



COVID-19 Impacts on Beaches and Coastal Water Pollution at Selected Sites in Ecuador, and Management Proposals Post-pandemic

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The COVID-19 pandemic has obliged Governments all around the world to implement confinement and social distancing measures. Leisure and business activities on beaches and in ports have restricted direct and indirect contamination from, for example, plastics, hydrocarbon spillage, microbiological loads, and noise levels. This has led to temporarily improved environmental conditions, and the beaches having conditions closer to Marine Protected Areas. Here we report some impacts that have been studied using local surveys and qualitative observations in Ecuador at the popular beaches and ports of Salinas, Manta, and Galapagos. Satellite data support this information. Online surveys were carried out at critical moments of the pandemic: May (15th) and just after when measures were relaxed a little, but within lockdown in July (21st) 2020. Respondents were asked to compare conditions before and during the pandemic lockdown. Most (97–99%) suggested that beaches had significantly improved from visual observations during confinement. On a scale from 1 (worst) to 5 (best), the beaches of Salinas and Manta respectively were rated 2.2 and 2.8 (less than acceptable) before quarantine, and 4.5 and 4.3 after; results from the second survey (after 18 weeks of restrictions) were much the same. Replies from Galapagos showed a similar trend but with less marked differences. In addition to the beaches having less plastic and garbage, more fish, and large marine organisms, including humpback whales (*Megaptera novaeangliae*), dolphin (bottlenose, *Tursiops truncatus*), and manta ray (*Manta* sp.) were observed near to shore. At Galapagos beaches, turtles, sea lions, and sharks were observed many more times than pre COVID. Quantitative satellite data on Chlorophyll and attenuation coefficient (Kd, 490 nm) support the qualitative survey data that there is an improvement in coastal environment quality. Here we recommend that this unique opportunity resulting from the COVID-19 pandemic is used locally, regionally and globally to construct baseline data sets that include information on physical, chemical, biological, and microbiological factors in coastal zones. These parameters can then help establish

an effective Coastal Zone Management Plan based on beach description and quality (water standards, noise pollution), as well as the human dimension (tourist load, cultural heritage, and economic value indices). This data and information gathering ideally should be done before the beaches become more heavily used again as the pandemic recedes.

Keywords: COVID-19, confinement, beaches, pollution, noise, tourism, ecuador

INTRODUCTION

“As the COVID-19 pandemic sweeps through the world, we must reassess the principles that guide our individual and collective responses and the way we operate in society. In the face of crisis, we must lead with science and humanity,” Nat Cancer (2020) (No Author, 2020a) recently asserted. At the end of April 2021, the COVID-19 pandemic globally had 148,894,033 confirmed cases and 3,139,309 deaths (Johns Hopkins Coronavirus Resource Center, 2021), and these figures are only going to increase even though vaccinations have started in many countries. In Ecuador, cases and deaths (both probably underestimated) are respectively 375,329 and 18,389 (28 April 2021¹), which means 2.2% of its population have been infected and 0.11% has died. Cases are rapidly increasing once more in April 2021, and a further partial lockdown is underway.

National economies have been dramatically hit by the pandemic as a result of (1) air, water, and road transportation very limited or completely prohibited in some places, (2) many public utilities closed such as parks, beaches, and museums, and (3) very low consumer demands for products and services. Bloom et al. (2018) warn that the impacts of the pandemic on economies can be sizable over short and long terms, at both individual and societal levels. Nightmarish economic impacts in 26 countries include a possible drop in sales of 50–75% relative to pre-COVID conditions (De Vito and Gómez, 2020). One of the most affected activities is tourism. According to UNWTO (2020), the economic decline since the arrival of COVID-19 is around 52–78%, with estimated losses just in Q1 2020 of around 80 billion US\$, and for the whole year 100 to 120 billion US\$. In Ecuador, the tourism sector could lose 540 million US\$ in 3 months of standstill (Statista, 2020), with marine and coastal tourism one of the most affected activities. The beach zones of Salinas, Manta, and Galapagos in Ecuador would be expected to be most impacted. It is accepted that tourism exerts strong pressures on natural systems and directly or indirectly contributes to pollution (Navarro, 2019), and excessive demand on coastal benthic and pelagic fisheries (Budzich-Tabor et al., 2014).

Those impacts expected to decrease over the pandemic include plastic (see Li et al., 2016), or any type of debris, and increased microbiological loads due to beach tourism (Natural Resources Defense Council [NRDC], 2014). Another example is noise contamination, which can impact the individual and social behavior of adult fish and mammals as well as metabolism, recruitment, and overall health of marine ecosystems (Peng et al., 2015). Anthropogenic noise has become a real threat to the coastal environment and ecosystem health. Specific examples of

impacts include those on turtle behavior and ecology (Samuel et al., 2005), and noise pollution from boat engines disturbing all fish species and particularly marine mammals, sea birds, and turtles (Hazel et al., 2007; Ketten, 2008; Leduc et al., 2021). Artificial light from human activities can also affect multiple trophic levels, by deterring fish (Stocker, 2007; Becker et al., 2013; Bolton et al., 2017) and impacting the hatchling behavior of turtles (Kamrowski et al., 2012; Thums et al., 2016). Noise and illumination (energy contamination, GESAMP, 1991) have been shown to be important even in isolated places like Galapagos, where recently positive impacts of reduced energy pollution have been reported (Jiménez-Uzcátegui, 2020) with populations of seabirds and penguins recovering.

An important aspect of plastic contamination is the exponential increase in the use of bottled water since the outbreak of COVID-19 in countries such as Ecuador, because access to good quality tap water is often restricted as Ogunbode et al. (2021) has reported for developing or underdeveloped countries. The resultant increase in discarded plastic containers will keep growing (Eljarrat, 2020), especially in places with high tourism activity including for Ecuador Galapagos, Salinas and Manta. The use of bottled water is particularly intense on the Galapagos islands, where the potable water is of poor quality (Grube et al., 2020). An additional source of plastic over the COVID-19 pandemic, is masks and gloves that are frequently mandatory. Their random disposal generates a new type of waste that is beyond conventional sanitary disposal management, which is poor and inappropriate for these new plastics (Calma, 2020), and adds to plastic bottle contamination in coastal water zones (Hyde, 2020). Many measures to help disposal of single-use plastic materials have been postponed, so there is potential for increases in plastic pollution during the pandemic (da Costa, 2021).

Despite the above problems, the COVID-19 pandemic measures of confinement and social distancing are producing some positive impacts (at least temporarily) on the environment, such as less atmospheric pollutant gases (CO₂, SO₂, NO₂, etc.). Rosenbloom and Markard (2020) report that air pollution and emissions of greenhouse gases are notably decreasing, while Le Quéré et al. (2020) have reported 17% less daily emissions of CO₂ as well as reductions in other gases; see also Ju et al. (2021). Other intrusive pollution types (e.g., noise, waste) in the atmosphere and biosphere (Arora et al., 2020), have also decreased significantly in some populated areas due to reductions in transportation, electricity usage, industrial production (Rosenbloom and Markard, 2020), leisure and fishing activities.

The reduction in contamination on beaches and in coastal water has been seen globally where quarantine measures exist. Beaches in Acapulco (Mexico), Barcelona (Spain), and Salinas

¹<https://www.who.int/countries/ecu/>

(Ecuador) now have much more transparent and cleaner waters (Zambrano-Monserrate et al., 2021); the largest lake of India (Vembanad) has around 16% less suspended solids than before the pandemic (Yunus et al., 2020). Also, anecdotal reports in social media talk of marine mammals close to beaches, perhaps in response to the considerable reduction of noise levels. Therefore, in general, environmental conditions have at least temporarily improved (Yunus et al., 2020), and beaches have moved toward the status of temporary Marine Protected Areas. However, there is still very limited information on changes in environmental quality in South American coastal waters that feeds into this more global view.

Whilst there has been an improvement in environmental conditions, perceptions of people who are impacted day by day in places where the economy depends on tourism or fishing activities are not well known. Additionally, we need to have a scientific baseline of data and information that can be combined with public perceptions to articulate a proper tourism, coastal fishing and pollution management plan post the COVID-19 pandemic. The work reported here seeks to provide information and priorities based on environmental qualitative information that is supported by satellite quantitative data at three main Ecuadorian beaches in Salinas, Manta, and Galapagos. We think this is a unique opportunity globally to create a scientific baseline at a time of reduced environmental impact, as beaches and near-shore waters have taken on temporary features of Protected Marine Areas. Such baseline information can help initiate comprehensive management programs (Partelow et al., 2015) for the future, and recommendations stemming from the present study are proposed below.

MATERIALS AND METHODS

At the time of full lockdown and strict restrictions (12th March to 12th September 2020), conventional environmental survey techniques were not possible due to restricted access, lack of staff, and minimal (if any) laboratory facilities in Ecuador. Therefore, online surveys using web-based applications were carried out. Recently, Torrentira (2020) has validated the use of such online interviews under pandemic conditions, and both Abir et al. (2020) and Steele et al. (2021) have successfully used the on-line methodology for surveys under lockdown restrictions.

The main objective of the surveys was to determine if the perceived quality of the beaches and adjacent waters had improved post, relative to pre, COVID-19 lockdown. Three sets of questions were prepared, one for each location, with those from Salinas and Manta being practically the same, except for one question, while the Galapagos questions were slightly different (see **Supplementary Material**). The differences reflected variations between the specific locations. The Galapagos islands are at the core of one of the most important marine reserves in the world, and in general its population is much more aware of environmental conditions and the marine species present. Additionally local people rely almost 100% on

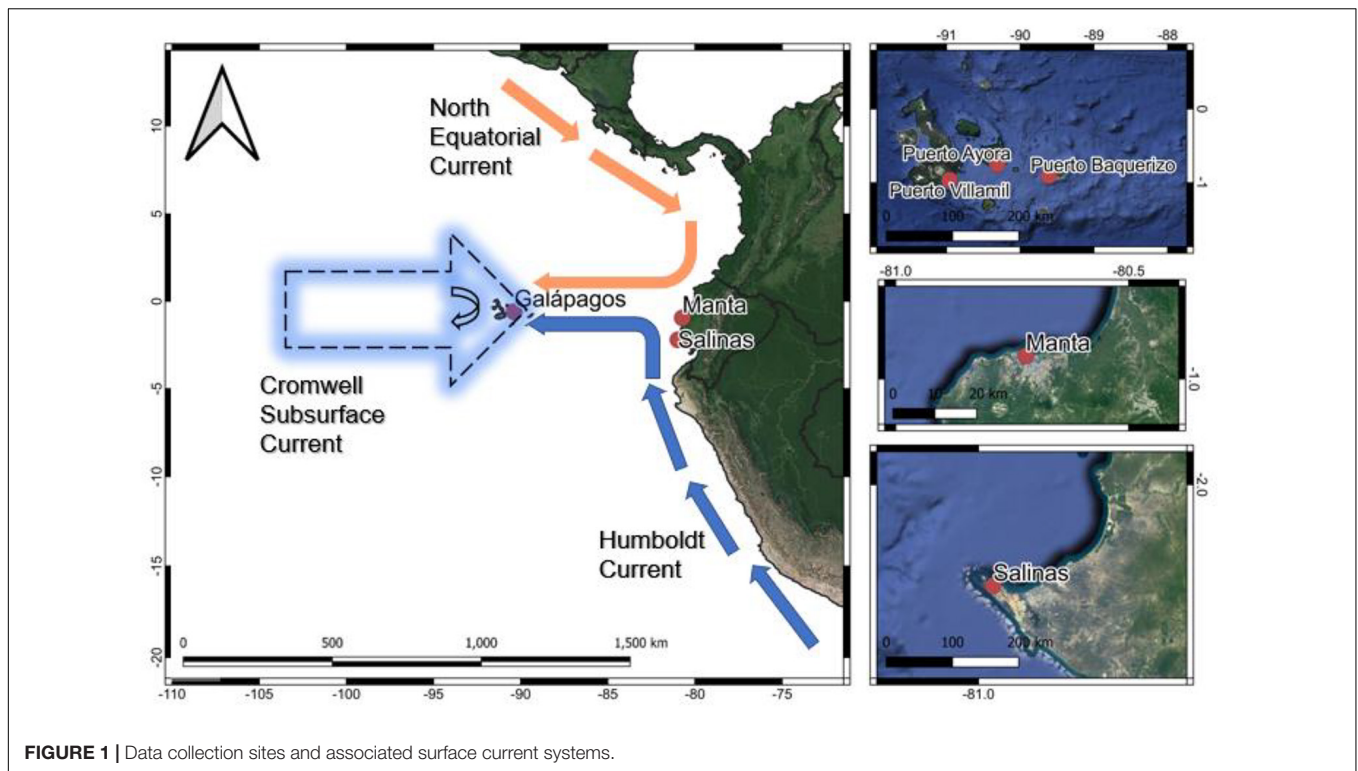
sustainable tourism and are therefore well educated in environmental matters.

The data obtained are from the visual observation of beaches and nearshore aquatic wildlife. The first survey was a cross-sectional type (see Setia, 2016) that reported opinions and sightings during May (from 15th) 2020. At this time national lockdown restrictions obliged people to be at home most of the time, beaches were fully closed, no travel between cities was allowed, police, and military guarded the streets and COVID-19 cases and deaths were increasing rapidly. The surveys were carried out over a time window of 76 h, using a form modified from a Google template (Google Forms: Free Online Surveys for Personal Use). The surveys were targeted to have confidence and interval levels of 95 and 5.16% respectively, following the approach of Taherdoost (2017) for example.

The questionnaires (see **Supplementary Material** – SM) were slightly different for each studied site, taking into consideration the main activities at each site and main types of employment. To examine reproducibility, a second round of surveys was carried out over a period of 7 days, 2 months later (from July 21st), using the same form and protocol. During this second survey, some restrictions were eased, for example you could move from city to city at certain times of the day. Observations reported are from respondents living adjacent to the beach zones. Collection of data from face-to face or/and focus group interviews was not possible, because even though the lockdown and restrictions were eased, it was difficult to visit the beaches, and people showed reluctance to talk due to stress from the social confinement and pandemic (see Arnsten, 2020), and because COVID-19 cases were increasing again. This reluctance still exists today (April 2021), as the pandemic situation has worsened.

Both surveys used Instagram, Twitter, Facebook, and WhatsApp to contact a range of individuals living in the named cities close to or in front of the beaches and water's edge, and who also had links to seaside activities including tourism and academic research, as well as normal citizens. The survey form (see **Supplementary Material**) sought information on the individual's observations, knowledge of local beaches and water quality, as well as views on improving environmental quality and tourism. Also, an observer in a quarantined boat in Galapagos reported sightings of turtle, sharks, and other aquatic species from 15 March to 30th April. In two questions (8 and 9) a numerical scale was used to indicate the extent of changes seen going from 1 (no change) to 5 (much change/improvement). Two of the authors live in Salinas and have videos and photographs that give qualitative information about beaches and shore water aquatic species activities (see **Supplementary Material**). The surveys were designed in a very simple way to encourage participation, as they could be completed in less than 5 min.

In order to support the qualitative surveys, quantitative data and information from the NASA satellite instruments Terra (EOS AM-1) and Aqua (EOS PM-1), which are payloads for the "Moderate Resolution Imaging Spectroradiometer – MODIS" (NASA, 2019), were used to measure temporal and spatial



changes of chlorophyll and the diffuse attenuation coefficient K_d (490 nm), over the timescale of the study.

Study Area

The study sites of Salinas, Manta, and two ports of Galápagos (Puerto Baquerizo Moreno and Puerto Ayora; **Figure 1**) were chosen for local interviews and observations. COVID-19 cases during the first interview period were increasing at all survey sites, deaths were rapidly escalating to dozens per day, and the population was frightened as elsewhere in the world. In Galapagos, even though it is a relatively isolated site, cases were also increasing. Salinas (centered on $2^{\circ}12'S$, $80^{\circ}56'W$) is the most popular and visited beach on the Ecuadorian coast; its economy depends almost completely on tourism, with its diverse beaches ranging from cliffs to fine sand beaches and there are safe swimming areas. However, it has one of the most plastic polluted beaches in Ecuador (Mestanza-Ramón et al., 2019a). Manta ($0^{\circ}57'S$, $80^{\circ}42'W$) is the second most important port and the fourth largest economic center in Ecuador. The port takes a variety of large tourist cruisers, industrial vessels, artisanal fishing craft, and cargo ships, and is the most important fishing port in Ecuador (second largest tuna port in the world; Martínez-Ortiz et al., 2015). According to Mestanza-Ramón et al. (2019a) its wide, long beaches are less contaminated by plastic than in Salinas. In the Galapagos Islands Puerto Ayora ($0^{\circ}45'S$, $90^{\circ}18'W$) and Puerto Baquerizo Moreno ($0^{\circ}54'S$, $89^{\circ}36'W$) are the main harbors, where the economy is solely based on foreign tourism. The islands of Galapagos are a protected Marine Reserve of 133,000 km², one of the biggest and most important in the world (Caryl-Sue et al.,

2011; Paladines and Chuenpagdee, 2015) and the first World Heritage Site named by UNESCO (Walsh and Mena, 2013) due to its unique ecosystem; Mestanza-Ramón et al. (2019b) have found that the beaches of Galapagos are some of the cleanest in Ecuador. It is noticeable that the three locations above have poor or no domestic water treatment plants. These sites are covered within a recent study (Gaibor et al., 2020) who reported that the southern and central beaches are most affected by the anthropogenic deposition of debris (plastic, paper, cigarette butts, metal, glass, others; plastics represent around 60% of the total debris) that are of local origin. In this study, the clean characteristics of Galapagos beaches are noted as Mestanza-Ramón et al. (2019a) also report.

The study sites provide differing coastal environments where any impacts resulting from COVID-19 measures can be followed. Salinas-Santa Elena (Photo 1, **Supplementary Material**) is one of the most visited beaches in southern Ecuador, and around 400 thousand tourists arrive in the Province between January and June. Half of these come to Salinas, where its baseline population is only around 70 thousand people (Castro-Rodas, 2016; Gad-Salinas, 2020). Manta is a city located on the central coast (**Figure 1**) with 230 thousand inhabitants (Instituto Nacional de Estadística y Censos (INEC), 2010), and is a tourist destination, that is visited by beachgoers from all over Ecuador. As a result of the tuna fishing industry and other activities its inshore waters have different anthropogenic contamination sources to the other sites. The Galapagos Islands (**Figure 1**) have a local population of around 30 thousand people, but it is a popular foreign tourist destination. Thus, in 2019, 271 thousand tourists arrived in the Galapagos protected areas (PNG, 2020), and inefficient planning

TABLE 1 | Results from Salinas and Manta.

Place	Surveys	Salinas			Manta		
		Run 1 (n = 69)	Run 2 (n = 75)	Total (n = 144)	Run 1 (n = 36)	Run 2 (n = 52)	Total (n = 88)
Question	Answer	%	%	%	%	%	%
Q1	Yes	98.6	98.7	98.6 (2)	86.1	86.5	86.4 (7)
	No	1.4	1.3	1.4 (2)	13.9	13.5	13.6 (7)
Q2	It is cleaner	44.6	49.6	47.1 (8)	43.8	43.0	43.3 (10)
	There are less plastic	26.8	29.2	28.0 (7)	35.9	34.4	35.0 (10)
	More transparent	28.6	21.2	24.9 (7)	20.3	22.6	21.7 (9)
Q3	Yes	97.1	96.0	96.5 (3)	97.2	96.2	96.6 (4)
	No	2.9	4.0	3.5 (3)	2.8	3.8	3.4 (4)
Q4	Yes	88.4	89.3	88.9 (5)	91.7	92.3	92.0 (6)
	No	11.6	10.7	11.1 (5)	8.3	7.7	8.0 (6)
Q5	Fish in general	62.5	61.8	62.1 (8)	52.9	60.3	57.1 (10)
	Sharks	1.3	2.2	1.8 (2)	0.0	0.0	0.0
	Manta-ray	5.0	4.5	4.7 (3)	3.9	2.9	3.4 (4)
	Dolphins	20.0	19.1	19.5 (6)	29.4	23.5	26.1 (9)
	Whales	6.3	7.9	7.1 (4)	11.8	11.8	11.8 (7)
	Others	5.0	4.5	4.7 (3)	2.0	1.5	1.7 (3)
Q6	Contamination, garbage, new cases of COVID-19 (Salinas)/Garbage, insalubrity, new cases of COVID-19 (Manta)						
Q7	Yes	92.8	90.7	91.7 (4)	91.7	90.4	90.9 (6)
	No	7.2	9.3	8.3 (4)	8.3	9.6	9.1 (6)
Q8	Average	2.2	2.2	2.2	2.8	3.0	2.91
Q9	Average	4.5	4.4	4.5	4.3	4.3	4.29
Q10	Yes	23.2	–	23.2 (7)	61.1	–	61.1 (10)
	No	76.8	–	76.8 (7)	38.9	–	38.9 (10)
Q11	Academic	31.9	32.0	31.9 (8)	0.0	3.8	2.3 (4)
	Research	2.9	4.0	3.5 (3)	2.8	1.9	2.3 (4)
	Tourism	11.6	10.7	11.1 (5)	8.3	11.5	10.2 (6)
	General citizen	53.6	53.3	53.5 (8)	88.9	82.7	85.2 (7)

Run 1 (15th May) and Run 2 (21st July), 2020. Numbers in brackets are confidence interval (\pm).

and management of the local marine environment have been reported (Walsh and Mena, 2016; Mestanza-Ramón et al., 2019b), which in turn is exerting high pressure on marine resources and leading to contamination (Pecot and Ricaurte-Quijano, 2019; Ricaurte-Quijano et al., 2019), including micro plastics. Given the high volume of visitors under normal conditions, these environments should provide good examples of the impact of reduced human pressures caused by the COVID pandemic.

RESULTS

The first survey was kept online for up to 72 h; and the average times it took participants to complete them were 4.7, 3.5, 3, and 1.9 min for Salinas, Manta, and Galapagos (San Cristobal Y Santa Cruz islands) respectively. The number of respondents from the total population of these sites (roughly 330,000 people) of the study sites was 280. Thus, at a 95% confidence level, the confidence interval is around $\pm 5.8\%$ according to Taherdoost (2017). The confidence interval for the whole sample per answer varied between ± 2 and ± 5.8

with 95% confidence. The confidence interval averages for Manta, Salinas, and Galapagos were ± 5 , ± 7 , and $\pm 10\%$ respectively. In the first surveys for Salinas, Manta (Table 1) and Galapagos (Table 2, Puerto Ayora and San Cristobal), 69, 36, and 15 people respectively responded to the survey, with $>90\%$ being returned within 24 h. In the second run, there were similar average form completion times with 75, 88, and 32 forms returned respectively, and so total responses for each of the beaches in turn were 144, 89, and 47. Response times in Galapagos were slower in both runs, perhaps due to the internet services that are sometimes poor (Walsh and Mena, 2013).

Responses to the question (see Supplementary Material) “has the beach and water visually changed” for Salinas, Manta and Galapagos respectively during and after the lockdowns, were 99, 86, and 73% “Yes,” and 1, 14, and 27% “No”; while in the second run they were >99 , 87, and 75% “yes,” and for “no” 1, 13, and 25% respectively. The respondents said this positive change was because the beaches were free of people over a period of approximately 5 months. In Salinas, 47% said that beaches and water are now cleaner (see Supplementary Material

TABLE 2 | Results from Galápagos.

Place	Galápagos						
	Surveys	Run 1 (n = 15)	Run 2 (n = 32)	Total (n = 47)	Run 1 (n = 15)	Run 2 (n = 32)	Total (n = 47)
Questions	Answer	Amount	Amount	Amount	%	%	%
Q1	Yes	11	24	35	73.3	75.0	74.5 (12)
	No	4	8	12	26.7	25.0	25.5 (12)
Q2	Average	4.05	3.55	3.8			
Q3	Yes	7	13	20	46.7	40.6	42.6 (14)
	No	8	19	27	53.3	59.4	57.4 (14)
Q4	Average	3.94	3.28	3.61			
Q5	Yes	9	22	31	60.0	68.8	66.0 (12)
	No	6	10	16	40.0	31.3	34.0 (12)
Q6	Yes	10	19	29	66.7	59.4	61.7 (12)
	No	5	13	18	33.3	40.6	38.3 (12)
Q7	Average	4.1	3.24	3.67			
Q8	Yes	11	19	30	73.3	59.4	63.8 (14)
	No	4	13	17	26.7	40.6	36.2 (14)
Q9	Yes	1	19	20	6.7	59.4	42.6 (14)
	No	1	29	30	6.7	90.6	63.8 (14)
Q10	Yes						
	No	1	29	30	6.7	90.6	63.8 (14)
Q11	Tourism	12	20	32	80.0	62.5	68.1 (13)
	Academy	0	4	4	0.0	12.5	8.5 (8)
	Merchant	3	5	8	20.0	15.6	17.0 (11)
	Fishery	0	3	3	0.0	9.4	6.4 (7)

Run 1 (15th May) and Run 2 (21st July), 2020. Numbers in brackets are confidence interval (\pm).

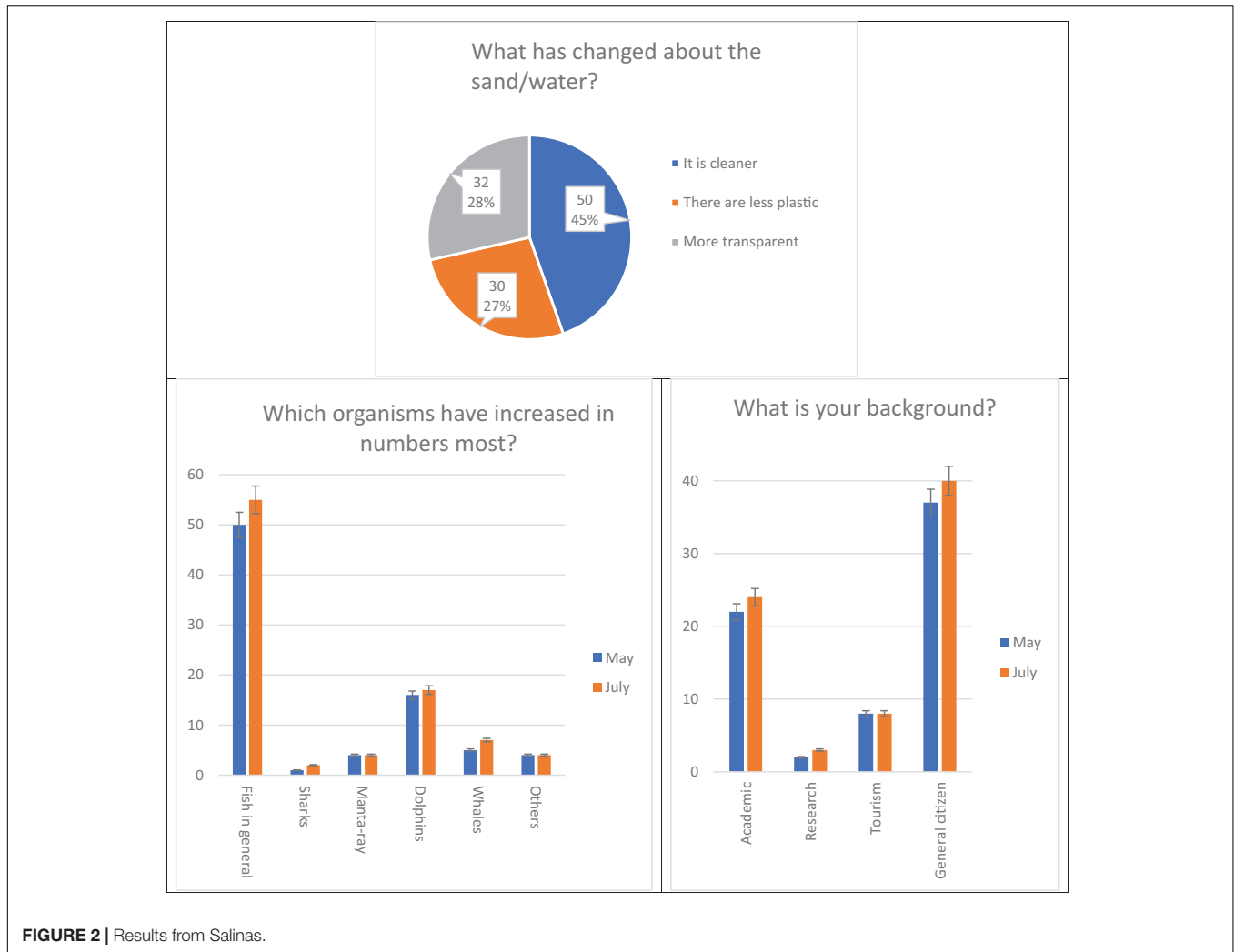
Photos), 28% said there was less plastic, and 25% that the water was more transparent (Figure 2). For Manta beach the answers (Figure 3) were 43, 35, and 22% in the same order. In July, the answers were very close to the earlier survey in both places (see Tables 2, 3). In Galápagos, 47% (Puerto Ayora) and 41% (Puerto Baquerizo Moreno) of respondents deem there is less plastic on beaches and 60 and 69% think the water is much clearer than before the pandemic (Figure 4), for the first and second survey rounds, respectively. Quantification of plastic volume or weight was not possible, because access to beaches was not allowed during the strict lockdown. The obvious plastic garbage on Salinas beaches (macroplastics: >5 mm) has been monitored by Ormaza-González and Vera-Mosquera (2021) since June 2019 every fortnight at least, and report mass of plastic for a specific area of 100 m² (see Supplementary Material Photos 2, 3). Macroplastics typically represented 80–100% of total debris, and weighed 500–600 g, for an accumulation period of 7–14 days at station D (2°12'S, 80°59.9' W). These types of plastic are reported to be of local origin (Gaibor et al., 2020) and are largely from fishing, beach and coastal tourism activities and untreated wastewater. The chemistry of the plastics has not been studied in detail, but visual inspection indicates: polyethylene terephthalate (PET, carbonated drink bottles, jars, microwavable packaging etc.), polyethylene (PE, wide range of

uses including bags, plastic bottles), High-density polyethylene (HDPE, detergent bottles, milk jugs, etc.), polypropylene (PP, bottle caps, drinking straws, etc.), polyester (PES, fibers, cord, fishing nets, etc.). Natural materials including, wood, charcoal and seeds, are also found.

Over 96% of surveyed people in both surveys and all places believed that there had been no noise pollution during confinement, which is beneficial to the marine ecosystem, as well as residents. Most surveyed people during the first run (88 and 92% respectively for Salinas and Manta) had seen increased marine organism activity during the quarantine period. After 5 months, similar percentages (89 and 94%) were recorded. These increases most probably reflect the lower impact of humans and there is no noise on the beach or at the seashore. In Galápagos, the observer reported this is particularly true for turtles and sharks, which have been observed frequently during this period. In Salinas, in May 62 and 20% (Figure 2) of surveyed people had seen more fish (sardines, mackerel, etc.) and dolphins respectively, close to the beach; in July, the percentages were 62 and 19% in the same order. While in Manta (Figure 3), in May 53 and 30%, in July 60 and 23%, of people saw the same change, but also between 18 and 16% of respondents (in both places during May and July) saw whales (humpback and whale-sharks), turtles, manta rays, and other large species. These marine species generally do not get close to the beach, whilst many videos on the web and social media have shown the usual whale-sharks and orcas offshore along the Ecuadorian coast (Zambrano-Alvarado, 2020; see Supplementary Material). In Galápagos (Figure 4), where sea lions, turtles and shark are observed quite commonly, between 73 and 59% of respondents over both surveys reported an important increase in sightings, scoring between 3 and 4 on a scale from 1 (no change) to 5 (a lot of sightings).

Respondents gave an overall rating for the quality of Salinas beach before and after the 10 weeks of quarantine, as 2.23 and 4.48 respectively on a scale from 1 (worst) to 5 (best). The perceived improvement is clear to see. In Manta, the categorization was similar, 2.83 before and 4.33 after. In July, 18 weeks later, survey results were practically the same in both places (2.24 and 4.44; 2.98 and 4.25). Respondents deemed overall that the beaches had improved their quality in every sense, even in Galápagos where beaches are generally in very good condition, 41–47% of respondents indicated a noticeable quality improvement.

Galápagos, Salinas, and Manta residents in both surveys were afraid that if beaches were suddenly opened, garbage, and noise contamination would increase, and these conditions may contribute to a new pandemic outbreak. At the same time, 95, 90, and 94% respectively of all surveyed people agreed that tourism should be reactivated carefully to revive the local economy, while avoiding a new pandemic outbreak. People in Galápagos agreed with taking scientific data and information to manage tourism properly. A large fraction of all respondents in Salinas and Galápagos (77 and 66%) were unaware of the existence or not of wastewater treatment plants in the area, while in Manta nearly half assumed their presence. Finally, most of the people surveyed in Salinas (Figure 2) were general citizens (54–53%), followed by 22–32% with an academic background, and the rest researchers and people



involved with tourism, whilst in Manta 89–83% (Figure 3) regarded themselves as common citizens, and 8–12% and 3–4% were involved with tourism and academics, respectively. In Galapagos (Figure 4), results were 80–63% tourism and 20–35% fish-traders.

Quantitative satellite information about chlorophyll (Figure 5) and diffuse attenuation coefficients (Figure 6) along the Ecuadorian coast supports the survey perceptions of improvements in water quality over the lockdown period. The difference between concentrations of Chl in 2019 relative to 2020 (i.e., 2020 minus 2019) changed over the period March (−22 mg.m^{−3}) to April to May (−0.6 mg.m^{−3}) in a progressive manner, indicating a general drop in the difference of Chl. Chlorophyll concentrations from close to Salinas and Manta over these periods were higher in 2019 than 2020, except in May 2020 (Manta). The diffuse attenuation coefficient (Kd), which is an indicator of turbidity of the water column, was used quantitatively to measure water transparency. These data (Figure 6) show that over the same period as chlorophyll changes, the water column in 2020 was clearer than in 2019, except where there were coastal phytoplankton blooms. For the

Salinas zone in 2019 the Kd values were 0.21, 0.97, 0.14 and in 2020; 0.11, 0.12, and 0.18 m^{−1} for the same months respectively, while near Manta the equivalent data were: 0.24, 1.19, 0.78; and 0.15, 0.34, and 0.01 m^{−1} respectively. The lower Kd in 2020 showed generally less suspended particulate matter in the water column, thus the photic layer increased, and clarity improved.

DISCUSSION

The COVID-19 pandemic has put populations under emotional, economic, and health stresses, and therefore to conduct face to face or online surveys under these circumstances is difficult (Labott et al., 2013; Arnsten, 2020; Steele et al., 2021), and recently Lardone et al. (2021) have reported how these circumstances could affect cognitive processes. Both face-to-face and focus group approaches were tried in the second survey, but people were not prepared to respond, and thus it was executed in the same way as the first. The surveys were designed to be the simplest possible, to ensure responses, because under the stressful and unique pandemic conditions, concentration,

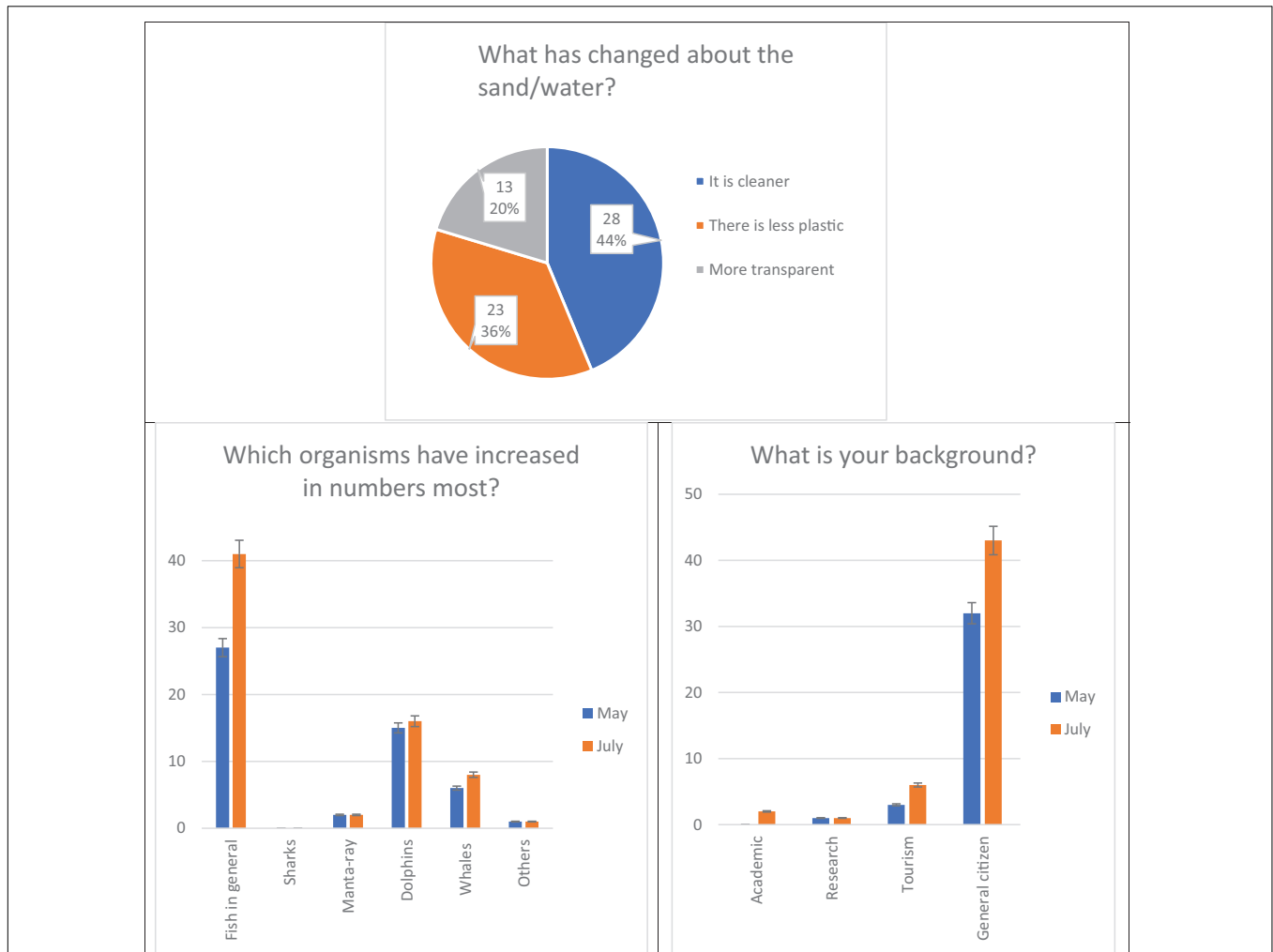


FIGURE 3 | Results from Manta.

reasoning, empathy, patient, and control of emotions as well as thoughts and actions could be compromised (Arnsten, 2020; Lardone et al., 2021). Studies using social media (Google forms) are increasingly accepted and web-based surveys have become one of the most common methods to collect data for research (e.g., Vasantha and Harinarayana, 2016). Steele et al. (2021) reported a full study on cross-sectional surveys on people activity directly affected for the lockdowns, one of the characteristics are the short and unambiguous questions and replies to them; yes, or not for example; like the surveys presented here. Even though the results of second interview confirmed the first one, it must be clear that interview data is based on the perception of interviewed. Biases during on line questionnaires during COVID-19 pandemic restrictions have been studied by Schaurer and Weiß (2020), and should to be considered in survey interpretations

The questionnaires (see **Supplementary Material**) were quite simple with just 11 straightforward questions that took respondents between 2 and 5 min to complete: id est, Salinas,

4.73; Manta, 3.48; Puerto Baquerizo Moreno, 2.96; and Puerto Ayora 1.9 min. The quicker answer time from Galapagos could be due to people of these islands being aware of environmental matters given the importance of the marine reserve. The surveys from Salinas and Manta were mostly responded to within 24 h, but from Galapagos it took longer, and fewer people responded, compared to Salinas and Manta. Fortunately, there was one marine biologist quarantined from March to April (6 weeks) on a boat in Puerto Ayora who reported turtle and shark activity as well as water quality on a regular basis.

There is almost a unanimous view that beach zones (sand and coastal water) have notably improved during confinement, at least from a visual point of view (see **Supplementary Material** Photos and Video). The beaches have less garbage in general and plastic in particular, even though there has been an increase in plastic and face mask production and disposal around the world (Calma, 2020; Eljarrat, 2020). Tourists tend to litter beaches, as they seem to lose good behavior regarding the management of their garbage (Oigman-Pszczol and Creed, 2007), Williams et al.

TABLE 3 | Parameters to be measured to create a data baseline for coastal zone management.

Type of parameters	Land	Water
Physical	Geologic studies, textural, petrological, and geochemical variation, types of beaches, sand (granulometry, minerals), gradient of beaches, dunes, erosion rates, macro-micro plastics, Surf zone, sand column	Tides (height and frequency), Waves (swell, fetch), optics (color, transparency, Suspended total Particulate Matter), odor Salinity, Temperature, Currents (littoral and tides) Detailed bathymetry
Chemical	Heavy metal, crystal composition, organic matter, redox equilibria, N, S, Mn. Interstitial water chemistry, Natural and anthropogenic hydrocarbons	pH, dissolved Oxygen, Redox equilibria, dissolved inorganic nutrients (Nitrogen, Phosphorus, Silicate, Mn, Fe, Mg), Dissolved and particulate organic matter, Chlorophyll, Carbonates, Total Dissolved metals (Cr, Pb, Hg, Cd, etc.). alkalinity, total hardness, calcium BOD and COD
Biological	Sand and dune vegetation. Beach species (lizards, crabs) Coastal- Marine birds Identification, population. Genera, species, Bacterial load, parasites, fungi, viruses Fecal index organisms, total coliforms, thermotolerant coliforms, <i>E. coli</i> and intestinal enterococci, <i>Staphylococcus</i> spp., <i>Pseudomonas aeruginosa</i> . <i>Vibrio parahaemolyticus</i> , <i>Candida</i> spp., Limits: Those recommended by World Health Organization (WHO)/United Nations Environment Programme (UNEP) (1994)	<i>Escherichia coli</i> , total coliforms, thermotolerant coliforms, <i>E. coli</i> and intestinal enterococci, <i>Staphylococcus</i> spp., <i>Pseudomonas aeruginosa</i> , <i>Vibrio parahaemolyticus</i> , <i>Candida</i> spp, adenoviruses, polyomavirus, hepatitis A virus, and noroviruses. Phytoplankton and zooplankton communities. Marine species from level 3–5 of trophic chain.

For details see Eagle (1983), World Health Organization (WHO)/United Nations Environment Programme (UNEP) (1994), Moresco et al. (2012); Patil et al. (2012), and Soto-Varela et al. (2021).

(2016) and Mestanza-Ramón et al. (2019b) have reported cases of littering of popular beaches at Rio de Janeiro, the north Caribbean coast, and Ecuador (including Galápagos). More recently, Gaibor et al., 2020 have found that anthropogenic debris (plastic, paper, cigarette butts, metal, glass, others; plastics, 60%) is mainly of local origin. Thus, if there is limited local anthropogenic activity, the presence of debris tends to reduce. They also reported that the highest concentration of debris was found in the south (Salinas) and central (Manta) coasts. Furthermore, Ormaza-González and Vera-Mosquera (2021), under a Citizen Science remit, have one observation site (so called Station D [2°12' S and 80°59' W]) in Salinas, which has been visited almost

every fortnight since June 2019. Plastics have been collected from a specific area of around 100 m², and after weighing, identification and classification, its possible origin is established. Initial results have not been published formally, but they are reported via twitter immediately after measurements; see photos (**Supplementary Material**). Generally, a range of 300–600 g of plastics per week is washed ashore and collected at the study site. Just a few days before the lockdown, on March 7, 2020, 250 g were collected, but by September there was almost no plastic found (**Supplementary Material** Photo 1, lower panel). The impact of plastics on marine ecosystems is clearly recognized, e.g., (Santander-Rodriguez, 2017); Amelia et al. (2021) have reviewed the impact of microplastic on marine ecosystems organism (food web). The range of plastics found is given in the results. Beach tourism has also been reported to increase microbiological load (Natural Resources Defense Council, 2014), although it was not possible to follow this in the current study. The observed reduction in litter and contamination reported here seems to directly correspond to less use of beaches during the lockdown.

There is a direct relationship between fish demand and tourism (Budzich-Tabor et al., 2014), and as tourism activities stopped, the fishery markets of both cities were partially closed, resulting in less artisanal fishing impact. Different species in the three locations, including small pelagic fish and marine mammals (dolphins, orcas, whales, sea lions) as well as sharks and turtles have been reported in the survey, as well as on social networks (Zambrano-Alvarado, 2020). A marine biologist from Galapagos reported seeing turtles close to the bay (I. San Cristobal) between 10 and 15 times a day; before the confinement, turtles were seen rarely in that area. In a recent press release by the Charles Darwin Foundation (CDF, 2020), Galapagos penguins (*Spheniscus mendiculus*) and flightless cormorant (*Phalacrocorax harrisi*) which have been tracked for the last 30 years are showing increased numbers of individuals, 1,940 and 2,290 respectively, which is a record for these species. The most plausible reason for this is the decrease in noise during pandemic restrictions (Spennemann and Parker, 2020), as it has been shown to affect the behavior of dolphins, sea turtles, sea birds, and other species (Samuel et al., 2005; Hazel et al., 2007; Ketten, 2008), also the event la Niña event 2020–2021 is playing role on this growing number (Lerma et al., 2020). Nonetheless, specific research must be conducted to investigate these possible reasons.

Improvements in the color of coastal water, which is now clearer and bluish-turquoise, has been reported by news (Ramos, 2020; Zambrano-Alvarado, 2020), papers (Zambrano-Monserrate et al., 2020) social networks, and in public and authors videos (see Supplementary Information). This improvement reflects less suspended particulate matter and/or phytoplankton in the water. There is natural flushing of mainland coastal waters by the North Equatorial current, and the Humboldt currents, as well as the residues of the Cromwell current (**Figure 1**). The Cromwell (Knauss, 1963) is a sub-surface current that upwells to the west of Galapagos and can be detected further east (Pak and Zaneveld, 1973) at around 84W and thus closer to the coastline of Ecuador. The Humboldt (Montecino and Lange, 2009) is a coastal current from the Antarctic that reaches Chilean, Peruvian, and Ecuadorian coasts

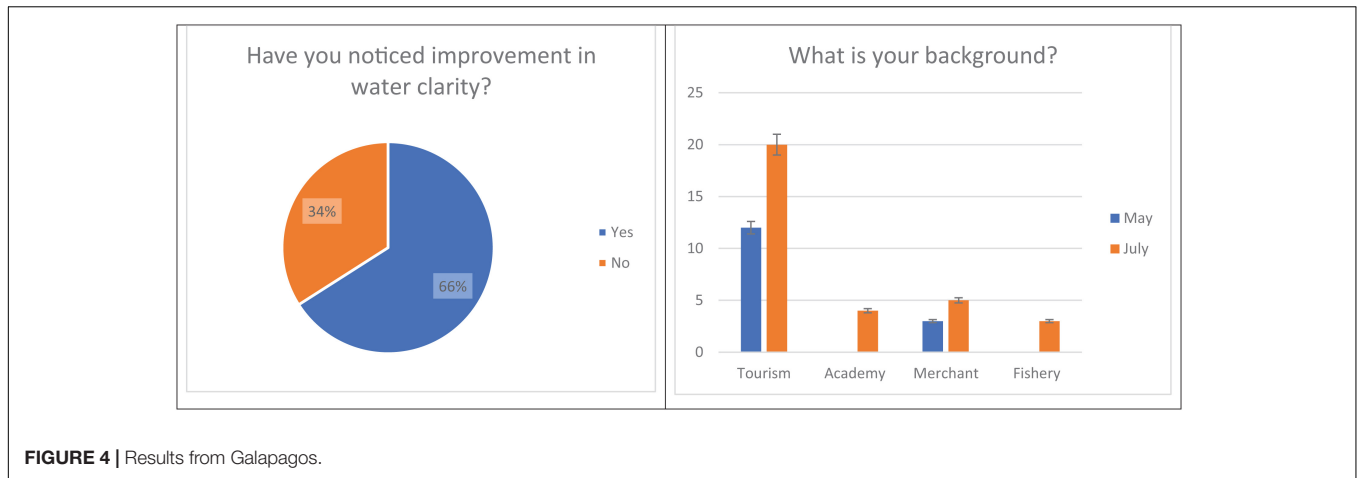


FIGURE 4 | Results from Galapagos.

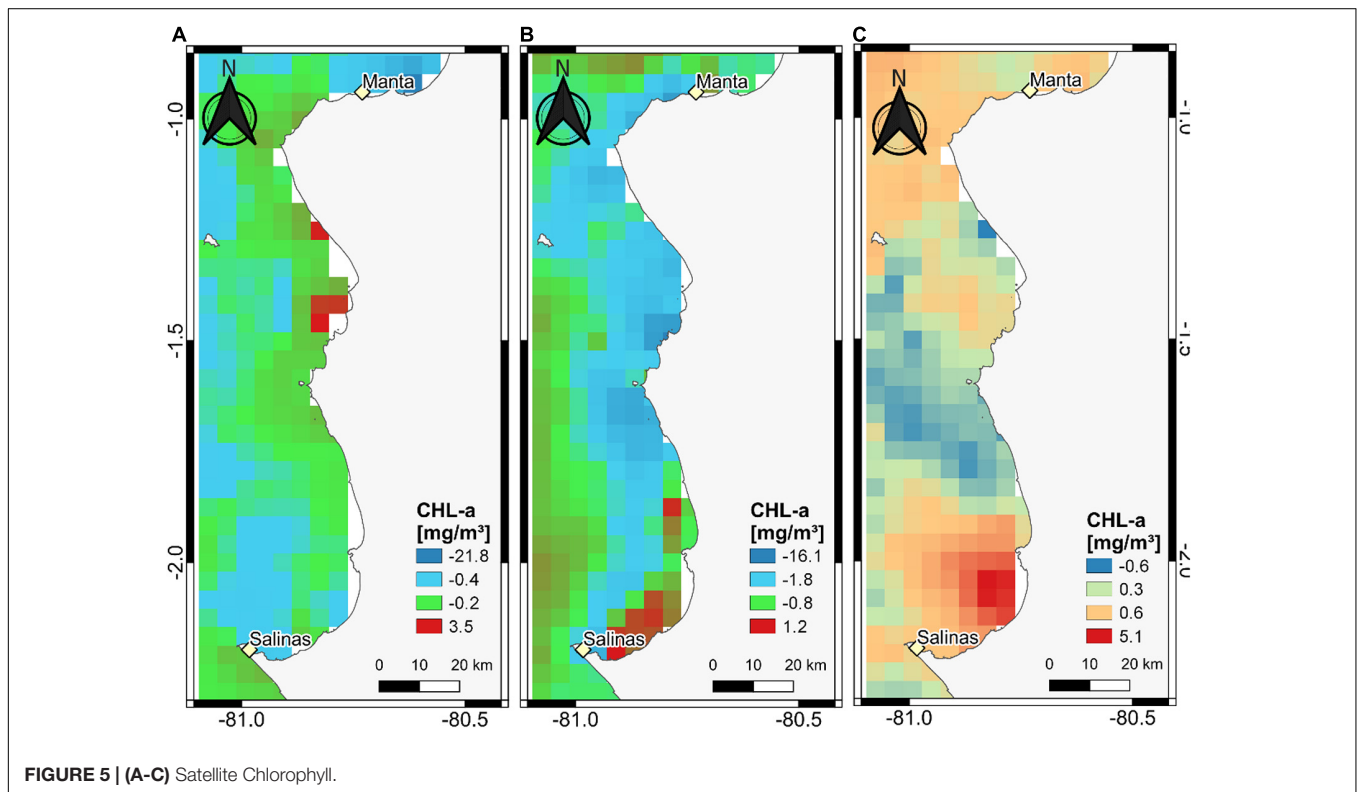


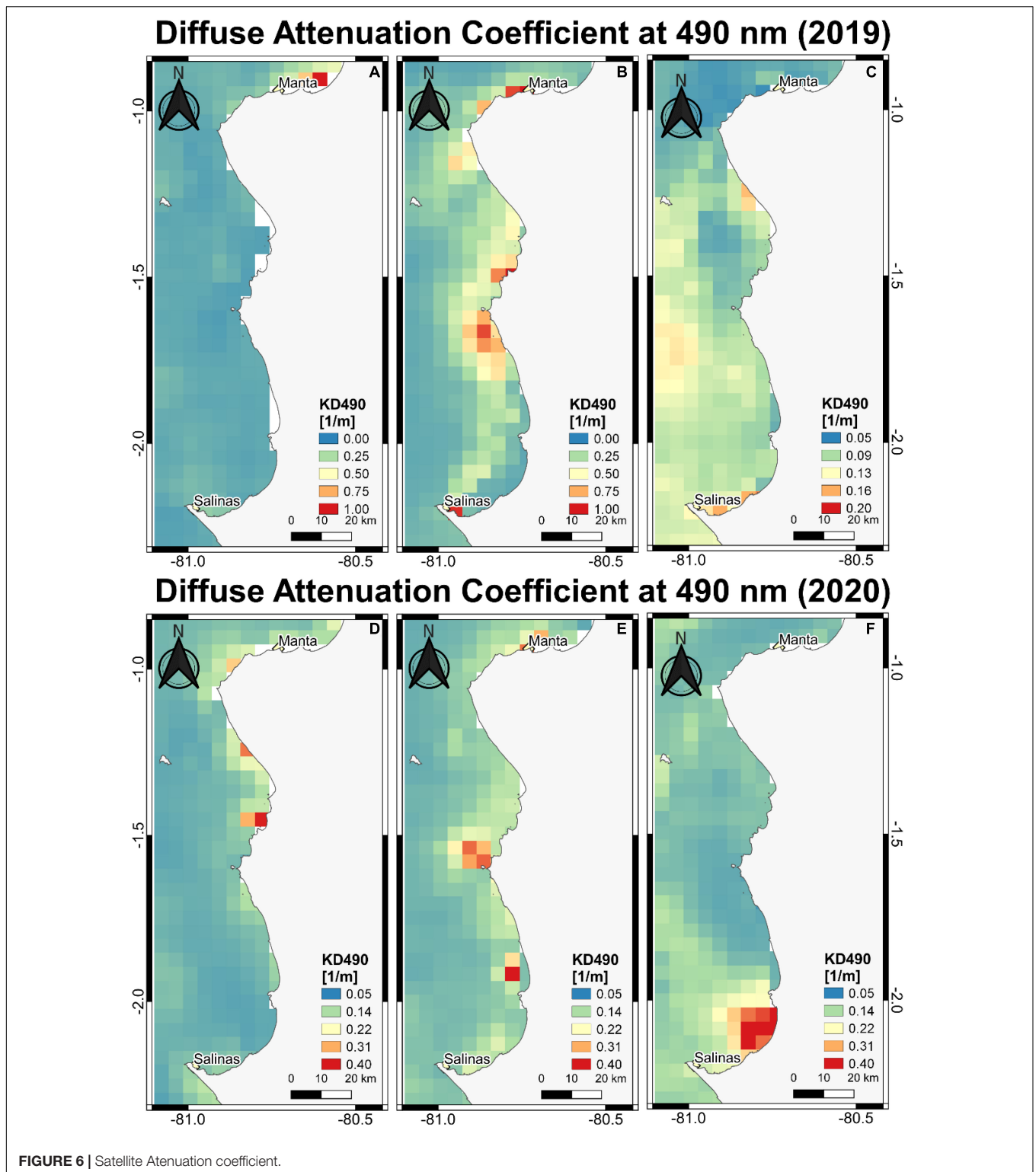
FIGURE 5 | (A-C) Satellite Chlorophyll.

(May-December). Additionally, the north equatorial current (0.2–1.3 m/s)² flows toward Ecuadorian coasts and north Galapagos during Jan-April. The Cromwell and Humboldt alone provide flows of 39 and 12 Sverdrup, and these can renew coastal surface waters down to about 100 m. On a global scale there are other coastal systems, in addition to Ecuador, where strong surface oceanic currents replenish nearshore waters and diminish pollutant concentrations (Dalbosco et al., 2020). The replenishment of coastal waters with cleaner offshore water, combined with reduced pollutant inputs during the lockdown, will be expected to transform these zones into an improved

environment for biota. These changes have been perceived by people responding to the survey and have also been seen in other beaches and coastal zones around the world (Zambrano-Monserrate et al., 2021), lakes (Yunus et al., 2020), and rivers (Arora et al., 2020).

The data from satellite, which shows that nearshore Chlorophyll concentration and the attenuation coefficient K_d (490 nm) were less in 2020 than 2019, support overall the observations from local people that water was clearer and looked much cleaner in 2020 lockdown than in 2019 over a similar period. The water bodies were less polluted because there was less untreated or partially treated wastewater being introduced, with an improvement in conditions. With less nutrients (N

²<https://www.windy.com/- Currents>



and P) and photosynthetic activity, Chl decreased despite the thicker photic layer. Castro-Rodas (2016) showed that in Salinas coastal waters the concentration of Chlorophyll was associated with discharges of untreated or partially treated waste water.

Yunus et al. (2020) has also reported that the largest lake of India (Vembanad) has around 16% less suspended solids than before the pandemic. Also, survey respondents indicated that the water was much clearer. Recently, Cherif et al. (2020) have

also reported an improvement in coastal water quality from Tangier (Morocco) using satellite tools (WST Sentinel-3). As the water quality improves (less contamination, and suspended particulate matter), the photic layer thickness will increase and so photosynthesis may be enhanced if there are adequate nutrients. Thus, satellite data from March, April, and May for 2019 and 2020, before and during pandemic periods, were examined (Figures 5, 6).

For the first occasion in modern times, most of the coastline studied has developed features of marine protected areas. Recent reports from the southeast coast of India (Prakash et al., 2021) and in Brazil (Pereira et al., 2021) contain similar findings to those here.

Most people in the survey responded that they did not know if there were local wastewater plants. Ecuador has a deficit of wastewater treatment plants, with only 29.3% (Instituto Nacional de Estadística y Censos (INEC), 2016) of the wastewater produced being treated. Salinas sewage works serve only 30% of the local population (Castro-Rodas, 2016), and so only a small part of the sewage has primary treatment with the rest being discharged directly to the sea or indirectly through badly constructed latrines. Walsh and Mena (2016) also reported contamination from domestic non-treated sewage in Galapagos. These facts indicate that additional wastewater produced by tourists would generate more health risks. Recently, Quilliam et al. (2020) and Randazzo et al. (2020) have reported the COVID-19 virus in feces and domestic residual waters, and thus Larsen and Wigginton (2020), and Medema et al. (2020) have proposed to correlate the presence of SARS-Coronavirus-2 RNA in Sewage with reported COVID-19. The impact from untreated wastewater on the marine environment and the whole trophic chain (Karen, 2019; Amelia et al., 2021) is a well-known fact.

The absence of tourism has greatly reduced the pressure on the few already overloaded sewage treatment plants in Salinas, Manta, and Galapagos, and therefore eutrophication, plastic and fecal contamination have dramatically decreased; Castro-Rodas (2016) found a direct relationship between phytoplankton growth and dissolved P present in residual untreated waters in Salinas. However, as most surveyed people do not know about the lack of wastewater treatment plants, they are unlikely to be aware of the problems associated with the untreated sewage water. The reduced tourism, whilst economically damaging, has produced less wastewater pollution, and coupled with background renewal of the coastal waters due to oceanic currents have led to cleaner sandy beaches as well as nearshore waters.

The COVID-19 pandemic would ideally merge into a neat, organized, and sustainable return of tourism, industry, and fishing activities in spite of the economic constraints expected immediately post-pandemic. As Pearson et al. (2020) have suggested, COVID-19 with its social, economic, health and economic consequences gives an opportunity to reshape near, medium, and long-term management plans, especially for environments such as beaches and their associated marine resources.

A recommended way ahead is adoption of Integrated Coastal Zone Management (ICZM) processes (Mestanza-Ramón et al.,

2019a) that are recognized by the UN (Chapter 17 of Agenda 21, Rio de Janeiro, 1992). This holistic approach provides a framework for planning sustainable tourism and coastal fisheries (Mestanza-Ramón et al., 2019a; Cantasano et al., 2021). It is important to realize that technical approaches alone (including improved wastewater treatment, controlling pollutant sources) are not adequate to provide a solution. An improvement in cultural awareness of environmental quality is needed, as provided through education via schools, colleges, public engagement activities, and media. A different approach to beach tourism should be promoted, organized, and incentivized, in order not only to protect environmental quality, but to stimulate a cultural local heritage (Cantasano et al., 2021). It is suggested that low noise sea-side activities be encouraged in order to reduce acoustic impacts on marine species (Leduc et al., 2021). These and related activities all require active involvement of government decision-makers and managers at local and national levels. Management measures would include assessing tourist load with risk analysis (Silva et al., 2007) as well as regular checking of water and beach quality indexes as described by Lucrezi et al. (2015, 2016).

The ICZM approach requires baseline data and information against which changes caused by reactivation of industry, tourism, fishing, and other activities with an impact on marine nearshore systems, can be measured. Setting of this baseline before changes to the present improved environmental quality occur is an urgent recommendation. Parameters (Table 3) must at least include, coastal hydrodynamic (surface, littoral, tidal currents), beach and inshore flora and fauna biodiversity, anthropogenic microbiological load (intestinal and fecal bacteria load), chemical characterization of water bodies (Patil et al., 2012) and beaches, quality indices (Anfuso et al., 2014; da Costa Cristiano et al., 2020), and noise.

CONCLUSION

All three sites examined are under an aggressive and generally poorly organized tourism-driven economy and, as Stumpf et al. (2013) warned, this has produced littered beaches and polluted waters under normal conditions. The COVID-19 pandemic has led to changing conditions, and the public seems to appreciate an improved environmental quality as they value and depend on the natural resources of their surroundings. The populations residing in Salinas, Manta, and Galapagos have clearly noticed a positive change in the quality of beaches due to the absence of tourists caused by COVID-19 (Zielinski and Botero, 2020). The return of marine species and reduction in levels of noise and environmental pollution are the highlights of the survey results, and they corroborate the general perceptions found in social media. These survey observations are consistent with quantitative satellite data on Chl and the diffuse attenuation coefficient for the areas studied. The environmental improvement during the pandemic provides an unparalleled opportunity to construct a baseline dataset for these almost pristine beaches and coastal waters, and to consider future viable management options based on such datasets, as discussed here.

In the future as awareness of the environment grows in the population, and new easier to use technologies become available, there will be an increasing role for collection of data through “citizen science.” Examples of improving technologies include: (1) on-line surveys; (2) the development of more sophisticated cell phone applications for measurement of environmental parameters such as water clarity (Secchi disk depth³). Initiating Citizen Science could therefore help to develop a science educated society that will respond more positively to better environmental management. However, there are diverse and important concerns about such “citizen-based” data collection and subsequent interpretation (Baker et al., 2021), and care must be taken with evaluating such data.

The COVID-19 pandemic is causing enormous and unpredictable changes in society that will affect lives for generations to come (Nat Ecol Evol, 2020) (No Author, 2020b). Adoption of the recommendations above are needed to limit coastal impacts on these future generations.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

PFO-G designed the idea of the research and survey, analyzed, and wrote part of the manuscript. DC-R carried out the

survey, organized and worked on survey results, downloaded and worked on satellite data. PS contributed to analysis of information and helped write and edit the whole manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2021.669374/full#supplementary-material>

³ <https://www.eyeonwater.org/>

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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