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Data assessment for water demand and supply balance on the island of Santa Cruz (Galápagos Islands)

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ABSTRACT:

The island of Santa Cruz, the most populated of the Ecuadorian Galápagos Islands, is currently experiencing extreme pressure on its water resources due to exponential increase in tourism and corresponding growth of the local population. Because of that, the municipal water supply system has not been able to provide reliable and continuous service of safe drinking water. This study aims to describe the current situation related to the scarcity of water, by analysing and quantifying the total supply as a first step towards further development of a water balance for Santa Cruz. It elaborates on three different water sources, the differences between the two main urban settlements and constraints which the Municipal Department of Potable Water and Sanitation have been dealing with. The conclusions include among others, that the specific demand supplied from different sources is ±370 lpcpd, which is surprisingly high figure for a water scarce area.

Keywords: Water supply system; Water demand; Supply from crevice; Bottled water; Water tariff structures; Galápagos; Tropical insular environment; Tourism

1. Introduction

Santa Cruz is the most populated island located in the central part of the Galápagos Archipelago belonging to Ecuador. The airport located at the neighbouring island of Baltra has been receiving visitors from all over the world since the 1980s. Fig. 1(a) shows the location of the Galápagos Islands and Fig. 1(b) shows the map of Santa Cruz, indicating the location of the two main settlements, Puerto Ayora and Bellavista, with total population of 61.3% of the archipelago [1]. Puerto Ayora is the biggest, yet a small town of approximately 12,000 inhabitants [2] located on the south coast, followed by the village of Bellavista, located at 180 m above sea level, 7 km inland, with population of approximately 2,500 inhabitants. A number of housing developments alongside the main road connecting the two settlements are characterized with lower population density. The access to basic water supply services there is possible through the existing network, but is more costly than in the concentrated areas of Puerto Ayora and Bellavista. Currently, there are new developments occurring, which cause additional problems as the public water supply network does not reach those areas yet.

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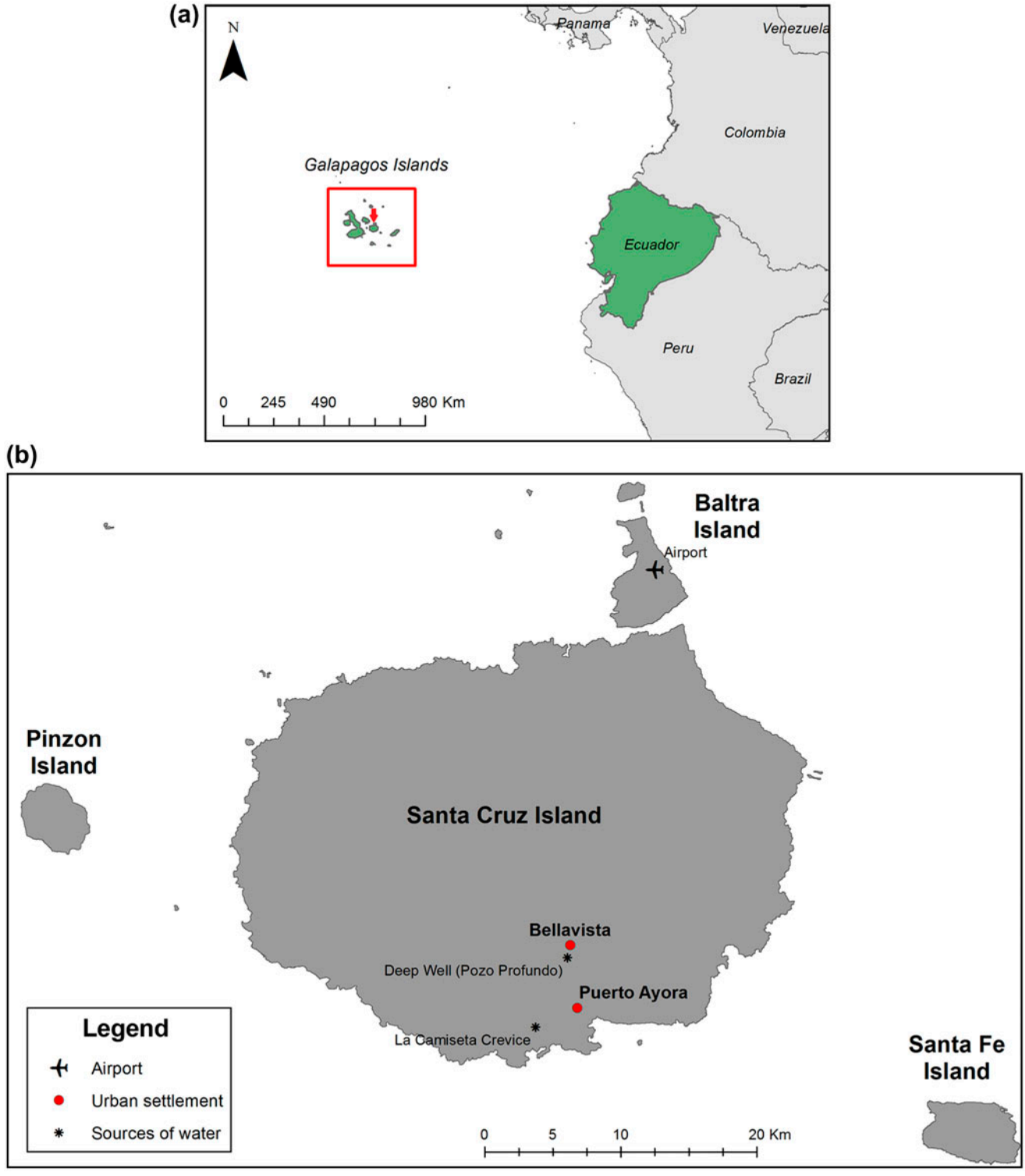

Fig. 1. (a) Map of Ecuador and the Galápagos Islands and (b) map of Santa Cruz Island and the main urban settlements.

Puerto Ayora is the main tourist centre in the Galápagos Islands. The recognition of ecological uniqueness and need for conservation of the Galápagos has enhanced tourist activities significantly, becoming undoubtedly the biggest and the fastest growing business on the islands. The increased

number of tourists has also resulted in the rapid population growth, which has had significant economic impact [3] on the island. The main driver for this significant increase in population (from the mainland) over the last years has been to support the tourism industry, as well as an opportunity to generate income. Consequently, there has been a noteworthy increase in the number of travel agencies, restaurants, hotels, bars, etc., additionally stressing the water resources and environment in general. As a means of controlling this trend, the Galápagos Special Law was brought out in 1998 with the aim of controlling migration towards the islands [4].

According to the Galápagos National Park records in 2013, the islands welcomed 180,831 visitors compared to only 17,445 visitors received in 1980. According to [2], there has been an exponential increase in the number of visitors and in the local population [5]. In the 1970s, the "floating hotel" model was the main form of tourism, where visitors stayed on ships and brief visits were allowed to the different sites on the islands. Nevertheless, most of these vessels used to get potable water from Puerto Ayora. During the 1990s and the 2000s, the tourism model changed to land-based tourism, with the island infrastructure and services upgraded to host more guests staying on the islands. Nowadays, most of the ships visiting the islands have their own desalination plants on board and put no more additional demand on scarce water resources.

Available information regarding tourism in Galápagos is not always consistent. Also, there is a lack of cross-checking of information originating from different institutions. For instance, according to the Ministry of Tourism, in 2013, there were 159 tourist accommodations, of which only 53 were registered legally. On the other hand, according to the Municipality of Santa Cruz, there are only 118 tourist accommodation facilities [1]. In contrast, the Department of Potable Water and Sanitation (DPWS) reports that only 32 service connections have been registered as tourist accommodation (big and small hotels). These discrepancies suggest that some important data need to be validated.

The growth in the local population and tourism in Santa Cruz has increased the pressure on natural resources, which is a consequence of greater demand for basic water supply services [6]. Unfortunately, the municipal supply system cannot cope with the current demographic expansion. Among the numerous reasons are financial constraints, lack of personnel and fixed tariff structures as a foundation of the water billing system [7]. Also, the volcanic nature of the soil makes expansion of water supply network extremely difficult. Due to these constraints, water is perceived as scarce and the service as poor [6]. The water distributed through piped networks has no treatment and is of very low quality. The high concentration of chloride (from 400 to 1,200 mg/L) makes it brackish and not suitable for human consumption. Several studies have confirmed contamination by *Escherichia coli* and many water-related diseases have been reported [8]. Proper sanitation is lacking as a result of the absence of sewerage system and proximity of precarious septic tanks from urban settlements. The aged and unreliable water distribution networks also contribute to the contamination problem. Hence, the islands are confronted with low quality, contaminated and undrinkable water [9]. Moreover, the water supply system is intermittent since the supply is provided on average only three hours a day. Consequently, this limited service has influenced inhabitants to build their own water storage in form of cisterns and elevated tanks. In fact, the roots of these problems seem to be deeper and refer to technical shortcomings as well as issues such as decentralized water supply, lack of consumers' awareness of water conservation and inadequate tariff setting.

Although some scattered studies related to the water resources have been done in the past, a complete assessment of the current situation, including all important aspects of water supply in Santa Cruz, is yet to be conducted. Research has been carried out regarding the nature of the water resources, as well as the supply issues and bacteriological contamination in [10–12]. Another research [6] addressed the perspectives, usage and management of water in Galapagos.

Yet, the implementation of management measures and solutions is still absent. The Galápagos Islands are in urgent need of water management solutions, which require reliable data and an integrated approach to the water supply and demand, in order to assess the magnitude of the problem accurately. The existing initiatives include those carried out by Water Management International, who are monitoring water losses and the (pilot) installation of water metres. Furthermore, the available literature that could serve as a basis for this research is insufficient both in quality and quantity. Though there is more literature on the issue of water resources in the Galápagos Islands than before, there is a lack of integrated and systematic data. This is a direct consequence of local institutions not conducting any follow up of previous research, studies and consultancy. In such an environmentally fragile ecosystem, researchers tend to conduct studies towards conservation and environment, becoming less aware of the link of human impacts on water and the direct relation to environment degradation. The

environment is affected by overexploitation of sources for water supply and discharge back of untreated wastewater; therefore, this research points the relevance of achieving good quality information on the water cycle (balance), so that the measures can be taken with greater confidence.

This study presents and analyses the current water supply situation in Santa Cruz by integrating the available information in order to arrive at a sustainable balance between demand and supply. Furthermore, the results of this study will support the implementation of water management measures. Also, the study presents a framework to determine the maximum economic impact from tourism, preserving a fragile and unique ecosystem, which may be used in other similar case studies of tourist islands. This is a first step in the direction of determining suitable procedures due to the lack of data and contributes to an holistic solution by pointing the relevance of water supply and its link with the environment. At a later stage, the aim of establishing a water balance will be to maximize the economic benefits of tourism while preserving the fragile environment.

2. Water supply in other touristic islands

Many small tropical islands worldwide are arid and have limited water resources, experiencing excessive population density, water demand and consequently potential for pollution of the resources [13]. The major impacts for these islands originate mainly from tourism and corresponding population growths. Tourism has been identified as the most dominant sector of the economy in several islands and island states, becoming a major source of income and employment [14]. However, tourism increases overall per capita water consumption, concentrating it in time (often the dry season). For example, in some areas of the Mediterranean, the ratio of local population to tourists may change over the year, reaching a magnitude by more than six to one. Specifically, in the Balearic Islands, water use during peak months of tourism (e.g. in July 1999) was equal to 20% of the water use of the entire population for the whole year [15].

Though tourism generates significant revenues, it causes a significant demand for natural resources, inflicting environmental and infrastructural costs and threats, which unfortunately are often not taken into account [16]. As a result, tourism growth has caused deficiencies in the provision of water supply and sewerage systems in many islands and island states [17,18]. For example, according to [16], a tourist consumes in Malta on average, three times more water than a local resident, creating a challenge for water supply utilities.

Increased water demand is therefore mainly caused by the tourist sector; for example, in the Mediterranean Islands, an average tourist consumes between 440 and 880 litres per capita per day (lpcpd) [19], while in Jamaica, Barbados, St. Lucia and the Philippines, the reported specific demands are 992, 756, 662 and 1,499 lpcpd, respectively [20]. The locals, on the other hand, consume on average as follows: in Mediterranean Islands 200 lpcpd, in Jamaica 160 lpcpd, in Barbados 200 lpcpd, etc.

This freshwater availability is mainly attributed to the geology and formation of the different islands. In case of volcanic islands, the lack of freshwater is significant. Their main source is brackish groundwater, which is the mixture of intruded seawater and rain in the basal aquifers. Water availability may also vary depending on the levels of precipitation, making some regions more water scarce than the others. The most common source has been identified as groundwater in the Caribbean islands such as Bahamas, Barbados, Jamaica and St. Kitts. Some other islands do have supply from surface water, such as St. Lucia and Trinidad & Tobago [21]. Several Mediterranean islands, such as the Greek Aegean, as well as Malta, have desalinated seawater as their main source [22]. In extreme situations, freshwater is imported on tanker ships from the mainland such as in Bahamas, Antigua, Mallorca and the Greek Islands [23].

According to [24], small islands and island states are restricted in various ways, namely by physical isolation, lack of organizational expertise, deficient human and financial infrastructure, limited availability of freshwater, poor prospects for water harvesting, high leakage levels, and absence of effective pricing and cost recovery systems. Due to these reasons, supply alternatives need to be explored [25]. The literature points to several technical options to increase available water capacities, especially addressing desalination [22,26]. Furthermore, several environmental measures for creating awareness have helped urban water consumption to drop and stabilize as in the case of the Balearic Islands [27].

Therefore, research is needed to understand the weaknesses of current supply systems in order to develop appropriate solutions. Also, understanding the use of water will contribute to less environmental degradation and better management. Water supply in scarce regions is very complex, especially in the Galápagos Islands, where the supply system is old and unreliable, conveying mainly brackish water.

3. Methodology

A fieldwork being a key part of the research was carried out between September 2013 and January 2014. During this period, the aim was to review the locally available information. Furthermore, several meetings were organized with the main representatives of local institutions to verify the information compiled and investigate whether there was additional work done on water supply. The purpose was also to identify gaps or overlaps in the information. This qualitative method was used, preparing different questions for the different experts, depending on their position, knowledge and experience on water issues. This also provided the tool to assess all water-related problems from different angles and evaluate different initiatives. Table 1 shows the institutions and the respondents.

4. Main stakeholders involved in water resources management of Santa Cruz

Santa Cruz is an area, denominated as a county, with a decentralized autonomous municipality. It is one of the three counties in the archipelago. Water resource management in Santa Cruz is therefore also not centralized. Several public institutions and entities are involved in the management and/or conservation of water. Table 2 summarizes the main water-related institutions within the island of Santa Cruz and their main responsibilities.

Because of the governance structure, the communication among the institutions and the exchange of information are irregular. The consequence is occasional overlap between similar studies carried out by various public institutions and NGO's.

Table 1
Institutions and responsible person selected for the meetings

Institution	Respondent
Municipality of Santa Cruz	Mayor's advisor
DPWS	Chief of department
National Water Secretariat (SENAGUA)	Chief of department
Ministry of Tourism	Expert responsible for the monitoring programme
Charles Darwin Foundation	Chief of the scientific department
DPNG	Chief of applied research department

5. Main sources of water at the island of Santa Cruz

Water supply in the island of Santa Cruz originates from three sources: (a) municipal water supply system, (b) desalinated water from private water purification companies sold in different forms and (c) supply from so-called private crevices (boreholes), the latter being out of public control.

5.1. Municipal supply

Water provided by the municipality is supplied through two different systems belonging to Puerto Ayora and Bellavista, each one consisting of a different source and a separate distribution network. None of the conveyed water is treated. It is mainly brackish and consequently not suitable for human consumption according to national and international water quality standards. The DPWS of Santa Cruz reports that 95% of the population of Santa Cruz has access to a centralized water supply system, while the remaining 5% of population have their own supply (from "private" wells and/or from vendors) [7].

Water from the distribution network is used for most activities except for drinking and cooking. It is regularly used for showering, toilets and other household activities. The water supply system is unreliable and intermittent, as supply never exceeds a few hours per day.

Table 3 shows the main differences between the supply systems in Puerto Ayora and Bellavista.

5.2. Desalinated brackish water

Bottled water is sold to compensate the lack of potable water from the municipal system. The purified water is produced by desalination of brackish water by private companies owing small-scale reverse osmosis plants. There are six desalination companies in the island with unknown production rates [8]. According to the only possible interview with one of the owners, the average production rate per company per day could be around 25 m^3 to satisfy the demand from local and tourist population. Another study [8] estimates the average daily production of 30.7 m^3 per company. The water is sold in containers of different size and in bulk. This water is mostly used for drinking and cooking, and some hygiene, depending on the family habits and ability to pay for this option.

The cost of desalinated water is high (2 USD for a 20 Litre container) for it is publicly accepted as the safest water and is the only source of drinking water. According to the recent researches [6], 75% of surveyed homes buy bottled water for human

Table 2
Main institutions and their responsibilities related to water supply in Santa Cruz

Institution	Role	Responsibility	Comments/remarks
CGG	It is the authority that articulates the regional planning of the islands. Also defines roles and responsibilities of other entities and links them together for the benefit of the islands	This entity is responsible for developing and dictating the policies for Galápagos	CGG is also responsible for generating different regulations in order to preserve the islands and control migratory fluxes and illegal immigration
DPNG	Administer and manage the protected areas, which is 97% of the total territory of Galápagos	This is the supreme authority in terms of conservation within the islands and is also the responsible for scientific research in order to understand different natural processes and generate lacking data	Since water is a strategic resource and should be managed by SENAGUA, the national constitution dictates that protected areas and biodiversity are mainly managed by the environmental competent institution, in this case, DPNG
SENAGUA	Highest authority in Ecuador (national level) in charge of managing water patrimony with an integral focus per source (SENAGUA 2012)	Strengthening of the regulations, control of water resources planning and management, private and public concessions and activities that may affect the quality and the quantity of these resources	Opened operating offices in Santa Cruz only in 2012, with the aim of controlling extraction of water from different crevices; nevertheless, the lack of personnel has made this assignment difficult and long
Municipality of Santa Cruz	It is the institution in charge of providing some basic services to local population, as well as planning the urbanization expansion and projections of future areas for settlements	Its department of Potable Water and Sanitation has the competence of providing the water services to the whole island, including the maintenance of the system	This department is the one in charge of presenting projects for supplying potable water
WMI	It is a private institution that signed a cooperation agreement with the Autonomous Decentralized Municipal Government of Santa Cruz in 2012	The project is specific for the implementation of optimization and sustainable development of potable water and sanitation systems, (WMI-GIZ 2013)	It has financial support of the Deutsch Cooperation "Deutsche Gesellschaft für Internationale Zusammenarbeit–G.I.Z"

Table 3
Comparison between water supply systems of Puerto Ayora and Bellavista

Characteristic	Puerto Ayora	Bellavista
No. of connections	2,591	444[a]
Tariff Structure	Fixed	Metered
Extraction site	Crevice "La Camiseta"	Constructed deep well
Type of water	Brackish (800–1,200 mg of Chloride/L)	Brackish (490 mg of Chloride/L)
Potable treatment (including chlorization)	No	No
Extraction rate	Approximately 3,000 m^3/d	Approximately 260 m^3/d
Constant supply	No	No
Management	Department of potable water	department of potable water

Source: Personal communication with the Municipality of Santa Cruz [34].
[a]Up to December 2013.

Table 4
Private crevices and their uses throughout the urban settlement of Puerto Ayora

Name of crevice	Uses
Misión Fransciscana	Desalination of water for private company
Tortuga Bay (3 crevices)	Hotels and private properties from Punta Estrada neighbourhood, laundries, etc.
El Barranco (2 crevices)	Private trucks for water sale
Gallardo	A mechanic place and water desalination company
Martin Schereyer A&B	Own cruises and hotels from owner
Pampas Coloradas	Private selling with water trucks

Source: SENAGUA, 2013 [35] and Refs. [1,4].

consumption and 67% for cooking, showing the potential for this business. There has not been a large-scale plant installed due to the lack of financial means from the municipality and local investors. Therefore, the business has been far more feasible by inflicting a rather small investment and bringing relatively high revenues. According to the survey made by [28], 46% of the population in Puerto Ayora and 32% in Bellavista pay the water bill between 5 and 10 USD per month, while 29 and 35% pay more than 20 USD per month, respectively. This corresponds to 1 and 3% of a minimum family income of 600 USD per month.

With the approximate population in Puerto Ayora and Bellavista of 14,500 inhabitants, the average daily consumption of desalinated drinking water is estimated at about 10 lpcpd. This looks high for only drinking and cooking purposes, but the water is also sold in bulk to numerous institutions, restaurants and hotels, which are considered to be the major customers of desalinated water. Therefore, the high value per capita can be attributed to the non-domestic consumers.

5.3. "Private" extractions

This source of water refers to brackish water found deep in the crevices emerging from the volcanic origin of the island. Ten registered crevices are located throughout the coastal area covered by the town. The uncontrolled water extraction from these sources is done by pumping; the exact number of private pumps in each crevice and the quantities extracted is not known, which presents a challenge for the authorities.

Consequently, different owners manage the water resources available on their properties as their own, despite the fact that the water is a public good and belongs to the government. The crevices not located on private properties have pumps and pipes installed illegally, which have been difficult to quantify. Some of these private extractions are for personal purposes and others sell and distribute the water by water trucks. Table 4 shows the major private water sources with approximate extraction based on data provided by SENAGUA and the Municipality of Santa Cruz [28]. The problem to quantify the total amount of water supplied from the crevices exists since the characteristics of the private pumps are mostly unknown. To illustrate the complexity of the situation, Fig. 2 shows a typical group of pipes from one of the crevices, named "Misión Franciscana", with no clear indication of the ownership of the different pipes, as well as the quantities extracted.

6. Water supply systems in Puerto Ayora and Bellavista

6.1. Water Supply in Puerto Ayora

Puerto Ayora water supply system consists of 2,591 service connections (up to December 2013). Its main supply source is from the crevice named "La

Fig. 2. Picture of different pipes in Mision Franciscana Crevice.

Camiseta" located 2.8 km from the urban settlement. Extraction from "La Camiseta", started in 2011 and is done by pumps that supply water to the storage tanks on the site, from where it is distributed to the town by gravity.

The pumping station consists of three 37.8 kW submersible pumps, (only two currently working). Both pumps have an extraction rate of 70 L/s during 12 h/d and convey water through a 315-mm-diameter PVC pipe to two storage tanks (of 600 m^3 and 800 m^3, respectively), located 2.8 km from the crevice and 64 m above sea level. The average supply is 3 h per day; however, in some town districts, it is once every 2 d. Two pipelines link the storage tanks with the main network; one is directed to the northern part of Puerto Ayora, and the other to the central part. Typically, houses in Santa Cruz have their own storage tanks, which vary from house to house (cisterns, elevated tanks, etc.).

There is a fixed water tariff structure in Puerto Ayora based on the category of the customer as established by the Municipality of Santa Cruz.

6.2. Water supply in Bellavista

In case of Bellavista, the water extraction takes place from a constructed deep well called "Pozo Profundo". This source is located 200 m above sea level and has a depth of 160 m, which taps into a basal aquifer. The water is pumped with a 18.6 kW pump, at an extraction rate of 6 L/s, with an average operation of 12 h/d. From there, it is conveyed to a 300-m^3 storage tank and from this tank further pumped with a stationary pump of 22.4 kW with a flow of 12 L/s during 4 h/d, supplied to two reinforced concrete storage tanks (of 500 m^3 and 100 m^3, respectively) as the last stage before distribution. In 2013, another 1,000 m^3 tank was built, and all three are now located on the same site, 218 m above sea level. From there, the water is conveyed to different neighbourhoods of Bellavista by gravity. Bellavista has only 444 connections (up to December 2013), corresponding to approximately 2,500 inhabitants.

All service connections in Bellavista are metered and the water is charged based on the amount consumed, at a price of USD 1.21 per cubic metre. Illegal bypass pipes are occasionally installed around the metres to reduce the measurements and the water bills. The service is provided for approximately 2–3 h per day. Rainwater collection is more popular in Bellavista than in Puerto Ayora due to higher precipitation levels and is a significant additional water source for people living there, 81% of locals collect it, in comparison with 8% in Puerto Ayora [28]. The annual average rainfall over the last ten years in Bellavista is around 1,100 mm, while in Puerto Ayora is 380 mm [29]. Table 5 shows the main differences between the two supply systems. The leakage levels are assessed very roughly by the municipality, based on the condition of the networks, and these data would need to be scrutinized.

7. Differences in tariff structure between the two supply systems

The tariff structure differs considerably between the two supply systems. These tariffs (fixed in Puerto Ayora and linear volumetric in Bellavista) were established by the municipality by regulation in 2000 and then modified in 2004. Later, a complementary regulation established new prices, as well as an increase of 10% every six months, starting from January 2005. However, in 2006, another resolution was created, abolishing the biannual increase of costs, fixing the prices and maintaining them until nowadays [30,31]. This portrays a clear example of the dynamic of politics regarding water issues on this island. For the regional government, potable water is not an urgent matter; therefore, the tariffs have not been modified due to the fear of rejection from local population

Table 5
Differences between two municipal supply systems belonging to Puerto Ayora and Bellavista

Name	Population size	Pumping flow (l/s)	Pump Power (kW)	Average pumping (h)	Approximate leakage[a] (%)	Extraction (m^3/d)	Volume (m^3/year)	Water treatment
La Camiseta (Puerto Ayora)	12,000	35 (2 pumps)	37.8	12	25	3,024	1,103,760	No
Deep Well (Bellavista)	2,500	6	18.6	12	15	259.2	94,608	No

[a]Approximate leakage is according to the Municipality of Santa Cruz.

Table 6
Water tariffs and number of connections in Santa Cruz

Category	Number of connections[a]	Fixed value (USD)
Metered (Bellavista)	444	1.21/m^3
Domestic	1,156	5.24
Commercial	944	11.24
Hotels	14	45
Industrial/ Laundries	21	45
Residential	20	28.50
Official	28	6.12
Pool	1	28.50
Total	**2,628**	–

[a]Up to December 2013.

based on the low quality of water and the service. Consequently, the current water tariffs are significantly subsidized by the municipality [32].

Table 6 shows different categories for fixed tariffs and the corresponding costs per category, as well as the total number of water connections for each category according to the DPWS. Domestic category refers to the premises smaller than 100 m^2, while "Commercial" are premises larger than 100 m^2, which also includes the businesses. The water tariff in Bellavista is also higher due to the quality of distributed water, which is less brackish than in Puerto Ayora.

According to the study made by [6], the customers in Bellavista tend to be more aware about saving the water. Also, because of the payment depending on the actual quantity used, rainwater harvesting is more popular alternative there. Premises in Bellavista have some sort of storage for this type of water, because the precipitation levels are higher than in the lower lands [28]. On the other hand, based on the answers of the study by [6]), the families in Puerto Ayora do not feel comfortable with rainwater harvesting because they perceive it as an outdated method of water collection. For that reason, they expect that local authorities supply enough water and at affordable prices. Consequently, the lack of awareness in Puerto Ayora is evident due to excessive water wastes, such as spilling of storage tanks, due to low tariffs.

8. Assessment of water consumption for various categories in Santa Cruz

The municipality has been struggling in the last decades to extend the service and improve the supply both in terms of quantity and quality. Different demand categories have been established by the regulations in 2000 and 2004 ("Ordinance which regulates the water service in Santa Cruz County") and then reformed in 2005 ("Modified and Complementary Ordinance which regulates the water service in Santa Cruz County"). By law, the municipality has a mandate to fix the tariffs for water consumption and other public services. These tariffs are defined based on the analyses of supply schedules for different categories and service areas, and also include maintenance of the system. Nevertheless, the collected revenues do not cover 100% of the operation and maintenance costs; this deficit has to be covered/subsidized by the municipality.

The exact water demand in Puerto Ayora is still unknown due to the lack of metering. It is therefore difficult to allocate the water demand to different categories, except that it is known that the hotels are major consumers within the island. According to an interview at the Ministry of Tourism, in study made in 2012 by the Spanish Scientific Society called "Estudio de Subsidio y Huella Ecológica" for Galápagos, the daily consumption of an average tourist was specified at 260 lpcpd. Such a high figure has been mainly influenced by the construction of swimming pools in the hotels. Therefore, the Ministry of Tourism has developed a project named "Buenas Prácticas" (Good Practices), where 17 hotels voluntarily subscribed to the plan in order to become more environment-friendly, including the introduction of water saving practices [33].

According to the information provided by these hotels, the average expenditure on water per premise is around USD 127 per month. The average expenditure also considers water bought from water trucks as well as bottled water, to compensate the lack of municipal water. This amount may be considered high when compared to usual tariffs for hotels of USD 28.50 or USD 45 per month, depending on the size. Furthermore, on a study made by [32], the average price paid by hotels was calculated between 0.12 and

Fig. 3. Picture of a typical elevated tank in Puerto Ayora.

0.24 USD per cubic metre for municipal water. Though these prices are extremely low, the municipality has not considered to change them.

The water wastages are overwhelming and excessive, especially in Puerto Ayora. The major water losses occur within customer's premises, especially at individual storage systems when they are being filled up and spilling occurs because the faucets are kept open much longer than necessary. This is a common negligence in Puerto Ayora, of which the DPWS is aware of, yet there are no policies regarding this, nor structured system in place to monitor and control it. Fig. 3 shows a typical elevated tank.

Centralized potable water and sewerage systems have been promised by the Municipality of Santa Cruz for the last 20 years. Nevertheless, the proposed project for potable water has not been finished yet. In 2012, the sewerage pipes were installed in the main (central) neighbourhood of Puerto Ayora, and also around 40% of water pipes were renewed. As of December 2013, the water pipes have been rehabilitated to conclude the potable water component of the project by mid-2015. Nevertheless, the project has been suspended due to political issues.

9. Management problems in the Municipal Department of Potable Water and Sanitation

Currently, there are 12 employees in this department. The department is led by a civil engineer with two personal assistants, and 10 staff for technical and administrative tasks. The technical tasks include operation and maintenance of the supply systems and the water metres reading in Bellavista. Furthermore, the

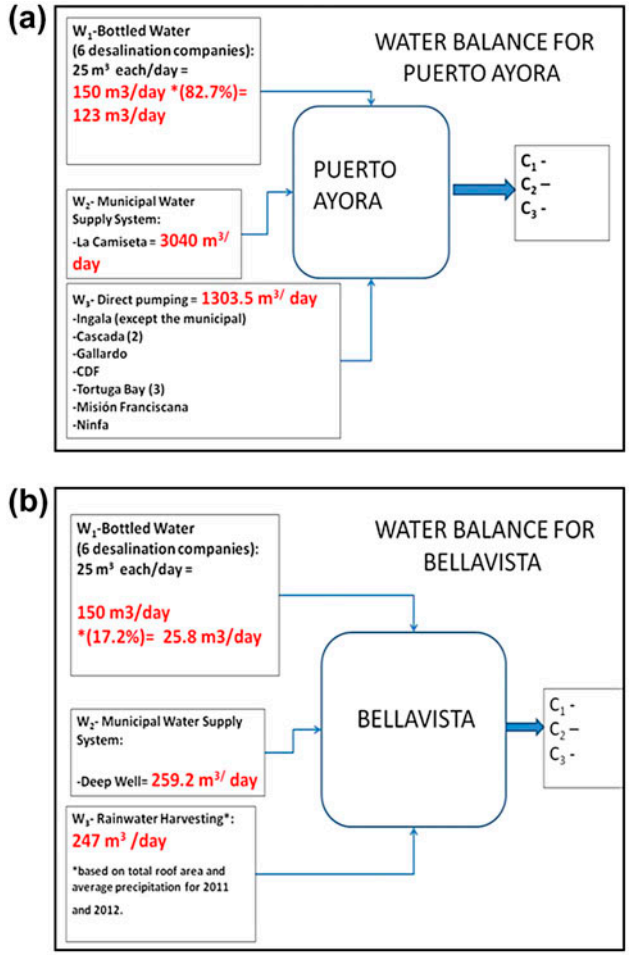

Fig. 4. Water balance of (a) Puerto Ayora and (b) Bellavista.

employees are responsible for billing, fixing pipe leakages or bursts, general maintenance of equipment and water metres, and cleaning of septic tanks. Obviously, the staff capacity is not sufficient, and therefore, many activities have to be postponed or skipped.

The limited number of staff as well as the level of expertise is one of the reasons why the municipality is not able to cope with the current population growth, as well as the increase in premises for tourists, restaurants, hotels, etc. The department has stated the need to prioritize their activities, focusing to the reparation of bursts in pipes and evident or reported water leakages. As a consequence, when the leaks are reported, any other activity is put on halt, leaving the regular work postponed, which suggests that regular maintenance and monitoring are neglected.

The DPWS also has to cope with the restricted budget. According to the municipality, the current budget is not sufficient for all the activities and

Table 7
Estimations on total water supply in Santa Cruz Island

Supply source	Quantity supplied (m^3/d)	Quantity supplied per capita (lpcpd)
Municipal Water (La Camiseta and Bellavista)	3,283.2±	226.4±
Bottled (Desalinated Water)	150.0±	10.3±
"Private" Extractions	1,951.5±	134.6±
Total	**5,384.7**±	**371.4**±

expenses of the water supply system due to the old age of the 60% of the network. According to the DPWS, the water tariffs cover only 80% of regular daily operations and management, hence not providing income for reliable water service. The deficit of 20% is subsidized by the municipality, generating a significant annual loss which could be covered if the tariffs were higher and differently structured. This economic limitation also portrays a challenge for the water department to expand accordingly as expected and provide a better service.

10. Institutional issues in Santa Cruz

One of the main problems in Santa Cruz is the lack of governance and policies developed specifically for this type of fragile ecosystem. The different institutions in charge have not yet defined clearly the comprehensive legislation and roles and responsibilities of different entities involved in water resources. Another issue is the lack of communication and organization among the different entities. There is an urgent need of policies and regulations development on water resources management to improve the current situation.

Though SENAGUA is the lead agency of water resources management in Ecuador, their personnel at Santa Cruz headquarters is quite limited. In fact, there is only one person in charge of the office in this island. This person has to deal solely with all the activities and responsibilities, which demonstrates the lack of enforcement and therefore the local population continues to withdraw water from "private" crevices at their will. This presents a problem to regulate water concessions of "private" crevices. Since SENAGUA is relatively new, the population shows a certain rejection, complicating the monitoring and control. Nevertheless, some managers of private crevices have voluntarily acceded to present the required paperwork so that the institution can monitor periodically the quantities of extraction and the water quality.

Furthermore, SENAGUA has not yet developed specific policies or regulations for the Galápagos Islands, regarding the ecosystem fragility. The regulations that are applied are the same ones as in the mainland, though the majority of the territory has been declared a National Park, and therefore, the conservation practices need to be specific.

11. Water supply input as component of water balance for Santa Cruz

A water supply assessment in Puerto Ayora and Bellavista was performed based on the information provided by the Municipality of Santa Cruz, as well as from SENAGUA during the fieldwork. Fig. 4(a) shows the components on the supply side of the water balance for the supply system in Puerto Ayora and Fig. 4(b) in Bellavista, based on the different sources. It also reflects the first step towards establishing a water balance by approximating the input volumes into the system.

Furthermore, with the approximations made from available data, an estimated proportion of per capita demand supplied per source type is shown in Table 7. The result of 371.4 lpcpd looks very high but by default, it includes leakages; the real consumption would therefore be lower. In the absence of good monitoring, the real leakage levels are yet to be assessed.

11.1. Estimations of NRW for Puerto Ayora

It is equally difficult to estimate the NRW due to the lack of information on water demand in Puerto Ayora. Because Puerto Ayora does not have water metering but a fixed tariff billing system, the consumption per premise and/or per category is unknown. Missing this basic information for calculating the NRW in the municipal network, and also for completing a water balance within the island, asks for further research regarding the demand in Puerto Ayora.

11.2. Estimations of NRW for Bellavista

Table 8 summarizes the consumption based on the water cadastre for the year 2013 from DPWS [34]. The

Table 8
Total water demand, average working and non-working devices and estimation of demand per capita for Bellavista

Month	Consumption (m^3)	Consumption[a] (m^3)	No. of working devices	No. of non-working devices	% of non-working devices	Average consumption per premise (m^3)	Estimated population of non-working devices[c]	Demand for estimated population of working devices (lpcpd)
January	5,375.6	5,454.6	348	79	18	15.4	450.3	87.4
February	5,370.2	5,453.2	345	83	19	15.6	473.1	88.3
March[b]	330.2	734.2	25	404	94	13.2	2,302.8	55.8
April[b]	440.8	847.8	12	407	95	36.7	2,319.9	81.6
May	4,605.4	4,676.4	358	71	17	12.9	404.7	73.3
June	6,513.0	6,585.0	360	72	17	18.1	410.4	103.9
July	6,262.2	6,342.2	353	80	18	17.7	456	102.1
August	5,559.0	5,641.0	352	82	19	15.8	467.4	91.2
September	5,653.8	5,742.8	347	89	20	16.3	507.3	94.6
October	5,653.8	5,743.8	347	90	21	16.3	513	94.8
November	5,097.8	5,185.8	352	88	20	14.5	501.6	85.0
December	4,964.8	5,051.8	356	87	20	13.9	495.9	82.6
Total (2013)	**55,826.6**	**57,458.60**	**3,555**	**1,632**	**–**	**206.5**	**9,302.4**	**1,040.6**
Average/month	**4,652.2**	**4,788.2**	**296**	**136**	**31.5**	**17.2**	**775.2**	**86.7**

[a]This consumption refers to 1 m^3 for non-working devices.
[b]Months with high non-working devices due to unknown reasons.
[c]The estimated population was calculated with 5.7 inhabitants per premise.

Table 9
Non-revenue water with two scenarios (average registering metres and with average consumption for non-registering metres) for Bellavista

	System input volume (m^3/year)	Revenue water (m^3/year)	Non-revenue water (m^3/year)	Percentage of NRW (%)
With average working devices	94,608	55,826.6±	38,781.4±	40.99
With all devices working	94,608	80,363.24±	14,244.76±	15.06

table shows relatively large number of malfunctioning metres (32%) and the consequent calculations of average consumption of water for 2013. As an approximation, the department assumes an average consumption of 1 m^3 per month per non-working connection, which seems to be a gross underestimate.

As observed in the above table, the monthly average of non-working devices corresponds to approximately 136 metres of 434 metres. This high percentage reflects the figures of the months of March and April (which seem to be outliers). The real reasons of this huge deviation are unknown and the municipality did not have valid explanations. As a result, these non-working devices contribute to a higher value of NRW, which can be considered leakage and/or water theft.

The calculated average consumption per premise per month is ±17.2 m^3. After some preliminary calculations based on the previous figures, and assuming on average ±5.7 family members per premise, the estimated consumption per capita is approximately 87 lpcpd for Bellavista, which can be treated mostly as a domestic use. Furthermore, the figure seems to be low, but excludes demand from bottled water, estimated at approximately 10 lpcpd. Moreover, with known actual demand and the approximations for non-registering devices, it was possible to calculate two values of NRW, one for the year 2013 and the other scenario with optimal metering conditions. These two calculated figures help to draw evident conclusions about how the value of NRW could be reduced up to 25% if there would be an improved water-metre management programme (Table 9). Complementarily, these two percentages give an idea of what could be an estimated leakage percentage, being the difference between the two NRW values.

12. Discussion

The data obtained throughout this research have helped to draw an holistic view of the water supply problem on this island; nevertheless, there have been some inconsistencies found between the information provided from different institutions. Even though the interviews helped to cover all aspects of the water issue, the information provided may become too general and broad.

The estimations of water supply and demand have provided a general idea about the quantities regarding the different sources and losses, contributing to the water balance of each urban settlement. However, the data obtained from "private" extractions need to be further researched because those might be underestimated, which could affect the water balance. Furthermore, the water supply quantities and exact schedules should also be verified and monitored, since it could impact the supply quantities. Currently, all the calculations are based on average working time of pumps of 12 h/d.

The percentage of non-working metres contributes to a higher value of NRW in Bellavista. As observed in the tables, the NRW could be lowered to approximately 25% if all the devices would be registering true average domestic consumption. Evidently, with more appropriate metre management, more accurate water demand per capita could be determined. Furthermore, a verified figure on NRW could help the estimation of the real leakage percentage, and the DPWS would have higher revenues, improving the service and addressing the financial constraints.

Also, instead of charging one m^3 for non-working devices, an average consumption of working metres should be calculated and charged. For example, if for the year 2013, for the months of very low consumption (March and April), an average tariff would have been charged for non-registering devices, the annual revenue would have increased by approximately 40%.

Water demand in Puerto Ayora needs further research and approximations. A survey method from a representative sample will provide better understanding of the situation in Puerto Ayora. Also, some private metres could be placed in premises belonging to different categories in order to assess the specific consumption more accurately. In addition, fixed tariffs

should be abolished in order to create awareness within the population. There is an indiscriminate waste and disuse of water on local's premises, since people tend to use it without any limits. Therefore, the metres should be placed as a part of water demand management strategy. In order to shift the populations' perspectives, diverse economic incentives should be developed. The local population, in general, tends to react when money and affection to their economies are involved. By preventing excessive use, as well as the losses along the system, the quantity provided by the supply system could be sufficient for a 24-h service.

13. Conclusions

By studying the literature, it can be concluded that in fragile ecosystems, there is no significant awareness on water use. The islands with environmental issues are focused specifically on biodiversity conservation or ecological problems, ignoring the link between water use and the environment. It is necessary to understand how people and the different categories use water.

The research summarizes all the current problems affecting the water supply in Santa Cruz. Involving the collection of information from different sources and institutions, it is intended to help the authorities seek for specific solutions to the problems portrayed. Also, it suggests that regulations and policies for the conservation of water resources in this fragile ecosystem need to be created and developed, defining exclusive tasks and specific responsibilities among institutions. The increase in tourism is one of the government's objectives; therefore, eventually it would be necessary to arrive at a full level scale solution, since currently, is local based. Therefore, there is a need for an holistic solution, where the government needs to get involved by organization and facilities management.

The current situation in Santa Cruz is similar to other tropical islands, which are dealing with water supply problems due to massive tourism. As observed in the literature review, desalination predominates in many islands, such as the Mediterranean, nevertheless, most of these islands do not deal with political issues and lack of governmental management. Also, increasing availability of water supply does not mean solving the problem, but (perhaps) increasing the water demand (as already happened in the Aegean Greek Islands). In order to obtain results in such poor-data case study areas, it is fundamental to assess available information and estimate the gaps. With tangible outcomes, the authorities would invest in the generation and verification of accurate data.

Findings so far indicate that there is no (absolute) water scarcity in Santa Cruz, but excessive losses and wastage, resulting in high NRW, and lack of proper management. The population's perception needs to be shifted to a more sustainable one regarding the conservation of water.

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