.
- Lack of disposal facilities. This is an issue for municipalities everywhere.
- Lack of suitable waste technology. Assistance with waste disposal/treatment/incineration *etc*. Need regional cooperation in disposal management.
- Economic limitations. Funding is required to clean up the environment.
- Lack of profile of marine debris among private sector and government.
- Poverty. - The poor are not easily changed
- Lack of education and awareness of marine debris. Publicity and education are required at all levels.
- Lack of law enforcement.

What are the recommendations from the workshop participants?

- The public awareness of marine debris as a national issue is low.
- The workshop identified that marine debris is an important issue to be dealt with and the public, socialisation, training, public education, outreach and extension program.
- All levels of government and community should be involved in addressing the impacts of marine debris.
- There are sufficient laws, but improved enforcement is required.
- Improved cooperation between key government agencies: public works fisheries and environment is necessary.
- Technical assistance is required with waste disposal technology.
- The ‘polluter pays’ approach should be adopted.

- The extent of derelict fishing gear should be established, as it is not currently perceived as an issue in Indonesia.

- Incentives are needed to address marine debris issues recognising the economic benefits of controlling marine debris.

- Create a new office between the fisheries and environment offices for marine debris management?

- APEC should promote the links between marine debris damage and the economy in Indonesia

Appendix 4. Case studies of economics in marine debris control programs in APEC economies

The following are six different case studies which cover a range of typical situations that policy makers in the APEC region face in respect of the costs and benefits of controlling marine debris. They are drawn from a range of literature, conference information and responses made to the short project survey undertaken by the project in late 2007.

A4.1 Case study one: The Korean approach to solving watershed and coastal marine debris (Chun 2005, 2009; Nam and Jung 2005)

Background

In the past decade Korea has had several national initiatives to implement practical measures to reduce marine debris. *A practical strategy to control input of marine vessels and land based inputs in order to assess their impacts on the marine environment and to remove accumulated litter on the seabed* (Chun 2005). This program was led by the Ministry of Maritime Affairs and Fisheries (MOMAF) and involved technical, administrative and management steps, which are described in Appendix Table 2.

Nam and Jung (2005) outline the approach applied to clearing up marine debris by a watershed approach in the management of land-based debris in Han River Basin, Republic of Korea. An initial survey of marine debris in three cities in Korea determined a division of litter cost sharing in proportions of: Incheon (50.2%), Gyeonggi (27%) and Seoul (22.8%) (Ha *et al*. 2006). The total cost of the program was US$20 million (2000–2006). The main activities were surveying, collection, treatment and building a debris retrieval vessel. The approach included sharing, stewardship, cooperation and partnership based on scientific information.

Appendix Table 2: Outline of the Korean approach to managing marine debris (Chun 2005).

Technology	Administration	Integrated management
Prevention (MOERI /KORDI)	Korean Maritime Institute	R&D prevention—floating debris containment booms, dams, rivers and channels, trials on different designs
Survey	Mitigation	Field survey—research on density of debris
Recovery	Education	Recovery—multi functional MD recovery system; surface vessel, recovery devices, orange grapple, rake, wire cutter and pick up net
Treatment recycling	Monitoring	Treatment and recycling—pre-treatment, Refuse Derived Fuel (RDF) production facility, waste polystyrene buoys recycling system, marine debris incinerator, on-board combined treatment system and waste FRP vessels treatment system
	Legislation	Management education and miscellaneous issues—effective policy, national monitoring program, legislation, mitigation strategy, education and campaign, International coastal cleanup activities

Key: KORDI Korea Ocean Research and Development Institute; MOERI Maritime and Ocean Engineering Research Institute; KMI Korean Maritime Institute

The first stage saw:

- the installation of marine debris fences during heavy rains in summer (April 1999–2000)
- purchase of marine debris collected by fishers (US$5/60 litre bag)
- collection of industrial fishing debris by collection barges
- clean up of the coastline and islands by workers and public collections
- building suitable vessels and environmental monitoring, and
- further installation of marine fences across large estuarine areas.

Lessons learnt from the program (Nam and Jung 2005)

- There needs to be a concrete definition of the debris issue to make parties address it.
- Determine the linkages of the coastal area to the watershed ocean basin.
- Use scientific data on the marine debris pollution level for cost allocation to avoid conflict.
- Establishment of a Memorandum of Understanding (MOU) between the key institutions.
- Apply the 'polluters-pay' principle.
- The approach can be applied to other marine environment issues.
- Need to manage socio-economic activities and address human impacts.
- Need to take responsibility and then cooperate.

A4.2 Case study two: Controlling marine debris in a shipping port—example Hong Kong SAR (Source: HKSAR Marine Department)

Background

The Hong Kong Special Administrative Region (SAR) Marine Department have an active collection program for marine debris to prevent shipping in the enclosed Harbour region being fouled. The Pollution Control Unit of the Marine Department hires contractor services to collect floating refuse from the sea surface. The cleansing contractor runs a fleet of 70 scavenging vessels to cover a sea area of about 50km^2. There are four barging points to land the collected refuse from sea for further disposal to landfill.

Appendix Figure 2: A scavenging vessel collecting marine debris in Hong Kong Harbour (Photographs A. McIlgorm).

The total cost of the clean up program

The current contract price is about $HK 30 million a year (circa US$ 3.85 million). The price includes scavenging floating refuse from the sea surface, and providing free domestic refuse collection service for ocean and local vessels. These services are offered in daytime, seven days a week, public holidays included. The price (cleansing cost) is fixed and independent from the amount of refuse to be collected by the cleansing contractor. The total cost of the scheme is paid by HKSARG, and no contribution has ever been sought from any industries.

Fisheries/industry losses due to debris

High speed ferry service operators had claimed delays due to floating refuse. In the 12 month period 1 December 2006 to 30 November 2007, the accumulated time loss was claimed to be 12.36 hours with fiscal loss estimation of $HK 148,320 (circa US$19,000).

What are the benefits of the program?

A three-pronged approach is adopted to prevent floating refuse on Hong Kong waters; namely, education, cleansing effectiveness and enforcement. A cleanliness index (score 0–10), using photographs for reference, is used to rate and control each contractor's performance. Score 10 stands for no floating refuse. The territory-wide average score last year was about 8.4. The cost of the program is met by the government with no contribution from users. A score of 7 would be unacceptable. The index scoring system is a proxy for the effectiveness of the clean-up system and hence the benefits accruing from it.

What dictates the 'right level' of marine debris?

> *We took a set of photographs on the harbour to define the 'cleanliness indexes' in our harbour cleansing contract. From a scale of 0 to 10 (index 10 for no floating refuse), the cleansing contractor is to restore the harbour cleanliness condition when it falls below index 7. Citizens also provide refuse sighting reports to a 24 hour hotline. Harbour with cleanliness level at index 7 means 'amount of floating refuse rarely observable' or 'reasonably free of floating*

refuse' as defined by the photograph in the cleansing contract (K.K Wong, Pers. comm.).

Policy implications

Apart from free domestic refuse collection services, developments in Hong Kong are governed by environmental impact assessments and a permit control system. Site contractors are required under land grant conditions to control spread of floating refuse using booms and other means to reduce refuse generation.

Legal mechanisms for prosecuting people not complying with regulations

A fixed penalty of $HK1,500 (circa US$ 193) system is imposed on any minor littering offence. When the volume of floating refuse littered is substantial the offender may be summoned and become liable to a fine of $HK50, 000 (US$6,418) and to imprisonment for one year. Control on the 'dumping' of sizable or heavy object(s) at sea is to be enforced by the Hong Kong Environment Protection Department. The penalty for 'dumping' can be up to $HK500, 000 (US$64,185) and imprisonment for two years. Apart from the penalty on 'dumping', the government may order an offender to remove 'dumped material' at his/her cost. A further penalty of $HK10, 000 (US$12, 836) per day can be imposed on failure to comply.

Benefit-cost discussion

The port of HK SAR has a multi-million dollar volume of shipping trade and the Marine Department of the government considers that the expenditure of US$3.85 million will bring significant returns in respect of reduced marine debris impact on vessels. The Marine Department does not explicitly measure the benefits.

We propose that the cleanliness index could actually serve as a proxy for the effectiveness of the clean-up scheme—appraising the total annual benefit. Following from the discussion of the optimal amount of marine debris in Figure 5, we can compare total costs and benefits. For the total contract cost of US$3.85 million the Marine Department gains an index score of 8.3 which equates to an acceptable debris stock level. Whether this is the optimal level depends on the relationship between marginal benefit and marginal cost. Marginal cost of clean up might be estimated by a cross-sectional analysis of expenditures and cleanliness index scores across operators in different areas of the harbour. Estimating marginal benefit would require estimating a relationship between the level of the index score and the amount of annual damage occurring in each area. The two relationships could be combined, as in Figure 5, to estimate the optimal level of annual clean up expenditure. We would suggest the approach of using a photograph index is a pragmatic way of appraising the stock of debris in this harbour case.

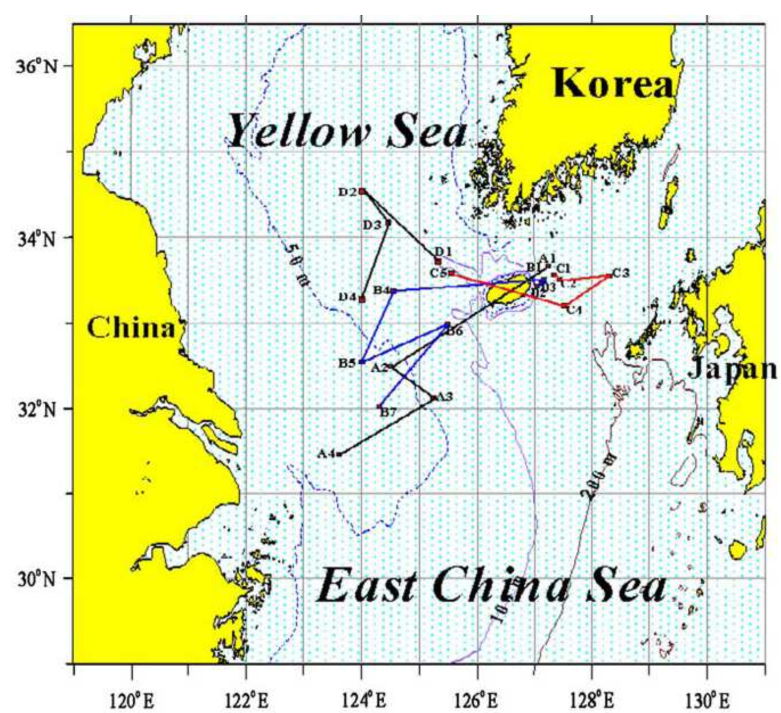
A4.3 Case study three: Controlling marine debris in a trans-national regional context

Background

There are many seas in the APEC economies where there are reasons that a shared or cooperative approach to controlling marine debris is worthy of investigation. The Yellow and East China Seas is an area in which China, Korea and Japan share the total coastline. A recent study by Lee *et al*. (2006) has sampled the marine debris in the area as shown in Appendix Figure 3. There are no benefit and cost data available for an analysis, but the study can be used as an instructive example to illustrate the key issues in improving marine debris control policy in a regional context.

Lee *et al*. (2006) summarise the situation as follows:

> *The types, quantities, and distribution of marine litter found on the seabed of the East China Sea and the South Sea of Korea are surveyed. Surveys were evaluated using bottom trawl nets during 1996-2005 cruises. Mean distribution densities were high in coastal seas, especially in the South Sea of Korea offshore from Yeosu, with 109.8kg km^2, and low in the East China Sea, with densities of 30.6kg km^2. Fishing gear, such as pots, nets, octopus jars, and fishing lines, accounted for about 42-72% and 37-62% of litter items in the East China Sea and the South Sea of Korea, respectively, whereas the contributions of rubber, vinyl, metal, plastic, glass, wood, and clothing were below 30% mainly. Rope and drum composition fluctuated greatly, between 54% and 0%. Eel and net pots dominated the marine debris of the South Sea of Korea, and some vinyl, plastics, and fishing gear made in Korea, China, and Japan were collected in abundance in the East China Sea. Fishing gear was probably discarded into the sea, deliberately or inadvertently, by fishing operations. A comprehensive joint approach by Korea, China, and Japan is needed for the continuous monitoring of input sources, the actual conditions, and the behaviour of marine litter for protection against litter pollution and fisheries resource management in this area* (Lee *et al*. 2006).



Appendix Figure 3: Trawling debris study sites in the Yellow and East China Seas as reported by Lee *et al*. (2006).

This case is illustrative of the type of situation described by Table 6 where three economies have a common ocean area impacted by marine debris, the majority of debris being sourced from these economies, and the benefits and costs of prevention/clean up potentially shared unevenly among the three countries.

Policy implications

The following text is from a recent NOWPAP Meeting (NOWPAP 2007) held in China and it discusses the range of issues economies face in this situation.

The capacities of the four NOWPAP member states vary across and within countries, and have resulted in their different approaches toward marine environmental protection and varied outcomes of pollution control. In Korea and Japan, the establishment of many volunteer-based survey and clean up schemes has indicated the improved public awareness on the protection of the marine environment. However, challenges remain in many areas in these countries to protect better their marine environment, and more active and coordinated measures among them are necessary to promote regional cooperation. In this respect, Japan suggests an ultimate solution to address the pollutant sources of the region by all the member states and to strive for more efficient communication in the development and circulation of documents among these states. Russia considers a series of exhibitions and conferences focusing on the prevention of marine pollution is the best way to exchange experiences.

It is obvious that the NOWPAP member states still face many of the marine environmental challenges, and marine litter will be taken up more in the four states as part of environmental protection policies in the future. An integrated approach needs to be adopted to reduce the problems created by fragmentation of competing regulatory authorities. Further considerations on some specific issues could start from tackling the root causes of environmental problems including marine litter issues. A specific legislation on marine litter and an appropriate coordinating mechanism is necessary to fulfil the aim of reducing the input and impact of litter. With concerted efforts, a better solution will be worked out to control marine litter of this region (NOWPAP 2007).

A4.4 Case study four: The costs and benefits of cleaning up derelict fishing gear (a) Puget Sound (NRE, 2007) (b) Alaskan case (c) Korean and Hawaiian examples

(a) Puget Sound

Background

In this recent study by NRE (2007) information was collected over four years (2004-2007) during the Northwest Straits initiative's derelict fishing gear survey and removal program in Puget Sound, Washington, and this information was used to estimate costs and directly measurable benefits of derelict fishing gear removal.

The total cost of the debris removal program

Costs of derelict net survey and removal totalled US$4,960 per acre of net removed. Costs of survey and removal of derelict pots/traps totalled $193 per pot/trap.

The benefits of the program

Directly measurable monetized benefits of derelict fishing gear removal were based on the commercial ex-vessel value of species saved from mortality over a one-year period for derelict pots/traps, totalling $248 per pot/trap and a ten-year period for derelict nets, totalling $6285 per net.

The benefit-cost ratio

The benefit/cost ratio was positive and similar for the removal of both gear types measuring 1:1.28 for pots/traps and 1:1.27 for derelict nets.

Policy implications

> *Although values of indirect benefits such as improved human safety, fewer impediments to vessel navigation, habitat restoration, reduction in mortality of non-commercial and protected or endangered species and pollution removal were not monetized, the derelict fishing gear removal program nonetheless compared favourably in cost effectiveness with habitat restoration and oiled wildlife rehabilitation projects. Given the expected long-term lifespan of these mainly synthetic-based derelict gears, negative impacts may continue for many years or decades beyond the 10-year period used in the cost-benefit analysis. The cumulative costs of not removing this derelict gear now, will likely be much higher in the future* (NRE 2007).

(b) Alaskan case

Background

The marine debris associated with fishing in Alaskan waters has been noted in several studies. Merrell (1984) identifies different types of fishing-related debris on beaches in Alaska. The marine debris problem was still prevalent in the late 1990s, Hess *et al*. (1999) finding 7.1 to 35 debris items per km^2 in bottom trawls around Kodiak Island.

The extent of the problem

Merrell outlines the different fishing that takes place in the Alaskan fishing zone. Prior to extended fisheries jurisdiction foreign vessels had been fishing the area. Merrell lists the various types of debris found in the zone: trawl nets, trawl floats, synthetic rope, inflatable buoys, beer and soft drinks crates, gill net floats and strapping for bundles and crates. His estimate is that six out of seven marine debris items are associated with fishing, litter being relatively minor. Hess *et al*. (1999) found that fishery related waste was 38% to 46% of total marine debris in the three years surveyed.

In consultations through the current project the origin of the debris is questioned:

> *This debris is not necessarily from the domestic fishing fleet. These waters have been fished heavily by foreign and domestic fleets for over 50 years, since well before MARPOL, and a lot of the junk we find is from that legacy. Over 70% of the nets we find are foreign manufactured and not types used by the domestic fleet today* (Bob King, MCA Foundation, Alaska).

If correct this requires consideration of the stock of marine debris in policy as shown in Figure 1.

The total cost and benefits of the clean up programs

The MCA Foundation conducts several debris clean ups annually along the Alaska Coast and gives the only available cost information available to this study.

> *In 2007, we conducted 12 clean ups from the Southeast Panhandle to the Aleutian Islands totaling approximately 250 miles and that removed some 171 metric tons of debris. Direct clean up costs totaled $302,115. Add in project administration, travel, some outstanding disposal fees and etc., and the total is closer to $400,000. We also funded debris assessment surveys of over 2,100 miles of shoreline that cost about $50,000. This past year we removed 822 pounds of debris off 1 km beach that had been cleaned the previous year and 60 percent (by weight) was linked to the crab fishery. Every year thousands of crab pots are lost when the ice pack in the Bering Sea shifts and shear off their buoy lines. There were 52 plastic bottles that weighed less than seven pounds. Most had foreign labels* (Bob King, MCA Foundation, Alaska).

From the available information it appears that with volunteer labour an expenditure of $400,000 is required to collect 171 metric tonnes of debris. However the past stock of debris may well still be impacting and discouraging current clean-up efforts.

Policy implications

One issue that has been significant among fishers is the cost of disposal of fishing net debris. Disposal costs are high in Alaska.

> *One fisherman came across a 5 ton section of net floating in the middle of the Bering Sea last year and brought it back to port to throw into the landfill, only to find they were going to charge him $10,000 in landfill fees. It appears the port already has 10,000 tons of nets in its landfill and they are having to spend millions to expand it. The fisher hauled the net back to Seattle and we worked out a deal to give it to a plastic recycler. We're looking at other options for plastic recycling and waste-to-energy that may help make disposal more reasonable* (Bob King, MCA Foundation, Alaska).

(c) Korean and Hawaiian examples of derelict fishing gear removal

Fishing leads to fishing gear being lost and it is costly to have it removed as can be seen in the following two cases.

The total cost and benefits of the clean up programs

Raaymakers (2007) reports data on the economic costs of derelict fishing gear (DFG) removal and clean up from the Republic of Korea, where over seven years (2000 to 2006), 12 429 million Won (approximately: US$13.5 million) were spent by the government to remove 10 285 tonnes of DFG from coastal areas, through a national coastal clean-up campaign, representing a cost of around US$1,300 per tonne of DFG collected (Hwang and Ko 2007).

The Korean effort is relatively cost-effective when compared to entangled net retrieval in the North-West Hawaiian Islands, which costs an estimated US$25,000 per ton (Raaymakers

2007). Wiig (2004) states that the 2003 expedition retrieved 120 tons of net at a cost of US$3,000,000, the major expense being two chartered boats at a cost of US$10,000 per day. This estimate does not include donated staff time or waived fee at the garbage disposal plant.

Policy

Wiig (2004) also states that in terms of costs per ton of removing DFG, the range from least to most expensive is (1) beached debris, (2) floating debris, (3) ghosts nets, (4) traps and (5) tangled net.

He recommends that the most cost effective approach is to provide economic incentives to fishermen to recover and return waste fishing gear themselves. In a Korean example of an 'incentive scheme' Incheon City pays fishers to collect and bring marine debris and DFG (Cho 2005). 'The compensation is $5 per 40 litre bag. If Icheon City collects and removes the derelict fishing gear directly, the cost would be at least US$48 per bag' (Cho 2005, 2009). However Cho also notes a concern that fishers may still believe it is acceptable to throw away fishing gear and if the incentive scheme was to stop in the future, debris may still be discarded and accumulate to unacceptable levels.

A4.5 Case study five: Can local municipal authorities meet the costs of collecting marine litter? An example from Peru.

Background

All through the APEC region local town and city municipalities face the responsibility of the collection of marine debris on the coastline. This case looks at one example from an APEC economy, but it is an issue in all APEC economies.

Extent of the problem

There are many cases of government being unable or unwilling to meet the cost of beach litter collections and non-government organisations often become involved due to the public benefit of clean beaches and a cleaner ocean.

The total cost of the debris removal program

There are no estimates of the magnitude and monetary costs related to the impact of marine litter in the Southeast Pacific. Much of the cost of cleaning the coastline falls to municipalities, picking up residues that are not totally generated by their resident populations or by tourists and visitors.

Alfaro (2006) presented the case of the municipality of Ventanillas, in Peru, which would have to invest around US$400 thousand per annum in order to clean its coastline, while its annual budget for public cleaning is US $200 thousand per annum. Alfaro also estimated that it would require approx US$2.5 million to cover labour costs for cleaning the entire Peruvian coast (in addition to the requirements of machinery and materials).

Marine litter puts pressure on the capacity for waste cleaning and management of coastal municipalities. Alfaro (2006) cites the experience of Playa de Carpayo, a beach which is only 500 metres in length, where the litter brought in by the sea is of such magnitude that it nullifies cleaning efforts. It must be pointed out that many coastal municipalities have severe technical and financial limitations to being able to remove marine debris to the required degree.

Costs and benefits

This example illustrates that many coastal municipal councils do not have any financial indicator of the benefits of their cleaning programs. Without such information additional marginal expenditure on clean up is unlikely to occur. This is an area where empirical cost benefit studies may assist the policy process.

A4.6 Case study six: The economic impact of marine debris on beaches and marine tourism in the US

There are numerous arrangements in APEC member economies to address marine debris on beaches. The clean up can be by government agencies, NGOs or even private sector interests. The presence of marine debris reduces the recreational value of beaches thereby discouraging some beach-users and reducing the net benefits of those who remain. Both sets of users suffer costs as a consequence, and there may be a further cost borne by industries which cater to beach users. This latter cost may be particularly serious in local economies which are heavily dependent on foreign tourists.

The value of beach recreation

A study by Edwards and Gable (1991) analysed property values in Southern Kingston, Rhode Island, to determine the economic value of beach recreation. Property values vary with distance from the beach, as well as with other attributes of the property, and it is possible to estimate the effect of distance from the beach on property value by means of cross-sectional analysis. The demand for closeness to the beach is the marginal property value with respect to distance plotted against distance. The consumer surplus generated by an individual - the value of beach recreation net of access costs - is calculated by integrating the demand curve. The capitalised value of consumer surplus for the average property and household income level was $20 100 (1980 US dollars), corresponding to an annual value of $1643 per household or $469 per person.

The economic impact of marine debris on beaches

A study of the benefits of a program of reducing marine debris would estimate the effect of less beach debris on the level of consumer surplus per beach user. The Edwards and Gable study does not address this question, but a paper by Smith *et al*. (1997) does. The approach was to show sample respondents in North Carolina and New Jersey a photograph of a debris-strewn beach and one of a series of four photographs of the beach after some degree of clean up. They were asked how much they would be willing to pay annually to effect the degree of improvement suggested by the latter photograph selected as compared with the former.

Depending on the degree of improvement indicated by the two photographs, willingness to pay varied from $72.18 to $21.38 (1993 US dollars) per respondent. The willingness-to-pay identified could represent a combination of use and non-use values: potential users of the beach are willing-to-pay for an improvement; and people who wish to have the option of using the beach in the future, or who never intend to visit the beach, are nevertheless willing to pay to have it cleaned to some extent.

Benefits and costs

Some of the results for beaches reported in Appendix Table 13 are similar to those of the Smith *et al*. study; the cost of a marine pollution incident is the difference between the annual consumer surplus yielded by the beach before and after the incident. However the expenditure losses reported in these studies may not be directly relevant. Expenditures on visiting the beach fall as a result of consumer visits being discouraged by the pollution, but this is not a net loss to the consumer; the money involved is diverted to other uses such as visiting inland parks instead. The net loss due to the pollution incident is the reduction in gross value - consumer surplus loss plus reduced expenditures - less the expenditures which are diverted elsewhere. In other words, the consumer surplus loss represents the cost of the incident to beach users.

The other examples in Appendix Table 13 represent the cost of damage to commercial or recreation vessels as a result of encounters with marine debris. These costs would be avoided if the marine debris were not present, and hence measure the benefit of a program which would eliminate the debris which caused the damage.

Appendix Table 3: Some examples of the economic effects of marine debris (Ofiara and Seneca 2006).

Beach closures		**Loss in consumer surplus (US$2002 millions pa)**	**Loss in expenditures (US$2002 millions pa)**	**Damage to commercial vessels (US$2002 millions pa)**	**Damage to pleasure vessels (US$2002 millions pa)**
Location	**Event**			**Repair cost**	**Repair cost**
Long Island NY 1976	Marine debris wash-ups		$31.4		
NY Bight 1988	Marine debris, medical waste	$1554	$2142	$792	$41
New Jersey	Marine debris medical waste bacteria wash-ups	$ 603	$1148		

It can be seen that the costs of marine debris on beaches reported in Table 13 are quite substantial. Beach users incur costs of between $0.5 and $1.5 billion per annum as a consequence of a single spill event. These figures are probably atypical in the APEC region as New York and New Jersey are very high income areas with heavily used beaches in close proximity to the population centres. The table also identifies reduced expenditures by those who decide not to frequent the beaches as a consequence of the spill. The issue of whether reduced expenditures should be regarded as a cost of marine debris spills was raised in the general discussion of the benefit-cost analysis methodology. There it was argued that reduced expenditure is not an additional loss to the beach user, who can switch her budget to other goods, and it is not necessarily a loss to the economy as reduced output in the beach recreation sector could be matched by increased output in sectors producing alternative goods.

However in some beach recreation sectors there may be significant fixed costs, such as hotel accommodation, and these sectors may suffer significant losses in the short and medium term. This outcome may be particularly relevant to developing economies with significant tourism industries. The third category of cost reported in Table 13 are control or clean up costs, which are a real cost to the economy. These are costs which have been undertaken to mitigate the damage caused by the spill. They are in the nature of an investment with returns in the form of lower damage costs than would otherwise have been the case; in the absence of clean up or control, the consumer surplus losses and expenditure reductions reported in Table 13 would have been even higher.

4.6.1 Discussion of the case studies

The case studies show the range of economic issues in the six different cases. The experience of economies like Korea in case study A4.4, is seen in their accounts of cities cooperating in cost sharing of marine debris clean up, the cost share for each city being based on accurate scientific data. This experience with cost sharing mechanisms could be used to address the international debris issues evident between China, Korea, and the Japanese economies in the East China and Yellow Sea area as seen in case study A4.3. Cost sharing mechanisms between economies can be used for remedial action such as the international debris problem in the North Pacific Gyre (Moore et al, 2001).

Korea has experience with a range of litter trap and litter boom/fence devices. The economics of these are important information for appraising future marine debris control in many other economies. Retrieving litter has led to innovative payment schemes to encourage fishers to collect and land marine debris and schemes to retrieve DFG. The case study information from Alaska indicates the range of issues in the source of the DFG, the cost of collection and the need to provide dump space or affordable recycling for old fishing gear. The case study in Puget Sound attempts to estimate the benefits of removing DFG and finds the return to removing DFG is positive in that study.

The case of the high marine debris expenses faced by a local council in coastal Peru, is one of the most common issues for municipalities in all the APEC economies. These costs need to be identified within economies and links with debris sources investigated. Preventative measures could then be applied.

The case of Hong Kong Harbour illustrates the way a marine debris cleaning scheme can be conducted and monitored in a closed water port area creating a useful monitoring index. The marine monitoring debris density index is a practical measure that could be used to indicate the marginal benefits of clean-up and is a measure evident to both administrators and cleaning contractors.

Overall the case studies show that economies are aware on a local level of the high cost of cleaning up marine debris. This study suggests that the clean up costs should be calculated nationally and consideration given to using funds to prevent debris from entering the sea, rather than just doing beach clean up.

These cases also show that there has been innovation in APEC economies in developing cost sharing agreements for clean-up operations in Korea, practical port based debris cleaning regimes in several economies and appraising the removal of derelict fishing gear to give sustainable fishery benefits.

Fuller development of prevention is required to yield greatest economic cost savings to economies. In several economies technical floating debris barrier devices have being deployed, but more needs to be done on prevention measures to reduce land sourced debris. This can involve economic instruments, such as sales taxes, deposit schemes and replacing plastics with degradable materials.

Reference for citation:

McIlgorm, A., Campbell H. F. and Rule M. J. (2008) Understanding the economic benefits and costs of controlling marine debris in the APEC region (MRC 02/2007). A report to the Asia-Pacific Economic Cooperation Marine Resource Conservation Working Group by the National Marine Science Centre (University of New England and Southern Cross University), Coffs Harbour, NSW Australia, February.

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