Chapter 2
Analysis of Water Supply and Demand Management Strategies in Overcoming Water Scarcity in Santa Cruz

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Abstract Water resources in the Galapagos Islands have been severely strained by exponential increase in tourist visitors. Santa Cruz Island, the main tourism hub in the Galapagos, is facing significant challenges of too many people and not enough available water. There are no permanent freshwater resources on this island, and the municipal water supply system provides only (untreated) brackish water, intermittently.

In view of the scarce data found on water demand, this study involved extensive fieldwork with the aim of generating water-consumption figures from different types of premises (common households, hotels, restaurants and laundries), in order to assess current water demand. Several methodologies were used including 400 surveys and the installation of water meters, aiming to quantify water figures. The study quantified water demand from different categories and sources of water using several methodologies as means to create mitigation options regarding the fragility of the ecosystem.

Results indicated that domestic water demand varies between 163 and 428 litres per capita per day (lpcpd), which is extremely high for such a water-scarce island. Also, total water supply, without taking into account any losses, suggests around 350 lpcpd, which is also a high figure considering water scarcity threats in Santa Cruz Island. The results also suggest the that the presence of non-registered tourist accommodations or excessive water wastage from domestic premises is presenting a significant issue in the total water balance, leaving some premises without water.

This study provides scientific insights for the improvement of water resources management and further contributes for the creation of effective policies to preserve these resources.

Keywords Water demand · Water consumption · Water resource management · Tropical insular environment · Tourism

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2.1 The Island of Santa Cruz

Santa Cruz is the main island (economic and tourism centre) of the archipelago and has a surface area of 985 km^2. Brackish water is supplied by the municipality of Santa Cruz to the settlements, where the technical capacities continue to be limited. The biggest town is Puerto Ayora, located on the south coast, followed by the village of Bellavista, located at 180 m of elevation and 7 kms inland (GADMSC 2012a). Puerto Ayora has approximately 12,000 inhabitants (INEC, 2010), holding 61.3% of the total population of the archipelago, and Bellavista has a rural population of approximately 2500 inhabitants. Over the past 10 years, the rate of development in the highlands has been very high.

The population density in Puerto Ayora is the highest in the archipelago, with approximately 80 inhabitants per km^2 (INEC 2010). On the other hand, Bellavista is practically a suburb of Puerto Ayora, and it is a popular part of the island characterized by private properties distinguished by tranquillity and silence. Currently, there are new developments taking place further than Bellavista which cause additional problems, as the public network does not reach there yet.

The main driver for the significant increase in population (from the mainland) over the last years has been to support the tourism industry and to generate income. Consequently, there has been a noteworthy increase in the number of travel agencies, restaurants, hotels, bars, etc., stressing the water resources and environment in general (GADMSC 2012b). The growth in the local population and tourism in Santa Cruz has increased the demand for basic services, such as water supply without concurrent ways to cover the costs of these services, overwhelming the municipalities and so resulting in deficient services and untrained staff (Guyot-Tephiane et al. 2012).

Because of this exponential increase, low-cost hotels have also increased significantly, as well as the number of backpackers. This has also boosted the creation of small private accommodations with no environmental consideration. In addition, more restaurants (also informal) have started, as well as the number of local tourist agencies, offering day tours of occasionally questionable quality. The problem of tourism is further enhanced by the lack of monitoring by the Ministry of Tourism (MINTUR). Consequently, the lack of control and regulation boosts these illegal accommodations. According to the MINTUR, as of December 2013, there were 106 unregistered accommodations out of a total of 159 (Reyes et al. 2017a, b). Moreover, according to the Department of Potable Water and Sewage (DPWS), there are only 40 service connections belonging to the category of hotels (Sarango 2013).

Similarly, the number of laundries has grown as well. However, in the land cadastre of Santa Cruz, there are no premises categorized as laundries, while according to the DPWS, there are only five service connections of this category. An update of the land cadastre is lacking and stricter control over this type of premises regarding operating licenses. It is commonly known that laundries are a profitable business.

The main source of supply in Santa Cruz, which is extracted from the basal aquifer, is non-potable due to high concentration of chlorides (800–1200 mg/L) and is

further distributed without any prior treatment (d'Ozouville and Merlen 2007). In addition, the water is also contaminated with *Escherichia coli*, due to the lack of sewerage system (d'Ozouville et al. 2008). Wastewater is mainly disposed into septic tanks, which are installed individually by each household. It has been identified that most of these septic tanks are not constructed technically, resulting in infiltration to the water sources (Liu and d'Ozouville 2013).

As a consequence of uncontrolled urban growth, the local government councils are blocked of providing a permanent and optimal service to the local population. Furthermore, the water supply is intermittent and rationed, with an average supply of 2–3 h per day (Reyes et al. 2016), which has influenced inhabitants to build their own water storage in the form of cisterns and elevated tanks. Also, there is an excessive water loss in Puerto Ayora, which is caused by aging pipes and lack of maintenance along the distribution system. This problem has further worsened by the lack of water meters in the town of Puerto Ayora, which results in excessive water wastage within the households. This is also a consequence of the lack of water-saving practices or specific policies promoting water conservation in this fragile ecosystem. In addition, there are also financial constraints that contribute to the difficulties faced by the municipality to improve the water service.

On top of this, the lack of communication among different entities and unclear distribution of responsibilities within the institutions regarding water management contribute to the situation (Reyes et al. 2016). Lastly, there is a significant absence of data and information, causing difficulties in the assessment of the current situation and the future planning for the improvement of the water scarcity.

2.2 Quantification of Water Demand

The data for this study were collected from a survey carried out to 374 households in Puerto Ayora and Bellavista. This section reveals the daily average water demand per capita and how it differs between the two settlements, as well as the impact resulting from difference in the water tariff structures. Also, it analyses the type of consumer in the tourist category and how much it accounts of the total water demand within the island.

2.2.1 Research Methodology

In order to assess the water demand in Santa Cruz, a quantitative survey was carried out during the fieldwork conducted from November 2013 to January 2014 in Puerto Ayora and Bellavista. The minimum sample size was calculated based on the total number of land properties according to the 2012 cadastre from the municipality of Santa Cruz. With a total of 2460 properties in Puerto Ayora and 435 properties in Bellavista, the minimum sample size was calculated at 339, by applying the

confidence interval of 95% (DeVault 2014). Next, the actual sample size per consumption category was determined. The surveys were carried out during a period of 6 weeks.

The final version of the domestic survey contained five main parts: (i) general information about the location, (ii) family habits, (iii) water demand (bottled, municipal and/or from trucks), (iv) water-saving practices and (v) sanitation practices.

The surveys for other demand categories were less detailed and contained four groups of questions: (i) general information, (ii) average capacity of customers, (iii) water demand quantification regarding different type of sources and (iv) environmental awareness.

2.2.2 Analyses of Results in Puerto Ayora and Bellavista

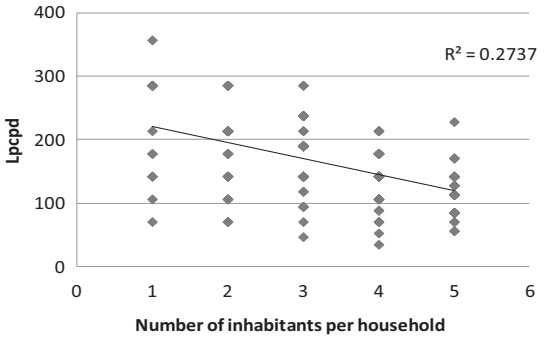
2.2.2.1 The Domestic Category

The results of the survey show several similarities and differences between the two settlements. Firstly, the percentage of connections to the municipal service is higher in Puerto Ayora (91%) than in Bellavista (81%), which could be attributed to the faster growth in the number of households in Bellavista and the consequent inability of the municipality to cope with it. The average annual increase of connections from 2005 to 2013 was approximately 9% in Bellavista, while in Puerto Ayora, it was only 2%. Furthermore, the frequency of service is worse in Bellavista, which differs from the information provided by the municipality, which claims that water is supplied every day.

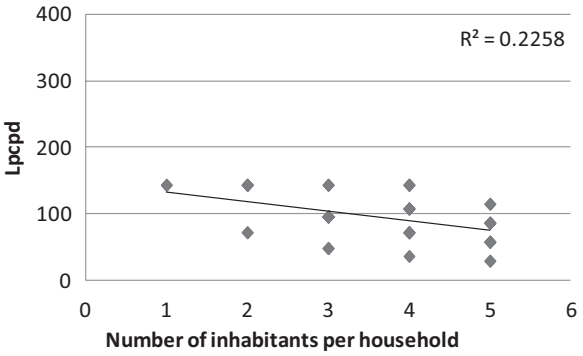
Using the capacity of household storage units (tanks or cisterns), the reported frequency of filling these and the number of users per household, an attempt was made to estimate the total water demand from the municipal supply system, as well as the specific demand per capita. This is shown in Fig. 2.1a for Puerto Ayora and in Fig. 2.2b for Bellavista.

From Fig. 2.1, it can be seen that larger households tend to have lower demand per capita. This can be explained by the fact that the water consumption for general activities like watering gardens, cleaning common areas and cooking is independent of the number of occupants. Furthermore, the figures for Puerto Ayora show a wider range of demand for the same number of inhabitants, suggesting diverse water use, probably due to different living standards and/or habits than in Bellavista. The average specific demand and standard deviation for Puerto Ayora is 163 ± 80 lpcpd and in Bellavista is 96 ± 34 lpcpd. This average differs significantly between the two settlements, probably due to different water tariff structures.

Puerto Ayora has fixed water fees per month for different categories established by the municipality. On the other hand, Bellavista has a metered system, with a consumption-based tariff structure (USD 1.21/m^3). As a consequence, the population in Bellavista tends to consume less than in Puerto Ayora. However, they



(a)



(b)

Fig. 2.1 Municipal water demand per capita and number of inhabitants per household in (**a**) Puerto Ayora and (**b**) Bellavista

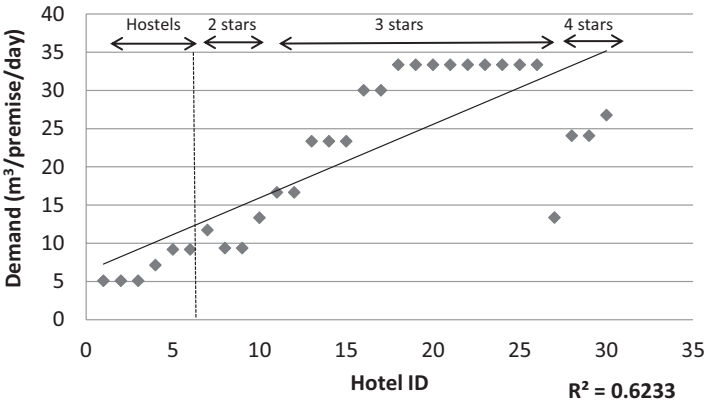


Fig. 2.2 Demand per surveyed hotel regarding rating

supplement their demand with rainwater, increasing the total water demand per capita. In Bellavista, customers are more aware of the value of water, unlike in Puerto Ayora, where higher wastage of water is evident with spilling of tanks. The fixed monthly fees in Puerto Ayora seem to be the main reason for such behaviour. According to the municipality, the biggest losses occur at the moment of filling household storage when faucets are not closed when tanks are full, resulting in significant overflow of water. It was observed during the fieldwork that these overflowing tanks were left unattended for more than half an hour in some cases. Lack of metering and low tariffs in Puerto Ayora appear to encourage the population to waste water. However, some households have shown to use much lower quantities of water than the others, for the same number of occupants, which in broader terms reflects different styles of living and/or habits. The high standard deviation on both settlements suggests that locals use water randomly per household, and there is no obvious tendency regarding social stratum or number of occupants, or the neighbourhood.

A high percentage of responses in Puerto Ayora (32%) identified leaks within their households. Unfortunately, these leaks are rarely fixed, probably due to the fact that the water lost is not charged to the consumer. On the other hand, the leaks within premises in Bellavista are much lower (reported in 15% of responses), meaning that the tariff structure influences the decision to fix them. The majority of leaks were reported to be in old and inefficient toilets, suggesting high losses since toilets account for major water use in a household of nearly 30% of total water consumption (EPA 2012). Finally, the less frequent spilling of individual tanks in Bellavista confirms overall higher awareness of the customers, which can be also explained by the difference in water tariff.

2.2.2.2 Total Demand Quantification for Domestic Sector

The quantification of domestic water demand was done for all types of sources used. This was possible based on the questions regarding the frequency of service/purchase and volumes of the different sources for every household. The results are shown in Table 2.1 with total demand per capita calculated for both settlements.

Table 2.1 Water demand per different sources of water in Santa Cruz

Settlement	Municipal supply (m^3/year)	Bottled water (m^3/year)	Water trucks[a] (m^3/year)	Rainwater[b] (m^3/year)	Total demand (m^3/year)	Approximate population[c] (no. of inhabitants)	Specific demand (lpcpd)
Puerto Ayora	712,188	7243	57,518	N/A*	776,949	12,000	177
Bellavista	82,481	2683	48,307	97,444	30,914	2500	253
Total	794,669	9925	105,825	97,444	1,007,863	15,000	190

Note: [a]Water from trucks refers to partial pumping from 'private' crevices. [b]Rainwater was not considered in Puerto Ayora for it is practised by less than 10% of surveyed households. [c]Based on the last national census carried out in 2010

Table 2.1 indicates relatively high specific demand in view of the widespread intermittency and scarce water sources. The public perception in both settlements is clearly that additional water next to that supplied by the municipality is necessary. Nevertheless, rainwater is barely collected in Puerto Ayora. One reason is lower precipitation levels than in Bellavista, but also that this practice is considered archaic (Guyot-Tephiane et al. 2012). Oppositely, people in Bellavista collect rainwater regularly and use it for all types of household activities. Furthermore, in both settlements, the bottled-desalinated water is used mainly for drinking and for personal hygiene, while brackish groundwater is used for other domestic activities such as cooking, dish washing, laundry, toilet flushing and showers.

Moreover, the supply by water trucks has high contribution to the high total demand in Bellavista, which could be explained by lower number of municipal service connections. In summary, the average per capita consumption is considerably higher in Bellavista than in Puerto Ayora. It is however to be noted that all the results are based on the personal assessments of the respondents; this certainly needs to be verified by more accurate measurements.

2.2.2.3 Analysis of Tourist and Laundry Category

The total demand was also assessed for tourist facilities in Puerto Ayora: private apartments, hotels and restaurants as shown in Table 2.2. The figures have been derived based on the survey questions regarding the volume of storage facilities and the frequency of refilling of storage tanks, as well as the amount of bottled-desalinated water and water supplied by trucks.

Figure 2.2 shows the daily demand of surveyed hotels; the horizontal axis represents each hotel, given by a serial number. For example, from 1 to 6 are hostels with capacity of 25 to 45 people to be accomodated per day, from 7 to 9 are two-star hotels with capacity of 20 to 25 people, from 10 to 26 are three-star hotels with

Table 2.2 Water demand quantification for hotels and restaurants in Puerto Ayora

Type of accommodation	Average capacity (customers)	Municipal water (m^3/day)	Water trucks (m^3/day)	Bottled water (m^3/day)	Specific demand (lpcpd)
Hostel	40	8.1	0	0	205
2-star hotel	35	4.0	12.3	0.1	470
3-star hotel	45	6.0	29.7	0.3	667
4-star hotel	35	9.6	9.0	0.1	535
Average	**38**	**7.0**	**11.3**	**0.1**	**469**
Restaurants	15	0.2	0.9	0.1	126
	25	0.5	1.7	0.1	158
	45	0.4	0.9	0.2	46
	50	0.4	1.8	0.3	79
Average	**34**	**0.4**	**1.3**	**0.2**	**102**

capacity of 10 to 50 people and from 26 to 30 are four-star hotels with capacity of 25 to 50 people. The water demand varies according to the type of accommodation (hotel rating) and the average capacity.

The majority of the hotels and restaurants are connected to the municipal supply, but some hotels (mainly three stars) and virtually all restaurants are mainly supplied by water trucks. The four-star hotels mostly have their own purification systems (by desalination) and are less dependent on the municipal supply, using it less than lower class tourist accommodations do. Moreover, three-star accommodations use more water because of higher occupancy. In Galápagos, the tendency is towards middle-class tourists, therefore, those who cannot afford luxurious accommodations at average rate of 350 USD/night (which seem to be more careful with water use).

The average water demand per bed, estimated by the survey respondents, was 168 lpcpd, which is far from reality, since the calculated average is 469 lpcpd, i.e. almost three times higher. Furthermore, in 10 out of 30 restaurants, the water demand estimate was approximately 0.5 m^3 per day.

Finally, the total water demand for Puerto Ayora was calculated based on the average consumption derived from the survey, multiplied by the total number of premises per category according to the land cadastre of the municipality. Table 2.3 shows the highest demand from the hotels for municipal water and from trucks. Approximately 24% of total demand of municipal water is from unregistered accommodations, which account for 66% of the total in the category of hotels. As in many other tropical islands, the biggest consumers are tourist accommodations, proportionally to the ranking of the hotel. The restaurants and laundries do not contribute significantly to the total demand in Santa Cruz, although the total number of registered restaurants and laundry premises in the land cadastre may be higher than reported.

Table 2.3 Total water demand quantification considering all categories

Category	Municipal supply (m^3/day)	Bottled water (m^3/day)	Water trucks[a] (m^3/day)	Total demand (m^3/day)
Domestic	1951.2	19.8	157.6	2128.6
Hotels	1107.2	20.6	1788.8	2916.6
Restaurants	69.3	7.6	51.1	128.0
Laundries	28.5	0	20.1	48.6
Total	3156.2	48.0	2017.6	5221.8

Note: [a]Water trucks refers to pumping from ‘private’ crevices

2.3 Assessment of Domestic Consumption in Puerto Ayora's Intermittent Supply Network

The intermittent water supply system, which is caused mainly by the lack of proper management and by sensitive political issues (Reyes et al. 2016), promotes a perception that the system is unreliable. The previous sections suggested the average total municipal water demand ranges from 40 lpcpd to 380 lpcpd. The possible subjectivity and uncertainty of some of the responses in the surveys from Sect. 2.2, pointing the extreme ranges of consumption, question the real effectiveness of the intermittent mode of supply in Puerto Ayora, where the estimates of the domestic consumption ranges from 163 to 177 lpcpd ±60 lpcpd.

WMI, a private organization financially supported by the German Cooperation G.I.Z, installed approximately 300 water meters in the period from 2013 to 2015, in three different pilot zones. Pilot Zone 1 (PZ 1), located in the northern part of the town, included 115 installed water meters. The readings took place in the period from August 2013 to June 2015. This zone was chosen by the municipality due to the prevalence of domestic premises. Furthermore, 140 water meters were installed in Pilot Zone 2 (PZ 2), located in the south-western part of the town. The readings in this zone correspond to the period from February 2014 to June 2015. Lastly, Pilot Zone 3 (PZ 3) was designed to cover the two main avenues of the town where most tourist facilities are located (Av. Baltra and Av. Charles Darwin). The readings in this zone were taken from 54 domestic water meters in the period from September 2013 to June 2015. All of these water meters were placed in the distribution network before the individual storage facilities, accounting also for spillage and wastage. The results from these readings indicate average specific demand ranging from 156 lpcpd to 568 lpcpd, for the different pilot zones and the different years.

This section aims to verify the findings of the survey conducted on water demand estimation presented in the previous section, as well as to establish domestic demand patterns using more accurate measurements. Also, it analyses the lack of equity in attempt to find a correlation between the schedules of intermittent distribution applied by the municipality and the water consumption. The preliminary findings showing extreme high figures of consumption raise the question whether the intermittency is really necessary.

2.3.1 Research Methodology

To get more insight and verify the data obtained in previous researches, a fieldwork was carried out from June to August 2015. In collaboration with the municipality, 18 water meters (Flodis-single jet turbine device) were installed in private premises based on their willingness to cooperate and accessibility to install the meters. Figure 2.3 shows the locations of the installed water meters. These were installed on the pipe after the individual storage facility, therefore not accounting for spillage of

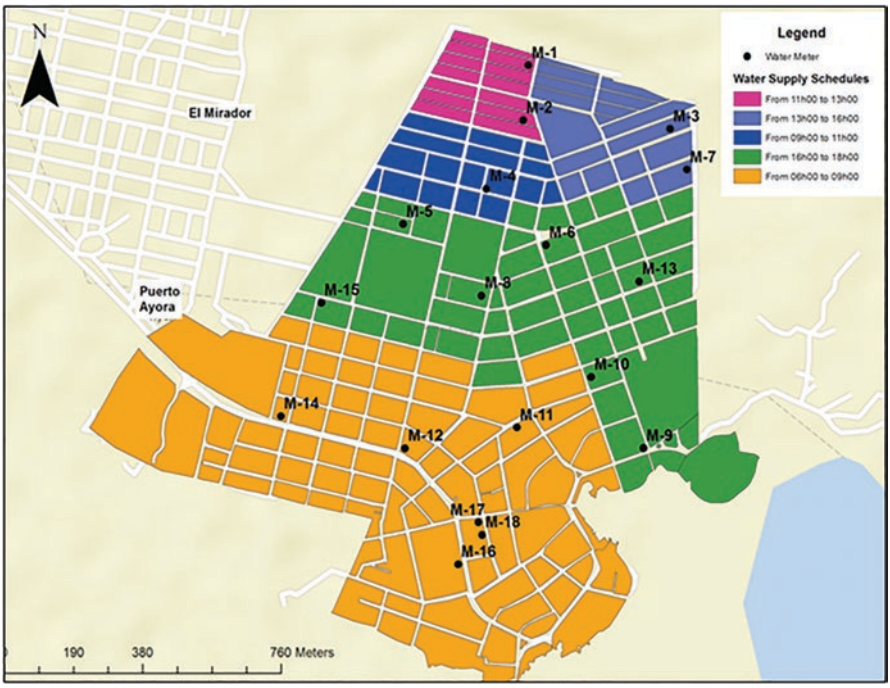


Fig. 2.3 Distribution of installed water meters in Puerto Ayora

tanks or cisterns. The devices were kept for 30 days and then dismantled (for they were borrowed by the municipality of Santa Cruz). Hourly readings from 6 am until 8 pm were observed, and then the following day at 6 am, to observe cumulative demand overnight. The readings were taken during two working days and one weekend day, to compare and register possible change in habits with respect to water use.

Finally, the information from the water cadastres belonging to the pilot zones was thoroughly assessed for each zone. The results were also analysed with the aim of finding some (co)relation between schedules of distribution and wide ranges of consumption.

2.3.2 Results Based on Installed Water Meters

2.3.2.1 Water Consumption

Table 2.4 shows the values obtained from 18 water meters over a period of one month. The average specific demand refers to the weighted average of the readings corresponding to the three days (Eq. 2.1), and the monthly specific demand refers to the per capita average from the 30 days the meter was installed.

Table 2.4 Consumption registered in two working days and a weekend day of 18 installed water meters

Water meter	Consumption working Day 1 (lpcpd)	Consumption working Day 2 (lpcpd)	Consumption weekend (lpcpd)	Average specific demand[a] (lpcpd)	Monthly specific demand[b] (lpcpd)
M1	151	117	208	153	158
M2	101	82	94	91	150
M3	132	78	143	115	140
M4	48	187	216	144	172
M5	257	169	90	176	172
M6	176	114	74	124	288
M7	62	25	76	52	52
M8	247	117	116	162	223
M9	238	238	269	244	275
M10	370	215	97	235	410
M11	140	175	241	179	250
M12	105	71	129	99	86
M13	56	90	80	74	96
M14	80	151	116	114	126
M15	90	54	80	73	71
M16	79	147	51	94	127
M17	78	46	90	69	80
M18	113	50	52	72	75
Average	**140**	**118**	**123**	**126**	**164**
Standard deviation	**±87**	**±62**	**±66**	**±56**	**±94**

[a]Refers to the average of specific demand of the three days of measurement, and [b]refers to the average specific demand based on the monthly measurement taken when the water meters were uninstalled after 30 days and considering the number of inhabitants

$$\text{Weekly specific demand} = \left(\frac{C_{w1} + C_{w2}}{2}\right) * 0.714 + \left(C_{wk} * 0.286\right) \tag{2.1}$$

In Eq. 2.1:

C_{w1} = refers to consumption on the working Day 1
C_{w2} = refers to consumption on the working Day 2
C_{wk} = refers to the consumption in the selected day of the weekend

As can be observed, the average specific demands for the measured week, as well as the specific demands for the whole month, vary significantly. Moreover, most of the monthly-average demands are higher than the weekly-average demands. Furthermore, the results show surprisingly high figures (up to 410 lpcpd), as well as low demands (minimum of 46 lpcpd). For a deeper analysis, the measurements were further assessed from the perspective of the water meter location in a particular

distribution zone and its specific schedule of supply, as well as by anticipating the standard of living of the premises that were metered.

Comparisons could not result in correlations between the demands and a specific zone, i.e. schedule of intermittency. At first, the possible influence of the network pressure due to the location of the households was considered. Also, it was thought that the households located the furthest from the sources of supply could experience lower network pressures and consequently the lower consumptions. However, these hypotheses could not be verified because of the random distribution of demands, regardless the location. Remarkably, the meter M10 with the highest observed specific demand is located in the zone which according to the municipality has a supply for only 2 h per day. Alternatively, these figures may be explained by significant difference in lifestyles and/or volume of individual storage, as well as more negligence in some households than in others, and/or an indication of some sort of informal/illegal tourist business. For example, after the analysis, it was found that one of the households had a small laundry business, explaining the high consumption registered.

On the other hand, low-demand households were also interviewed in order to find the reasons of the low use. In most cases, it has been observed that those families were spending only part of their time in their homes, otherwise spending their time in the premises of their relatives'. Also, in other cases, some members of the family were on holidays.

2.3.2.2 Water Demand Patterns

Daily demand patterns were created from the hourly measurements taken during two weekdays and one weekend day. Since an average for the night hours was calculated, the night period is represented by a straight line. The schedule of intermittent supply reported by the municipality does not specify any supply between 6 pm and 6 am, suggesting that the use of water in this period is, exclusively, from the individual storage.

Figure 2.4 shows the variation in peak factors between different consumption days. The highest peak was observed in the weekend (Saturday), due to the fact that cleaning, laundry and gardening are usually performed during this day. Also, the lower peak was observed in the weekend, portraying the variation in the schedules of the household habits; since it is a non-working day, families tend to leave the premises. Furthermore, in the two weekdays (Tuesday and Thursday), the three peaks (morning, midday and night) are more evident.

2.3.3 Analysis of Water Demand in Pilot Zones

The information from the water cadastres of the municipality were thoroughly organized and analysed. Table 2.5 summarizes the water consumption of the three pilot zones which shows that the average specific demand differs between years and pilot

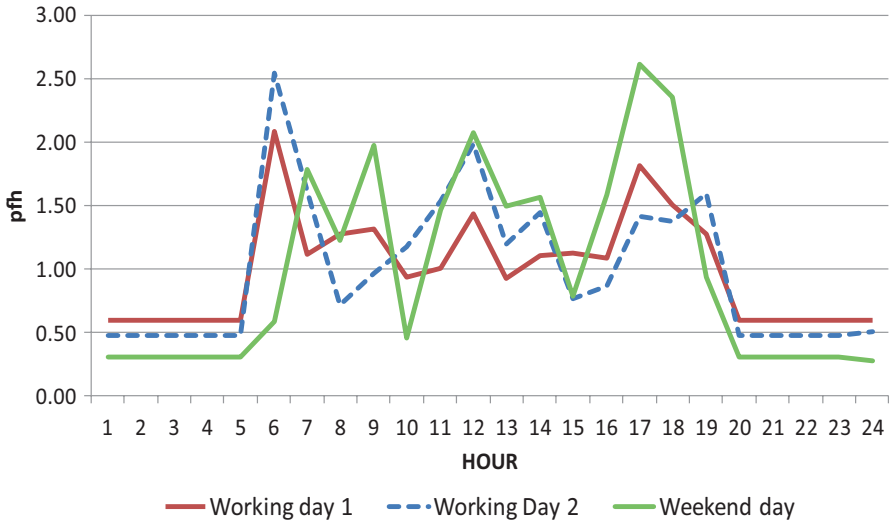


Fig. 2.4 Hourly peak factors for three type of days from 18 installed water meters

Table 2.5 Summary of water demand for three metered pilot zones in Puerto Ayora for 2013, 2014 and 2015

Pilot zone	Year	Total average consumption per month (m^3)	Average consumption per premise (m^3)	Specific demand (lpcpd)	Standard deviation (lpcpd)
PZ 1	2013	2689	23	156	±19
	2014	1039	29	191	±39
	2015	3449	30	200	±36
	Average	**2393**	**27**	**182**	**±31**
PZ 2	2013	–	–	–	–
	2014	2175	24	158	±37
	2015	4877	35	232	±93
	Average	**3526**	**26**	**195**	**±80**
PZ 3	2013	2197	33	217	±32
	2014	4041	75	499	±88
	2015	4599	85	568	±92
	Average	**3612**	**64**	**428**	**±70**

Source: Water cadastres from the municipality of Santa Cruz

zones. PZ 1 and PZ 2 have similar averages of specific demand, as well as standard deviations, showing a wide range of consumption for different households. However, this range of consumption is significantly wider when compared to the results obtained from the surveys in Sect. 2.3. The highest average values of specific demand are in PZ 3. However, most of the tourist facilities are also located in this zone, meaning that it could be a mixture of different consumption categories.

In order to visualize graphically the broad ranges of consumption for the three pilot zones, Fig. 2.5 (a), (b) and (c) show the maximum, minimum and average specific water demand per month, assuming five inhabitants per household.

As observed in Fig. 2.5, per capita demands differ significantly between each pilot zone and each household. There are households consuming as high as 1500 lpcpd and others as low as 50 lpcpd in PZ 1 and PZ 2. Evidently, the highest values indicate some sort of informal tourist accommodation or excessive wastage in form of spilling elevated tanks or cisterns. According to a survey done by WMI (2013), some of the metered premises had informal tourist accommodation businesses. Moreover, on PZ 3, there are premises consuming as high as 4500 lpcpd, implying that these 'households' are actually not 'domestic'. Furthermore, most of the peaks observed are in the months of March, April, May and June, which correspond to the warmest months of the year, while the lowest consumptions are observed in August, September and October, suggesting some influence regarding the season. However, the temperature variations in the Galapagos Islands are not abrupt as in other tourist islands.

2.3.4 Analysis on Scarcity of Water in Puerto Ayora

Table 2.6 shows the comparison of the average water supplied per day obtained from the municipal records, against the estimated average water demand from different scenarios (3 pilot zones and 18 installed water meters). The assumed figure of 17.5% for leakage is the lowest possible based on previous analysis (Reyes et al. 2016; UNICEF 2000; Chowdhury et al. 2002).

By assessing these figures, it can be observed that for most of the scenarios, there is sufficient water to satisfy several average specific demands (even if they are high). Only for the case of PZ 3 scenario (2014 and 2015), the average amount of supplied water would not suffice. However, these averages of specific demand are extremely high and very unlikely to be the representative ones for domestic households.

This also indicates that the perception of limitation of water is not entirely accurate. Furthermore, if the number of unreported tourists in private accommodations is high, it could lower the extreme values of domestic specific demand significantly. If the supplied average is observed, the figure from 2014 increased compared to 2013 by ±1000 m^3/day. Since 2014, one of the pumps has been operating the 24 h per day (according to the municipality), while the other one is still operating 12 h per day; in previous years (e.g., 2013), both pumps were on average extracting water only 12 h per day. Further increase in extraction capacity is questionable due to the extra pressure on the basaltic aquifer and possible increase in salinity of the resource. Also, because of the fixed tariffs and storage tanks, if more water is available, then more water is most likely to be consumed or wasted (some as spillage of tanks). This seems to be the case for the latest years (2014 to 2016), since the amount of water extracted has increased by 50%, but the total supply hours have not increased at all.

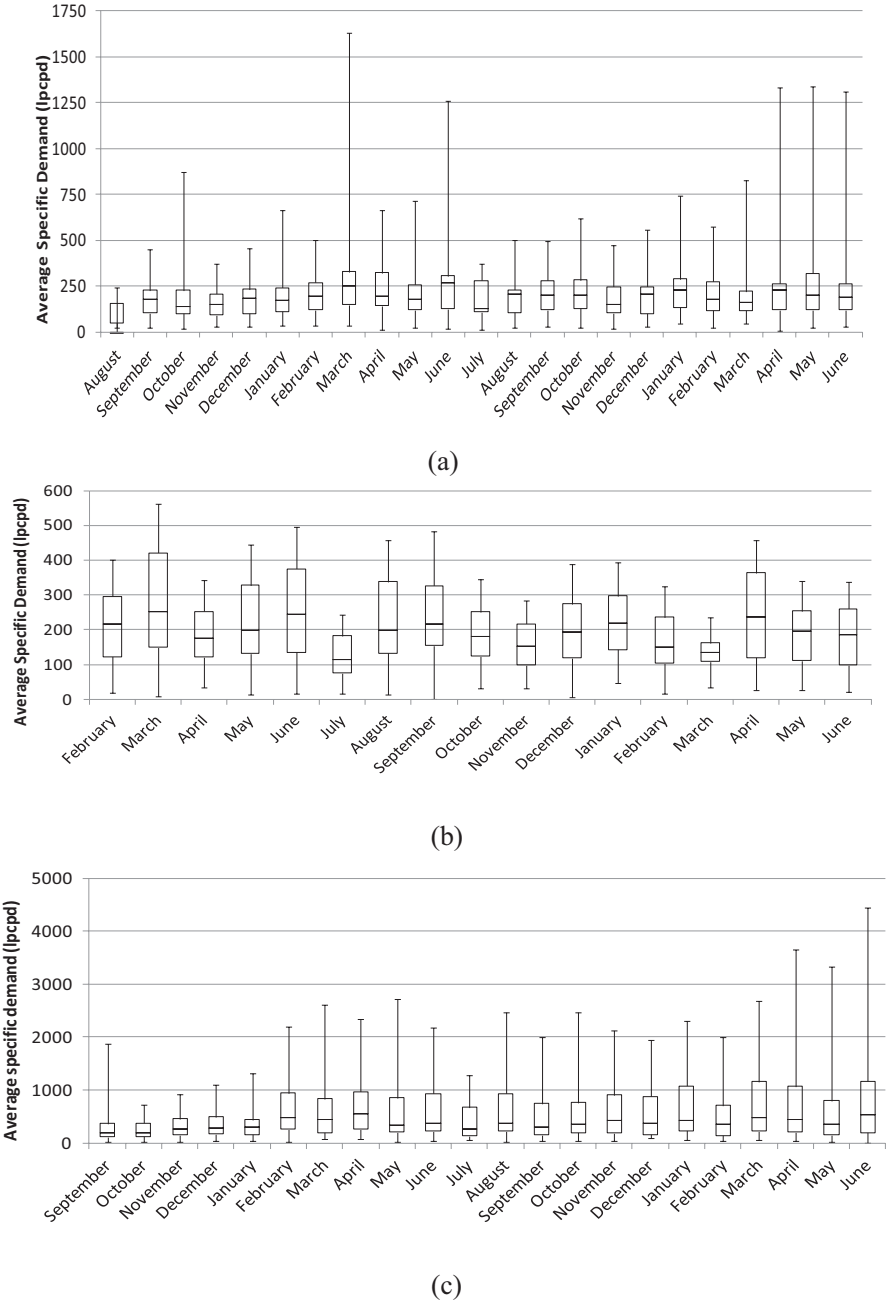


Fig. 2.5 Box plots showing the maximum, upper quartile, median, lower quartile and the minimum values of specific demand on (**a**) Pilot Zone 1, (**b**) Pilot Zone 2 and (**c**) Pilot Zone 3

Table 2.6 Estimation of water remaining based on different scenarios of consumption

2013						2014					2015				
Senarios of consumption	Average specific demand 2013 (lpcpd)	Total demand 2013 (m3/day)	Total average supply 2013 (m3/day)	Leakage[a] (m3/day)	Remaining (m3/day)	Average specific demand 2014 (lpcpd)	Total demand 2014 (m3/day)	Total average supply 2014 (m3/day)	Leakage[a] (m3/day)	Remaining (m3/day)	Average specific demand 2015 (lpcpd)	Total demand 2015 (m3/day)	Total average supply 2015 (m3/day)	Leakage[a] (m3/day)	Remaining (m3/day)
Pilot zone 1	172	2235	3224	403	586	208	2699	4305	538	1067	219	2846	4303	538	919
Pilot zone 2	–	–	–	–	–	221	2875	4305	538	891	207	2693	4303	538	1072
Pilot zone 3	217	2819	3224	403	2	499	6483	4305	538	−2717	568	7378	4303	538	−3613
Water meters	–	–	–	–	–	–	–	–	–	–	164	2130	4303	538	1635

[a]Leakage was assumed to be 50% of previously calculated Non-Revenue Water by Reyes et al. (2015)

The discussion of the results points to an evident lack of management regarding the water distribution system. With the figures obtained for demand and supply, the quantity of water does not seem to be the key issue, but it is more the quality. As observed from specific demand figures, despite the fact that some premises are registered as domestic, they seem to have some sort of informal accommodation or tourist business, especially in PZ 3. This refers also to the lack of cross-checking of information among institutions. As mentioned before, the accurate registration of tourist premises, as well as the information about number of tourists, is essential to get real figures about the domestic (and tourist) specific water demand. Moreover, there is evidence that some households consume extremely high quantities of water. This hints that there is enough water, for at least more hours of distribution than the current ones. It can also be inferred that the storage systems may not be aiding the intermittency, as originally considered, but complicating the situation. This also proves that there is a lack of equity in the distribution of the water, which can be attributed directly to the storage facilities. The bigger the storage facilities, the less the availability of water for the rest of the consumers. Therefore, the individual storage does not necessarily seem to be the best alternative regarding equity within the local population and solving the scarcity issue of the town.

2.4 Conclusions

In this poor-data case study area, the generation of this data is fundamental for decision-makers. Involving the collection of information from different sources and institutions, the lack of communications and cooperation among relevant organizations influences the current water supply crisis since there is no cross-check of information or follow-up of studies. Therefore, this thorough assessment intends to help the authorities seek for specific solutions to the problems portrayed in this fragile ecosystem. Since one of the government's objectives is the exponential growth of tourism, it is necessary to arrive at a full-level scale solution, and not locally-based (as it is currently). Therefore, there is a need for a holistic solution, where the government needs to involve and manage different stakeholders and develop multidisciplinary, interdisciplinary and transdisciplinary approaches.

The survey provided a scenario reasonably close to reality and has enabled preliminary calculations of demand for different consumption categories. The highest water demand was observed for the hotels, with an average consumption of 469 lpcpd, which accounts for 49% total water demand on this island. Regarding the domestic water use, there is an evident difference in per capita averages of consumption of municipal water (163 lpcpd in Puerto Ayora and 96 lpcpd in Bellavista) suggesting that different tariff structures may influence the consumption. In Bellavista, where water is charged per cubic metre, the demand per capita is reduced by nearly 40% than the demand in Puerto Ayora.

The total domestic per capita demand, including all types of sources, is significantly higher in Bellavista (253 lpcpd). This is due to a high consumption from

rainwater and water purchased from trucks. Based on these findings, it can be concluded that in general there is no real scarcity of the water resources within the island (190 lpcpd in average is consumed per inhabitant in Santa Cruz), but instead there is a deficient management of water supply and demand.

This study also addressed the issue of domestic water demand in Puerto Ayora (Santa Cruz Island). For critical analyses of specific domestic water demand, 18 installed water meters were installed, and the meter readings from three pilot zones made available by the municipality of Santa Cruz were analysed. The average specific demand from the different scenarios provided the same conclusion for all three sources of information: There is a wide range of consumption in Puerto Ayora (averages ranging from 156 lpcpd to 568 lpcpd). The wide range of per capita consumption can be most likely attributed to the different habits within the local population. Also, it can be explained by the lack of awareness and consequent wastage of water within premises, which could be a direct consequence of a fixed tariff structure. Spilling of elevated tanks has been identified as a major problem, and it can be supported by the figures in this chapter.

The reported range of consumption is surprising for an island where water resources are perceived as scarce. Thus, the figures clearly portray that currently there is sufficient brackish water available. Finally, the results obtained also suggest that the intermittency could be reduced if the distribution system would be better managed and demand management practices would be taken into account. This study has shown that the hours of intermittency need to be re-evaluated or even completely eliminated. Storage tanks are not necessarily helping the local population as has been thought over the last two decades, but has contributed to the limitation on the performance of the supply system. This also calls for a change on tariff structures, creating awareness within population. Finally, the leakage needs to be further assessed, since this is an important figure when calculating the amount of total actual supply to consumers.

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