Swedish University of
Agricultural Sciences

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Master Thesis in Soil Science
Minor Field Study report

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Sammanfattning

En näringsbudget för ekoturistön Chumbe, Zanzibar, har genomförts för att kunna bedöma import- och exportflödena av fosfor (P). Fosforinnehållet i importerade livsmedel och varor beräknades utifrån inköpslistor, där mängderna av varor var specificerade, och livsmedelsdatabaser. Prover för fosforanalys togs på varor som inte fanns med i databaserna. Totalt importerades 41 kg P per år till Chumbe. Det importerades mer P till gästköket (13.2 kg P/år) än till personalköket (9.1 kg P/år) trots att gästköket tillredde färre måltider (9333 jämfört med 14113). Detta kan förklaras med att gästköket serverar måltider med ett större fosforinnehåll. Personalköket använder både kol och ved medan gästköket bara använder kol som ett komplement till gas. När kol och ved räknades in blev summan av P i importerade livsmedel och varor lika stora i båda köken.

Aska och nedbrytbart avfall, såsom fruktskal, komposterades på ön och används sedan för att främja nedbrytning i torrtoaletterna. Tillsammans slängde de båda köken 4.8 kg P/år med det komposterbara avfallet, medan askan tillförde uppskattningsvis upp till 17.4 kg/år till komposthögen. Trots osäkerheter i beräkningen av askans och köksavfallets P innehåll kan en fosforförlust uppskattas från alla steg i komposteringsprocessen, från komposthögen, från den mogna komposten och slutligen från det kompostmaterial som senare används i toaletterna. Detta kan bero på utlakande regn och på de djur och fåglar som sprider kompostmaterialet då de äter av den.

Gästköket har ett gråvattensystem där slam och fett avskiljs från vattnet innan det hälls ut i ett litet mangroveträsk medan personalköket häller ut sitt gråvatten orenat i en lerpöl. Trots detta släppte gästköket ut mer P (0.3 kg P/år) än personalköket (0.2 kg P/år). Dessutom innehöll slammet, som tömdes på olika ställen på eller utanför ön, ytterligare 0.1 kg P/år. Fettet, som las på komposten, innehöll inget P.

Exporterat tillbaka till Zanzibar blev matresterna från båda köken, som uppskattades innehålla 2.4 kg P/år, och det komposterade toalettavfallet (21.6 kg P/år), dvs. hälften av det importerade P. Den andra hälften förlorades från komposten, vid gråvattenutloppen, som slam eller med flygaska.

För att undvika upplagring av P på ön Chumbe bör all aska och toalettkompost i fortsättningen exporteras eftersom de innehåller näringsämnen som är användbara i jordbruket på Zanzibar men är skadliga för korallrevet utanför ön. Personalen bör också se över de platser där det för närvarande sker P utsläpp.

Abstract

In this case study, a nutrient budget was made to estimate import and export flows of phosphorus (P) on the ecotourism resort of Chumbe Island, Zanzibar. The P content in imported foods and goods was calculated using supply lists containing information on quantities of items bought and standard food composition data. Foods and goods not included in the standard data were subsampled for P analysis.

Total P import to Chumbe Island was 41.0 kg/year. More P was imported with foods to the guest kitchen than to the staff kitchen (13.2 and 9.1 kg P/year, respectively) although the guest kitchen served fewer meals (9333 and 14113 meals, respectively). This is explained by the more P-rich foods served in the guest kitchen. When charcoal and firewood were included, the staff and guest kitchens imported equal amounts of P since the staff kitchen used both firewood and charcoal while the guest kitchen only used charcoal as a complement to gas.

Ash and biodegradable waste such as fruit peel were composted on-site and used to facilitate the degradation process in composting toilets. Biodegradable waste from both kitchens contributed 4.8 kg P/year to the compost heap, while the ash from kitchen stoves contributed an estimated max. 17.4 kg P/year. Despite uncertainties regarding P amounts in the kitchen waste, estimations showed that P was lost from the compost heap during all stages of decomposition. Animals and birds scattering the compost during feeding and leaching during the rainy season are possible reasons for these losses.

In the guest kitchen greywater system, sludge and grease were removed before the greywater was discharged into a small mangrove swamp, while staff kitchen greywater was poured untreated into a mud-hole in rocky ground. The guest kitchen contributed slightly more to P discharge (0.3 kg P/year) than the staff kitchen (0.2 kg P/year). The sludge (discharged at unspecified locations on Chumbe) contained another 0.1 kg P/year. The grease (added to compost) contained no P.

Food scraps from both kitchens containing 2.4 kg P/year and composted toilet waste containing 21.6 kg P/year were re-exported to Zanzibar, i.e. approx. half the P imported was exported. The other half of imported P was lost from compost, greywater outlets, as sludge or dissipated through fly ash dispersal.

To avoid P accumulation on Chumbe Island, I recommend that all toilet waste and ash be exported in future, since they contain nutrients useful on agricultural land on Zanzibar but harmful to the reef. Furthermore, Chumbe Island management should act to counteract current sources of P losses.

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Introduction

Eutrophication in reefs

Coral reefs can be described as an oasis in a desert, with a density and diversity of life that can be compared to that of rainforest. Global and local human activities in complex interactions may have varying negative impacts on the reefs, e.g. destructive fishing (blast/dynamite fishing) and overfishing, damage and breakage of corals by diving and snorkelling tourists, coral bleaching, increases in water temperature due to global warming and eutrophication. Clearing of land for agriculture and domestic use and the development of tourist resorts, including service and leisure facilities such as gardens and golf courses, have increased terrestrial run-off, i.e. sediments, organic matter and inorganic nutrients, and pesticides and herbicides commonly associated with these (Dubinsky & Stambler, 1996). Urban and rural coastal developments also produce nutrient-rich sewage disposal and agricultural wastewater.

The anthropogenic impacts of eutrophication may lead to long-term stress, which in the event of an additional acute natural stress, such as hurricanes or coral bleaching, may be sufficient to cause a phase shift, as the coral reef will not be able to recover when already weakened. Phase shifts in the coral reef community, from coral-dominated to algae-dominated reefs, are complex and not fully understood (McCook, 1999). Algae do not necessarily have enhanced competitive ability to incorporate nutrients, but terrestrial run-off containing particles and dissolved nutrients may favour algae growth, as corals are covered by sediments. The reduced ability to spawn coral recruits caused by eutrophication further diminishes coral reef survival in the longer term (Hunte & Wittenberg, 1992). To prevent increased standing crops of algae, a vital population of herbivorous fish is needed. Even without increased nutrient levels, overfishing of grazing fish may thus involve a phase shift as algal biomass increases.

Sewage and greywater contain nutrients and varying amounts of organic matter giving rise to biochemical oxygen demand, BOD. When the particles sediment on the corals, microorganisms decomposing the organic matter consume oxygen, thus creating anoxia around the coral (Mitchell & Chet, 1975). Even when treated to low BOD, sewage water contains most of its original nutrients, hence causing eutrophication (Dubinsky & Stambler, 1996).

Phosphorus is the second most growth-limiting nutrient in the open sea, after nitrogen, but in coastal zones close to carbonate reefs the situation might be the opposite, i.e. phosphorus becomes limiting before nitrogen (D'Elia & Wiebe, 1990).

Aim of this report

The aim of this Minor Field Study/Master's thesis in Soil Science was to investigate the extent of phosphorus accumulation on Chumbe Island, Zanzibar, due to the import of foods and goods. In the event of insufficient phosphorus export, there is a possible eutrophication threat to the reef, which Chumbe Island Coral Park Ltd. (CHICOP) intend to protect. In this case study, a nutrient budget was made to estimate the import and export flows of phosphorus.

Background

Phosphorus and eutrophication

Terrestrial run-off and sewage disposal due to human activities contain organic and inorganic forms of nutrients, such as nitrogen (N) and phosphorus (P). Microorganisms are able to transform organic and inorganic nitrogen into its gaseous phase, reducing the nitrogen load to the oceans but making the nutrient inaccessible in the atmosphere to all except the nitrogen-fixing bacteria, which have the ability to incorporate nitrogen in organic matter, making it available to terrestrial organisms again. Unlike nitrogen, phosphorus does not have this cycling link from the oceans through the atmosphere back to land, making it an even more important nutrient to preserve in soils and a greater problem to the oceans, where it may be buried in sediment.

A phytoplankton common in many ocean waters (Westberry & Siegel, 2006) is the nitrogen-fixing cyanobacteria *Trichodesmium* spp. A study on the central and northern lagoon of Great Barrier Reef, Australia, showed that the standing crop of *Trichodesmium* in those areas adds ‘new’ nitrogen to the lagoon water in amounts at least of the same order of magnitude as those discharged by the rivers (Bell *et al.*, 1999) and that the standing crop has increased since 1928-29. This is believed to be caused by increased run-off of the *Trichodesmium* growth-limiting nutrient phosphorus. Since the most common growth-limiting nutrient for non-nitrogen fixing organisms is nitrogen, this ‘new’ nitrogen originating from *Trichodesmium* together with that discharged by the rivers may cause increased net primary production. The increased phytoplankton concentration in the ocean water also reduces light penetration, thereby slowing down photosynthesis in corals (Dubinsky & Stambler, 1996).

Phosphorus not only enhances growth of N-fixing bacteria but also interferes with the coral community in other ways. Eutrophication studies showing contradictory results reflect the contrasting roles that phosphorus has, as apart from being a tissue-growth stimulant it also interferes with skeletal calcification (Dubinsky & Stambler, 1996). Other studies have not been able to verify that phosphorus has a negative effect on the calcification organisms (Koop *et al.,* 2001) but confirm an increased growth of the dinoflagellates that inhabit the coral, the zooxanthellas.

Apart from water transport, phosphorus may be carried by wind and deposited on water and land surfaces. Phosphorus in the atmosphere originates from volcanoes, combustion processes or PO_4 adhering to pollen or dust. In Africa, more than half the total biomass burnt during late 1970s was from savannah fires and the fraction is believed to have increased since then (Hao & Liu, 1994). Experimental burnings of typical southern Africa grass and shrubs show a median loss of 82% of the phosphorus content through the dispersal of fly ash (Keene *et al*., 2006). Biomass burning is assumed to influence the phosphorus deposition in the region. A study of wet and dry atmospheric phosphorus deposition at three sites around Lake Victoria showed loading rates between 1.8 and 2.7 kg P/ha/year (Tamatamah *et al.,* 2005), while Bootsma *et al.* (1999) measured dry and wet deposition to be 2.5 kg P/ha/year around Lake Malawi.

Site description of Chumbe Island

Chumbe is a 22 ha small island situated on the west coast of Zanzibar, Tanzania (see map Appendix 2). Since 1994, the reefs on the west side of Chumbe Island have been protected as a reef sanctuary by a privately run organisation, Chumbe Island Coral Park Ltd. (CHICOP). In 1998 seven bungalows and a tourist centre, built in eco-architecture style, were build to house visitors and have since then experienced increasing occupancy rates, both overnight stays and day-guests. During low season, school classes from Zanzibar and mainland Tanzania visit to learn more about coral reefs, their marine life and environmental issues. There are no local residents on Chumbe Island. A total of 22 staff members at a time work on the island and for their needs a staff kitchen, two toilets and sleeping huts have been built. There is also a manager's house with a shower and toilet.

The island is an old fossilised coral reef with hard, porous rock and therefore there is no groundwater or actual soil layer. The coral rag forest on the island has to rely on moisture in the air or water collected during the bi-annual rainy seasons and grows in soil accumulated in holes in the coral bedrock.

The native fauna of the island is mainly made up of birds, hermit crabs, green snakes, insects, the endangered coconut crabs *(Birgus latro)* and a small number of the Ader's duiker (*Cephalophus adersi*). The reefs around Zanzibar have experienced increased populations of the coral-eating crown-of-thorns starfish (*Acanthaster planci*) since 1995 but these were not seen in the Chumbe reef until 2004 (Daniels, 2004). Since then, the CHICOP staff have removed all individuals detected. Within an ongoing monitoring system, fish and invertebrates as well as the different kinds of substrates, such as hard and soft corals, are surveyed along transects. The fish commonly found belong to genera usually under pressure from overfishing. So far, no algae indicating nutrient excess have been found, the only concern is the large number of sea urchins (*Diadema* and *Echinoidea*).

A comparative study of protected reefs, including Chumbe, and unprotected reefs along the Tanzanian and Kenyan coast showed that the protected reefs had 3.5 times more fish biomass than the unprotected and that there were large differences in the coral community composition (McClanahan *et al.*, 1999). The Chumbe reef is situated upstream from Stone Town, capital of Zanzibar, with its heavily used fishing grounds. Therefore the protected Chumbe reef is of importance as a breeding ground and is assumed to have a spill-over effect on the overfished neighbouring reefs.

System description

The phosphorus imported with foods and goods to Chumbe Island flows through different paths within the island before being exported to Zanzibar or lost on or around Chumbe. Food scraps, food containers and hard organic waste (e.g. coconut shell) are exported without any further handling on the island. Other solid or liquid wastes are either composted and used in the toilets to facilitate aerobic decomposition or disposed of in the greywater treatment system on the island. The system description (Fig. 1) is based on personal observations and interviews with the CHICOP staff.

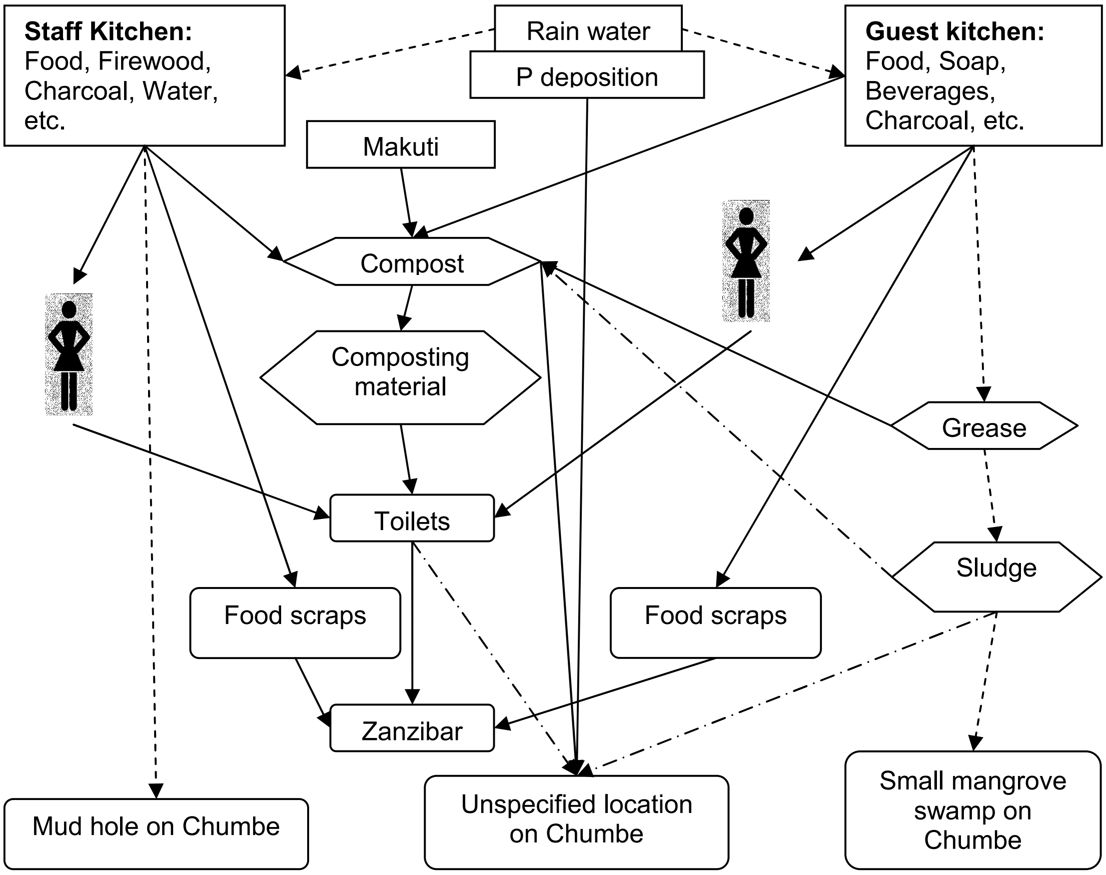

Fig. 1. Diagram showing the flows of phosphorus: water flows (dashed lines); material flows (solid lines); occasionally material flows (dotted-dashed lines); import of P (square-corner boxes); exported P or P losses (rounded-corner boxes); internal flows of P (hexagonal boxes). (Makuti is palm leaves used as roofing)

Water collection and water discharge

To fulfil the aim of protecting the reef and island of Chumbe, buildings and facilities are designed to minimise human impact. The seven bungalows, tourist centre and guest kitchen are built from wood and other natural materials and the makuti-covered roofs, i.e. palm-thatch (palm leaves tied to metre-long sticks), are designed to collect rainwater. The water is filtered through sand, stored in large cisterns underneath the buildings and used in showers, hand-basins and for washing up. Water for drinking and food preparation is imported from Zanzibar, amounts depend on occupancy. Visitors are allowed to use their own shampoo and conditioner but a home-made biodegradable soap from Zanzibar is placed in the shower of each bungalow daily. The wastewater from showers and hand-basins is piped to a garden with a shallow layer of soil in which different kinds of native bushes and herbs grow. The water from the guest kitchen is piped through a greywater purification system, ending up in a small mangrove swamp. Staff huts and staff kitchen do not have cisterns like the bungalows but depend on the water collected on the tourist centre roof. Washing-up water and other liquids from the staff kitchen are piped without treatment to a sandy and, nowadays, muddy hole.

Foods and goods to Chumbe Island

All supplies (Appendix 1) are brought to the island by a supply boat. Depending on the occupancy (number of day and night guests) the guest kitchen staff orders food and beverages using a supply list for the following days. These are then purchased by the staff at the main office on Zanzibar. The guest menu is repeated weekly, and basically consists of a continental breakfast and a buffet for lunch and evening meal. Staff members have one cooked meal a day (at lunchtime); breakfast and evening meal are tea and bread, sometimes complemented with porridge or soup. The guest kitchen and staff kitchen are regarded as two separate parts in this report since they have separate supply lists, menus and greywater treatment systems.

Toilet facilities and compost

In both the guest and staff kitchens, there are two buckets into which waste is thrown. Ash from the fireplace and biodegradable waste such as fruit peel are thrown into the first bucket and taken to the compost heap. Food scraps, however, are thrown in the second bucket and taken from the island to Zanzibar, together with glass, metal and other hard waste, e.g. coconut shells.

All eleven toilets are constructed to compost urine and faeces in a space below the toilet seat. When the makuti on the roofs starts to leak it is replaced and the old leaves are piled until needed. They are then chopped into smaller pieces and mixed with mature kitchen compost to be used in the composting toilets. When the toilet has been used, a ladle of this composted material is thrown into the toilet to prevent bad smells and to facilitate quick aerobic decomposition during the composting processes (Fig. 2).

When considered full, the toilets are left for three weeks before being emptied through a small trapdoor at the rear of the building. The small toilet at the tourist centre is usually emptied two to three times a year, the toilet at the manager's house and the larger staff toilets once or twice a year. Bungalow toilets are usually emptied once a year but this depends on occupancy rates. For the past two years, a farmer on Zanzibar has received most of the ready toilet compost, whereas prior to this the compost had been spread in the forest on Chumbe Island.

Fig. 2. Toilet and bag with composting material.

The compost site where the kitchen waste is composted and toilet composting material is prepared has three compartments. The first compartment is used for fresh biodegradable waste from both guest and staff kitchens (Fig. 3). Since it is not covered or fenced, hermit crabs, coconut crabs, birds and lizards thrive among the fruit peel and insects attracted to it.

Fig. 3. The first compost compartment of the compost site where ash and biodegradable waste are thrown.

The second compartment contains waste undergoing decomposition. This is covered with makuti and after two months considered ready (Fig. 4). The waste is never mixed with air during the decomposing process except when moved to the third compartment. There, the compost is mixed with old makuti chopped into small pieces and thus made ready for use for the toilets.

Guest kitchen greywater system

The current guest kitchen greywater purification system is designed mainly to reduce the biochemical oxygen demand, BOD (Wyatt, 2005). A pipe conducts the water from the kitchen sink to a 35 cm deep grease-trap from where grease floating on the surface is regularly removed with a sieve and thrown on the compost, while heavier particles sinking to the bottom are removed as sludge.

Fig. 4. The second compost compartment. During the two-month composting period, the ash and biodegradable waste are covered with makuti until ready for use as composting material in toilets.

From the grease-trap, the water moves on into three consecutive 1000-litre water tanks for further sedimentation and reduction of BOD. No air is mixed in and therefore anaerobic degradation of BOD to methane gas must be the main result. From the bottom of each of the three tanks is a pipe for sludge discharge. The last step in the purification system is a sand filter in a 200-litre tank with small holes at the bottom. This sand has never been changed since the system was built in 2005. From the bottom of the sand tank the water percolates into a small mangrove swamp where the nutrients and remaining BOD are diluted to a varying degree with seawater, depending on the tides, i.e. the volume of water in the mangrove swamp. At the lowest tide level there is no water in the mangrove swamp, while at the highest tide level the water reaches to just below the bottom of the sand-filled tank.

Methods and observations

Weighing and sampling were carried out during the everyday routines of the Chumbe Island staff, and thus the results reflect the conditions during the time of this field study. In this case study, a limited number of repetitive samples were collected.

Weighing and sampling

Staff kitchen greywater system

Part of the phosphorus imported in foods is later cooked in water, with some ending up in the cooking water or washed off plates and saucepans, and hence poured out into the sink. To estimate volumes of water used per day and the phosphorus load in the greywater, a bucket was placed at the end of the pipe collecting water from the sink during two 24-hour periods. The bucket was monitored and emptied regularly, with number of bucketfuls and degree of fullness recorded. A 100 ml subsample was taken from every full bucket, a 50 ml subsample from every half-full bucket 50 ml and so on. All subsample bottles from one 24 hour-period were mixed and a representative sample of 100 ml was kept for analysis. Observations and interviews about water volume used daily were made to confirm the measurements.

Guest kitchen greywater system

The water samples from the guest kitchen were collected on six occasions at three different places. The first batch of water samples was taken from the washing-up water and rinsing water, i.e. water before entering the greywater system. The second lot of samples was from the grease trap 5 cm below surface, i.e. below grease accumulation level and above sludge accumulation level, representing the water quality after the first, rough removal of grease and sludge. The third lot of water samples was collected from underneath the 200-litre sand-filled tank from which water percolates out into the mangrove swamp. A 15-litre bucket was placed underneath the sand tank and water was collected during breakfast and lunch preparation time and washing-up. The flow-through time in the greywater system is unknown, and thus the breakfast 'end of system' samples do not reflect the purified water from the breakfast washing-up, but that pushed out of the system when the washing-up water is poured out into the sink.

To estimate the amount of phosphorus removed from the greywater in the grease-trap and transferred to the compost by grease removal, the grease was weighed once a day during three days. Two samples of grease from the grease-trap were collected for determination of phosphorus concentration. To estimate the corresponding amount transferred to unspecified locations by sludge, a sample of sludge from the grease-trap was collected from one of four buckets (approx. 25 litres each) when the grease-trap was emptied. The sludge is normally removed every second week but the samples taken here represent the amount of sludge sedimented during approximately one month, diluted with the water in the grease-trap at the time of sampling. It was not possible to take samples from the three 1000-litre sedimentation tanks since no sludge removal was carried out during the sampling period. Where this sludge is disposed of is unclear, sometimes in a hole in the coral bedrock in the centre of the island and sometimes at the unprotected east coast of Chumbe Island.

A sample of washing-up liquid was taken for analysis. As a reference for the greywater samples, a water sample was taken from the cistern at the guest kitchen. No sampling or measurements of water use or phosphorus content were carried out for greywater from guest bungalows, staff showers or the manager's house.

Compost, fruit peel and other solid samples

Measurements and weighing were conducted during February and March 2007 but data were assembled from the CHICOP office for the year 2005. The phosphorus concentration of most foods was found in food composition databases, see Calculations: Import section. Items not included in the food composition tables, or of high importance due to great imported amounts and/or of a regional nature, were sampled and analysed (see Appendix 1). Standard food composition tables only report the phosphorus value of edible parts of e.g. fruits. Therefore non-edible peel and kernels were also analysed.

During 2005, 1600 pieces of makuti were imported to Chumbe Island and the same number of old ones were assumed to be chopped for composting. Analytical data on samples and measurements of new and old makuti weight were used to calculate the phosphorus imported with new makuti and the phosphorus added to the composting material with old makuti (Table 1).

Table 1. *Analysis of non-food samples from Chumbe Island. (Makuti is palm leaves used as roofing)*

Dry samples	P in fresh matter (mg P/100g)
New makuti	130.08
Old makuti	74.87
Mature compost	394.40
First composting material	453.83
Second composting material	511.69
Charcoal	157.16
Grease trap: sludge	8.86
Grease trap: grease day 1	8.25
Grease trap: grease day 2	10.23

The charcoal used in the staff and guest kitchens was also imported to Chumbe Island and was thus included in the phosphorus budget. A sample was collected from each of four bags of charcoal and analysed (Table 1). The guest kitchen used charcoal as a complement to gas, while the staff kitchen had firewood, mainly eucalyptus wood from Zanzibar. Samples of the firewood were not collected, but a total phosphorus concentration were calculated from standard data, see Calculations: Import. The home-made soap from Zanzibar used on Chumbe Island was also sampled and analysed (Appendix 1).

Weight measurements of compost and food scraps thrown in the guest and staff kitchen were performed during three days. Because of problems in getting a representative sample from the large amounts of sticky and non-homogeneous material in the first compost compartment, no samples were taken for phosphorus concentration analysis. Instead, the phosphorus concentration was estimated according to Calculations: Internal flow section.

To sample the mature kitchen compost (second compartment), the cover of makuti was removed and five equal samples were collected from the four corners and the middle of the heap. The samples were mixed and a composite subsample was taken for analysis (Table 1). The same method was used for collecting a sample of the composting material (used in toilets), present in the third compartment at the beginning of the field study ('first composting material'). Three weeks later this material was finished and the mature compost had been moved from the second to the third compartment and mixed with makuti, and a sample of this 'second' composting material was taken (Table 1). The volume of the compost compartments/heaps and their densities were estimated. All eleven composting toilets were in use during the sampling period and no samples could therefore be collected due to health risks and practical difficulties**.**

Analyses

Samples for analysis were collected on Chumbe Island during February and March 2007. Water samples were kept in 100 ml bottles with 1 ml 4 M sulphuric acid (H_2SO_4) to halt any biochemical processes in the water. There was no fridge/freezer on Chumbe Island where the water samples could be stored, so they were stored for a maximum of four days in ambient temperature (30-35ºC) before being taken to a freezer at the Institute of Marine Sciences (IMS), Zanzibar. Total phosphorus in water samples was determined after sulphuric acid and potassium peroxide sulphate ($K_2S_2O_8$) digestion according to Swedish Standard SS-EN 1189-1.

Composting material, mature compost, makuti and food samples were dried for 72 hours in an oven at 100ºC and then stored in plastic bags before being milled, homogenised and analysed at Soil Science laboratory, SLU. Total phosphorus was determined after nitric acid digestion according to Zarcinas *et al.* (1987).

Calculations of total phosphorus

Imported phosphorus

The total amount of phosphorus imported to Chumbe Island during one year was calculated using supply lists together with the phosphorus content from analysis or standard food composition tables, corrected for the ratio of edible and non-edible parts as well as recalculations of tins, bunches, bundles, packages, pieces and bottles to kilograms. The soap, firewood, charcoal and makuti imported to the island every year for maintenance of the roofs were also included.

To calculate the import of phosphorus to Chumbe Island, the amounts of all the different foods and goods brought to the island during one year were estimated using the supply lists for October and December 2005. Since the staff kitchen and guest kitchen menus are repeated every week, an annual average import list could be calculated relating to the number of staff and guests consuming the foods and goods. In the case of the staff kitchen, however, the supply list of October 2005 represented Ramadan, when the menu for staff differed.

To confirm the accuracy of the information in the supply lists, the amounts ordered were compared against the actual imports to the island, which most often confirmed the amount ordered. Most items were ordered and bought in kilograms but there were also bunches, bundles, pieces, tins, bottles and packages. Where amounts were mentioned in kilograms a balance was used most often showing the number of kilograms ordered, but sometimes less and seldom more. This was probably due to the heat and handling time, during which vegetables and fruits may lose some of their water, depending on their water holding properties. Therefore the amounts ordered were assumed to be correct. Fruits and vegetables bought as bunches or pieces were weighed to get a mean weight in kilograms per bunch and piece, but because of the possible loss of water there might be some underestimations. Since this check of supply lists was performed in February-March 2007 and the lists used for calculations were from 2005, there might been some change in the size of tins or bunches imported during this time but due to the impossibility of checking this, such variation was assumed to be negligible in the total sum.

King fish, calamari, red snapper, tuna, octopus and chicken were bought as pieces or portions and therefore total weight had to be estimated according to this. Some of the species of fish were not found in the food composition tables and an average 'saltwater fish' phosphorus value was used. Another exception was some supplies bought a few times but in large amounts, e.g. rice and wheat flour, which were found when all supply lists for the year 2005 were examined.

The total phosphorus content of the edible parts of the foods was found in food composition tables published by Svenska livsmedelsdatabasen, the African Food Composition Table, the American National Nutrient Database for Standard Reference and the nutrient database NUTTAB95 from Food Standards Australia & New Zealand, from which mean values from one to four of the tables could be calculated. Some of the supplies, as well as the non-edible parts, were not found in the food composition tables and analytical data from samples were used (Appendix 1).

The number of charcoal sacks imported was found in the supply lists, phosphorus content analysed and the sum added to import. A bunch of wood was estimated to weigh 15 kg and phosphorus in eucalyptus wood was estimated from data for six-year-old eucalyptus trees, using data for branches with a mean phosphorus content of 9.6 mg/100g dry wood (Bennet *et al.*, 1997), recalculated to 8.16 mg/100 g wood when corrected for a probable moisture content of 15% due to the humid climate.

Internal flows

The phosphorus imported to Chumbe Island flows through different paths, ending up being lost or exported (Fig. 1). The compost, composting material used in the toilets, grease and sludge were included in the internal flow, as well as the food consumed by humans and ending up in the toilets.

The compost disposed of daily was weighed but since no samples for analysis were collected from the compost estimations had to be made, balancing the imported amounts of non-edible parts of different fruits with their concentration. The grease from the grease-trap was added daily to the compost heap and thus added to the sum of total phosphorus content of compost, as was the phosphorus content of the ash from the burnt charcoal and firewood.

Phosphorus is not emitted in a gaseous phase during burning of wood and charcoal but remains in the ash (Werkelin *et al.*, 2005), which is divided into bottom ash and fly ash, where the latter is emitted with the smoke. The amount of fly ash relative to bottom ash depends on the combustion device and properties of the material burnt. No estimations of phosphorus losses through the dispersal of fly ash were conducted during this field study and little has been found in literature, see Results and Discussion: Internal flow section. Therefore this report assumed that a negligible amount of phosphorus is lost with fly ash during the burning of firewood and charcoal. Hence the phosphorus in the imported charcoal and wood was added to the compost sum.

The phosphorus content of the composting material was calculated using a mean of the 'first composting material', 'second composting material' and the sum of the mature compost and old makuti, see Table 2: 'Composting material'. The estimated volumes and the phosphorus concentrations, together with the measured density, gave the phosphorus content of each heap. The compost heap was left for approximately two months to mature, thus a heap of composting material was prepared and emptied five to six times a year, giving the approximate sum of phosphorus turnover per year. The composting material was used in the toilets or composted and exported as toilet compost, see 'Exported phosphorus' below.

The phosphorus content in sludge from the guest kitchen grease-trap had to be estimated from the single sample taken from one of the four buckets on the only occasion of emptying during the field study. Even though emptying was said to be done every second week, calculations was based on the assumption that it is done in total twelve times a year, taking into account the fact that occupancy varies during the year, thus giving a varying sludge load. The disposal site of the sludge differs from time to time, sometimes on the compost heap and other times elsewhere on the island or in the sea outside the reef sanctuary. Thus the phosphorus in sludge is more or less lost in the vicinity of Chumbe Island and was therefore included in the 'Losses' budget item (Table 2).

Exported phosphorus

Food scraps from both kitchens are regularly exported from the island. Total phosphorus concentrations of the food scraps from each kitchen were estimated using a mean of the phosphorus content of prepared foods from the food composition tables, taking into account that staff kitchen food scraps do not contain as much meat as guest kitchen food scraps.

Since no samples of toilet compost were collected, a standard phosphorus value from daily mean excretion of urine and faeces from one human (Wolgast, 1993) was used and multiplied by number of staff nights, number of overnight guests or 50% of the number of day guests. This was added to the calculated mean of composting material to estimate the amount of phosphorus exported through the removal of toilet compost from Chumbe Island.

Dissipated phosphorus

The phosphorus in the greywater from the staff kitchen, piped to a mud-hole, and the semi-purified water from the guest kitchen, drained into a small mangrove swamp connected to the ocean, was more or less dissipated in the thin soil layer of Chumbe Island and diluted in the nearby water. Sludge can also be seen as dissipated since it often is poured out on or in the immediate vicinity of Chumbe Island. Even when thrown on the compost heap, the phosphorus in the sludge might be lost due to lizards, hermit crabs and other animals and insects consuming it. This is also the reason why part of the compost might be expected to be dissipated, see Table 2.

Table 2. *Total phosphorus (P) imports, the flows within Chumbe Island and total phosphorus exports. Two scenarios are shown: (1) Toilet compost is exported to Zanzibar; or (2) Toilet compost is spread on Chumbe Island. *= see Appendix 1.*

Phosphorus budget	**1.**	**2.**
1. Imported P, total (kg P/year)	41.0	
Guest kitchen: Food, Beverages, Soap, Charcoal *	18.7	
Staff kitchen: Foods, Charcoal, Firewood *	19.6	
Makuti	2.7	
2. Internal flows		
2.1. Compost, total (kg P/year)	20.9	
Ash from Guest kitchen & Staff kitchen	16.1	
Guest kitchen: Grease from Grease-trap	0.011	
Guest kitchen: Compost	3.6	
Staff kitchen: Compost	1.2	
2.2 Composting Material, mean (kg P/year)	5.0	
Old makuti	0.9	
Mature compost	4.6	
Sum of 'Old Makuti' & 'Mature compost'	5.6	
First Composting material	4.4	
Second Composting material	5.0	
2.3. Toilet, mean (kg P/year)	21.6	
Composting material, mean (g P/year)	5.0	
Standard P-content of human faeces & urine/year	16.6	
Sum of 'Composting mtrl' & 'Standard P of human…'	21.6	
3. Exported P to Zanzibar, total (kg P/year)	24.0	2.4
Staff kitchen: Food Scraps	1.0	1.0
Guest kitchen: Food Scraps	1.4	1.4
Toilet Compost	21.6	0
4. P lost through dissipation, total (kg P/year)	19.7	41.3
4.1. Mud-hole on Chumbe, mean (kg P/year)	0.2	0.2
Staff kitchen: Washing-up water	0.2	
4.2. Mangrove swamp on Chumbe, mean (kg P/year)	0.3	0.3
Guest kitchen: End of system water, mean	0.3	
4.3. Unspecified location on Chumbe, (kg P/year)	19.2	40.7
Guest kitchen: Sludge from Grease-trap	0.1	0.1
Toilet compost		21.6
P loss at compost site & from makuti	19.1	19.1

The water used in the showers and hand-basins of the guest bungalows contained phosphorus partly originating from soap and shampoo. This was regarded as dissipated but the amounts were not estimated.

Chumbe Island has an area of approximately 22 hectares. If a mean wet and dry phosphorus deposition (2.1 kg P/ha/year) measured by Tamatamah *et al.* (2005) around

Lake Victoria is used for estimations of the natural influx of phosphorus to Chumbe Island, the input through atmospheric deposition would be 47 kg P/year.

Results and discussion

In 2005, the number of guest meals served on Chumbe Island was 9333 and staff meals 14113. For the same year, the number of overnight guests was 2770, day guests 636 and staff nights 7005. The various foods and goods needed to run the tourist facilities imported to Chumbe Island are specified in detail in Appendix 1. Through different paths explained in the System description section, phosphorus-containing items are moved around the island, ending up being dissipated on Chumbe Island or sent back to the main island of Zanzibar.

Imported phosphorus

It was no surprise that protein-rich foods such as fish, meat, beans, seeds, nuts, dairy products and eggs contributed to a great extent to the sum of phosphorus imported. However, fruit and vegetables imported in large volumes, such as coconuts, garlic, onions, peas, potatoes, spinach and tomatoes, also contributed substantially. Since the edible and non-edible parts of fruits were separated in the foods and goods supply list (Appendix 1), it was possible to conclude that the peel and kernel of some fruits contributed more to the phosphorus import than the edible part.

The amount of phosphorus imported with foods to the guest kitchen was greater than to the staff kitchen (13.2 and 9.1 kg P/year, respectively) even though the guest kitchen served fewer meals than the staff kitchen (9333 and 14113 meals, respectively). The guest kitchen supply list contained more phosphorus-rich items such as meat and fish, and both breakfast and evening meal were more substantial than corresponding staff meals.

Charcoal and firewood for the stove made up half the total imported sum of phosphorus to the staff kitchen, 10.5 of a total of 19.6 kg P/year. Since charcoal was used only as a complement to gas in the guest kitchen, the charcoal imported made up less than a third of the total phosphorus imported to the guest kitchen, 5.6 of a total of 18.7 kg P/year. Because of uncertainties in the weight estimations of wood bundles and charcoal sacks, these budget items have to be considered with some caution. Furthermore, the number of charcoal sacks and firewood bundles was calculated on the basis of the supply lists of 2005. In 2006, the staff kitchen stove was rebuilt and fuel consumption was said to be reduced by 50-70% (CHICOP Newsletter July 2007). Thus the calculated phosphorus import reported here is overestimated relative to the current consumption. The phosphorus imported with the makuti was merely 6% of the total import.

Internal flows

This study assumed that a negligible part of phosphorus converted during the burning of charcoal and firewood was lost as fly ash taking off with smoke, and that the majority resided in the bottom ash, which was thrown on the compost. The bottom ash thus was estimated to add 16.3 kg P/year to the compost heap (Table 2). Compared with the sum of the biodegradable waste from both kitchens (4.8 kg P/year) the bottom ash made a huge contribution to the total annual load of phosphorus on the compost heap of 20.9 kg P/year. Compared with the mature compost heap (4.6 kg P/year), there is obviously a great loss of phosphorus during the two months of degradation, from 20.9 to 4.6 kg year, a difference of 16.3 kg P/year. However, due to lack of analysis data on phosphorus content of the kitchen ash, this figure is uncertain. Also there are some contradictory findings on the proportion of phosphorus emitted to the atmosphere via the fly ash: Keene *et al*. (2006) did two experimental burnings of Malawian charcoal in a small brick oven and found that 79% and 99% of the phosphorus was emitted with the smoke, i.e. 1-21% remained in the bottom ash. They also did an experimental burning of 4-6 cm branches from Namibian trees, which emitted 33% of the phosphorus. This is the only literature found in this matter but since the burnings were only carried out twice and once, respectively, the results only serve as an indication. The amount of phosphorus lost with fly ash on Chumbe Island is therefore still unknown but has to be regarded as dissipated somewhere on the island or the nearby ocean.

There is an additional loss of phosphorus from the compost site during the two months of degradation. The hermit crabs, lizards and birds observed on the compost heaps might be a reason for this loss. Compost lying exposed to the rains during the rainy season might also lose some of its phosphorus, since the rains are said to be heavy and hence easily wash particulate organic matter off the fossilised rock down into holes and off the island (Fig. 5).

Fig. 5. Leafy pineapple tops and other waste spread from the compost heap (lower left) to the forest (upper right) by animals.

Ash excluded, the guest kitchen contributed three times as much phosphorus to the compost heap as the staff kitchen (3.6 compared with 1.2 kg P/year). This was partly due to the high amount of phosphorus contained in the leafy tops and peel of pineapple (Appendix 1). The guest kitchen also imported higher amounts of fruit including non-edible fruit peels and kernels with high phosphorus content, which ended up on the compost heap. In comparison, grease from the guest kitchen grease-trap contained almost no phosphorus, only 0.05%.

Of the phosphorus imported annually with makuti, more than two-thirds were lost before it was chopped into pieces and mixed with the mature compost (Table 2). Some particulate-bound phosphorus was probably lost due to the mechanical impact of rainwater falling on the thatched roof and this phosphorus ended up in the cistern water. Some was probably lost and dissipated due to degradation while the makuti was lying in piles.

The first and second heaps of prepared composting material both had a somewhat lower content of phosphorus than the sum of old makuti and mature compost together (Table 2). The first composting material lay heaped for another two months before use in toilets and kept losing phosphorus during this period, hence the lower concentration (Table 1) and content (Table 2) in this than in the 'second composting material' from which samples were collected in a newly prepared composting material heap. This indicates that phosphorus was lost during all stages at the compost site, from the time when the wastes were thrown on the compost (sum of fresh compost unknown but minimum 4.8 to maximum 20.9 kg P/year) to mature compost (4.6), and from when mixed and prepared with old makuti (5.6) to second composting material (5.0) to first composting material (4.4).

Exported phosphorus

The food scraps from both staff kitchen and guest kitchen are exported daily from Chumbe Island. Although concentrations had to be estimated, calculations indicated that only small proportion (approx. 10%) of the phosphorus imported annually was exported with the food scraps. Regularly exporting the toilet compost is thus of greater importance, since half the imported phosphorus was retained in the toilet compost.

Scenario 1 in Table 2 provides a picture of the prevailing practice, with all toilet compost being exported to Zanzibar. Under this practice, estimated phosphorus exports amounted to 24.0 kg P/year during the study period, whereas phosphorus losses were estimated at 19.7 kg P/year. The importance of this export is shown in Scenario 2 in Table 2, where phosphorus losses made up more than one hundred percent of the imported phosphorus (41.3 kg P/year of 41.0 kg P/year) compared with 44% of the phosphorus losses in Scenario 1. The phosphorus losses are calculated as a percentage of the amount imported, not the sum of exported and dissipated phosphorus, which would be 43.7 kg P/year, i.e. 2.7 kg more than calculated import, and give a loss of 45% and 95%, respectively, for scenario 1 and 2.

Dissipated phosphorus

The phosphorus concentration in the water collected in the washing-up buckets was lower than that in the 'grease-trap' and 'end of greywater system', except for washing up water sample 6, in which the phosphorus concentration was ten times higher than in numbers 1-5 (Table 3). The significantly higher concentration indicates that high phosphorus-load liquids were poured into the greywater system on occasion. Six samples from the washing-up water might not give a fair picture of the amount of phosphorus draining into the greywater system. The mean of low values of washing-up water was lower than the mean concentration of grease-trap water, also indicating that liquids other than washing-up water and rinsing water enter the first purification step in the greywater system. Grease-trap water having a higher mean concentration than end of system water was expected, the phosphorus concentration of the end of system water was on average 75% of that of the grease-trap. This corresponds to the report by Dubinsky & Stambler (1996) on BOD-treated water retaining most of its nutrients. The greywater system is not constructed for nutrient removal apart from sludge removal but focuses on BOD reduction (Wyatt, 2005), which also is of great concern since it can cause anoxia in mangrove swamp sediments and hence the coral reef. However, there are plans to rectify this lack of nutrient removal with a constructed wetland as the last step in the guest kitchen greywater system (Riedmiller, S., pers. com. 2007).

The phosphorus accumulated in the mangrove swamp was relatively low compared with that imported, but a more careful removal of the sludge, both from the grease-trap and the three tanks, might lower the discharge even more. Even though the annual phosphorus load, calculated from the single sludge sample, was relatively low, the organic matter content highlights the importance of careful management of sludge removal and dispersal to protect the environment from the negative effects of both sediments and nutrients. In addition, a simple filter installed in the staff kitchen illustrates the necessity of a better solution for the sludge from the staff kitchen. After three weeks in use, the filter (a bucket filled with gravel) was clogged with black sludge (Fig. 6).

Table 3. *Phosphorus concentrations in guest kitchen greywater. Washing-up water sample 6 differs significantly from the others, therefore a mean of samples 1-5 is included in the table.*

Guest kitchen	**Tot-P mg/l**
Washing-up water sample 1	2.3
Washing-up water sample 2	4.4
Washing-up water sample 3	2.6
Washing-up water sample 4	1.5
Washing-up water sample 5	6.3
Washing-up water sample 6	71.8
Mean (min- max)	14.8 (1.5 - 71.8)
Mean samples 1-5 (min- max)	3.4 (1.5 - 6.28)
Grease-trap water sample 1	18.4
Grease-trap water sample 2	18.4
Grease-trap water sample 3	17.9
Grease-trap water sample 4	13.6
Grease-trap water sample 5	17.0
Grease-trap water sample 6	18.1
Mean (min - max)	17.2 (13.6 - 18.4)
End of system, sample1	14.0
End of system, sample2	14.2
End of system, sample3	7.2
End of system, sample4	9.1
End of system, sample5	18.0
End of system, sample6	16.0
Mean (min - max)	13.1 (7.2 - 18.0)
Cistern water	0.28

Charcoal and wood excluded, the guest kitchen imported more phosphorus than the staff kitchen. It also discharged more phosphorus into the surrounding environment than the staff kitchen, even though it had a greywater treatment system.

Although it is important to control the greywater discharge, the amounts lost with greywater are much less than those lost with ash. The amount of phosphorus that might be dissipated on Chumbe Island mostly depends on how much is exported from the island. This study shows that it is vital to export all the toilet compost, since half the imported phosphorus ends up in this compost. In broad terms, the other half constitutes the phosphorus contained in the ash. The bottom ash is thrown on the compost heap but since the amount of phosphorus in fly ash is unknown, it is difficult to trace the phosphorus lost by this route.

Another factor controlling the amount of phosphorus lost from the system is the construction and management of the compost site. The phosphorus lost during the composting process, from the time waste is placed on the heap until the material is degraded and mature, might become a long-term problem. As the stated aim of CHICOP is to provide tourism with minimum environmental impact, they might need to reconsider the populations of hermit crab, lizards and birds roaming the compost heap since they were observed eating and/or dragging off the waste. The abundant supply of food increases the animal populations and/or spreads nutrients to the surrounding vegetation. In the forest behind the compost site the ground was covered with more or less degraded fruit peel mixed with ash during the study period. An uncontrolled flow of waste to the forest floor might lead to flushing of organic matter and mineralised phosphorus through the porous fossilised coral rock during heavy rains. Non-degraded organic matter flushed into the ocean might create anoxia in sediments and around corals during degradation, releasing phosphorus. Although some phosphorus may be bound to the limestone bedrock of Chumbe Island, leaching of phosphorus-rich water might be expected since the sorption capacity of limestone is dependent on the specific surface in contact with the water (Meifang, Z., Yuncong, L. 2001) and heavy rain is more easily rinsed through porous bedrock than through e.g. a soil layer of ground limestone.

The shampoo and soap in the greywater from the showers and hand-basins of the seven bungalows, the staff houses and manager's house were not measured or analysed but contribute to an unknown amount of dissipated phosphorus.

Fig. 6. Water sample collection in staff kitchen, with the simple filter filled with sludge in the right-hand corner.

The background wet and dry phosphorus deposition on Chumbe Island was estimated to be approximately 47 kg/year, somewhat more than the anthropogenic phosphorus import of 41.0 kg/year. The origin of the deposited phosphorus is believed largely to be particulate matter blown by the winds from the burning of savannas (Hao & Liu, 1994). The calculated amount of natural phosphorus deposition used here can only be regarded as an indicator, since the measurements were made around Lake Victoria in inland Africa (Tamatamah, 2005). Furthermore, Jassby *et al.* (1994) found that phosphorus deposition decreased with increasing distance from the lakeshore and suggested that phosphorus deposition was of a terrestrial nature. Thus the calculation here probably over-estimates the deposition rate, at least if the amount of phosphorus emitted with fly ash from the kitchen stoves is low.

Accuracy and reliability of estimated flows and overall P budget

A brief calculation of the estimated flows gives an indication of the accuracy and reliability of the budget. The total imported phosphorus, calculated from supply lists of 2005, was 41.0 kg P/year. However the total exported and dissipated phosphorus, calculated from measurements, volume and density estimations, and food composition tables or sample analyses, was 43.7 kg P/year, a difference of 2.7 kg/year or 6%.

Considering the large number of estimations made, it is surprising that the estimated phosphorus import correspond so well with the estimated subsequent phosphorus flows. In particular, errors concerning the large items would have a major impact on the budget. Thus, a relatively small over-estimation of phosphorus in the exported toilet compost or over-estimation of the imported firewood and charcoal could easily distort the budget.

Conclusions and management proposals

The staff needed to run the tourist resort and manage the reefs and forests of Chumbe Island contribute the same amount as the tourists to the phosphorus import, although the number of nights spent on the island and number of meals cooked for staff are much greater than for the tourists. To avoid an accumulation of phosphorus on the island, two things need to be considered: 1) All the toilet compost has to continue to be exported from Chumbe Island in the future; and 2) measures have to be taken to prevent the large amount of phosphorus imported with charcoal and wood being dissipated on Chumbe. To achieve this, further investigations of the phosphorus content of bottom ash are needed in order to calculate the amount of phosphorus dissipated with fly ash and to evaluate the problem. This could be accomplished by collecting the ash of each kitchen and analysing it for total phosphorus content. If most of the phosphorus is retained in the bottom ash, it needs to be disposed of more carefully. The best solution would then be to not throw the bottom ash on the compost but to actively collect it and export it, preferably as a fertiliser since the ash contains several kinds of nutrients and does not have any sanitary risks, unlike the toilet compost. The compost heaps might also need to be fenced and roofed to avoid phosphorus being dissipated through the action of rainwater and/or dispersal by animals.

By constructing a wetland as the final purification step in the guest kitchen greywater system, the phosphorus will be taken up by plants instead of being discharged into the mangrove swamp. To avoid nutrient saturation in the system and hence nutrient leakage, the wetland plants have to be harvested regularly and exported from the island. A greywater treatment solution for the staff kitchen is also recommended.

Accumulation of phosphorus on Chumbe Island will eventually lead to sediment and nutrient discharge into the surrounding waters. Unless water flow-through is sufficiently large, this might lead to negative effects on the coral reefs. Since Chumbe Island is located upstream from Stone Town, the town’s sewage discharge outlet is not a problem. It is thus even more important that Chumbe Island control its own phosphorus losses in order to retain the pristine and undamaged coral reef.

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Appendix 1. Foods and goods import to Chumbe Island, Zanzibar

Items of foods and goods imported to Chumbe Island; phosphorus concentration (P), in items (gP/100g); amounts imported ($kg*year^{-1}*kitchen^{-1}$) and imported phosphorus to each kitchen in gram ($g*year^{-1}*kitchen^{-1}$) (staff kitchen= SK; guest kitchen= GK).

Mean phosphorus values from four food composition tables; Svenska livsmedelsdatabasen, the African Food Composition Table, the American "National Nutrient Database for Standard Reference" and the nutrient database "NUTTAB95" from Food Standards Australia & New Zealand.
Otherwise:
1.) Analyzed according to Zarcinas, B.A et al 1987, see References.
2.) Estimated phosphorus value, see Calculations: internal flow.
3.) Analyzed according to (Swedish Standard Ss-EN 1189-1)

Foods & goods	P mg/100g	SK: imported kg/year	SK: total P(g)/year	GK: imported kg/year	GK: total P(g)/year
aubergine	28.8	59.8	17.2	375.5	107.9
avocado	39.5	0.0	0.0	84.4	33.4
avocado kernel & peel 1.)	39.3	0.0	0.0	31.6	12.4
banana	22.8	50.1	11.4	308.3	70.1
banana, peel	21.1	24.9	5.2	152.9	32.3
banana, green-	36.0	584.0	210.2	0.0	0.0
banana, green peel 1.)	21.1	604.5	127.5	0.0	0.0
banana, long	22.8	0.0	0.0	182.6	41.5
banana, long peel	21.1	0.0	0.0	90.5	19.1
beans 1.)	403.9	297.2	1200.4	35.0	141.4
beef GK	180.0	0.0	0.0	202.4	364.3
beef SK	160.0	394.7	631.5	0.0	0.0
beef, minced-	156.0	0.0	0.0	85.3	133.1
biscuits	75.5	0.0	0.0	11.7	8.8
black pepper	173.0	4.6	7.9	3.4	5.8
bombay mix 1.)	198.0	0.0	0.0	22.7	0.0
bread (white)	98.8	728.4	719.2	0.0	0.0
bungo (like passion fruit)	59.0	0.0	0.0	34.1	20.1
butter	24.0	18.2	4.4	199.9	48.0
cabbage	30.0	281.5	84.4	190.2	57.1
calamari	152.5	0.0	0.0	23.2	35.4
cardamom, powder	178.0	6.9	12.3	16.6	29.5
carrot	27.7	0.0	0.0	431.5	119.4
cashew nuts	547.8	0.0	0.0	78.0	427.3
cassava	76.7	11.0	8.4	0.0	0.0
cassava chips 1.)	56.0	0.0	0.0	6.2	0.0
cauliflower	48.2	0.0	0.0	143.8	69.3
cheese tin 1.)	882.0	0.0	0.0	14.2	125.2

Foods & goods	P mg/100g	SK: imported kg/year	SK: total P(g)/year	GK: imported kg/year	GK: total P(g)/year
chicken	173.0	0.0	0.0	266.7	461.3
chili, fresh	55.0	0.0	0.0	41.4	22.8
cinnamon	61.0	5.5	3.3	6.8	4.2
coconut	104.3	934.5	975.0	273.7	285.6
coffee	318.7	0.0	0.0	0.8	2.5
coffee, ground-	1.0	0.0	0.0	50.5	0.5
coriander, fresh	481.0	0.0	0.0	1.3	6.0
corn flour	66.0	418.8	276.4	2.0	1.3
cotimili	54.5	0.0	0.0	17.1	9.3
cucumber	25.8	0.0	0.0	204.8	52.8
cumin	499.0	5.6	27.8	1.2	6.1
curry	350.0	0.0	0.0	3.5	12.3
dates	54.0	16.0	8.6	0.0	0.0
eggs	185.0	0.0	0.0	280.9	519.6
fish SK	310.0	334.6	1037.2	0.0	0.0
garlic fresh	163.5	51.7	84.5	34.1	55.8
ginger, green	16.3	75.5	12.3	34.1	5.6
grapefruit	17.0	0.0	0.0	209.4	35.6
grapes	16.5	0.0	0.0	85.3	14.1
green pepper	32.1	0.0	0.0	346.2	111.2
jam "Golden Africa" 1.)	4.3	0.0	0.0	16.4	0.7
king fish	310.0	0.0	0.0	315.0	976.5
lettuce	30.2	0.0	0.0	243.8	73.7
lime	18.8	95.8	18.0	248.7	46.6
liquid dish soap 3.)	24.9	145.3	36.2	39.0	9.7
mango	14.3	28.6	4.1	421.9	60.1
mango, kernel & peel 1.)	42.2	20.3	8.6	299.8	126.4
margarine	17.3	0.0	0.0	25.0	4.3
mayonnaise	27.7	0.0	0.0	58.0	16.0
milk, long life	92.0	113.6	104.5	63.4	58.3
milk, powder	828.1	0.0	0.0	19.2	159.0
noodles	206.0	18.0	37.1	63.4	130.6
octopus	152.5	0.0	0.0	253.6	386.7
oil, cooking-	0.0	312.8	0.0	178.5	0.0
okra/ladies fingers	74.3	56.8	42.2	114.6	85.2
onion	35.0	219.9	76.9	407.2	142.5
orange	20.8	13.5	2.8	248.7	51.6
orange, peel	21.0	4.2	0.9	78.0	16.4
passion fruit	59.0	0.0	0.0	692.6	408.6
passion fruit, peel 1.)	32.2	0.0	0.0	468.0	150.7
pasta	201.0	0.0	0.0	16.0	32.2
paw paw	7.8	616.9	47.8	1257.3	97.4
peanuts	422.3	0.0	0.0	30.3	128.1
peas	109.8	0.0	0.0	173.1	190.0
pineapple	9.3	308.6	28.5	1030.8	95.3
pineapple, peel & top 1.)	136.0	197.7	268.8	660.2	897.9

Foods & goods	P mg/100g	SK: imported kg/year	SK: total P(g)/year	GK: imported kg/year	GK: total P(g)/year
porridge 1.)	206.1	101.5	209.2	0.0	0.0
potato	42.8	599.9	256.8	804.6	344.4
potato, sweet-	35.5	2.0	0.7	0.0	0.0
potato chips	90.0	0.0	0.0	63.2	56.8
prawns/shrimp	223.7	0.0	0.0	290.1	648.9
pumpkin	41.8	36.0	15.0	325.2	135.8
radish	29.2	0.0	0.0	64.9	18.9
red snapper	345.0	0.0	0.0	238.9	824.3
rice 1.)	66.2	1145.7	758.8	120.0	79.5
salt 1.)	0.0	41.1	0.0	45.0	0.0
sesame seed	647.3	0.0	0.0	317.0	2051.5
sour tomato	28.8	54.8	15.7	0.0	0.0
spinach	54.5	202.7	110.5	243.8	132.9
sugar	0.0	354.7	0.0	90.0	0.0
tea leaves 1.)	339.0	26.8	90.9	39.0	132.2
tomato	25.0	410.5	102.5	597.3	149.2
tomato paste	76.7	110.5	84.7	51.8	39.7
tomato sauce	27.0	0.0	0.0	3.1	0.8
tuna	245.0	0.0	0.0	76.6	187.7
watermelon	9.3	0.0	0.0	615.7	57.0
wheat flour	116.5	1100.2	1281.7	272.0	316.9
vinegar	15.0	0.0	0.0	18.9	2.8
yeast	1146.7	0.0	0.0	3.0	34.4
soap 1.)	1.2	0.0	0.0	46.250	0.6
Beverages, sum:					116.9
charcoal 1.)	157.2	6487.1	10195.4	3535.2	5556.1
wood 2.)	8.5	3811.7	311.0	0.0	0.0
SUM of import:			**19574.8**		**18740.1**
SUM without charcoal & wood:			**9055.4**		**13184.0**

Appendix 2. Chumbe Island Coral Park