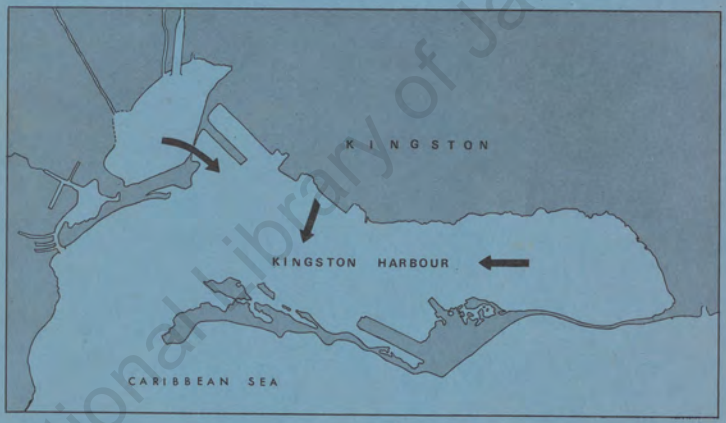
Barry A. Wade

THE POLLUTION ECOLOGY OF KINGSTON HARBOUR; JAMAICA

SCIENTIFIC REPORT OF THE U.W.I. - O.D.M.
KINGSTON HARBOUR RESEARCH PROJECT
1972 - 1975

VOLUME 3



BY

BARRY A. WADE

RESEARCH REPORT FROM THE ZOOLOGY DEPARTMENT
UNIVERSITY OF THE WEST INDIES. MONA
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THE POLLUTION ECOLOGY OF KINGSTON HARBOUR, JAMAICA

Scientific Report of the U.W.I./O.D.M.
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Volume III

Part 5 - Pollution Abatement and Harbour Improvement

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FOREWORD

This volume comprises Part 5 of a 5 - Part report on the pollution ecology of Kingston Harbour, Jamaica, which is arranged as follows:

Volume I		
Part	1.	General Introduction
	2.	Water Quality
	3.	Oxygen Balance
Volume II		
Part	4.	Benthic Ecology
Volume III		
Part	5.	Pollution Abatement and Harbour Improvement.

The work has been made possible by a 3 - year grant from the United Kingdom Ministry of Overseas Development to the University of the West Indies (Scheme R 2669) and by previous funding from the University's Research and Publication Fund. Much of it was done in conjunction with the monitoring program of the Government's Harbour Quality Monitoring Committee on which the author served as Vice-Chairman and supervisor of field work. I am therefore greatly indebted to these sources for their support.

I have benefited much from discussions with my colleagues in the Zoology Department and on the Kingston Harbour Quality Monitoring Committee, especially Professor Ivan Goodbody who has been a steady source of encouragement and advice.

I am grateful to the technical assistants who helped me in this work and to the many Government Agencies which willingly offered services of one kind or another. They have all been listed in the Foreword to Volume I.

I particularly wish to thank Mr. C. Bernard Lewis, former Director of the Institute of Jamaica, for many enlightening discussions on Kingston Harbour as it used to be and for bringing one reference to my attention which I would otherwise have missed.

To all who have been associated in any way with the publication of this report, I express my deep gratitude.

The work is dedicated to my wife and family who swim in Kingston Harbour no more.

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1. INTRODUCTION

Until the early 1960's, very little attention was paid to Kingston Harbour as a discrete biological or physical system although it had generally been regarded as a valuable national asset, contributing in no small measure to the success of the City of Kingston. However, following the establishment of the University of the West Indies Marine Laboratory at Port Royal, work was begun there in 1962 to investigate the biology of the harbour. This work, centering mainly on plankton and productivity, produced a picture of a highly productive body of water, however with certain environmental factors near their critical limit for the maintenance of a properly balanced system (Steven, 1965, 1966; Moore, 1967). Later, Munro (1968) conducted a bottom fish and shrimp survey of the harbour and revealed the prospects for a small-scale trawling industry there, while Goodbody et al (1969, 1970) reported on the important fish and shrimp nursery function of Dawkins Pond and Plumb Point Lagoon within the harbour. These studies, along with an earlier observation by Smith (1950), thus provided proof that Kingston Harbour was a highly productive body of water and therefore potentially capable of contributing significantly to food production in Jamaica.

However, by 1967, there was evidence that water quality in Kingston Harbour was deteriorating and, in that year, the Government of Jamaica (1967) reported on bacterial pollution from sewage in the harbour. The report, which was described as interim, drew attention to unacceptable coliform levels in much of the harbour and concluded "In view of the bacterial pollution indicated by this survey, waters along the north shore (of the harbour) and waterfront of Port Royal present an almost certain health hazard to bathers." Although the study was intended to be continued and despite the warning issued, no follow-up to this report was ever done.

Around the same time, the Government expressed some concern that physical development in and around the harbour was proceeding without due consideration to its effects on the harbour regimen . Hence, it was agreed that a plan should be formulated to ensure that neither development projects nor natural forces would in future jeopardize the harbour or existing facilities. A comprehensive engineering study was thus undertaken by a firm of consulting engineers (Government of Jamaica, 1968) leading to the preparation of an authoritative guide for the development of Kingston Harbour and environs. This study identified certain critical aspects of the physical regimen , and made several recommendations for ensuring the stability of the harbour. This work is still the major guide for physical development in the harbour environ.

Realising the increasing physical and biological stresses which were being brought to bear on the harbour and taking cognizance of further deteriorating conditions, Goodbody (1968, 1970) reviewed the essential physical and biological features of the harbour and made recommendations for an integrated study comprising a comprehensive biological survey of the harbour and an investigation of the effects of pollution and development on the communities of animals and plants. Also, realising certain inadequacies in the previous engineering report, a study of water movement and circulation in the harbour was proposed. However, these proposals were not immediately acted on although individual studies by scientists at the University of the West Indies Marine Laboratory continued.

The Government of Jamaica's (1967) and Goodbody's (1970) concerns about increasing pollution in the harbour were supported by a feasibility study on sewerage for Kingston and St. Andrew conducted by a firm of consultants for the Government of Jamaica (1970). This study considered the ability of Kingston Harbour to continue to receive domestic and industrial sewage effluents and concluded that "the dis-

charge of increased waste loads into the Inner Harbour will have a definite detrimental effect with eventual complete ecological breakdown." However, since it was not possible to quantify the effect of future discharges without certain baseline data on harbour conditions, an environmental monitoring program was recommended to collect data regularly on the harbour condition. This recommendation was accepted by Government and monitoring was begun in 1971.

In the meanwhile, however, accelerated deterioration of the harbour was being observed by Wade in his studies of the benthic communities and the alarming decline was reported in Wade (1972a, 1972b) and Wade et al (1972). In short, these papers documented an unexpectedly rapid spread of abiotic conditions in the harbour as organic pollution increased and predicted that if the pollution were not stopped, the entire bottom fauna of the harbour could be destroyed.

All of these warnings eventually resulted in the initiation of the following studies at the University of the West Indies Marine Laboratory: a study of physical conditions and water movement (1970 - 1972), funded by the Nuffield Foundation, U.K.; a study of zooplankton (1970 - 1973) (Grahame, 1974) and phytoplankton (1971 - 1973) funded by the Government of Jamaica; and a study of soft-bottom communities and oxygen balance (1972 - 1975) funded by the Ministry of Overseas Development, U.K. The present report is the result of work carried out under the O.D.M. grant , and, in a way, concludes the recent studies on the ecology of Kingston Harbour (see also Wade 1976a, 1976b).

All of these studies were conducted concurrently with the Government's monitoring program administered by the Kingston Harbour Quality Monitoring Committee. This committee, drawing its membership from the Government and the University, was set up under the chairmanship of Professor Ivan Goodbody of the Zoology Department, University of the West Indies,

while the actual monitoring functions were supervised by U.W.I. personnel at the marine laboratory. From 1972 to 1975 when monitoring ceased, this author was responsible for running the program.

During its active life, the Kingston Harbour Quality Monitoring Committee, produced two annual reports in 1971 and 1973 and a number of subject reports on special topics. These reports, while not comprehensive in the presentation of scientific data, highlighted the main conclusions and recommendations drawn from the monitoring program as well as from the work of the University of the West Indies scientists. However, none of the recommendations has yet been acted on and the committee has ceased to function.

The present report, of which this is the third volume, presents all the data collected under the O.D.M. project as well as the data collected for the Kingston Harbour Quality Monitoring Committee. It also refers to the work of other University of the West Indies scientists and discusses the conclusions and recommendations made by the monitoring committee. In so doing, the author hopes to synthesise all existing information on Kingston Harbour and to present the material in such a way as to evoke responses from those who are in a position to make the decisions necessary for abating pollution in the harbour and developing its resource potential to the fullest.

2. THE STATE OF KINGSTON HARBOUR

2.1 Physical Condition

Kingston Harbour (Fig. 1) is a physiographically complex system which, historically, has maintained fairly stable conditions of shape, depth and water characteristics. However, in recent times, man-made changes have occurred such as the removal of mangrove swamps, the reclamation of low-lying areas, river and drainage diversions, dredgings, fillings and a causeway construction. Specifically, within the past ten years, the following major works have occurred:

1) The construction of the Oil Refinery compound, Newport West and Newport East (1963 - 1968);
2) The construction of the transhipment port (1973 - present);
3) The construction of the Hunts Bay causeway (1969);
4) The reclamation and filling of much of Dawkins Pond (1969 - present);
5) The construction of a navigable channel linking Dawkins Pond with the Outer Harbour (1970); and
6) Filling of the shore adjacent to the cement factory (1965 - present).

Further works including the extension of the airport runway and the creation of one or more causeways are also proposed.

The recent works have served to alter the stability of the harbour in a number of ways such as the sedimentation of Hunts Bay and possibly sections of the ship channel, and the erosion of the Port Henderson spit. However, the full extent of these physical changes is not yet understood and is possibly not final since the process of readjustment to the altered conditions is still taking place. Nevertheless, as further major works are planned, it is likely that more and maybe greater changes may occur

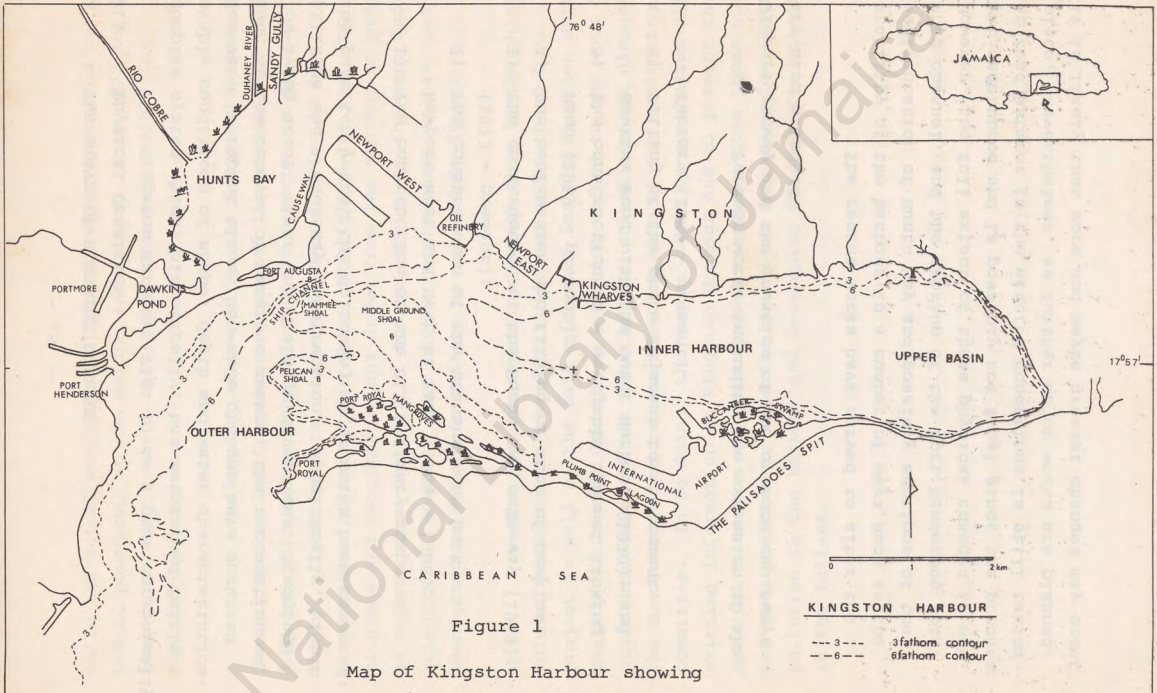

Figure 1

Map of Kingston Harbour showing its major features.

and, for this reason, resurvey programs should be carried out as recommended by the Government of Jamaica (1968) report.

2.2 Water Quality

Water Quality in Kingston Harbour may be discussed from the public health, ecological and aesthetic points of view. With regard to the first, the Government of Jamaica (1967) bacteriological survey clearly established the pattern of sewage pollution in the harbour and showed that at the time, the entire northern shore of the Inner Harbour and Hunts Bay as well as along sections of the Palisadoes and Port Royal had coliform bacterial counts which were in excess of 2,400 MPN / 100 ml or well above the limit regarded as safe for human contact (Fig. 2). Hence these areas were obviously unfit for bathing or any other recreational activities involving physical contact with water. More recent bacteriological measurements made in 1972 and 1973 have shown a similar pattern of bacterial pollution except that Buccaneer Beach on the south shore of Kingston Harbour and Dawkins Pond are now affected as well.

In that some of the polluted areas are used for intensive recreational activity, it is unfortunate that no action has been taken either to reduce the bacterial pollution or to control bathing where it occurs.

Ecologically, the most serious limiting factor in water quality is the dissolved oxygen (D.O.) concentration for, although the surface waters are well aerated, all parts of the harbour except the Outer Harbour have oxygen deficiency at the bottom (Wade, 1976a). This can be seen by reference to Figure 3 and to the following average bottom oxygen levels throughout the harbour for 1973 to 1975:

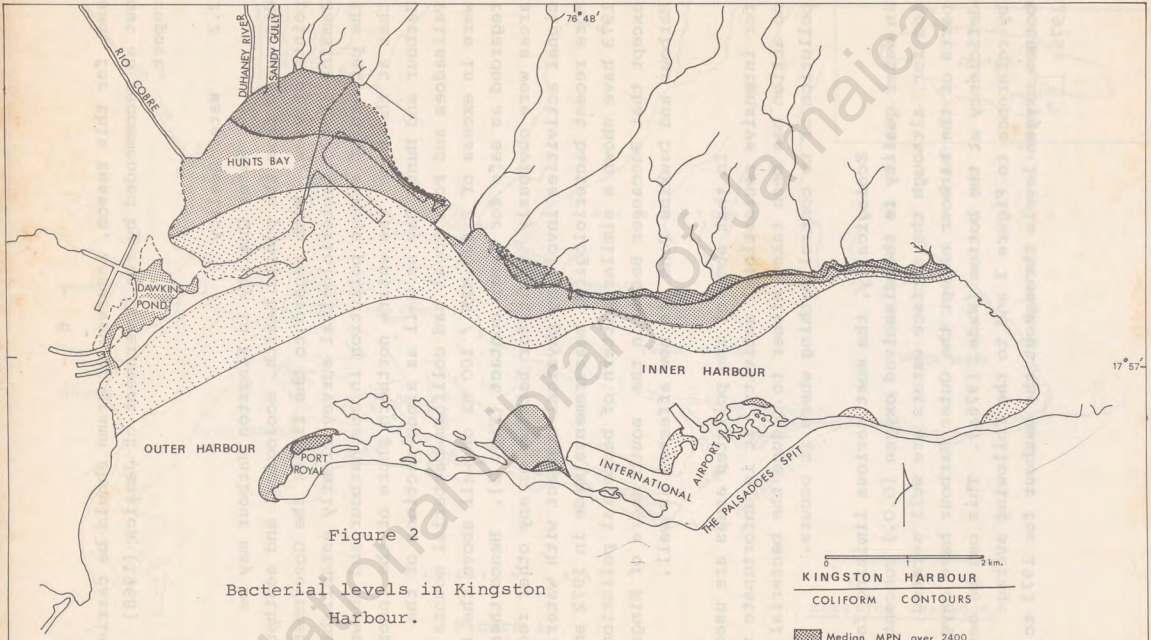

Figure 2

Bacterial levels in Kingston Harbour.

Outer Harbour	5.13 mg/l
Hunts Bay	3.68 mg/l
Inner Harbour (West)	4.34 mg/l
Inner Harbour (Central)	3.60 mg/l
Inner Harbour (East)	3.02 mg/l

The pattern of oxygen distribution is clear in that as one moves up the harbour, the D.O. levels at all depths below the surface decline. However, this decline is most rapid between the Outer and Inner Harbours and in the Upper Basin. In addition, bottom oxygen conditions in the Inner Harbour also deteriorate with depth and the worst conditions occur at the extreme eastern end of the Inner Harbour (the Upper Basin) where the average saturation level is less than 50%.

The monitoring data show that from 1971, the bottom oxygen conditions throughout the harbour have been deteriorating rapdily as may be seen from comparison of the oxygen saturation levels for the periods 1971 and 1973 to 1975:

	1971	1973-75
Outer Harbour	90.3%	82.7%
Hunts Bay	75.8%	59.3%
Inner Harbour (West)	72.6%	70.0%
Inner Harbour (Central)	56.5%	58.1%
Inner Harbour (East)	48.4%	48.7%

The greatest decline has occurred in Hunts Bay and the Outer Harbour in the main body of the harbour although smaller areas such as the Newport West shipping basin and parts of Dawkins Pond appear to have suffered even greater oxygen decline.

The main reasons for low oxygen levels in the Inner Harbour and Hunts Bay are poor tidal circulation and the

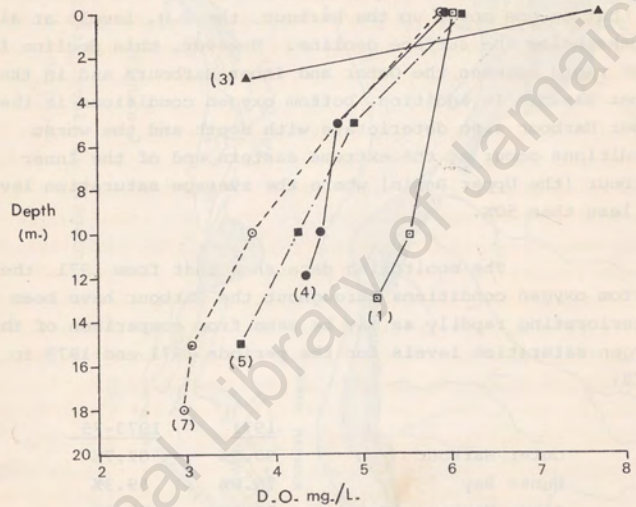

Figure 3

Average dissolved oxygen profiles (1973 - 1975) for 5 monitoring stations in Kingston Harbour: (1) Outer Harbour, (3) Hunts Bay, (4) Inner Harbour (West), (5) Inner Harbour (Central), and (7) Inner Harbour (East).

high demand for oxygen exerted by the water and bottom sediments. Under normal conditions in the Inner Harbour, the oxygen demand exerted by the water is 2.5 times that exerted by the sediments while in Hunts Bay the oxygen demand exerted by the sediments is similarly greater than that exerted by the water. During plankton blooms, however, which are now frequent, the oxygen demand of the water may increase by as much as five times. At such times, especially in the Inner Harbour , the total demand for oxygen exceeds the possible supply and the water becomes anoxic.

Under normal conditions, most of the oxygen demand (more than 80%) exerted by the water is due to dissolved organics consisting of soluble land discharges, waste effluents and metabolic byproducts of marine fauna and flora. Hence, suspended solids in the water exert only a minor portion of the oxygen demand. During plankton blooms, however, most of the oxygen demand is exerted by plant and animal cells which proliferate at such times along with faeces and detrital matter. Soluble organics also increase their oxygen demand during blooms, presumably on account of the greater amount of metabolic wastes generated by the plankton, but the increase is less than one tenth that of the particulate material.

The highest oxygen demand in Kingston Harbour is normally exerted by the water in Hunts Bay where the average 5-day Biochemical Oxygen Demand ($B.O.D._5$) is 7.25 mg/l, while the lowest is in the Outer Harbour where the average $B.O.D._5$ is 3.51 mg/l. All other areas in the main body of the harbour have intermediate values depending on their distance from Hunts Bay and the Newport West to Newport East area where the main waste discharges are situated. Normally, the surface water exerts a higher oxygen demand than the bottom water.

The harbour water usually exerts its highest oxygen demand during the rainy months due to increased run-off and waste discharges. However, with the addition of nutrients at such times, plankton growth is encouraged and blooms are

most common then. During one bloom studied, the B.O.D. reached as high as 31.2 mg/l.

Certain small areas have surface B.O.D. values which are higher than those for the main body of the harbour. For example, Dawkins Pond, which has frequent plankton blooms, has a B.O.D. of 7.2 - 19.8 mg/l. Other areas are the Newport West shipping basin (5.5 - 15.5 mg/l), Tivoli (7.2 - 39.3 mg/l), and Newport East (7.2 - 48.0 mg/l). All of these areas are marked by the discharge of at least one of the following wastes: sewage effluent, soap and detergent wastes, slaughter house wastes.

The proliferation of plankton in Kingston Harbour is due to the very high concentration of inorganic nutrients (nitrates, phosphates, silicates) which exist throughout the harbour. Hunts Bay has the highest concentration, followed by the Inner Harbour and the Outer Harbour, and all the nutrients show a seasonal distribution related to the rainfall pattern. Surface run-off after rains, waste discharges, submarine drainage and recycling of nutrients from the mud are the main factors affecting nutrient concentrations.

The increase in nutrient concentrations in the harbour since 1962 has been very great, especially for the phosphates and nitrates + nitrites and the greatest increases have been in the Outer Harbour(450% and 46% respectively). These have been attributed largely to the considerable increase in the amount of wastes being discharged to the harbour.

The increasing frequency of plankton blooms in all parts of the harbour may be linked to the increase in nutrient concentrations, and Kingston Harbour now exhibits all the typical characteristics of a eutrophic water body. Thus, whereas the surface waters have high oxygen concentrations, the bottom waters tend to be anoxic.

Kingston Harbour has never suffered from a major oil spill but minor spills occur fairly frequently due to the discharge of oil-contaminated bilge and ballast water at nights by smaller ships which do not have their own oil separation equipment. These discharges result in the formation of extensive slicks which, under the influence of land breezes at night, are transported over to the south shore of the harbour where they frequently foul recreational facilities at Gunboat Beach, Buccaneer Beach, the Yacht Club and Morgan's Harbour. In addition, the oil fouls fishermen's equipment and disfigures the paint work on boats. Hence, oil pollution in Kingston Harbour has aesthetic and economic nuisance effects but, as far as is known, does not significantly affect the harbour ecology.

Solid waste pollution in Kingston Harbour results in a considerable reduction in aesthetic appeal of the harbour water and consequently affects many recreational activities. There are three main sources of this pollution. First is the dumping of wastes in the landfill areas, notably along the Hunts Bay causeway and the cement factory fill. Second is the dumping of garbage in gullies which, during rains, discharge their contents into the harbour. And third, is the disposal of refuse from ships. These wastes also affect small boat operators with outboard engines by fouling and sometimes damaging propellers, and fishermen have made several complaints about the problem.

The common feature about all forms of pollution in Kingston Harbour is the rapid way in which deterioration has occurred. This deterioration has now been documented for several water quality parameters (Wade, 1976a) and no further proof should be necessary. If no steps are taken to abate the pollution, complete ecological and aesthetic destruction of Kingston Harbour will inevitably occur.

2.3 Biology

Kingston Harbour is an area of high primary production with large standing crops of plankton being supported by high nutrient concentrations. However, the water is over-enriched with nutrients and eutrophic conditions have resulted especially in the Inner Harbour and Hunts Bay. This has been evidenced by the frequent occurrence of phytoplankton blooms which cause supersaturation of oxygen in the surface waters and lack of oxygen in the bottom waters (Wade, 1976a). Due to this lack of oxygen, bottom-dwelling animals cannot survive and the plankton therefore cannot be effectively utilised in food chains which could produce food for man.

Wade (1976b) has shown that the mud-bottom communities in the Inner Harbour have been completely destroyed due to poor oxygen conditions and that the Hunts Bay communities have been greatly affected (Fig. 4). Also, the Outer Harbour communities are now being affected. If pollution continues to spread at the present rate, it is predicted that the entire harbour bottom below 5.5 m (3 fathoms) depth could become abiotic or dead by 1990.

Munro (1968) showed that a profitable trawl fishery could be developed in Kingston Harbour based on bottom-dwelling fish and shrimp populations. However, these resources have also been destroyed by pollution and the fishery potential no longer exists. Similarly, sport fishermen angling for pelagic fish have reported great reductions in catch due to declining populations especially in the Inner Harbour.

It is uncertain to what extent fish and shrimp nursery grounds in Dawkins Pond, the Port Royal mangroves, Plumb Point Lagoon and Buccaneer Swamp have been affected by pollution and the destruction of mangroves. However, my belief is that it has been great.

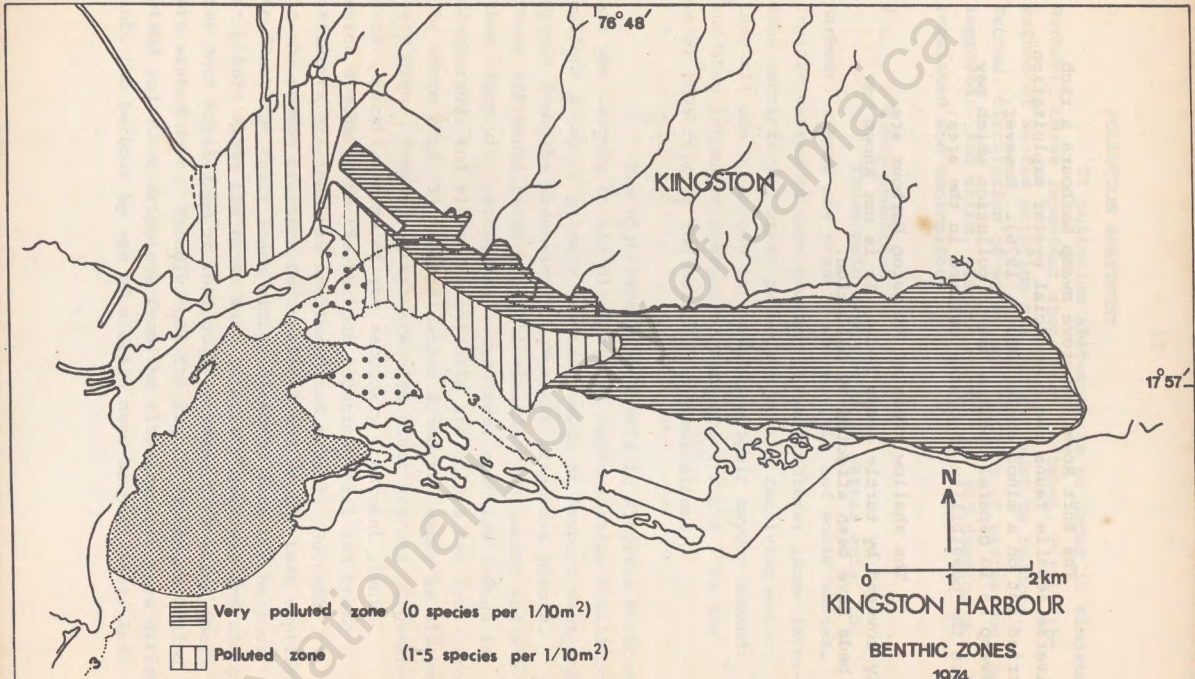

Figure 4
The distribution of benthic zones in Kingston Harbour according to the degree of pollution.

The Port Royal mangrove swamp harbours a rich and diverse sessile fauna and commercial oyster exploitation is carried out on a minor scale (Siung, 1976). However, this swamp is in general decline due to pollution which may threaten the possibility of oyster culture in the area.

The shallow areas of Kingston Harbour are largely covered by turtle grass beds. It is not known how these beds have been affected by pollution.

3. POLLUTION ABATEMENT

If pollution abatement is to occur in Kingston Harbour, three important steps must be taken. First, the volume of wastes entering the harbour must be reduced. Second, circulation of water and dilution of wastes must be improved. And third, illicit discharges and dumping must be regulated and controlled.

3.1. Waste Reduction

Three main categories of wastes enter the harbour. These are organic wastes, oil and solid wastes. Organic wastes in turn produce three problems: some introduce bacteria and other pathogens to the receiving water; they all use up oxygen in satisfying their oxygen demand; and they introduce inorganic nutrients (N & P) to the water thus raising the nutrient concentrations.

The high bacterial levels in Kingston Harbour are due largely to the discharge of approximately 7 million gallons a day of primary treated sewage at Newport West and Tivoli from the Greenwich and Western treatment plants. These effluents receive no chlorination whatsoever and are thus laden with pathogens. Sometimes, even raw sewage is discharged, and since the outfalls are only a few feet from the shore (Fig. 5), contamination along the shore is always very high. However, there are also other sources of pathogens. Firstly, some of the secondary treatment plants which discharge to the harbour sometimes fail and their effluents are then raw unchlorinated sewage. Secondly, it is the common practice for cesspool and septic tank emptiers to discharge their loads either directly into the harbour at points along the shore such as at the causeway and along the Port Royal road or into gully courses from which they are washed down. Thirdly, all the liquid wastes including blood and other drippings from the city abattoir flow directly into the harbour by way of a drain near Newport East. And

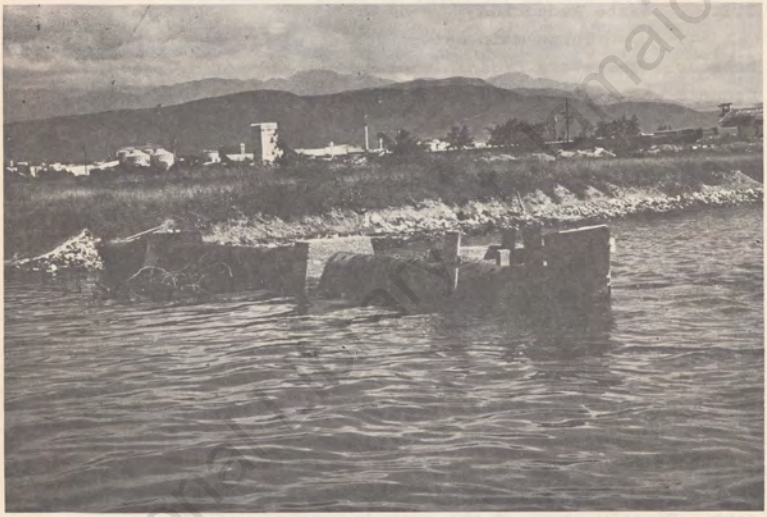

Figure 5

This sewer outfall from the Western Treatment plant discharges more than 3 million gallons a day of primary treated sewage into Kingston Harbour

fourthly, all the run-off from the roads, gullies and drains ends up in the harbour.

It is clear that no great improvement in bacterial levels will occur unless the Greenwich and Western treatment plant cease discharging unchlorinated effluent into the harbour, and this will only be feasible if the method of treatment is upgraded. However, while there is talk of this for the Greenwich plant, no such plans exist for the Western plant. Since both of these plants are owned and operated by the Government's Water Commission, the responsibility for remedying this unhealthy aspect of Kingston Harbour rests squarely with them.

The same is true for the city abattoir which is operated by local government. There can be no justification for this kind of operation polluting the harbour in such a gross way.

It is desireable that the illicit activities of cesspool and septic tank emptiers be stopped, and it should not be too difficult to do so. This, together with the discontinuance of the Greenwich and Western treatment plants and city abattoir practices would largely clear up the bacterial pollution of the harbour.

It has been estimated (Wade, 1976a) that if the oxygen demand in the Inner Harbour is not to exceed the supply and hence if proper oxygen conditions are to be restored, a B.O.D. reduction of the water of not less than 30% must occur (from 4.05 mg/l to 2.82 mg/l). But since approximately 50% of the B.O.D. load to the harbour is contributed by "natural" discharges over which there is no control, the overall 30% reduction would have to be directed at the deliberate discharges. This is equivalent to a 60% reduction of their present load and, in order to accomplish this, every major discharge would

have to be drastically reduced or discontinued altogether. This includes the two large municipal sewage treatment plant effluents plus those from thirteen smaller ones, the slaughter-house wastes, the soap and detergent wastes, the brewery wastes, the dairy wastes and a number of smaller food processing wastes (Fig. 6). No less a reduction would have the desired results.

This, however, is an undertaking of immense proportions and we should not lead ourselves into believing that it can be tackled in a piecemeal fashion by imposing effluent standards on individual dischargers. Only a comprehensive program aimed at providing a proper central domestic and industrial sewage collection, treatment and disposal (outside the harbour) system would seem to be adequate, and this should therefore be considered of highest priority. In the meanwhile, however, no new discharges of any size should be allowed so as not to increase the present problem and to make correction that much more difficult.

The dissolved oxygen deficiencies in the harbour can only be properly solved if plankton blooms are controlled. In order to do this, nutrient concentrations will have to be reduced at least as much as the B.O.D. levels and preferably to the pre-1962 concentrations in the Inner Harbour (for PO_4 - P from 0.77 µga/l to 0.23 µga/l or a reduction of 70%). Since like the B.O.D., much of the nutrients come from natural discharges, the necessary reduction will have to be brought about by the control of nutrient-laden wastes, and this too can only be accomplished by centrally collecting, treating and disposing such wastes outside the harbour.

It has been estimated by the Kingston Harbour Quality Monitoring Committee (1971) that nearly all the oil pollution in Kingston Harbour originates from about 30% of the

Figure 6

High B.O.D. soap and detergent wastes being discharged to Kingston Harbour.

ships which use the harbour and do not have their own oil separation equipment. Therefore, in order to prevent oil pollution, some on-shore tanks will have to be provided for these ships so that they may discharge their oil-contaminated bilge and ballast water directly into them. It has been suggested that the cost of providing such a facility plus an inspectorate could be met by a comparatively modest increase in harbour dues of the order of 10 - 15%.

Nevertheless, despite the best precautions, accidental spills are likely to occur from time to time, and it is therefore necessary that the port be equipped with proper facilities for dealing with these spills. At present, the only clean-up facilities in the port of Kingston are owned and operated by the Jamaica Oil Control Committee set up by the three oil companies operating in Jamaica. However, these facilities are modest and should be upgraded, perhaps in conjunction with the Government. Furthermore, oil clean-up capabilities should rely on containment and recovery of the oil by booming and pumping rather than on dispersing with detergents since this method would aggravate an already serious oxygen deficiency problem in the harbour and possibly cause toxic reactions in animals and plants.

The problem of solid waste pollution in Kingston Harbour is primarily the result of improper waste management practices in the city of Kingston and will only be solved when adequate waste disposal arrangements exist. These include the reliable collection of garbage, the maintenance of gully courses, and the provision of suitable dumping and sanitary land-fill sites some distance away from the edge of the harbour (Fig. 7).

3.2 Water Circulation

The problem of excessive waste discharges to Kingston Harbour is compounded by the fact that due to the

Figure 7

Solid waste dumping along the causeway in Kingston Harbour.

shape of the harbour and the small tidal amplitude, the harbour has a low flushing rate and hence the rate of removal of wastes from the harbour to the open sea is slow. Furthermore, circulation within the harbour is mostly wind-driven, and under low wind conditions, the waters of the harbour are not mixed very well (Wade, 1976a). Hence, two factors necessary for ensuring the health of a receiving body of water, namely good dilution and dispersion, are absent from Kingston Harbour. In addition, the creation of man-made enclosures and embayments within the harbour has made the problem worse by reducing circulation in these places even further.

The outstanding example of this is Hunts Bay where a solid-fill causeway was constructed across its mouth in 1969 leaving an opening of only 213 metres (700 ft.). With this construction, exchange of water between Hunts Bay and the rest of the harbour was immediately affected and the water in the bay became stagnant and oxygen depleted. As a result, pollution increased and the fauna became impoverished.

It has been estimated (Wade, 1976a) that in order for Hunts Bay to recover, the pollution load to it will have to be reduced by half and its flushing rate increased by as much as ten times the present. This is a virtual impossibility unless the existing causeway is completely modified to allow for free passage of water underneath its entire length and, since this seems unlikely, Hunts Bay appears to be doomed to a permanently polluted condition.

When the causeway was constructed, Dawkins Pond which was previously connected with Hunts Bay was cut off from it and a new opening was constructed across the Port Henderson spit and into the Outer Harbour. This opening has partly relieved the flushing problem in Dawkins Pond although

it has created new ones for the Outer Harbour (see Wade, 1976a) and the Port Henderson spit (see later on). However, with the subsequent development of Dawkins Pond, a number of long, narrow and sometimes deep finger canals have been constructed to provide boatways leading from the main body of the pond. Apparently, proper circulation in these finger canals was not a design criterion, and already some have become stagnant and polluted. It may not be too late to modify these canals and, since they are in residential areas and are subject to recreational use, due consideration should be given to this possibility.

The Newport West shipping basin is another area where circulation has been reduced by partial enclosure. However, it seems virtually impossible to make any improvements here.

It has been suggested that one way of abating pollution in the Inner Harbour is by constructing an opening to the sea across the Palisadoes spit at its eastern end, thus improving circulation and the flushing rate. Such an opening would either be a navigable channel or a subsurface pipe connection. Although this proposal has seemed attractive to a number of persons, it needs to be critically examined in the light of the criteria necessary for pollution abatement and the overall effects which such a scheme could have.

I have estimated (Wade, 1976a) that for such a scheme to be completely effective, it would have to increase the flushing rate in the Inner Harbour to six times the present, especially in the bottom water where the oxygen deficiency is greatest. In order to accomplish this, the opening would therefore have to be approximately 18 metres (60 ft.) deep to ensure exchange of bottom water between the Inner Harbour and the open sea and between 0.5 and 0.8 km (0.3 and 0.5 mile) wide to allow for free flow of the tidal prism without excessive

currents (0.6 to 1.0 knot) being created. Even then, it is uncertain that the tidal flow would properly flush the central parts of the harbour which could end up being in a tidal node between the east and west openings of the harbour.

The Government of Jamaica (1970) sewerage report for the city of Kingston recommended that with implementation of a central sewerage system, all the effluent should be discharged after only primary treatment to the open sea off Harbour Head. If this were done, then it is highly likely that opening the Inner Harbour to the open sea would result in sewage-contaminated water flowing back into the Inner Harbour from the open sea and thus contributing further to the pollution problem. Clearly, therefore, both of these schemes could not be implemented.

It is this author's opinion that those who have suggested opening the Inner Harbour have not considered the enormity and cost of the undertaking. Firstly, dredging a half mile channel to a depth of 18 m (60 ft.) across the spit and into the surf zone would require very major engineering. Secondly, the airport road would have to be modified and a long-span bridge constructed. And thirdly, the channel would have to be protected and maintained against destruction from storm waves and siltation by normal littoral drift. It is indeed doubtful that such effort and expenditure could be justified merely by the expected improvement in water quality in the Inner Harbour.

Most importantly, however, is the fact that the Palisadoes spit on which the Norman Manley International Airport is situated has been built up and is maintained by littoral drift of sediments from the east, and any interruption in this flow of materials would result in downdrift erosion and breaching of the spit. Hence, as the Government of Jamaica (1968) report has stressed, no development along the Palisadoes

that would interrupt the continuous flow of .ittoral drift along the seaward side should be allowed. S.nce it is certain that creating a deep channel between the Inn.r Harbour and the open sea would do just that, such a scheme w.uld have to be prohibited.

One other problem about creatig an eastern channel is the possibility that undesireable currents could be set up within the harbour possibly result.ng in new siltation patterns. If this occurred, the shippin lanes could become affected thus requiring more frequent and costly maintenance.

For all the reasons outlined above, I do not recommend that opening the Inner Harbour to .he open sea be adopted as a method of abating pollution in :ingston Harbour.

3.3. Regulation and Control

The maintenance of acceptable .ater quality in Kingston Harbour is only possible if wast. discharges can be regulated and controlled by enforceabe laws and a powerful regulatory body. At present none o these exists as the excerpt from the first annual report o the Kingston Harbour Quality Monitoring Committee (1971) .learly points out (Appendix). Hence, it is only possible .t this stage to discuss the criteria necessary for such r.gulation and control and to indicate how they should be a.plied in setting up the required mechanisms.

In order to restore acceptable bacterial levels in Kingston Harbour, it is imperative that t.e present primary sewage treatment plants and the city abattoir be upgraded or cease operation altogether. How.ver, since all of these are government owned and operated, t is unlikely that legal measures can be used to achieve t.e desired results. Hence, if the Government is serious about ab.ting this pollution,

it should be expected to take the required measures without the presence of a legal threat. In fact, the same is true if the total waste load to the harbour is to be reduced by 60% since there is no doubt that Government operations contribute by far the greatest amount.

If a proper central sewerage system is set up with disposal outside the harbour, then all the present government and private operations which generate sewage and other organic wastes should be made to connect to it and hence cease discharging into the harbour. Some of these wastes may have to be pretreated at the point of generation before linking with the system, but without this central system, it is unrealistic to expect that as much as a 60% organic waste reduction could be achieved by merely upgrading existing facilities or by improving housekeeping practices. Hence, until the central sewerage system is in, it is pointless to attempt the enactment and enforcement of any effluent standard legislation as the means of achieving the required waste reduction. Unfortunately, at the time when this could possibly have been effective, it was not done, and the fate of Kingston Harbour must therefore now rest on a much more comprehensive scheme involving the diversion of all wastes now being discharged to it. It is only after that that a really effective program can take place to regulate and control the discharge of sewage and other organic and nutrient-laden wastes to the harbour.

This does not mean, however, that no kind of waste control is desireable or possible at this time, for practices such as the discharge of the loads from cesspool emptiers and the dumping of garbage into the harbour are inexcusable and should be easy to control under existing public health legislation. That they are not can be interpreted more as a sign of apathy and inefficiency on the part of the relevant authorities than of inability.

One special case exists, however, with regard to the discharge of oil wastes, and the Kingston Harbour Quality Monitoring Committee (1971) has examined this problem in depth and recommended a number of very practical solutions. The following are direct quotes from their first annual report.

"Pumping bilge water or ballast water into the harbour is an offence under the Harbours Law but under existing conditions it is almost impossible to bring a successful prosecution for the following reasons:

(1) Unlike Harbour Departments in most ports the Harbour Department, Kingston, does not have as part of its staff a section dealing with the policing of the Port of Kingston.

(2) The Port of Kingston has no court dealing strictly with marine cases.

(3) Offences are usually committed at night.

(4) The Harbour Department can only take the same course as is open to any member of the public, i.e. request the police to prosecute.

(5) The delay in getting a case into court usually results in ships being allowed to sail, and returning with crew changes, making prosecution even more difficult.

(6) On the occasions prosecution has been successful, the fine imposed could hardly have been regarded as a deterrent.

(7) A successful prosecution often requires tangible evidence in Court in the form of a sample of bilge water collected from the effluent of the ship during discharge. This is almost impossible to collect."

"On the basis of its discussion so far the Committee therefore makes the following recommendations for urgent action:

(1) That the Harbour Department should have attached to it a Harbour Patrol Service, quite independent from the Water Police, charged with implementing the Harbours Law.

(2) That the Harbours Law should be amended in such a way as to permit summary action against offenders. The Committee considers that the best mechanism for achieving this is the establishment of a special Marine Court charged with trying offences against the Harbours Law and empowered to detain ships until such time as the Master or other Officers have appeared before the Court and, if necessary, either paid fine or a bond.

(3) That shore based facilities should be installed at all docks into which bilge or ballast water may be pumped for transfer to the refinery for separation.

(4) That when recommendations 1 to 3 above have been implemented, the Harbours Law should be amended so as to drastically increase the fine imposed for pumping oily wastes into the harbour whether from ships or from other sources."

These are only some of the recommendations of the Committee but, despite their pleas for urgent action, it is regrettable that since 1971 when they were made, they have not been acted on. Nevertheless, these recommendations are still sound and even more urgent today, and it is therefore hoped that they will soon receive the attention and action they deserve.

It is not known for sure whether any directly toxic wastes are discharged to Kingston Harbour. However, if such wastes were found, it should not be difficult to prohibit further discharge under the provisions of the Public Health Law providing that proper evidence and documentation

were obtained. Presumably, this would be done by the newly established Environmental Control Division of the Ministry of Health and Environmental Control.

Dredging, mangrove destruction and land reclamation are activities which have contributed to the deterioration of Kingston Harbour. These are now under the control of the Natural Resources Conservation Authority which administers the Beach Control Law, and it is hoped that with the greater technical expertise now available to this Authority, future applications for carrying out these activities in Kingston Harbour will be more critically examined in the light of their possible effect on the harbour ecology.

4. HARBOUR IMPROVEMENT

Despite the deterioration of Kingston Harbour, numerous plans exist for developing its resources even further. This section discusses some of these plans and comments on their likely impact on the harbour ecology. It also indicates how they might be improved by better results.

4.1. Physical Development

The most extensive physical development now taking place is the reclamation of the Hunts Bay and Dawkins Pond mangrove wetlands for real estate development. This scheme has involved the filling of several hundred acres of mangrove swamps, the blocking off of Dawkins Pond from Hunts Bay, the creation of a navigable channel across the Port Henderson spit linking Dawkins Pond with the Outer Harbour, and the construction of finger canals leading from Dawkins Pond. In addition, further mangrove clearance is envisaged for Hunts Bay.

The mangroves of Hunts Bay and Dawkins Pond once harboured a rich bird fauna, and the commercial Caribbean oyster used to be exploited heavily from the roots of the red mangrove in Dawkins Pond. These are no longer so, and it is not expected that further mangrove clearance in these areas will have any adverse effects.

Although the Government of Jamaica (1968) report on Kingston Harbour advised that a navigable entrance to Dawkins Pond across the Port Henderson spit could create an erosion problem at downdrift beaches, such a canal was nevertheless built in 1970. As predicted, this erosion is taking place and many houses on the spit have been damaged by the advancing sea or are being threatened. Elaborate beach protection works may now be necessary to prevent further erosion and, certainly, no more such channels should be created.

The finger canals in Dawkins Pond have very inadequate flushing characteristics and the water quality in them is already poor (a secondary sewage treatment plant discharges into one of these canalas and roads drain into others). It is recommended that these canals be modified by making them no more than 2 metres (6.6 ft.) deep or that they be filled in completely. It is also recommended that the construction of future finger canals be discouraged because of inadequate tidal circulation which makes the flushing rate very slow. Indeed, these finger canals have been an imported feature of real estate development from areas where, even though the tidal range is much greater, they almost always become polluted, and they must therefore be considered an undesireable feature of waterfront development in Jamaica. It is interesting to note that a similar recommendation has recently been made about these structures in Grand Cayman (Wickstead, 1976).

The Government of Jamaica (1968) report outlined a plan for the physical development of the Palisadoes spit between Harbour Head and the international airport for recreational purposes. This plan incorporates raising the level of the existing roadway for scenic viewing, landscaping, park development, and the construction of a beach walkway, fishing jetties and parking turnouts. An important feature of the plan is that there should be no development along the spit that would interrupt the continuous flow of littoral drift along the seaward side.

This is a good plan which, if implemented, would do much to enhance the aesthetic enjoyment of Kingston Harbour and help to ensure the stability of the Palisadoes spit.

There have been proposals from time to time to develop the Port Royal area into a hotel, recreational and historical resort, and part of the plans call for reclaim-

ing some of the mangrove swamps and creating marinas, boat channels, and the like. While much of the development concept is good, the severe alteration of the mangrove swamps would almost certainly result in altering the ecology of the area, thus affecting its food production potential as well as its natural recreational, educational, and scientific value. The case for preservation of the Port Royal mangrove swamps between Port Royal and the international airport has been strongly argued by Goodbody (unpublished report) and other scientists, and it is supported here in the light of its obvious merits. In the next section, the food production potential of these mangrove areas will be discussed.

The mining of sand for building material from Hunts Bay and shallow areas of the Inner and Outer Harbours has been proposed by some persons. While this is feasible in Hunts Bay and would ease the siltation problem there, it would be very harmful in the rest of the harbour since it would result in destruction of the turtle grass beds and increase the amount of suspended silt in the water. These would in turn depress the already critical oxygen levels in the harbour by cutting off the large contribution of oxygen from the turtle grass blades and by increasing the oxygen demand of suspended particulates. For these reasons plus the fact that the feeding grounds and nursery areas of several fish would be destroyed, no such mining in the Inner and Outer Harbours should be permitted.

The construction of the Hunts Bay causeway has proved to be ecologically disastrous, yet another causeway has been suggested linking the Palisadoes spit between the airport and Port Royal with the Hunts Bay causeway at a point near to Fort Augusta. This would reduce the road distance from the new town of Portmore to the airport from sixteen miles to six. Like the present causeway, this one

would also be solid-fill leaving only an opening across the ship channel for the free passage of ships. Since it has already been pointed out that circulation and tidal flushing in the Inner Harbour are poor and are partly responsible for its severe oxygen deficiency, it should be immediately obvious that any such construction would drastically increase the problem and lead to inevitable destruction of the Inner Harbour. Hence, no such plan should be entertained and if a road link must be built between the two points, it should be raised on stilts along its entire length to allow for uninterrupted flow of tidal water. The same is true for any other causeway links deemed necessary across Kingston Harbour.

4.2 Fisheries

As noted earlier, the bottom fish and shrimp fishery potential of Kingston Harbour has been destroyed by pollution. However, if pollution were abated, this could recover over a number of years.

Although the fish nursery grounds of Dawkins Pond, the Port Royal mangroves, Plumb Point Lagoon, and the Buccaneer Swamp have suffered some deterioration , they are still believed to play an important role in the life cycles of several commercially important species of fish. These grounds should therefore be safeguarded against further deterioration and their fish populations protected from over-exploitation.

The greatest fishery potential of Kingston Harbour now rests in mariculture and attempts are currently underway to initiate a pilot oysterculture research project based in the Port Royal mangroves. The project will examine the feasibility of cultivating the mangrove oyster, Crassostrea rhizophorae, on a large scale using experimental culture systems. This oyster occurs naturally on the roots of the red mangrove trees and is presently being harvested

by fishermen on a minor scale. However, if the culture techniques can be worked out and commercial production gets under way as in Cuba, then the returns could be worth several million dollars annually. Unfortunately, the pollution of the harbour could be a limiting factor on the production of oysters at Port Royal, and this possibility will have to be carefully examined during the pilot project. Moreover, before any long-term investment can be made in oyster culture in the Port Royal area, some assurance will be necessary that the environment will not be disturbed by real estate or other development. Since it is proposed that the pilot project will be completed by 1980 at the latest, the urgency for a commitment to the protection of the area is therefore pressing.

4.3 Recreation

Kingston Harbour is the largest, most accessible and most used open space in the city of Kingston, providing a wide range of recreational opportunities for its population. In addition, it has a largely untapped tourist potential as Riley (1969) has pointed out: "The Kingston Harbour region has the opportunity to develop into a very significant tourist playground and current developments are likely to be just the forerunner of much bigger things to come." However, since this was written, the recreational and tourist potential has been severely limited by pollution of the water, uncleanliness of the surroundings and lack of certain basic facilities although certain activities continue to be popular with the public, in particular bathing at the Gunboat and Buccaneer beaches.

There is no doubt that if water quality in Kingston Harbour were improved, many more persons would be disposed to using it as a recreational outlet. Indeed, it would appear that only those who are limited by lack of private transportation continue to bathe at Gunboat and Buccaneer

beaches or the beaches along the northern shore of the harbour, and therefore bathing in Kingston Harbour is not by first choice.

The development of certain facilities would also enhance the attractiveness of the harbour and the suggested conversion of the Palisadoes spit into an extensive marine park with boating marinas, floating platforms, beach walkways, parking turnouts and scenic corridors would go a far way towards drawing many more people towards Kingston Harbour as their major recreational outlet.

5. DISCUSSION

That Kingston Harbour is a multi-purpose resource of immense value to the city of Kingston and the island of Jamaica cannot be denied. It is the major deep water port of the island making Kingston its centre of trasnportation, trade and commerce. It has also been used for the creation of valuable real estate as several low-lying areas have been cleared and filled for the siting of industrial, commercial and residential complexes. Furthermore, despite the destruction of valuable nursery grounds and the decline in fish populations, it is still a major centre for the island's nearshore fishery and provides the basis of livelihood for more than two thousand fishermen and vendors. Finally, it is the largest and most accessible open space for the city and offers wide recreational opportunities to its residents.

These values are real and with the techniques of modern economics, they may be quantified in monetary terms. Yet, by and large, the worth of Kingston Harbour has apparently not been appreciated for it has not been sensibly managed and its resources ahave been allowed to deteriroate. Hence, the total resource potential has not been fully developed nor is it likely to be until certain present trends are reversed and planning for the harbour as a completely integrated system is implemented.

The deterioration of Kingston Harbour's resources began several years ago as a result of inappropriate physical changes, waste disposal, and improper fishing methods. Until about the early 1960's, this deterioration was apparently gradual and was not great enough as to cause any alarm. Since then, however, and especially in the last five years or so, the situation has changed dramatically for the worse, and the most rapid deterioration of Kingston Harbour has taken place due to

various forms of pollution. More than anything else, it is this pollution which now threatens to destroy the resources of the harbour and hence jeopardise its future development.

The amount of deterioration which has taken place in Kingston Harbour may be judged from the fact that the Inner Harbour once had a number of highly favoured beaches along its shore and also supported a very rich fauna including many edible forms such as lobsters, crabs, shrimp, clams and fish. Today, the beaches are shunned because of polluted water, and the bottom is largely devoid of life. Furthermore, as late as 1968, the possibility of developing a small-scale trawling industry in the harbour existed while today this is no longer so due to the destruction of the fish and shrimp populations. It is also interesting to note that as late as the 1950's, patch reefs of coral could be found in the shallow areas of the Outer Harbour between Fort Augusta and Port Henderson and large mussel beds were present and exploited for bait. These also no longer exist while other bottom fauna are disappearing .

The main form of pollution in the harbour is organic and is manifested in low oxygen levels. Although there have apparently been occasions from as early as the 1940's when mortality in the harbour resulted from oxygen deficiency (Goodbody, 1970 and MacBride, 1946) these were rare and were remarkable for their very occurrence. As pollution has increased, however, the oxygen deficiency has intensified and, in certain parts of the harbour, especially the Upper Basin, it seems to be approaching the worst possible. In this regard, the decline over the years seems to have followed the typical pattern of the oxygen sag curve in which the initial decline is gradual and is then followed by the most rapid decline after which there is a slowing down and finally a bottoming out. Indeed, taking the harbour as a whole, there is every evidence

that the decline is in its most rapid phase and, if allowed to continue, will eventually bottom out somewhere around 1990. At that stage, the harbour will no longer be able to support life in the bottom water and it will then be virtually dead except for plankton and a few pelagic fish in the surface water. At that time also, the food production potential of the harbour will have been destroyed.

It has frequently been asked at what time Kingston Harbour will have reached a crisis point, although those who have asked the question have not chosen to define what they mean by crisis. Presumably to some, a crisis is reached when there is no possibility of recovery and, to the decision makers, this is probably important since they want to know how much time is left and availabe for attempting abatement measures. However, if we accept this definition and wait for such a projection before taking any action, then we could find that by the time the crisis point has been identified, there is too little time left to effect the desired recovery. Hence, this definition could be virtually useless. To others, however, a crisis is reached at the turning point at which destruction becomes inevitable unless urgent remedial action is taken. Using the example of the oxygen sag curve with which the deterioration of Kingston Harbour has already been compared, this would therefore be the point at the end of the first phase of gradual decline and the beginning of the second phase of very rapid decline. Hence, if we use this definition for Kingston Harbour, then we must agreed that the crisis point has already been reached.

It is my own view that not only has Kingston Harbour reached a crisis point, but the urgent action required for preventing much further deterioration is probably no longer possible. In other words, the rate of deterioration has apparently outstripped our ability to plan

and execute effective pollution abatement measures and therefore the bottoming out will inevitably occur. However, I do not believe that recovery will be impossible although, like the oxygen sag curve, it will be gradual and will take a long time. This could be anywhere from 10 to 30 years after waste disposal to the harbour has been discontinued and will depend on a number of very unpredictable factors such as the possibility of storms or hurricanes, run-off from land following heavy rains, and waste management practices in the watershed and gully course areas of Kingston and its environs.

Dealing with such a long time-frame for abatement and recovery, one may well ask whether it is in fact worth it to try and save Kingston Harbour. To answer this, a number of separate considerations must be made. The first is that in order to accomplish these objectives, at least 60% reduction in organic waste disposal to the harbour is essential and this can only be done if a central sewerage system for Kingston and its environs is implemented and the effluent is disposed of other than in the harbour. But, in such a scheme, Kingston Harbour will not be the only beneficiary and indeed may not even be the main one since it has already been recognised that the scheme is necessary to prevent pollution of the Liguanea aquifer above which Kingston sits and hence to enhance its proper development as an essential water resource. Furthermore, since water is in short supply in the agricultural plains to the west of Kingston, it makes sense to reuse as much water as possible for irrigation purposes or for recharging the aquifer there. But this too can only be done if Kingston's sewage is centrally collected, treated and conveyed out of the area. Thus, for all these reasons, investment in a central sewerage system is worth it and should be implemented at the earliest opportunity.

Present estimates are that the shortest time in which a central sewerage system could be completed is 15 years after commencement. However, based on a plan to dispose of the effluent to the open sea off Harbour Head, disposal to the harbour could be discontinued after only five years although, in the interim, discharge to the harbour would actually be increased. If, instead, consideration is given to discharging the treated effluent to the St. Catherine plains, further feasibility and design studies would be necessary and, with this delay plus the necessary time for obtaining financing, it would not be realistic to expect that the scheme could be operational before about 1985. Despite this inevitably long wait, the scheme is still desireable from many points of view, and it is therefore hoped that it will soon be initiated.

If pollution abatement in Kingston Harbour is achieved, then development of fisheries and recreational resources can occur. While it is outside the competence of this author to cost the likely value of these developments, they must surely be substantial and, if proof of this is necessary, then elaborate cost benefit studies could be done. At any rate, taken with all the benefits to be derived from implementing a central sewerage system, there can be no doubt that these developments would fully justify all the expenditures necessary for abating pollution and restoring the harbour.

The experience of studying Kingston Harbour over a number of years and of investigating the ways and means of controlling its pollution has provided many insights into the attitudes and approaches to environmental management in Jamaica. In the first place, it has cast doubt on the kind of value we place on our natural environmental resources, for, although we are willing and eager to proclaim their merits in a general way, we show a great deal of hesitancy

in dealing with them as though they had real worth. Thus, it is surprising to me that a proper socio-economic study of Kingston Harbour has never been done although it is generally agreed that the development of Kingston has depended a great deal, and continues to do so, on the resources of the harbour. Hence, while there may be many generalities stated about the importance of Kingston Harbour, there is no economc inventory available anywhere of the benefits derived from it, and one is therefore involved continually in an exercise of trying to justify that the resources of Kingston Harbour are worth conserving and developing. My point is that if Kingston Harbour is really as important as it has been claimed to be, then this question should have been settled long ago.

Secondly, the delays in initiating any kind of pollution abatement measures have been partly the result of an inclination not to practise any form of environmental management until it is absolutely necessary to prevent catastrophe. Hence, there is a heavy dependence on the ability to predict a crisis situation before attempting a remedy. Unfortunately, however, by the time the crisis situation is predicted, it may be too late to do much about it. In other words, the old adage that prevention is better than cure needs to be firmly established as a policy of environmental management in Jamaica.

Thirdly, the means to control pollution in Jamaica must be critically examined. As the Kingston Harbour Quality Monitoring Committee found to their dismay, the present legislation is woefully inadequate and there is a great need for one or two strong regulatory authorities which are well staffed and equipped to be responsible for pollution control. While recent steps in this direction have been taken with the establishment of the Environmental

Control Division of the Ministry of Health and Environmental Control, this should be only the beginning. Furthermore, with respect to pollution control in the harbour, much consideration should be given to the suggestion that a special Harbour Patrol Service be set up within the Harbours Department, charged with implementing the Harbours Law.

Finally, the Kingston Harbour investigations have shown that there is a high level of scientific expertise, commitment and cooperation available in Jamaica for tackling these kinds of environmental problems, and the work of the University of the West Indies Marine Laboratory at Port Royal and the Kingston Harbour Quality Monitoring Committee must be highly noted. In all more than $150,000 have been invested in research in Kingston Harbour by the Governments of Jamaica and the United Kingdom, the University of the West Indies and the Nuffield Foundation of the U.K. It must be hoped that this investment will not be in vain.

What of the future? It is my estimate that if Kingston Harbour continues to deteriorate at its present rate, it will be virtually dead before the turn of the century and that even if the necessary abatement measures are taken as urgently as possible, much more deterioration will take place beofre real improvement commences. However, recovery, though slow, is possible with time and should be aimed for.

The harbour monitoring program which was commenced in 1971 has ceased functioning, but it is recommended that it be restarted on a less intensive scale in order to keep abreast of the changing situation. In addition, special investigations of the level of heavy metals (now being done at the U.W.I.) and pesticides in the water and sediments are necessary and should yield much valuable information. Further studies of the benthos (bottom-dwelling organisms) could also be undertaken to indicate the level of their responses to

the increasing pollution, and the mangrove environments and nursery grounds should be resurveyed at periodic intervals. This will be of special importance if oyster culture is attempted.

Kingston Harbour has shown all the typical responses of a water body that is under stress from intense human activity along its shores. Other coastal areas in Jamaica where similar stresses could have equally harmful effects are Montego Bay, Ocho Rios, Negril and Portland Bight. We should not underestimate the likelihood of this occuring and, if anything, we should at least profit from the mistakes of Kingston Harbour.

6. SUMMARY

(1) Kingston Harbour is a physiographically complex system which, historically, has maintained fairly stable conditions. Recently, however, man-made changes have occurred such as the removal of mangrove swamps, the reclamation of low lying areas, river and drainage diversions, dredgings, fillings, and the construction of a solid-fill causeway, which have served to alter the stability of the harbour by increasing sedimentation in some areas and causing erosion in others.

(2) It is recommended that resurvey programs be carried out to monitor the extent of these changes and to determine what future works are feasible.

(3) Water quality in Kingston Harbour is poor from the public health, ecological and aesthetic points of view.

(4) Since 1967, it has been known that bacterial levels along the north shore of the harbour as well as parts of the Palisadoes spit and the Port Royal waterfront are so high as to present an almost certain health hazard to bathers. However, no action has been taken either to reduce the bacterial pollution or to control bathing.

(5) Ecologically, the most serious limiting factor in water quality is the dissolved oxygen concentration as there is oxygen deficiency in the bottom waters in all parts of the harbour except the Outer Harbour. The worst condition is in the Upper Basin .

(6) The deterioration in bottom oxygen conditions has been rapid, and, since 1971, the greatest deterioration has occurred in Hunts Bay and in the Outer Harbour.

(7) Oil and solid waste pollution affect the

aesthetic attraction of the harbour and sometimes result in economic loss to boat owners and beach operators.

(8) Due to high nutrient levels, Kingston Harbour has become eutrophic. Hence, although plankton populations thrive in the surface waters, the bottom waters do not have sufficient oxygen to support much life and populations of bottom dwelling animals in the Inner Harbour and Hunts Bay have been destroyed as a result.

(9) It is estimated that if pollution continues to spread at its present rate, the food production potential of the harbour could be completely destroyed by about 1990.

(10) In order to abate bacterial pollution in the harbour, it is essential that the Greenwich and Western Primary Sewage Treatment Plants as well as the city abattoir cease discharging their effluents to it. It is also important that the illicit dumping of cesspool emptiers into the harbour or into gully courses which lead to the harbour be stopped.

(11) It is estimated that favourable oxygen conditions can only be restored in the harbour if there is a 60% reduction in the organic waste-load discharged to it. It is felt that such a reduction could only be accomplished if a central sewerage system were implemented to collect and dispose of all the city's liquid wastes somewhere other than in the harbour.

(12) A similar reduction in the nutrient load to the harbour is also essential to control plankton blooms, and this could also be accomplished by having a central sewerage system.

(13) The present level of oil pollution can only

be reduced if on-shore tanks are provided into which smaller ships may discharge their oil-contaminated bilge and ballast water rather than into the harbour. The cost of such a facility plus an inspectorate could be met by a 10 - 15% increase in harbour dues.

(14) Oil clean-up capabilities for Kingston Harbour should be improved and should rely on containment and recovery of spilled oil rather than on dispersion by detergents.

(15) Solid waste pollution should be controlled by improving the waste management practices in Kingston and providing proper sanitary land-fill areas away from the edge of the harbour.

(16) Circulation and tidal flushing in Kingston Harbour are naturally poor and this has compounded the pollution problem. However, the situation has been made worse by the creation of man-made enclosures and embayments within the harbour. The worst example of this is the Hunts Bay causeway which had had a very adverse effect on the ecology of that bay. If Hunts Bay is to recover, the flushing rate will have to be increased by at least ten times the present, but this will only be possible if the causeway is raised on stilts along its entire length.

(17) It has been suggested that pollution abatement in the Inner Harbour could be brought about by creating a channel between it and the open sea across the Palisadoes spit, thereby increasing the flushing rate. However, this is not considered feasible for a number of reasons and is not recommended.

(18) Mechanisms for the regulation and control of pollution in the harbour are very inadequate, and it is felt that until a central sewerage system is implemented, there can be no hope of regulating the discharge of sewage

and other organic and nutrient wastes to the harbour.

(19) However, the control of waste-oil disposal is urgently required and is possible if (a) onshore tanks are provided for receiving wastes, (b) a Harbour Patrol Service is set up under the Harbours Department, (c) the Harbours Law is amended to permit summary action against offenders, and (d) the fine is drastically increased.

(20) Physical development in and around Kingston Harbour should be carefully examined in the light of its possible effect on the entire harbour regimen. One clear example in which development was allowed to proceed despite engineering advice to the contrary was the creation of a navigable channel from Dawkins Pond to the Outer Harbour across the Port Henderson spit. As predicted, this has led to the erosion of downstream beaches.

(21) Some proposed developments such as the construction of a second causeway, the mining of sand in the Inner and Outer Harbours, and the modification of the Port Royal mangrove swamps, are considered to be unwise and should be prevented. However, the plan for development of the Palisadoes spit into a recreational park is highly recommended.

(22) The existing fish and shrimp nursery grounds in Kingston Harbour should be protected against physical alteration and over-exploitation, and the Port Royal mangrove swamps should be preserved intact because of their great potential for intensive oyster culture as well as their educational, scientific and recreational values.

(23) The recreational and tourist potential of Kingston Harbour is great, but is presently being limited

by poor water quality and the lack of certain physical facilities. If these are overcome, then many more people will be attracted to the harbour as their major recreational outlet.

(24) The resources of Kingston Harbour have not been fully developed and pollution now threatens to destroy some of them. In particular, the fisheries and recreational resources may be destroyed if urgent steps are not taken to prevent this.

(25) The deterioration of Kingston Harbour has been very rapid since about the mid 1960's and the decline may be compared with the typical pattern of the oxygen sag curve. If the present trend continues, conditions in the harbour will reach their worst about 1990. Hence, Kingston Harbour may now be said to be in a crisis state.

(26) However, even after then, recovery of the harbour from pollution will be possible if the waste discharges are discontinued, but it will be slow and could take anywhere from 10 to 30 years.

(27) Pollution abatement measures in Kingston Harbour may be justified on the basis of its fisheries and recreational development. However, the most important measure necessary, namely the implementation of a central sewerage system, may be entirely justified on other grounds and it should therefore be initiated as early as possible.

(28) Monitoring of Kingston Harbour should be restarted, but on a less intensive scale than before. In addition, heavy metal and pesticide investigations should be worthwhile.

(29) Many important lessons have been learnt from

the investigations of Kingston Harbour. If it is not saved, then it is hoped at least that other coastal areas such as Montego Bay, Ocho Rios, Negril and Portland Bight will be prevented from a similar fate and will thereby profit from the mistakes of Kingston Harbour.

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APPENDIX

Excerpt from the Kingston Harbour Quality Monitoring Committee's First Annual Report (1971) dealing with legislation relating to the harbour.

Legislation Relating to the Harbour

The Committee has enquired into the nature and effect of the laws which relate to Kingston Harbour and the problems for which law enforcement is required.

Law enforcement is required to control industrial and oil pollution, land reclamation and physical alteration to protect the biota and to preserve the social amenities. There are six different laws which in different ways are applicable to the harbour viz. The Beach Control Law, the Harbours Law, the Marine Board Law, the Public Health Law, the Wildlife Protection Law.

Industrial pollution can only be dealt with under the provisions of the Wildlife Protection Law while oil pollution can only be dealth with under the provisions of the Harbours Law. However, the provisions of the Wildlife Protection Law are such that it would be difficult to enforce in any case of industrial pollution and could not be used in a second action for a continuing offence. In cases of oil pollution there is no machinery for summary action against ships' masters or officers and delays in the ordinary Courts enable a ship to sail before action is taken. Since the action is taken against the ship's master and not the Shipping Company, the Company can protect the master by ensuring that he never has to bring a ship into this port again. In any event.....the evidence required at present in an action in the ordinary Courts is so difficult to obtain that it is a waste of time to attempt to bring action against an offending ship.

Control of land reclamation and other physical alteration is vested in the provisions of the Beach Control Law. There appears to be no provision outside of the Wildlife Protection Law which will prevent destruction of the biota.

The Committee have had lengthy discussions surrounding these problems and have enquired into the possibility of seeking an amendment to the Marine Board Law and the possibility of declaring Kingston Harbour a protected area under the provisions of the Beach Control Law. Legal advice in these matters has been provided by Mr. Ross Livingston (Marine Board Law) and Mr. R.N.A. Henriques and Mr. L.A. Young (Protected Area).

In the light of all these discussions, the Committee is of the opinion that certain amendments to the Marine Board Law should be sought as set out in the section on Oil Pollution in this report. In connection with the recommendations relating to the Marine Board Law and in particular to the recommendation that a Harbour Patrol should be set up under the Harbour Department, the Chairman has had meetings with officers of the Jamaica Constabulary and Water Police, and has received assurance that such a move would have their full support.

The Committee after considering in particular the advice of Mr. Young, Legal Adviser to the Geological Survey, deferred any decision on the suggestion that Kingston Harbour should be declared a Protected Area under the provisions of the Beach Control Law.

Nevertheless the Committee remains concerned about the complexity of legislation relating to the harbour but believes that no action should be taken at present and until our work has progressed further. When criteria for waste disposal are developed it will be necessary to have available legislation by which these can be enforced and it will have to be one of the tasks for the Committee during the coming year to investigate this matter in detail.