

Preliminary Assessment of Pharmaceutical Compounds in Cape Town Coastal Waters

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Non-Executive Summary

What did this study examine, and why?

- Pharmaceutically active compounds are biologically active chemicals that aid in the diagnosis, treatment, and prevention of illnesses and diseases in humans and animals.
- They are found in medicines administered by medical professionals and veterinarians and in medicines that can be purchased over the counter at pharmacies, such as headache tablets and certain creams.
- Modern society has benefitted immeasurably from the discovery and production of pharmaceutically active compounds.
- These compounds are not fully metabolised in the human and animal body. Humans excrete some of the compound in their urine and faeces, which end up in wastewater treatment works.
- Conventional wastewater treatment works cannot remove all pharmaceutical compounds from wastewater. As a result, pharmaceutical compounds are released into rivers and the sea in wastewater discharges.
- Pharmaceutical compounds can also come from agriculture, especially veterinary medicines used to treat farm animals. The compounds may pass from animal urine and faeces into rivers via land runoff. Veterinary medicines used to treat our pets are also a source of these compounds and can also pass from urine and faeces into rivers and the sea via land runoff.
- Today, pharmaceutical compounds are nearly ubiquitous in groundwater, rivers, estuaries, and seas in and near urban areas in many parts of the world, largely due to wastewater discharge.
- The pharmaceutical compounds may (and some definitely do) adversely affect the health of aquatic animals and/or plants.
- Pharmaceutical compounds have recently been found in seawater, sediment, seaweed, invertebrates, and fish in coastal areas in Cape Town.
- As part of its ongoing assessment of coastal water quality and pollution the City of Cape Town called for proposals for an assessment of the prevalence and concentrations of pharmaceutical compounds at sites on the Atlantic Seaboard and in False Bay.
- The Council for Scientific and Industrial Research (CSIR) was appointed to perform the assessment.
- The findings of this study provide a preliminary understanding on the extent of pharmaceutical compound contamination of water in Cape Town and estimates the possible environmental hazard the compounds pose to animals and plants.
- The findings will be used later to determine if future studies on pharmaceutical compounds are required.

How was the study performed?

- Water samples were collected in August and December 2021, at 35 sites between Bloubergstrand on the Atlantic Seaboard and Kogel Bay on the eastern shore of False Bay.
- Most sites (28) were on the coast, but five were in rivers and two were at stormwater discharge points.
- The sites represent a range of water quality conditions as determined from the City of Cape Town coastal water quality monitoring programme.
- The water was analysed for the presence of 58 pharmaceutical compounds.

What were the key findings of the study?

- At least one pharmaceutical compound was found in water at each site in winter and in summer. In winter, 37 of the 58 compounds were found, while 45 were found in summer.
 - Many pharmaceutical compounds were found at numerous sites more often in summer than in winter.
 - Salicylic acid was found most often, at 32 sites in winter and at 35 (*i.e.* all) sites in summer. Salicylic acid promotes skin exfoliation and is widely used topically in creams and lotions to treat acne, psoriasis, calluses, corns, and warts. It is also a precursor of the chemical found in aspirin. It is also a hormone found in many plants, notably in willow tree (*Salix* spp) bark, from which it derives its name.
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- Other compounds that were often found include:
 - Acetaminophen, also known as paracetamol. It is an analgesic and antipyretic used to treat mild to moderate pain and fever. It is the active ingredient in many headache tablets.
 - Ofloxacin, an antibiotic used to treat bacterial infections, including pneumonia and infections of the skin, bladder, reproductive organs, and prostate gland.
 - Valsartan, an antihypertensive drug used to treat high blood pressure, heart failure, and diabetic kidney disease.
 - Sulfamethoxazole, an antibiotic used to treat bacterial infections, including ear and urinary tract infections, and bronchitis.
 - Codeine, an analgesic and anti-inflammatory used to treat mild to moderate pain that is not relieved by non-opiate analgesics.
 - Bezafibrate, a lipid regulator used to lower cholesterol (mainly triglyceride) levels in the blood.
- The greatest number of pharmaceutical compounds found at any site in winter was 28 in the Salt River mouth and at Macassar Beach, followed by 27 at Lifebox23 Beach, 26 near the Athlone wastewater treatment works in the Black River, and 25 at Lagoon Beach and near the Gordon's Bay canal mouth.
- In summer, the greatest number of pharmaceutical compounds found at any site was 36 in the Salt River mouth, followed by 35 in the Diep River, 33 near the Athlone wastewater treatment works in the Black River and at Macassar Beach, and 30 at Lifebox23 Beach.
- The greatest number of pharmaceutical compounds were thus found at sites that are strongly directly influenced by discharges from wastewater treatment works (*i.e.* in rivers) and at coastal sites that are indirectly influenced by wastewater discharges (*i.e.* via catchment flows).
- The high number and concentration of pharmaceutical compounds found at coastal sites near river and estuary mouths highlights the importance of rivers and estuaries as vectors for the introduction of pharmaceutical compounds to Cape Town coastal waters.
- In winter, one pharmaceutical compound was found in water at Fish Hoek Beach, Glencairn Beach, and Miller's Point, while two compounds were found at Diaz Beach, Kommetjie Beach, Llandudno Beach, and Oudekraal Resort. Other sites where only a few compounds were found include Camps Bay Beach, Llandudno Beach, and Simons Town Long Beach.
- In summer, one compound was found in water at Kogel Bay and two compounds at Diaz Beach and Miller's Point. Other sites where only a few compounds were found include Llandudno Beach, Glencairn Beach, Fish Hoek Beach, and Simons Town Long Beach.
- Many pharmaceutical compounds were found in stormwater at Three Anchor Bay and Fish Hoek Beach. This implies the ingress of wastewater into the stormwater infrastructure.
- Coastal water in False Bay was more affected by pharmaceutical compounds than coastal water on the Atlantic Seaboard - more compounds were found, and their concentration was usually higher. This is probably related, at least in part, to the more efficient dilution and dispersion of wastewater in the sea on the Atlantic Seaboard.

Do the pharmaceutical compounds pose an environmental hazard?

- It is not easy to determine if the pharmaceutical compounds found in Cape Town coastal waters pose an environmental hazard because there is limited information on their toxicity to coastal animals and plants.
 - The environmental hazard posed by most pharmaceutical compounds found in this study to coastal animals and plants was estimated to be low or negligible, but some may pose a moderate hazard and a few a high hazard. The highest hazards are estimated for microalgae (single celled plants), while the lowest hazards are estimated for fish.
 - It should come as no surprise that the highest environmental hazards were estimated at sites that are strongly directly or indirectly influenced by discharges from wastewater treatment works.
 - The hazards at coastal sites were higher in False Bay compared to the Atlantic Seaboard.
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What are the key conclusions of the study?

- Many pharmaceutical compounds were found in river water, coastal water, and stormwater.
- No site was free of pharmaceutical compounds, but the number of compounds found and their concentration varied widely.
- Coastal water along parts of the Cape Town coast had low numbers and concentrations of pharmaceutical compounds, while other parts showed the opposite trend.
- The presence of pharmaceutical compounds in coastal waters in Cape Town is consistent with the findings of similar studies performed elsewhere in South Africa and in the world. Cape Town is thus not unique.
- The concentrations of some pharmaceutical compounds found in Cape Town coastal waters are higher than concentrations found previously in South Africa, including Cape Town, and are also higher than concentrations found in coastal waters elsewhere in the world. Other compounds were at comparable, or lower concentrations.
- The greatest number of pharmaceutical compounds were found at sites in rivers and at coastal sites that are strongly indirectly influenced by discharges from wastewater treatment works. This is not surprising considering the main source of pharmaceutical compounds to the environment is wastewater.
- Some pharmaceutical compounds were found in water at remote coastal sites. This implies the compounds were transported quite far from their source by coastal currents, or there were unknown sources near the sites.

Recommendations

- ❖ Pharmaceutical compounds are highly effective chemical tracers of wastewater in coastal waters. They can be used by the City of Cape Town to identify which parts of Cape Town coastal waters are being most affected by wastewater discharges.
 - ❖ They can also be used by the City of Cape Town to identify if wastewater is leaking into stormwater infrastructure and in this way is reaching the coast.
 - ❖ A challenge using pharmaceutical compounds for these purposes is they are expensive to analyse. There are some chemical and biological contaminants of wastewater that may be better suited and cheaper for tracing the presence of wastewater in the sea than pharmaceutical compounds.
 - ❖ The decision by the City of Cape Town to continue with studies on pharmaceutical compounds in Cape Town coastal waters, while encouraged, does require careful consideration depending on the aims and objectives of the study. Some strategies in this regard are provided in this report.
 - ❖ Reducing the load of pharmaceutical compounds in effluent discharged from wastewater treatment works should be a key goal of the City of Cape Town, and indeed of municipalities across South Africa.
 - ❖ The City of Cape Town might consider a programme to educate the public on the hazards posed by human and veterinary pharmaceutical compounds as environmental contaminants, to change personal behaviour in terms of their use and disposal. This could include sensitising and educating medical and veterinary professionals, so they do not over-prescribe medicines, and where alternative medicines for the same therapeutic use that have the same efficacy are available, they prescribe medicines that pose the least environmental hazard.
 - ❖ A mechanism should be established for the collection and proper disposal of unused or expired medicines from the public. Pharmaceutical producers and pharmacies could take the initiative in this regard.
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1. Introduction

Several recent studies (Petrik *et al.*, 2017; Ojemaye and Petrik, 2019; Ojemaye and Petrik, 2021) report on the presence of pharmaceutical compounds in seawater, sediment, seaweed, invertebrates, and fish in coastal areas in Cape Town. There are several possible sources of these compounds to aquatic ecosystems, but wastewater is acknowledged to be the major source. Wastewater discharged into the marine environment through outfalls at Green Point, Camps Bay, and Hout Bay (CSIR, 2017) and into rivers in Cape Town (*e.g.* Archer *et al.*, 2021) has been shown to contain various pharmaceutical compounds. The presence of these compounds in the city's coastal waters thus implies a wastewater influence.

Pharmaceutical compounds have been produced and used by man for over 100 years (the first synthetic pharmaceutical, aspirin, was produced in 1897), yet they are classed as so-called emerging pollutants since they are usually not covered by regulations and relatively little is known about their effects in the environment. The studies by Petrik *et al.* (2017), Ojemaye and Petrik (2019), and Ojemaye and Petrik (2021) have contributed importantly to our understanding on the prevalence of pharmaceutical compounds in Cape Town's coastal waters, sediment, and biota. However, apart from a study in False Bay by Ojemaye and Petrik (2021) there is no comprehensive spatial survey of pharmaceutical compounds in the city's coastal waters. As part of its ongoing assessment of coastal water quality and pollution and considering the findings of recent studies, the City of Cape Town called for proposals for an assessment of the prevalence and concentrations of pharmaceutical compounds at sites on the Atlantic Seaboard and in False Bay. The Council for Scientific and Industrial Research (CSIR) was appointed to perform the assessment. The purpose of this report is to provide the findings of the preliminary assessment.

2. Pharmaceutical Compounds: Uses, Sources, and Impacts to Aquatic Environments

Modern society has benefitted immeasurably from the discovery and production of pharmaceutically

active compounds that aid in the diagnosis, treatment, and prevention of illnesses and diseases in humans and animals. A downside is these compounds are not fully metabolised in the human and animal body and are released into the environment, to the extent they are now essentially ubiquitous in groundwater, rivers, estuaries, and seas in and near urban areas in many parts of the world, where they may adversely impact on biota (Kolpin *et al.*, 2002; Jobling *et al.*, 2003; Ferrari *et al.*, 2004; Glassmeyer *et al.*, 2005; Lee and Rasmussen, 2006; Ramirez *et al.*, 2009; Bu *et al.*, 2013; Klosterhaus *et al.*, 2013; Komori *et al.*, 2013; Luo *et al.*, 2014; Godoy *et al.*, 2015; aus der Beek *et al.*, 2016; Fabbri and Franzelitti, 2016; Prichard and Granek, 2016; Biel-Maeso *et al.*, 2018; Reis-Santos *et al.*, 2018; Letsinger *et al.*, 2019; White *et al.*, 2019; Branchet *et al.*, 2021).

Humans (and likely also animals) are estimated to excrete in their urine and to a lesser degree their faeces in the order of <5% to >90% of an orally ingested or injected dose of pharmaceutical compounds as the active (unchanged) compound, or as metabolites and/or conjugated compounds (see Jjemba, 2006; Lienert *et al.*, 2007; Mompelat *et al.*, 2009; Al Aukidy *et al.*, 2012, and references therein). Although excretion is the main pathway that human and veterinary use pharmaceutical compounds enter the environment, some are applied topically (*i.e.* to the body surface), such as gels containing anti-inflammatories. These are washed from the skin during showering, bathing, and swimming. In households with proper sanitation, excreted pharmaceutical compounds enter the sewer infrastructure and ultimately wastewater treatment works.

Conventional wastewater treatment processes are generally ineffective at removing or degrading pharmaceutical compounds in wastewater, but do to varying degrees reduce their concentration (Carbella *et al.*, 2004; Oulton *et al.*, 2010; Yang *et al.*, 2017). Acetaminophen and ibuprofen, for example, are generally effectively degraded, although not entirely removed from wastewater, but iopromide, hydrochlorothiazide, and carbamazepine are not (Drewes *et al.*, 2002; Petrović and Barceló, 2007; Kasprzyk-Hordern *et al.*, 2009; Petrović *et al.*, 2009; Oulton *et al.*, 2010; Kosma *et al.*, 2014; Kostich *et al.*,

2014; Lara-Martin *et al.*, 2014; Dong *et al.*, 2016; Archer *et al.*, 2017; Pereira *et al.*, 2017; Yang *et al.*, 2017). The main pathway for pharmaceuticals to the coastal environment after normal use is thus through the direct discharge of treated wastewater from wastewater treatment works via outfalls and indirectly via rivers that carry treated wastewater from inland wastewater treatment works to the coast (Roberts and Thomas, 2006; Petrović and Barceló, 2007; Watkinson *et al.*, 2009; Spongberg *et al.*, 2011; Gardner *et al.*, 2012; Meffe and de Bustamante, 2014; Godoy *et al.*, 2015; Wood *et al.*, 2015; Gaw *et al.*, 2016; Archer *et al.*, 2017; Faleye *et al.*, 2019). Other sources of pharmaceutical compounds are generally considered to be less important in terms of loads, but the concentration of individual compounds in these sources can be as high or higher than in wastewater discharged from wastewater treatment works. Pharmaceutical compounds may enter coastal waters through combined sewer system overflows or leaks that infiltrate the stormwater infrastructure (Petrović and Barceló, 2007; Tantam *et al.*, 2008; Kay *et al.*, 2017; Masoner *et al.*, 2019; Yin *et al.*, 2019). Septic tank systems in rural areas, agriculture (wastewater biosolids or manure application as fertiliser on land, the veterinary treatment of livestock), the veterinary treatment of pets, the use of reclaimed water for irrigation, aquaculture operations, pharmaceutical manufacturing sites, and the disposal of unused pharmaceuticals at waste landfill sites and their subsequent migration in landfill leachate are other sources of these compounds to aquatic ecosystems (Holm *et al.*, 1995; Heberer, 2002; Petrović and Barceló; Togola and Budzinski, 2008; Katz *et al.*, 2010; Lubick, 2010; Phillips *et al.*, 2010; Brauch and Rand, 2011; Rodríguez-Navas *et al.*, 2013; Fairbairn *et al.*, 2016; Gaw *et al.*, 2016; Launay *et al.*, 2016; Kay *et al.*, 2017; Kim *et al.*, 2017; Hong *et al.*, 2018). In South Africa, an undoubtedly important but unquantified source is inadequate or absent sanitary infrastructure in informal settlements, from whence these compounds can migrate to surface and groundwater. Further sources include recreational users of coastal waters, such as swimmers and surfers urinating in water or releasing topically applied compounds, but this is likely to be insignificant in the greater scheme of loadings compared to most other sources. Pharmaceutical compounds are, however, common

in swimming pool water (Ekowati *et al.*, 2016).

Although pharmaceutical compounds degrade in the environment through biotic and abiotic processes (*e.g.* by photolysis) or are removed from the water column by other processes (*e.g.* adsorption onto sediment), their continual release in wastewater and other sources leads to their ‘pseudo-persistence’ in aquatic environments (Daughton, 2002).

Pharmaceutical compounds have been found in a range of estuarine and marine biota, including macroalgae (seaweed), fish, molluscs, and sea urchins amongst others (McEneff *et al.*, 2014; Dodder *et al.*, 2014; Fabbri and Franzelitti, 2016; Petrik *et al.*, 2017; Moreno-González *et al.*, 2016; Ojemaye and Petrik, 2019; Fonseca *et al.*, 2021; Ojemaye and Petrik, 2021). They have been shown to induce a range of adverse effects in several of these biota (Prichard and Granek, 2016; Fabbri and Franzelitti, 2016; and references therein). In addition to toxicological concerns there is also concern about the potential for antibiotic residues giving rise to antibiotic resistance (Webb *et al.*, 2003; Boxall *et al.*, 2012; Gaw *et al.*, 2016; Scott *et al.*, 2016) and interfering with the structure and functioning of aquatic microbial communities (Brosché, 2010; Zhang *et al.*, 2021).

3. Materials and Methods

3.1. Sampling design

Surface water was sampled at 35 sites between Bloubergstrand on the Atlantic Seaboard and Kogel Bay on the eastern shore of False Bay (Figure 1; Table 1). Most sites (28) were on the coast, but five were in rivers and two were at stormwater discharge points. The findings of the City of Cape Town’s monitoring of *Escherichia (E.) coli* and faecal streptococci bacteria in coastal waters (CoCT, 2020) were used to guide the positioning of many sites. Many coastal sites are in fact in the same position as in the city’s monitoring programme. The water quality at these sites in the context of faecal indicator bacteria ranges from excellent to poor (Table 1). Wastewater is an important source of pharmaceutical compounds and faecal indicator bacteria in coastal waters. It was assumed the number and concentration of pharmaceutical compounds would reflect a mix of states amongst sites like that for faecal indicator bacteria. The



Figure 1. The positions where water for faecal indicator bacteria and pharmaceutical compound analysis was sampled in the City of Cape Town on the 24th of August and 7th of December 2021. Note that the prefix CT is not included in the site number symbols for presentation purposes (see Table 1).

purpose of sampling in rivers and at stormwater discharge points was to provide an understanding on their importance as vectors for faecal indicator bacteria and pharmaceutical compounds to Cape Town coastal waters, acknowledging that the few rivers and stormwater discharge points sampled do not represent all such potential sources in the city.

3.2. Water sampling

Water was sampled on the 24th of August and 7th of December 2021. Water was sampled at coastal sites by wading into the surf zone until about knee to mid-thigh depth. A sample of water was collected from just below the water surface using a high-density polyethylene jug. A high-density polyethylene jug

was also used to sample water at stormwater discharge points. In rivers, water was sampled from bridges using a plastic bucket attached to a nylon rope. Prior to water collection the jugs and buckets were rinsed with acetone and then with ambient water several times. Sample storage containers were 500 ml high-density polyethylene bottles. The bottles were soaked in 10% nitric acid and then rinsed sequentially with acetone, deionised water, and ultrapure water before fieldwork. The bottles were rinsed with ambient water several times in the field and then filled to ~80% of total volume to accommodate expansion of the water on freezing. Two samples were collected at most sites, one for pharmaceutical compound analysis and the other

Table 1. The positions where water for faecal indicator bacteria and pharmaceutical compound analysis was sampled in the City of Cape Town on the 24th of August and 7th of December 2021. Also included is the water quality rating for the 365 day period up to 21 October 2021 if the site is included in the City of Cape Town shoreline water quality monitoring programme.

Coast	Site	Site description	Latitude	Longitude	Comments	CoCT Water Quality
Atlantic	CT1	Bloubergstrand	-33.78464	18.45001	Popular bathing beach.	Good
Atlantic	CT2	Diep River	-33.83357	18.52147	Above Potsdam wastewater treatment works discharge.	
Atlantic	CT3	Milnerton Beach	-33.88133	18.48693		Poor
Atlantic	CT4	Lagoon Beach	-33.88218	18.49017	Near the outflow of Milnerton Lagoon.	Poor
Atlantic	CT5	Salt River mouth	-33.90859	18.47298	Affected by wastewater discharged into the catchment.	
Atlantic	CT6	Black River	-33.95089	18.50838	Downstream of point where Athlone wastewater treatment works discharges wastewater into river.	
Atlantic	CT7	Mouille Point	-33.89918	18.40407	Inshore of Green Point outfall that discharges wastewater to the sea.	Good
Atlantic	CT8	Three Anchor Bay	-33.90608	18.39724	Affected by contaminated stormwater flows.	Poor
Atlantic	CT9	Three Anchor Bay stormwater	-33.90585	18.39779	Stormwater flowing onto the shoreline.	
Atlantic	CT10	Milton Tidal Pool	-33.91434	18.38605	Outside of tidal pool.	Good
Atlantic	CT11	Clifton 4 th Beach	-33.94064	18.37431	Inshore of Camps Bay outfall. Popular bathing beach.	Good
Atlantic	CT12	Camps Bay Beach	-33.95090	18.37711	Inshore of Camps Bay outfall that discharges wastewater to the sea. Popular bathing beach.	Excellent
Atlantic	CT13	Oudekraal Resort	-33.98726	18.34976		
Atlantic	CT14	Llandudno Beach	-34.00843	18.34033	Popular bathing beach.	Excellent
Atlantic	CT15	Hout Bay River	-34.04200	18.35623	Affected by wastewater from upstream sources, including informal settlements.	
Atlantic	CT16	Hout Bay Beach	-34.04765	18.35987	Inshore of Hout Bay outfall that discharges wastewater to the sea. Also affected by the discharge of the Hout Bay River.	Poor
Atlantic	CT17	Kommetjie Long Beach	-34.13431	18.33291	Popular surfing beach.	Poor
Atlantic	CT18	Diaz Beach	-34.35523	18.48225	Arguably most remote site.	
False Bay	CT19	Miller's Point	-34.22984	18.47214	Potentially affected by wastewater discharge from the Miller's Point wastewater treatment works.	Sufficient
False Bay	CT20	Simon's Town Long Beach	-34.18719	18.42676	Potentially affected by wastewater discharge from the Simon's Town wastewater treatment works.	Sufficient
False Bay	CT21	Glencairn Beach	-34.15959	18.43220		Excellent
False Bay	CT22	Fish Hoek Beach	-34.14058	18.43330	Affected by contaminated stormwater flows. Popular bathing beach.	Poor

Coast	Site	Site description	Latitude	Longitude	Comments	CoCT Water Quality
False Bay	CT23	Fish Hoek stormwater	-34.13826	18.43281	Stormwater flowing onto the shoreline.	
False Bay	CT24	Muizenberg Pavilion	-34.10809	18.47280	Popular bathing beach and surfing beach.	Poor
False Bay	CT25	Zandvlei Estuary mouth	-34.10431	18.47517	Affected by wastewater discharged into rivers flowing into the Zandvlei Estuary.	
False Bay	CT26	Lifebox23 Beach	-34.09917	18.50234	Affected by wastewater reaching the sea after discharge from the Cape Flats wastewater treatment works.	Poor
False Bay	CT27	Strandfontein	-34.08928	18.54740	Near tidal pool that is popular for bathing.	Good
False Bay	CT28	Mitchells Plain Beach	-34.07778	18.59804	Affected by wastewater reaching the sea after discharge from the Mitchells Plain wastewater treatment works.	Poor
False Bay	CT29	Monwabisi Beach	-34.07327	18.69011	Near tidal pool that is popular for bathing.	Poor
False Bay	CT30	Moddergat Spruit	-34.07536	18.76938	Tributary of Eerste River, above Macassar wastewater treatment works outlet.	
False Bay	CT31	Macassar Beach	-34.08105	18.76189	Affected by wastewater discharged to sea from Macassar and other wastewater treatment works in Eerste and Kuils River catchments.	Sufficient
False Bay	CT32	Strand Beach/Lourens River	-34.10152	18.81155	Near the mouth of the Lourens River.	Good
False Bay	CT33	Gordon's Bay canal	-34.14643	18.85282	In the sea near the mouth of a canal that receives wastewater from the Gordon's Bay wastewater treatment works.	Poor
False Bay	CT34	Gordon's Bay Beach	-34.16169	18.86503	Popular bathing beach.	Poor
False Bay	CT35	Kogel Bay	-34.23669	18.85030	A remote site.	Excellent

for faecal indicator bacteria analysis. An additional sample was collected at five sites for quality assurance and quality control purposes. The water samples were kept on ice in the field. On return to the laboratory water samples destined for pharmaceutical compound analysis were frozen at -18°C while those destined for faecal indicator bacteria analysis were refrigerated at 4°C . Sampling was completed late in the day due to the large travelling distance between sites. Water samples were thus only analysed for faecal indicator bacteria the day after fieldwork.

3.3. Laboratory analyses

3.3.1. Faecal indicator bacteria

E. coli were analysed using the membrane filtration method by Water Analytical Laboratory. A sample was vacuum filtered through a membrane filter, which retained the bacteria. After filtration the membrane filter was placed on a modified mFC agar medium and incubated at $44.5 \pm 0.2^{\circ}\text{C}$ for 24 hr. The membrane filter was then transferred onto a nutrient agar medium containing MUG for 2 hr at $35 \pm 0.5^{\circ}\text{C}$. After incubation the membrane filters were inspected under ultraviolet light, and positive fluorescing colonies enumerated.

Faecal enterococci were also analysed using the membrane filtration method. A sample was vacuum filtered through a membrane filter, which retained the bacteria. After filtration, the membrane filter was placed on m-enterococcus agar and incubated at $35 \pm 0.5^{\circ}\text{C}$ for 48 hr. After incubation the membrane filters were inspected, and colonies were enumerated. Presumptive positive colonies of doubtful provenance were catalase tested and gram stained to confirm the colonies represented faecal enterococci.

4.3.2. Pharmaceutical compounds

The water samples were transported frozen to the Catalan Institute for Water Research in Girona, Spain, where they were held frozen until processing. The samples were analysed for 58 pharmaceutical compounds. Most of the targeted compounds are found in medicines and drugs to treat humans, but some also have a veterinary use (pets, livestock) (Table 2). The samples were analysed using the method outlined in Gros *et al.* (2012). The method is used for the analysis of multiple pharmaceutical

compounds in liquid matrices.

The concentrations of pharmaceutical compounds found in water samples are provided in Appendices 1 and 2. Pharmaceutical compound concentrations too low to be detected or quantified are reported as less than the Limit of Detection or Limit of Quantification respectively. The Limit of Detection is the lowest amount of an analyte that can be distinguished from the absence of that substance at a stated (usually 99%) confidence level. The Limit of Quantification is the smallest concentration of an analyte that can be determined with acceptable repeatability and accuracy.

Recoveries from spiked samples and associated Relative Standard Deviations, Limits of Detection, and Limits of Quantification for pharmaceutical compounds in fresh and seawater matrices are provided in Appendix 3. Limits of Detection and Quantification were usually lower for seawater than for freshwater. Since the analytical method is used to target pharmaceutical compounds with a range of properties the recoveries varied widely. Recoveries ranged from 25.1 - 146.0% (median = 79.5%) for freshwater and 22.9 - 127.0% (median = 60.3%) for seawater. The Relative Standard Deviation ranged from 1.1 - 33.8% (median = 5.4%) for freshwater and 2.5 - 59.5% (median = 22.0%) for seawater. Recoveries were higher for 39 of the 58 compounds in freshwater compared to seawater, while the Relative Standard Deviation was usually narrower for freshwater compared to seawater. Considering the targeted pharmaceutical compounds have different physical and chemical properties and seawater is a complex matrix, recoveries $>50\%$ were considered acceptable. For freshwater, 55 of the 58 compounds had recoveries $>50\%$, compared to 41 compounds for seawater. The Relative Standard Deviation is wide for some compounds in seawater, due to matrix interference, and in several cases exceeded a target of $\leq 30\%$. Compounds that did not meet quality assurance and quality control criteria are included in this study and the data are used for descriptive statistical purposes but are generally not discussed in any detail.

3.4. Data analysis

Pharmaceutical compound concentrations between the Limit of Quantification and Limit of Detection

Table 2. Pharmaceutical compounds analysed in this study and their therapeutic classification and use.

Anatomical Therapeutic Classification	Category	Pharmaceutical compound	Therapeutic use
Alimentary Tract and Metabolism	Histamine receptor antagonist	Cimetidine	Histamine receptor antagonist used to treat ulcers; gastroesophageal reflux disease, and inhibit stomach acid production.
Alimentary Tract and Metabolism	Histamine receptor antagonist	Ranitidine	Histamine receptor antagonist used to treat and prevent ulcers in the stomach and intestines, used to decrease stomach acid production.
Anti-infective for Systemic Use	Antibiotic	Tetracycline	Antibiotic used to treat bacterial infections, including acne, cholera, brucellosis, plague, malaria, and syphilis.
Anti-infective for Systemic Use	Antibiotic	Azithromycin	Antibiotic used to treat bacterial infections, including middle ear infections, strep throat, pneumonia, traveller's diarrhoea, and certain other intestinal infections.
Anti-infective for Systemic Use	Antibiotic	Cefalexin	Antibiotic used to treat bacterial infections, such as pneumonia and other chest infections, skin infections and urinary tract infections.
Anti-infective for Systemic Use	Antibiotic	Clarithromycin	Antibiotic used to treat bacterial infections, including strep throat, pneumonia, skin infections, Helicobacter pylori infection, and Lyme disease, among others.
Anti-infective for Systemic Use	Antibiotic	Erythromycin	Antibiotic used to treat bacterial infections, including respiratory tract infections, skin infections, chlamydia infections, pelvic inflammatory disease, and syphilis.
Anti-infective for Systemic Use	Antibiotic	Metronidazole_OH	Hydroxy metronidazole is the main metabolite of metronidazole. Has antibiotic and antiprotozoal activity.
Anti-infective for Systemic Use	Antibiotic	Sulfamethoxazole	Antibiotic used to treat bacterial infections, including ear infections, urinary tract infections, bronchitis, and prostatitis.
Anti-infective for Systemic Use	Antibiotic	Trimethoprim	Antibiotic used mainly in the treatment of respiratory and urinary tract infections, but also middle ear infections and traveller's diarrhoea. Often used in combination with sulfonamides (e.g. sulfamethoxazole).
Blood and Blood Forming Organs	Antiplatelet agent	Clopidogrel	Antiplatelet medication used to reduce the risk of heart disease and stroke in those at high risk.
Cardiovascular System	Analgesic/anti-inflammatory	Ibuprofen	Nonsteroidal anti-inflammatory drug used for treating pain, fever, and inflammation. This includes painful menstrual periods, migraines, and rheumatoid arthritis.
Cardiovascular System	Antihypertensive	Irbesartan	Antihypertensive used to treat high blood pressure, heart failure, and diabetic kidney disease. It is sometimes used in combination with hydrochlorothiazide.
Cardiovascular System	Antihypertensive	Losartan	Antihypertensive used to treat high blood pressure. It is also used to treat diabetic kidney disease, heart failure, and left ventricular enlargement.
Cardiovascular System	Antihypertensive	Valsartan	Antihypertensive used to treat high blood pressure, heart failure, and diabetic kidney disease.
Cardiovascular System	Calcium channel blocker	Diltiazem	Calcium channel blocker used to treat high blood pressure, angina, and certain heart arrhythmias.

Anatomical Therapeutic Classification	Category	Pharmaceutical compound	Therapeutic use
Cardiovascular System	Diuretic	Furosemide	Diuretic used to treat fluid build-up due to heart failure, liver scarring, or kidney disease, but may also be used to treat high blood pressure.
Cardiovascular System	Diuretic	Hydrochlorothiazide	Diuretic used to treat high blood pressure and swelling due to fluid buildup, and decrease the risk of kidney stones.
Cardiovascular System	Lipid regulator/ Cholesterol lowering agent	Atorvastatin	Cholesterol lowering agent used to prevent cardiovascular disease in those at high risk and to treat abnormal lipid levels.
Cardiovascular System	Lipid regulator/ Cholesterol lowering agent	Bezafibrate	Used to lower cholesterol (mainly triglycerides) levels in blood.
Cardiovascular System	Lipid regulator/ Cholesterol lowering agent	Gemfibrozil	Used to treat abnormal blood lipid levels.
Cardiovascular System	Lipid regulator/ Cholesterol lowering agent	Pravastatin	Cholesterol lowering agent used for preventing cardiovascular disease in those at high risk and for treating abnormal lipids.
Cardiovascular System	β -blocker	Atenolol	β -blocker used to treat high blood pressure and heart-associated chest pain, and migraines.
Cardiovascular System	β -blocker	Metoprolol	β -blocker used to treat chest pain (angina), heart failure, and high blood pressure.
Cardiovascular System	β -blocker	Nadolol	β -blocker used to treat high blood pressure, heart pain, and atrial fibrillation.
Cardiovascular System	β -blocker	Propranolol	β -blocker used to treat hypertension, angina, supraventricular and ventricular tachyarrhythmia, acute myocardial infarction, performance anxiety, essential tremors.
Cardiovascular System	β -blocker	Sotalol	β -blocker used to treat and prevent abnormal heart rhythms.
Dermatologicals	Analgesic/anti-inflammatory	Diclofenac	Nonsteroidal anti-inflammatory drug used to relieve pain, swelling (inflammation), and joint stiffness caused by arthritis.
Dermatologicals	Analgesic/anti-inflammatory	Salicylic acid	Analgesic and anti-inflammatory in some anti-acne products used to treat dermatological mycoses. It is a precursor to, and principal metabolite of acetylsalicylic acid (aspirin).
Genito Urinary System and Sex Hormones	Analgesic/anti-inflammatory	Naproxen	Nonsteroidal anti-inflammatory drug used to treat pain, menstrual cramps, inflammatory diseases such as rheumatoid arthritis, and gout and fever.
Genito Urinary System and Sex Hormones	Antibiotic	Metronidazole	Antibiotic used to treat bacterial infections, including infections of the reproductive system, gastrointestinal tract, respiratory system, skin, bones and joints, and other areas of the body. Metronidazole may also be used to prevent postoperative infections.

Anatomical Therapeutic Classification	Category	Pharmaceutical compound	Therapeutic use
Genito Urinary System and Sex Hormones	Prostatic hyperplasia	Tamsulosin	Used to treat symptomatic benign prostatic hyperplasia and chronic prostatitis and to help with the passage of kidney stones.
Musculo-Skeletal System	Analgesic/anti-inflammatory	Ketoprofen	Nonsteroidal anti-inflammatory drug used for treating pain, fever, and inflammation. It is generally prescribed for arthritis-related inflammatory pains or severe toothaches that result in the inflammation of the gums.
Musculo-Skeletal System	Analgesic/anti-inflammatory	Meloxicam	Nonsteroidal anti-inflammatory drug used to treat pain and inflammation in rheumatic diseases and osteoarthritis.
Musculo-Skeletal System	Analgesic/anti-inflammatory	Piroxicam	Nonsteroidal anti-inflammatory drug used to relieve painful inflammatory conditions like arthritis.
Nervous System	Analgesic/anti-pyretic	Acetaminophen	Used to treat fever and mild to moderate pain, such as headaches, muscle aches, minor arthritis pain, toothache, and pain caused by colds and flu.
Nervous System	Analgesic/anti-inflammatory	Indomethacin	Nonsteroidal anti-inflammatory drug used to treat pain, such as headaches and arthritis, and fever and inflammation.
Nervous System	Analgesic/anti-inflammatory	Phenazone	Nonsteroidal anti-inflammatory drug used to treat pain, congestion and swelling caused by acute middle ear infection.
Nervous System	Psychiatric drug	Carbamazepine	Anticonvulsant used primarily in the treatment of epilepsy and neuropathic pain, but also used to treat schizophrenia and bipolar disorder along with other medications.
Nervous System	Psychiatric drug	10,11-Epoxy-carbamazepine	Metabolite of carbamazepine.
Nervous System	Psychiatric drug	2-Hydroxy carbamazepine	Metabolite of carbamazepine.
Nervous System	Psychiatric drug	Acridone	Acridone constitutes the scaffold of some synthetic compounds with diverse pharmacological activities.
Nervous System	Psychiatric drug	Alprazolam	Tranquilizer used to treat anxiety and panic disorders.
Nervous System	Psychiatric drug	Citalopram	Antidepressant used to treat major depressive disorder, obsessive compulsive disorder, panic disorder, and social phobia.
Nervous System	Psychiatric drug	Diazepam (Valium)	Anxiolytic used to treat a range of conditions, including anxiety, seizures, alcohol withdrawal syndrome, benzodiazepine withdrawal syndrome, muscle spasms, insomnia, and restless legs syndrome.
Nervous System	Psychiatric drug	Fluoxetine	Anti-depressant used to treat major depressive disorder, obsessive-compulsive disorder, bulimia nervosa, panic disorder, and premenstrual dysphoric disorder.

Anatomical Therapeutic Classification	Category	Pharmaceutical compound	Therapeutic use
Nervous System	Psychiatric drug	Lorazepam	Anxiolytic used to treat anxiety disorders, trouble sleeping, severe agitation, active seizures including status epilepticus, alcohol withdrawal, and chemotherapy-induced nausea and vomiting.
Nervous System	Psychiatric drug	Norfluoxetine	Anti-depressant used to treat clinical depression (including paediatric depression), obsessive-compulsive disorder, bulimia nervosa, anorexia nervosa, panic disorder and premenstrual dysphoric disorder; metabolite of fluoxetine.
Nervous System	Psychiatric drug	Paroxetine	Anti-depressant used to treat depression, panic attacks, obsessive-compulsive disorder (OCD), anxiety disorders, and post-traumatic stress disorder.
Nervous System	Psychiatric drug	Sertraline	Anti-depressant used to treat depression, panic attacks, obsessive compulsive disorder, post-traumatic stress disorder, social anxiety disorder (social phobia), and premenstrual dysphoric disorder.
Nervous System	Psychiatric drug	Trazodone	Anti-depressant used to treat major depressive disorder, anxiety disorders, and, with other medications, alcohol dependence.
Nervous System	Psychiatric drug	Venlafaxine	Anti-depressant used to treat major depressive disorder, generalized anxiety disorder, panic disorder, and social phobia.
Respiratory System	Analgesic/anti-inflammatory	Codeine	Opioid analgesic and anti-inflammatory used to treat mild to moderate pain that is not relieved by non-opiate analgesics, including post-dental surgical pain, and coughing and diarrhoea.
Respiratory System	Bronchodilator	Salbutamol	A bronchodilator that opens the medium and large airways in the lungs and is used to treat asthma, exercise induced bronchoconstriction, chronic obstructive pulmonary disease.
Respiratory System	Histamine receptor antagonist	Desloratadine	Antihistamine used to relieve allergy symptoms, nasal congestion, and chronic idiopathic urticaria (hives). It may also be used to treat acne.
Sensory Organs, Ophthalmologic	Antibiotic	Ciprofloxacin	Antibiotic used to treat bacterial infections, including bone and joint infections, intra-abdominal infections, certain types of infectious diarrhoea, respiratory tract infections, skin infections, typhoid fever, and urinary tract infections.
Sensory Organs, Ophthalmologic	Antibiotic	Ofloxacin	Antibiotic used to treat bacterial infections, including pneumonia and infections of the skin, bladder, reproductive organs, prostate, eyes, and ears. In South Africa, used to treat multi drug resistant tuberculosis.
Various	X-ray contrast agent	Iopromide	An X-ray contrast agent used during various types of imaging tests, such as angiography and contrast computed tomography (CT) imaging tests.

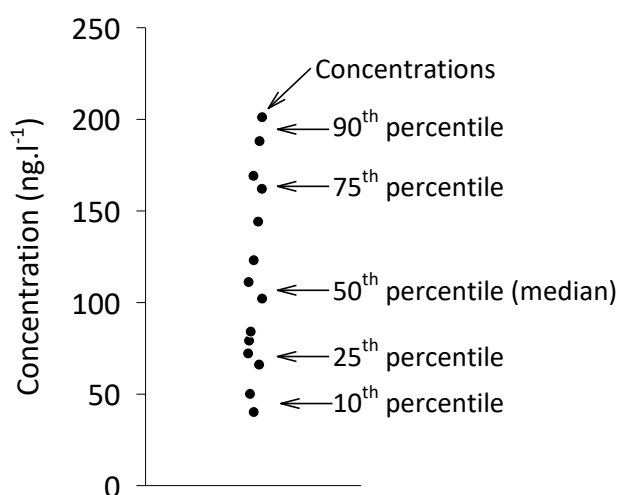


Figure 2. Schematic of a box-and-whisker plot. The box covers the interval between the 25th and 75 percentiles. The horizontal line that divides the box in two is the 50th percentile, or median (middle measurement). The whiskers are the lines outside the box that go from the 10th to the 25th percentile (start of the box) and then from the 75th percentile (end of the box) to the 90th percentile. The concentrations that the box and whisker plot summarises are overlaid on the plot (solid symbols).

were assigned a surrogate concentration of one-half the Limit of Quantification to compute descriptive statistics. Non-detects (*i.e.* less than the Limit of Detection) were assigned a surrogate concentration of zero. Only concentrations above the Limit of Quantification are included in graphs and other figures unless otherwise stated. Graphs and bubble plots are used to compare pharmaceutical compound concentrations. The bubbles are scaled so they are comparable between surveys. In the graphs and bubble plots, cyan coloured bars and bubbles represent water samples from rivers and stormwater discharge points. The concentrations of pharmaceutical compounds measured in coastal waters in this study are compared to concentrations measured in coastal waters elsewhere in the world. The comparison is made using raw concentrations and the concentration distribution is summarised using box and whisker plots. A description of box and whisker plots is provided in Figure 2 to aid the reader. Further details on data treatment for the concentration comparison is provided below.

3.5. Environmental hazard assessment

The European Medicines Agency considers a pharmaceutical compound concentration $\geq 10 \text{ ng.l}^{-1}$

to pose an environmental hazard. If a compound is found, or predicted to be found in surface water at a concentration $\geq 10 \text{ ng.l}^{-1}$ a risk assessment is required (EMEA, 2006). In this study, most pharmaceutical compounds were found at a concentration $\geq 10 \text{ ng.l}^{-1}$ and thus require further assessment. The environmental hazard posed by pharmaceutical compounds was estimated by computing a Hazard Quotient (HQ) following the European Union Technical Guidance Document on Risk Assessment (ECB, 2003), as:

$$\text{HQ} = \text{MEC}/\text{PNEC}$$

where MEC represents the measured environmental concentration of a pharmaceutical compound (*i.e.* the concentrations found in water in this study) and PNEC is the Predicted No Effect Concentration for the compound obtained from the scientific literature. The Predicted No Effect Concentration is the concentration below which a compound is unlikely to adversely impact on aquatic biota. The hazard posed by pharmaceutical compounds was ranked as (Hernando *et al.*, 2006; Minguez *et al.*, 2016):

HQ ≤ 0.01 :	negligible or no hazard
$0.01 > \text{HQ} \leq 0.1$:	low hazard
$0.1 > \text{HQ} < 1$:	medium hazard
HQ ≥ 1 :	high hazard

A major challenge in estimating the hazard posed by pharmaceutical compounds in coastal waters is the limited toxicological information for estuarine and marine biota (Gaw *et al.*, 2016). Predicted No Effect Concentrations for freshwater biota are thus often used to estimate the hazard posed to estuarine and marine biota, even though the sensitivity to pharmaceutical compounds might not be shared amongst estuarine, marine, and freshwater biota. A further challenge is the Predicted No Effect Concentrations for pharmaceutical compounds often differ widely amongst studies depending on their definition (see Ferrari *et al.*, 2003). The Hazard Quotient will thus differ depending on the Predicted No Effect Concentrations used for its computation. Three approaches were thus followed in this study to estimate the hazard posed by the pharmaceutical compounds, for comparative purposes.

First, Predicted No Effect Concentrations were

computed using EC₅₀'s (concentration causing toxic effect in 50% of organisms tested) provided by Kuzmanović *et al.* (2015) for freshwater biota (microalgae, crustacea [represented by *Daphnia*], and fish). Although the information is for freshwater biota, Kuzmanović *et al.* (2015) provide information for 42 of the 58 compounds analysed in this study, including many of the compounds found at a quantifiable concentration. The Predicted No Effect Concentration was computed by dividing the EC₅₀ by an Assessment Factor of 1 000 since toxicity was determined using acute rather than chronic toxicity testing procedures (see EMEA, 2006). Assessment Factors are used in the calculation of Predicted No Effect Concentrations to account for inter- and intra-species variability, ranges in species sensitivity, and to extrapolate from acute to chronic effects and from laboratory to field exposures (Forbes and Callow, 2002).

Second, Predicted No Effect Concentrations for marine and freshwater microalgae, and in one case a fish, provided by Minguez *et al.* (2016) were used to compute Hazard Quotients. The information covers 22 compounds analysed in this study. Minguez *et al.* (2016) used an Assessment Factor of 10 000 rather than 1 000 to compute the Predicted No Effect Concentration as a precautionary measure when extrapolating from freshwater to marine conditions.

The third approach is based on the 'fish plasma model' proposed by Huggett *et al.* (2003). The model assumes molecular drug targets are conserved in humans and fish, and human pharmaceuticals will interact with the targets in fish to cause a target-mediated pharmacological response as they do in humans (Meador *et al.*, 2017). Fick *et al.* (2010) calculated the surface water concentration, known as a 'Critical Environmental Concentration', that should theoretically elevate the plasma concentration in exposed fish to a level equal to the human therapeutic plasma concentration for a range of pharmaceutical compounds. The fish plasma model generates a Concentration Ratio (CR) computed as:

$$CR = CEC/MEC$$

where CEC represents the Critical Environmental Concentration and MEC the Measured Environ-

mental Concentration. If the Concentration Ratio is ≤ 1 then the plasma concentration in exposed fish is equal to, or higher, than the concentration known to cause a pharmacological response in humans. The Concentration Ratio estimates if a pharmacological response is likely to occur, but not if the response will be adverse.

In each approach, pharmaceutical compound concentrations reported as less than the Limit of Detection were replaced with a surrogate concentration of zero and those reported as less than the Limit of Quantification by a surrogate concentration of one-half the limit. Hazard Quotients were only computed for pharmaceutical compounds found at a quantifiable concentration in at least one sample. Pharmaceutical compounds reported as below the Limit of Detection in all samples, or that have no toxicological information were thus ignored.

4. Results and Discussion

4.1. Faecal indicator bacteria

The number of *E. coli* and faecal streptococci bacteria found in water in each survey is provided in Figure 3 (the data are provided in Appendices 1 and 2). The South African Water Quality Guidelines for Coastal Marine Waters: Recreational Use (DEA, 2012) rating for excellent water quality is included in Figure 3. The guidelines are designated to interpret the results of multiple samples at a site (*i.e.* are based on a percentile of multiple data), rather than one or two samples. The guidelines are also not designated to assess freshwater samples (*i.e.* river, stormwater sites), but they provide a convenient point for reference and used for this purpose.

In winter, *E. coli* bacteria were found in water at all sites apart from Hout Bay Beach, Miller's Point, and Kogel Bay. The colony forming unit counts at other sites ranged from one near Milton Tidal Pool, at Oudekraal Resort, and at Diaz Beach, to >50 000 near the Athlone wastewater treatment works in the Black River (Figure 3). The count at only one coastal site (Lagoon Beach) on the Atlantic Seaboard exceeded the water quality guideline for an excellent water quality rating but did so at five coastal sites in False Bay. In all cases the colony forming unit counts were far higher than the water quality guideline.

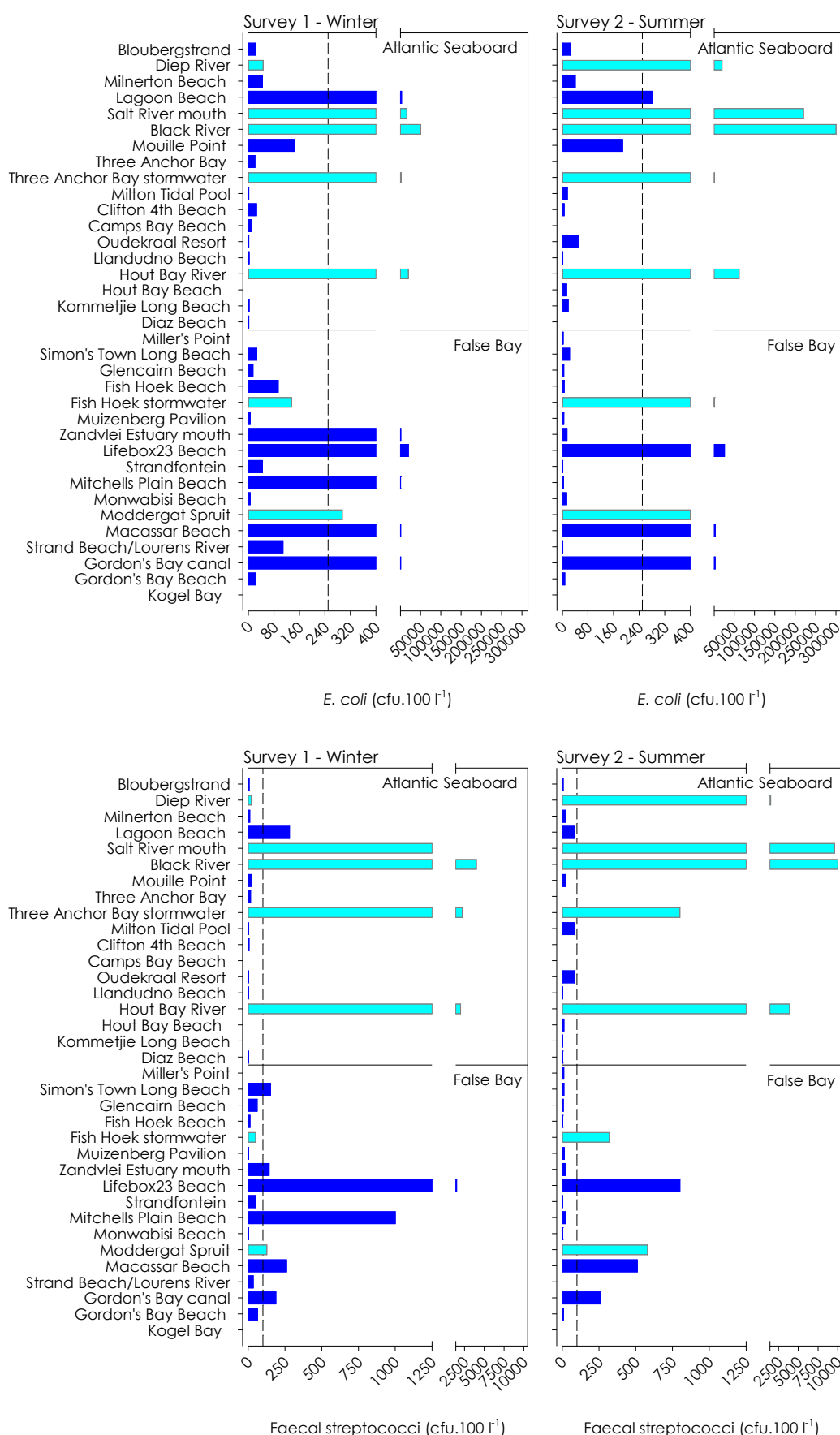


Figure 3. *E. coli* and faecal streptococci bacteria colony forming unit counts in water sampled in the City of Cape Town on the 24th of August and 7th of December 2021. The vertical dashed lines represent the guideline for an excellent water quality rating as per the South African Water Quality Guidelines Coastal Marine Waters: Recreational Use (DEA, 2012).

In winter, faecal streptococci bacteria were found in water at all sites apart from Camps Bay Beach, Hout Bay Beach, Kommetjie Long Beach, Miller's Point, and Kogel Bay. The colony forming unit counts at other sites ranged from one near Milton Tidal Pool and at Oudekraal Resort, Diaz Beach, and Llandudno Beach, to 4 000 near the Athlone wastewater treatment works in the Black River (Figure 3). The count at only one coastal site (Lagoon Beach) on the Atlantic Seaboard exceeded the water quality guideline for an excellent water quality rating but did so at four coastal sites in False Bay. The colony forming unit counts at Lifebox23 Beach and Mitchells Plain Beach were considerably higher than the water quality guideline.

In summer, *E. coli* bacteria were found in water at all sites apart from Three Anchor Bay, Camps Bay Beach, Diaz Beach, and Kogel Bay. The colony forming unit counts at other sites ranged from one at Llandudno Beach, Strandfontein, and Strand Beach at Lourens River mouth, to >300 000 near the Athlone wastewater treatment works in the Black River (Figure 3). The count at only one coastal site (Lagoon Beach) on the Atlantic Seaboard slightly exceeded the water quality guideline for an excellent water quality rating, but at six coastal sites in False Bay far exceeded the water quality guideline.

In summer, faecal streptococci bacteria were found in water at all sites apart from Three Anchor Bay, Clifton 4th Beach, Camps Bay Beach, Strand Beach at Lourens River mouth, and Kogel Bay. The colony forming unit counts at other sites ranged from one at Diaz Beach, Fish Hoek Beach, and Monwabisi Beach, to >10 000 near the Athlone wastewater treatment works in the Black River (Figure 3). The count at no coastal sites on the Atlantic Seaboard exceeded the recreational use water quality guideline for an excellent water quality rating but did so at three coastal sites in False Bay. The colony forming unit counts at Lifebox23 Beach and Macassar Beach were considerably higher than the water quality guideline.

Faecal indicator bacteria counts at freshwater sites, including the stormwater sites at Three Anchor Bay and Fish Hoek, were often higher than at coastal sites. Counts for the Black, Salt, Diep, and Hout Bay Rivers were especially high apart from the Diep River

in winter, when the counts were inexplicably low considering the river receives a high wastewater load (noting that the site was above the Potsdam wastewater treatment works discharge).

The faecal indicator bacteria results show that water quality at many coastal sites was, at the time of surveys, better than the rating revealed by the City of Cape Town's long-term coastal water quality monitoring programme (CoCT, 2020). In the city's programme, water quality at many sites was rated Sufficient or Poor due to (periodically) moderate or high faecal streptococci colony forming unit counts, but the counts at these sites were low in this study and result in a Good or Excellent water quality rating. These sites include Three Anchor Bay, Camps Bay Beach, Hout Bay Beach, Simon's Town Long Beach, Fish Hoek Beach, Muizenberg Pavilion, Monwabisi Beach, and Gordon's Bay Beach.

If the main source of the faecal indicator bacteria found in the water at coastal sites is wastewater, regardless of its source (these bacteria also come from household pets, birds, livestock, and marine mammals), then instances where water quality was better than the long-term means the prevalence and/or concentrations of pharmaceutical compounds might be less than could be expected on average. There is always a chance in infrequent water quality surveys of the type used in this study that the average condition is not captured, but rather is skewed to a better or worse than average condition. The relationship between faecal indicator bacteria counts and the number and total concentrations of pharmaceutical compounds in the water, and between faecal indicator bacteria counts and individual compound concentrations was weak. Pharmaceutical compounds were found at several sites where water quality is classified Good or Excellent based on faecal indicator bacteria counts at the time, implying that in cases where faecal indicator bacteria did not provide a clear signal of wastewater, it was evident in the presence of pharmaceutical compounds.

4.2. Pharmaceutical compounds

4.2.1. General trends

In winter, 37 of the 58 pharmaceutical compounds analysed were found at a quantifiable concentration in at least one water sample (site) compared to 45 in

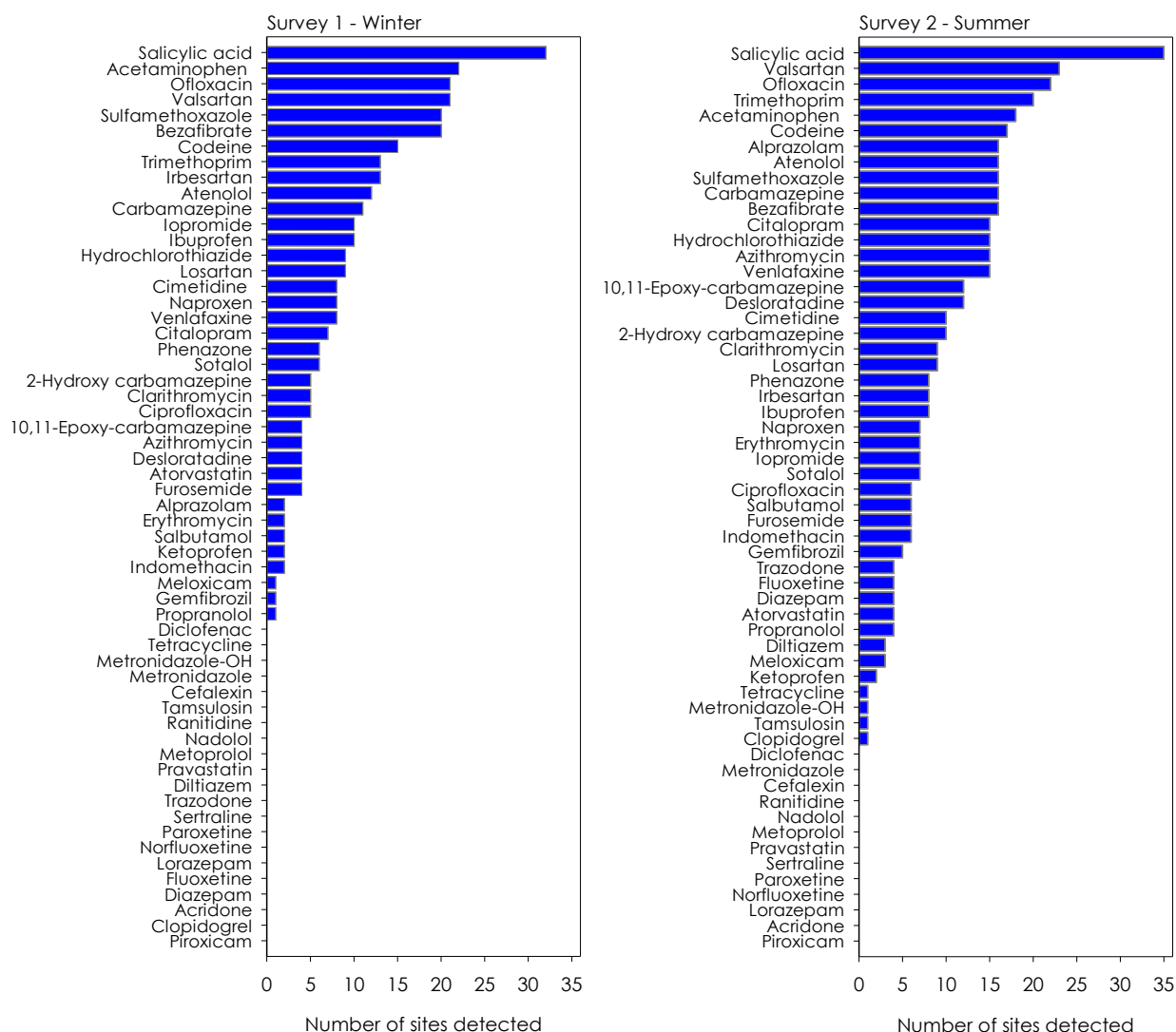


Figure 4. The number of sites at which each pharmaceutical compound was found at a quantifiable concentration in water sampled in the City of Cape Town on the 24th of August and 7th of December 2021.

summer (Figure 4; the data are provided in Appendices 1 and 2). To the best knowledge of the scientists that prepared this report these are the first records for many of the compounds in South African coastal and/or fresh waters.

Most (35) pharmaceutical compounds were found more often in summer than in winter, when five were found more often. The difference in the detection frequency was usually small, but for some compounds was large. Alprazolam, for example, was found at 14 more, azithromycin at 11 more, citalopram at eight more, and trimethoprim at seven more sites in summer than in winter. In contrast, irbesartan was found at five more sites in winter.

Salicylic acid was found most often at a quantifiable concentration, at 32 sites in winter and at 35 (*i.e.* all) sites in summer (Figure 4). The detection frequency

of pharmaceutical compounds undoubtedly reflects in part patterns in their prescription and use and hence their concentration in wastewater, although it must be borne in mind some compounds are more effectively degraded and removed in wastewater treatment works and/or are more resistant to degradation in the environment than others and the chance of their detection is thus higher.

Osunmakinde *et al.* (2013) ranked pharmaceutical compounds by their prescription frequency in the private and public health care sectors in South Africa. Acetaminophen was most often prescribed in the private sector and the second most often in the public sector. Other compounds highly prescribed in the public health care sector include atenolol, hydrochlorothiazide, sulfamethoxazole, salbutamol, and furosemide, and in the private health care sector acetylsalicylic acid, diclofenac, salbutamol,

ibuprofen, codeine, trimethoprim, and sulfa-methoxazole. As discussed below, these compounds were not always found in water at frequencies in line with their prescription, which may be due to many factors.

The greatest number of pharmaceutical compounds found at a quantifiable concentration in water at any site in winter was 28 in the Salt River mouth and at Macassar Beach, followed by 27 at Lifebox23 Beach, 26 in the Black River, and 25 at Lagoon Beach and near the Gordon's Bay canal mouth (Figure 5). In summer the greatest number was 36 in the Salt River mouth, followed by 35 in the Diep River, 33 near the Athlone wastewater treatment works in the Black River and at Macassar Beach, 30 at Lifebox23 Beach, and 28 near the Gordon's Bay canal mouth. The water at these sites is strongly directly or indirectly (*i.e.* coastal sites by catchment flows) influenced by discharges from wastewater treatment works. The Macassar Beach site in False Bay, for example, is near the mouth of the Eerste River that drains a large catchment containing numerous wastewater treatment works, including the Macassar works near the mouth. The Lifebox23 site, also in False Bay, is near the point where wastewater flows into the sea from the Cape Flats wastewater treatment works.

In winter, one pharmaceutical compound was found at a quantifiable concentration in water at Fish Hoek Beach, Glencairn Beach, and Miller's Point, while two compounds were found at Diaz Beach, Kommetjie Beach, Llandudno Beach, and Oudekraal Resort. In summer, one compound was found in water at Kogel Bay and two compounds at Diaz Beach and Miller's Point (Figure 5). Seven of the 12 sites where one, two, or three pharmaceutical compounds were found in winter are on the Atlantic Seaboard (Figure 5). In summer, three of the sites where this number of compounds was found were on the Atlantic Seaboard. Ten of the 17 sites with the lowest number of compounds found were on the Atlantic Seaboard. Some sites where few pharmaceutical compounds were found are quite far from densely populated parts of Cape Town and thus presumably also quite far from a strong influence of wastewater treatment works discharges, which probably contributes to the low frequency of pharmaceutical compound detection. However, even at Diaz Beach, which is arguably the

most remote site, the antibiotic ofloxacin and the analgesic salicylic acid were found in winter while the psychiatric drug alprazolam and salicylic acid were found in summer, but usually at a low concentration (Figure 5). Other sites where few pharmaceutical compounds were found, such as Clifton 4th Beach, Camps Bay Beach, Fish Hoek Beach, and Simonstown Long Beach, are in more populated parts of Cape Town and are thus nearer possible sources of pharmaceutical compounds. In these cases the infrequent detection might reflect oceanographic and meteorological conditions prevailing at the time of the surveys rather than the long-term status since the monitoring of faecal indicator bacteria by the City of Cape Town has revealed instances of impaired water quality at some of these sites (CoCT, 2020).

More pharmaceutical compounds were found in summer than in winter at 35 sites, while more were found at 10 sites in winter than in summer. At most sites the difference between winter and summer was small (≤ 3 compounds). The most pronounced difference was for the Diep River site, where 31 more compounds were found in summer than in winter. The far higher number of compounds found in the Diep River corresponds with a far higher count of faecal indicator bacteria in water at this site in summer, when the count was inexplicably low. The difference was ten compounds near Milton Tidal Pool and nine in stormwater at Three Anchor Bay and Strandfontein Beach.

The low number of pharmaceutical compounds found in coastal water at Fish Hoek Beach in winter (one) and summer (three) is interesting since 11 and 12 compounds respectively were found in water flowing from a stormwater pipe at the beach. Low faecal indicator bacteria counts were found at the Fish Hoek Beach coastal site in winter, but the counts were high in summer (Figure 3). At Three Anchor Bay, 17 compounds were found in water flowing from a stormwater pipe compared to three in coastal water nearby in winter, and 27 versus seven in summer. The faecal indicator bacteria results reveal excellent water quality at the Three Anchor Bay coastal site in winter and summer (Figure 3) compared to a poor water quality rating in the City of Cape Town's long-term monitoring programme.

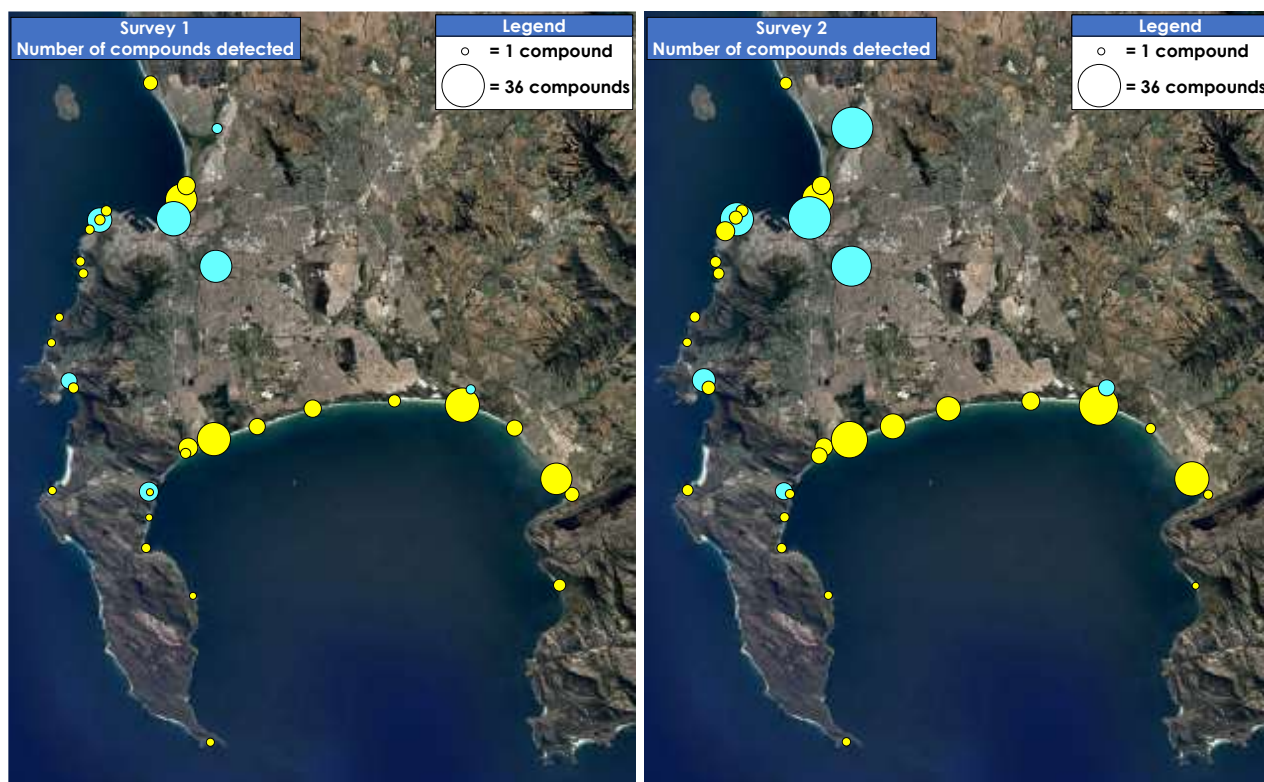
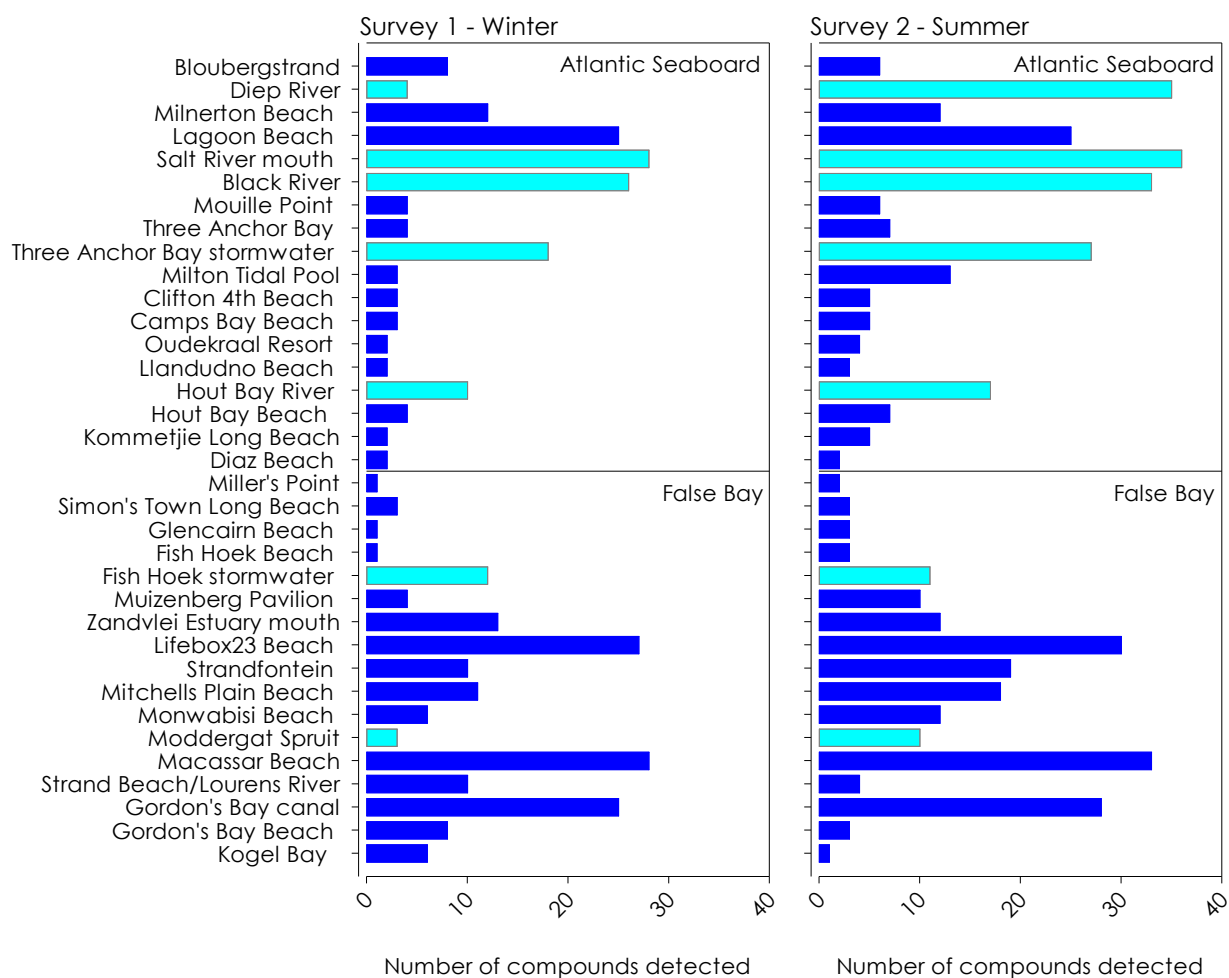


Figure 5. The number of pharmaceutical compounds found at a quantifiable concentration in water sampled in the City of Cape Town on the 24th of August and 7th of December 2021.

The faecal indicator bacteria counts in water flowing from the stormwater pipes were high in each survey. The presence of pharmaceutical compounds and faecal indicator bacteria in the water flowing from stormwater pipes suggests the ingress of wastewater into the stormwater infrastructure.

The disconnect between the stormwater source and coastal water at Fish Hoek Beach and Three Anchor Bay is likely a result of the low volume of water flowing from the stormwater pipes at the time of the surveys, allowing rapid and substantial dilution of water and associated contaminants in the coastal water. Also, the positions where water was sampled in the surf zone at Fish Hoek Beach and Three Anchor Bay were not immediately off the stormwater pipes.

Seven of the ten sites with the highest total concentrations of pharmaceutical compounds were the same in each survey (Figure 6). Apart from stormwater at Three Anchor Bay and Fish Hoek Beach, each of the sites is strongly directly or indirectly (*i.e.* via catchment flows) influenced by wastewater treatment works discharges. The total pharmaceutical compound concentration was low (defined here as $<250 \text{ ng.l}^{-1}$) at 17 sites in winter and at 15 sites in summer. Twelve of these sites were the same in each survey. There was thus a generally strong similarity in the sites where amongst the lowest or highest total concentrations were found in each survey. There were, however, strong differences at some sites, notably in the Diep River where the total concentration in winter was 129.3 ng.l^{-1} compared to $19\,765.2 \text{ ng.l}^{-1}$ in summer, and Mouille Point, where the total concentration in winter was 3506.8 ng.l^{-1} compared to 159.6 ng.l^{-1} in summer. If only coastal sites are considered, nine of the 15 sites where the total concentration was low in summer and ten of the 19 sites in summer were on the Atlantic Seaboard.

The high pharmaceutical compound concentrations at coastal sites near river and estuary mouths highlights the importance of rivers and estuaries as vectors for their introduction to coastal waters in Cape Town. The presence of pharmaceutical compounds in stormwater at Three Anchor Bay and at Fish Hoek Beach also highlights the importance of flows from stormwater infrastructure as a vector for pharmaceutical compounds to coastal waters in

Cape Town. It would not be surprising (but untested) if this extends to flows from other stormwater infrastructure in Cape Town as stormwater has been identified as an important vector for the introduction of pharmaceutical compounds to aquatic systems elsewhere in the world (*e.g.* Fairbairn *et al.*, 2018; Masoner *et al.*, 2019; Yin *et al.*, 2019). The way pharmaceutical compounds enter the stormwater infrastructure probably includes a combination of flows from unreticulated informal settlements, sewer leaks into and illegal sewer connections to the infrastructure, and sewer pump failures.

The number of pharmaceutical compounds found at a quantifiable concentration (Figure 5) and the total concentration (Figure 6) differed between sites on the Atlantic Seaboard and in False Bay, noting three sites were positioned in rivers along the Atlantic Seaboard compared to only one site in False Bay. In winter, the highest number of pharmaceutical compounds was found in the Salt River mouth on the Atlantic Seaboard and at Macassar Beach in False Bay, both recording 27 compounds, but the median was four for the Atlantic Seaboard and seven for False Bay. The median total concentration was not much different (Atlantic Seaboard = 117.4 ng.l^{-1} vs False Bay = 103.1 ng.l^{-1}), but the maximum was higher at sites in False Bay ($6\,327.5 \text{ ng.l}^{-1}$ vs $8\,451.1 \text{ ng.l}^{-1}$). If only coastal sites are considered the median (3 vs 7) and maximum (25 vs 28) number of pharmaceutical compounds found was higher at sites in False Bay. The median (27.3 ng.l^{-1} vs 103.1 ng.l^{-1}) and maximum ($3\,315.0 \text{ ng.l}^{-1}$ vs $8\,451.1 \text{ ng.l}^{-1}$) total concentrations were also (considerably) higher in False Bay.

In summer, the highest number of pharmaceutical compounds (35) was found at the Diep River site on the Atlantic Seaboard. The median was seven for the Atlantic Seaboard and ten for False Bay. The median total concentration (Atlantic Seaboard = 124.4 ng.l^{-1} vs False Bay = 246.1 ng.l^{-1}) was higher at sites in False Bay, while the maximum ($19\,717.5 \text{ ng.l}^{-1}$ vs $11\,419.1 \text{ ng.l}^{-1}$) was considerably higher on the Atlantic Seaboard. If only coastal sites are considered, the median (6 vs 7) and maximum (25 vs 33) number of compounds found was higher at sites in False Bay. The median (56.7 ng.l^{-1} vs 198.5 ng.l^{-1}) and especially maximum ($1\,619.4 \text{ ng.l}^{-1}$ vs $11\,419.1 \text{ ng.l}^{-1}$) total

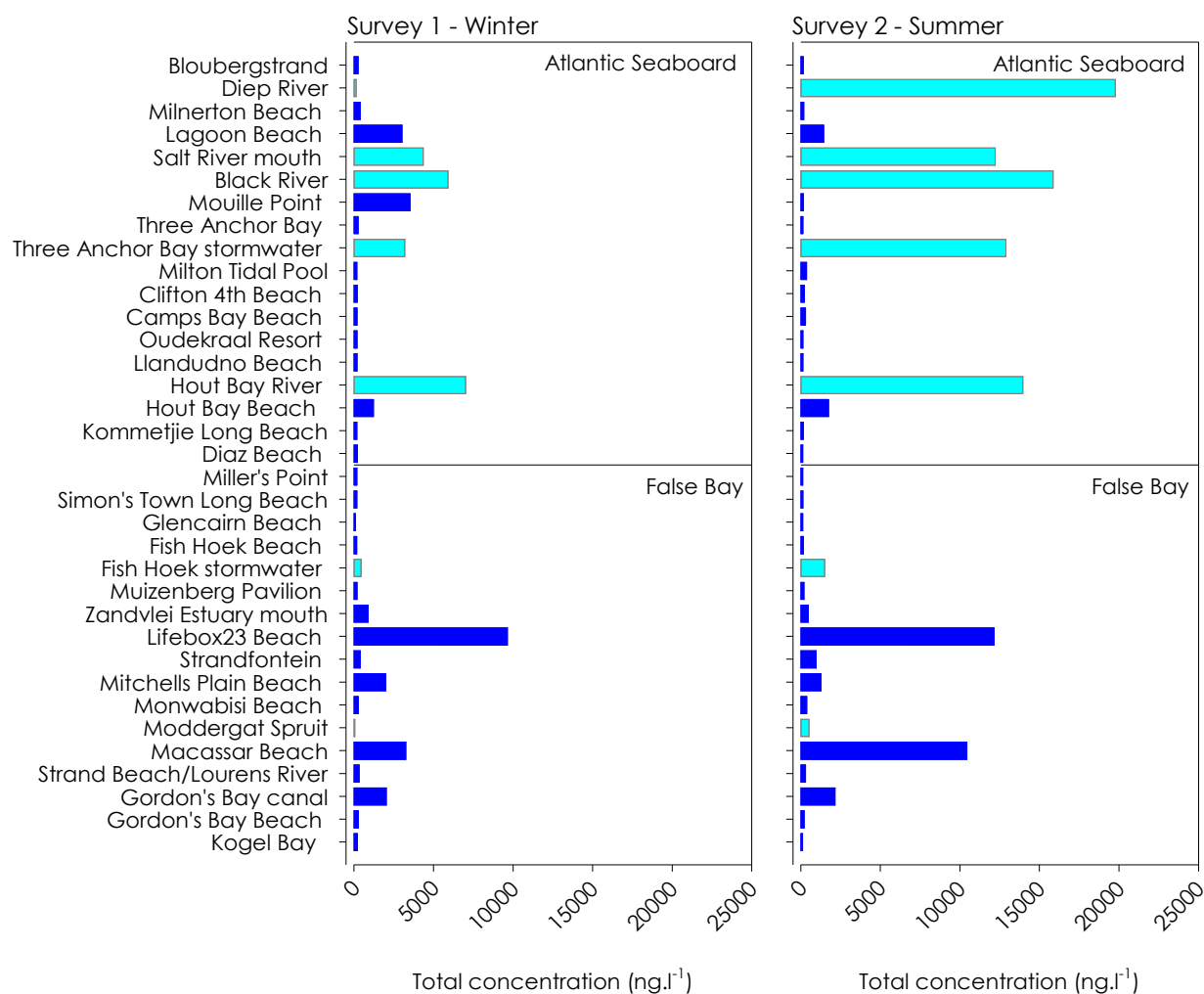


Figure 6. The total concentration of pharmaceutical compounds found at a quantifiable concentration in water sampled in the City of Cape Town on the 24th of August and 7th of December 2021.

concentration was also (considerably) higher in False Bay.

The above findings imply shoreline water in False Bay is more affected by pharmaceutical compounds and hence wastewater than coastal water on the Atlantic Seaboard. There is a greater dilution and dispersion potential in the sea on the Atlantic Seaboard due to the exposed coastline, while dilution and dispersion are likely retarded in the more sheltered False Bay. Wastewater also enters the False Bay coastal environment via the surf zone more so than on the Atlantic Seaboard. Surf zones retard the dilution and dispersion of wastewater, which is trapped until it is transported out of the surf zone to deeper water by rip currents. On the Atlantic Seaboard, three outfalls discharge a large volume of wastewater daily some distance off the coast rather than into the surf zone, promoting dilution and dispersion. The difference in the prevalence and concentration of pharmaceutical compounds between the Atlantic Seaboard and False Bay is supported by findings of the City of Cape Town's coastal water quality monitoring programme, which shows water quality is rated fair or poor at proportionally more sites in False Bay than on the Atlantic Seaboard (CoCT, 2020).

A comparison of the number and concentration of pharmaceutical compounds with different therapeutic uses is moot since varying numbers of compounds with different uses were analysed and their concentration in drugs and thus in wastewater or other sources will vary. Antibiotics, analgesics/anti-inflammatories, and psychiatric drugs were most often found at a quantifiable concentration across all sites, but not always in each survey (Figure 8). Psychiatric drugs were found less often in winter. Calcium channel blockers, antiplatelet agents, and a drug to treat prostatic hyperplasia were never found while the bronchodilatory drug sotalol was rarely found. There was usually little difference in the number of compounds in different therapeutic classes found between sites on the Atlantic Seaboard and in False Bay if all sites are considered. However, if only coastal sites are considered then lipid regulators, beta blockers, and the x-ray contrast agent iopromide were found at more sites in False Bay (Figure 7). Analgesics/anti-inflammatories, antihypertensives, and diuretics

were found at a considerably higher total concentration at sites on the Atlantic Seaboard compared to False Bay in one or both surveys if all sites are considered (Figure 8). This changes to False Bay for most therapeutic classes if only coastal sites are considered (Figure 8).

As stated above, large volumes of wastewater are discharged into the sea via outfalls at Green Point, Camps Bay, and Hout Bay. Based on the findings of this study the impact of the discharges on shoreline waters was limited at the time of the surveys. The number of pharmaceutical compounds found, and their total concentration was low at Camps Bay and Clifton 4th Beach, inshore of the Camps Bay outfall, and fairly low at Hout Bay Beach inshore of the Hout Bay outfall. The compounds found at Hout Bay Beach were more likely from the Hout Bay River outflow (10 compounds were found in the river in winter and 17 in summer). In winter, the Mouille Point site had the 5th highest total concentration (Figure 6), but this was contributed by only three compounds (Figure 5). Acetaminophen in fact contributed ~99.7% of the total concentration. It is unlikely wastewater from the Green Point outfall was the source of the pharmaceutical compounds at Mouille Point since wastewater usually contains a mixture of compounds (as evident at sites strongly influenced by wastewater treatment works discharges in this study). Indeed, the analysis (CSIR, 2017) of wastewater discharged via the Green Point outfall on four occasions revealed the presence of 14 - 19 pharmaceutical compounds in wastewater discharged through the outfall at any time (comparable numbers were found in wastewater discharged through the Camps Bay and Hout Bay outfalls). On the other hand, acetaminophen was found at a far higher concentration than other compounds in wastewater discharged through the Green Point outfall and wastewater could thus conceivably account for the high acetaminophen concentration in water at Mouille Point. There may of course be other sources of pharmaceutical compounds to coastal waters at Mouille Point, such as stormwater.

Diclofenac is often found in surface water in many parts of the world. In Cape Town, Petrik *et al.* (2017) and Ojemaye and Petrik (2021) found diclofenac in all seawater samples they collected in the Green

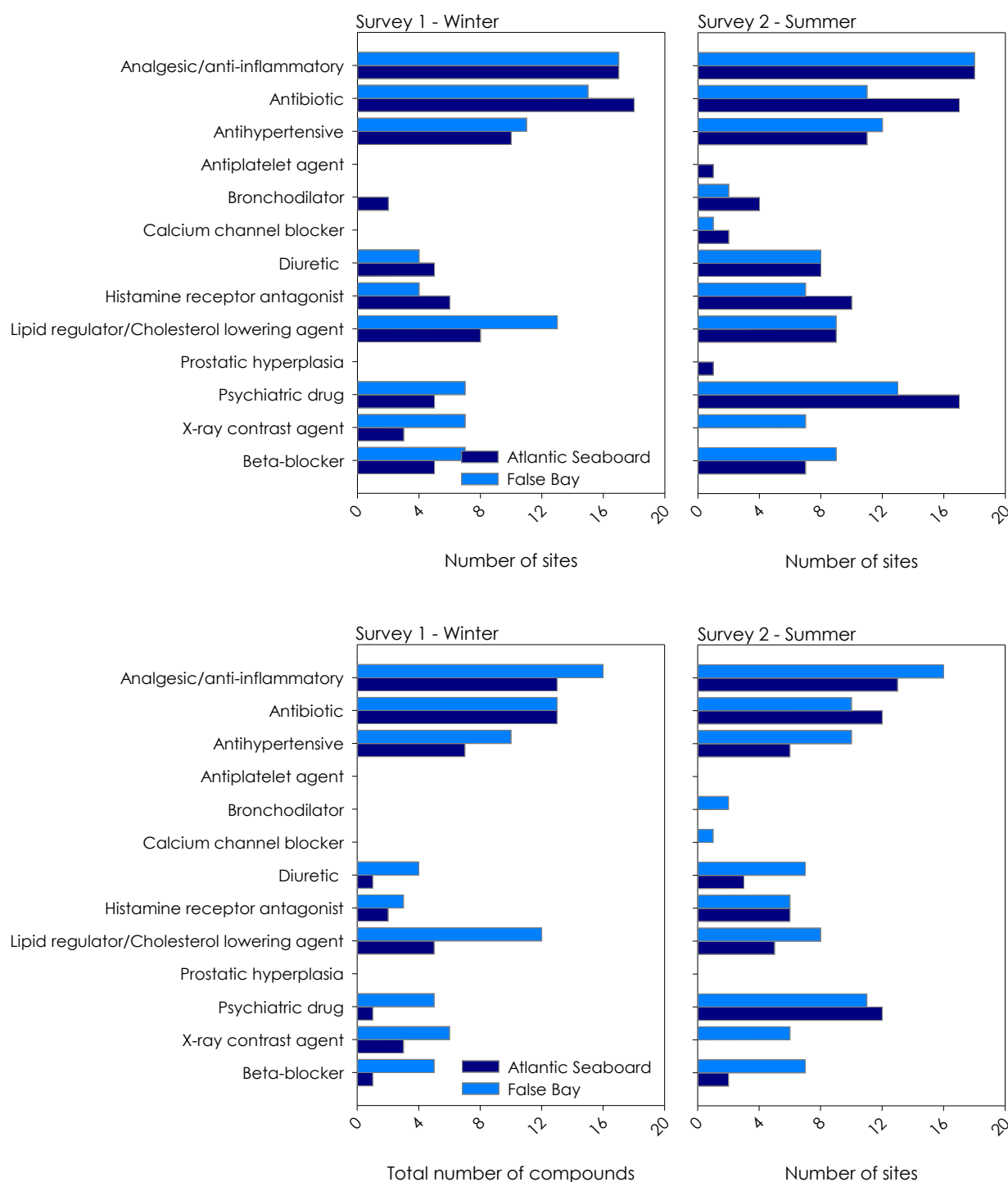


Figure 7. The number sites on the Atlantic Seaboard and False Bay coast at which pharmaceutical compounds falling into different therapeutic use classes were detected, considering all sites (top) and only coastal sites (bottom).

Point area on the Atlantic Seaboard and in False Bay respectively. In this study, diclofenac was not found at a quantifiable concentration in either survey, despite using two methods for its analysis (principal LC-MS/MS method, alternate HR-MS method). Interferences in the analytical method prevented its quantification.

4.2.2. Trends for individual pharmaceutical compounds

Trends for individual pharmaceutical compounds found at a quantifiable concentration in water sampled in Cape Town are provided in Figures 9 - 54. The figures include a comparison of pharmaceutical compound concentrations found in water sampled at coastal sites in this study to concentrations found in coastal waters elsewhere in the world.

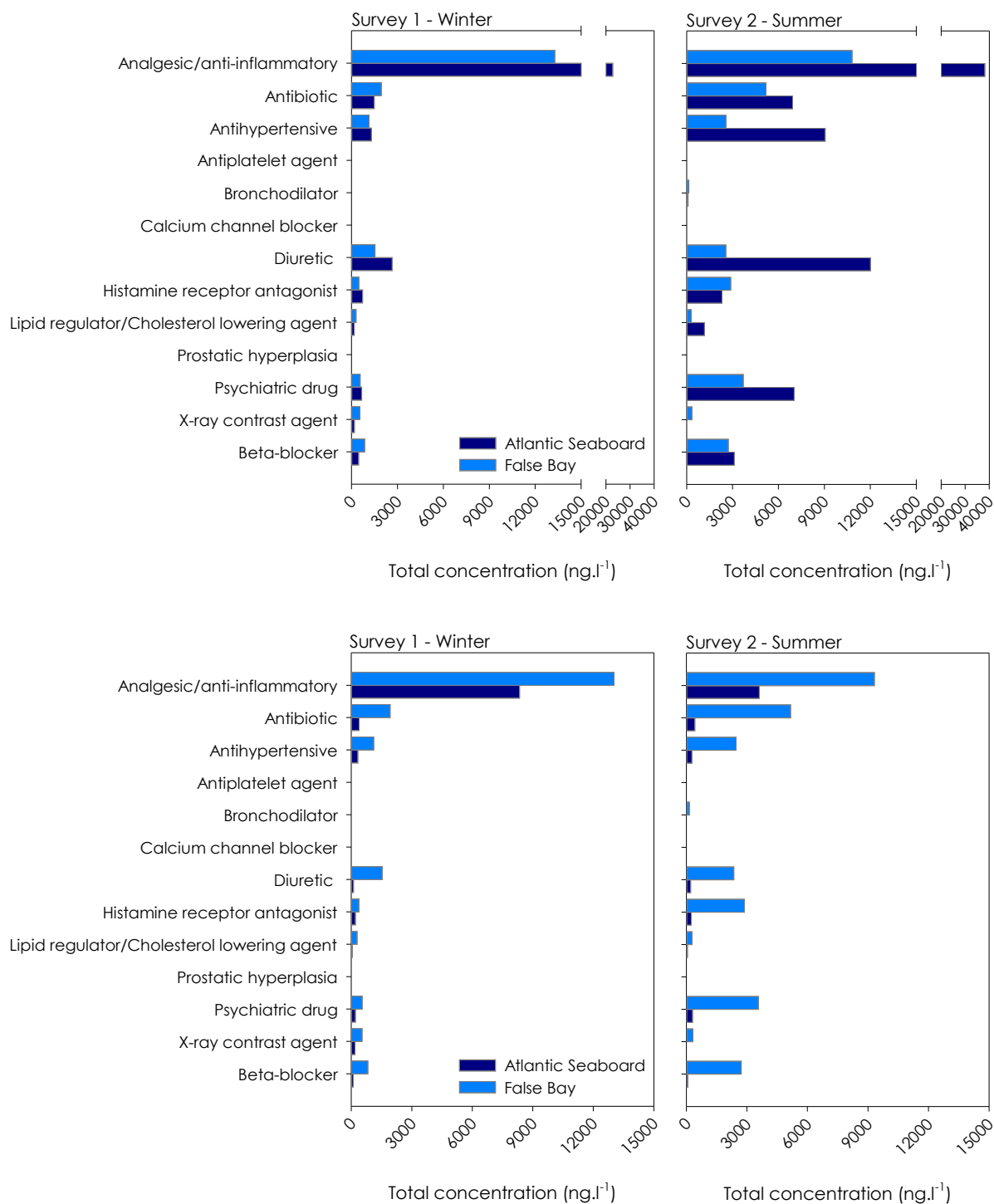


Figure 8. The total concentration for different therapeutic use classes of pharmaceutical compounds at sites on the Atlantic Seaboard and False Bay coast, considering all sites (top) and only coastal sites (bottom).

Concentrations reported as less than the Limit of Detection or Limit of Quantification in this and the comparison studies were replaced by a surrogate concentration of zero for the comparison. The comparison studies do not necessarily include studies reporting the highest concentrations recorded elsewhere in the world. Rather, the studies were identified as they represent studies in coastal rather than freshwaters and importantly, they

provide concentrations for individual compounds at each site rather than only the average, minimum, and maximum concentration across sites.

It is beyond the scope of this study to describe the trends for each pharmaceutical compound found. Rather, some compounds found most often or at the highest concentration, or that present other points of interest are discussed.

Salicylic acid

Salicylic acid is a hormone found in many plants (notably in willow tree *Salix* spp bark, from which it derives its name) (Krantz *et al.*, 2010). Salicylic acid is a precursor to, and a metabolite (degradation product) of aspirin (acetylsalicylic acid). It promotes skin exfoliation and is widely used topically in creams and lotions to treat acne, psoriasis, calluses, corns, and warts. It is also used as a food preservative, bactericide, and as an antiseptic in toothpaste. After the intake of aspirin, humans excrete ~2 - 30% as salicylic acid (Mompelat *et al.*, 2009).

Salicylic acid was found at a quantifiable concentration in water at 32 of the 35 sites in winter and at 35 (*i.e.* all) sites in summer (Figure 9). As such it was the compound found most often in both surveys. The widespread occurrence of salicylic acid in coastal waters has been reported in other studies (*e.g.* Biel-Maeso *et al.*, 2018). There was no clear spatial trend for salicylic acid concentrations within and between surveys apart from generally higher concentrations in stormwater at Three Anchor Bay, in Hout Bay River, and at Lifebox23 Beach than elsewhere. The general lack of a marked spatial trend in the occurrence and concentrations with respect to possible wastewater sources might reflect the natural presence of salicylic acid in coastal waters in addition to that from wastewater sources.

The salicylic acid concentration at most sites was considerably higher than concentrations reported in comparison studies. The 50th, 75th and 90th percentiles of the concentration distribution are thus also higher than for comparison studies (Figure 9).

There appears to be no information on salicylic acid in coastal waters in Cape Town or elsewhere in South Africa. No comparison to concentrations in local coastal waters is thus possible. Agunbiade and Moodley (2014) measured aspirin (acetylsalicylic acid) in water at Blue Lagoon in the Umgeni Estuary and reported a concentration of ~3.5 µg.l⁻¹, which is far higher than the salicylic acid concentrations found in water in Cape Town.

Acetaminophen

Acetaminophen, also known as paracetamol, is an

analgesic and antipyretic used to treat mild to moderate pain and fever. It is the active ingredient in many headache tablets. Acetaminophen was found at a quantifiable concentration in water at 22 (or ~63%) of the 35 sites in winter and 18 (or ~51%) sites in summer (Figure 10). The six highest pharmaceutical compound concentrations found in winter and three highest in summer were for acetaminophen. The highest concentrations were usually found in water at sites strongly influenced directly or indirectly by wastewater discharges, most notably (not in order) in the Diep River, near the Athlone wastewater treatment works in the Black River, at Lagoon Beach, in Hout Bay River, and at Hout Bay Beach, Lifebox23 Beach, Mitchells Plain Beach, and Macassar Beach (Figure 10). The acetaminophen concentration found in water near the Gordon's Bay canal in False Bay was amongst the lowest in each survey, which is interesting as this site is strongly influenced by wastewater discharged upstream of the canal and amongst the highest number of pharmaceutical compounds was found at this site in each survey (Figure 5). The very high acetaminophen concentration found in water at Mouille Point in winter is also interesting as only two other compounds (valsartan, ofloxacin) were found at a quantifiable concentration at this site (Figure 5). The valsartan and ofloxacin concentrations were low, acetaminophen contributing ~99.7% of the total concentration.

Acetaminophen was found in stormwater at Three Anchor Bay and Fish Hoek Beach in each survey, but the concentration was not as high as at many other sites (Figure 10). Acetaminophen was found at a very low concentration at the remote Kogel Bay site in winter but not in summer, and never at the arguably more remote Diaz Beach site.

Acetaminophen is reported at a high concentration in the influent and effluent of wastewater treatment works, including in South Africa (Gros *et al.*, 2010; Verlicchi *et al.*, 2012; Kostich *et al.*, 2014; Pereira *et al.*, 2015; Matongo *et al.*, 2015; CSIR, 2017; Yang *et al.*, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Archer *et al.*, 2021). This is despite the fact humans excrete only <~5% of the ingested dose as the parent acetaminophen compound (Jjemba, 2006) and much of the acetaminophen entering conventional wastewater treatment works is effectively degraded

and removed (Gros *et al.*, 2010; Oulton *et al.*, 2010; Gao *et al.*, 2012; Archer *et al.*, 2017; Yang *et al.*, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Archer *et al.*, 2020). The high acetaminophen concentration commonly found in effluent discharged from wastewater treatment works thus reflects the remainder of the high concentrations usually found in the influent that is not removed. The acetaminophen concentration in wastewater discharged through marine outfalls at Green Point, Camps Bay, and Hout Bay in 2016 was between 201 - 970 $\mu\text{g.l}^{-1}$, which is ~ 83 - 816 times higher than any other pharmaceutical compound found in the wastewaters (CSIR, 2017). The high concentrations found in wastewater undoubtedly reflect the wide use of acetaminophen, which is partly a result of the fact acetaminophen is found in many drugs and other products that can be purchased without a medical prescription. Sales information shows acetaminophen is often the most widely used and prescribed pharmaceutical compound in many countries. It is biodegradable and has a half-life of ~ 15 days in the environment (Benotti *et al.*, 2009; Čelić *et al.*, 2019).

The widespread occurrence and high concentration of acetaminophen in Cape Town coastal waters, in spite of its effective removal in conventional wastewater treatment works, short half-life, and its biodegradability in the environment, undoubtedly reflects a combination of its persistent release in partially or untreated wastewater (leading to its pseudo-persistence), its presence in runoff from unreticulated informal settlements, and its presence in wastewater reaching the coast via sewer leaks into, or illegal sewer connections to stormwater infrastructure.

The acetaminophen concentration found in water at Lifebox23 Beach and Mouille Point in winter, and at Lifebox23 Beach in summer exceeds the highest concentration reported in comparison studies, while the concentration in water at several other sites, including Lagoon Beach, Camps Bay Beach, Hout Bay Beach, Mitchells Plain Beach, and Macassar Beach, is at the higher end of the range for comparison studies (Figure 10). The 75th and 90th percentiles of the concentration distribution in both surveys are higher than for comparison studies. In other words, the acetaminophen concentrations at some coastal

sites in Cape Town are amongst, and possibly the highest reported for coastal waters in the world.

All quantifiable acetaminophen concentrations found in this study exceed those found in water sampled in the Green Point area by Petrik *et al.* (2017) and in False Bay by Ojemaye and Petrik (2021). The highest concentration found in water at a coastal site in this study (5 327.3 ng.l^{-1}) is $\sim 2\,830$ times greater than the highest concentration found by Petrik *et al.* (2017) and Ojemaye and Petrik (2021) (1.88 ng.l^{-1}). In fact, the lowest concentration found in this study (14.4 ng.l^{-1}) is ~ 7 times greater than the highest concentration reported by Petrik *et al.* (2017) and Ojemaye and Petrik (2021). Petrik *et al.* (2017) and Ojemaye and Petrik (2021) found acetaminophen in each seawater sample they analysed, compared to a detection frequency of $\sim 61\%$ in winter and $\sim 43\%$ in summer in this study. The acetaminophen concentrations found in water in False Bay by Ojemaye and Petrik (2021) showed no pronounced spatial trend relative to wastewater treatment works discharges, in contrast to this study. Several of the highest acetaminophen concentrations found in this study exceed the average concentration of 1 260 ng.l^{-1} reported by Matongo *et al.* (2015) for water at Blue Lagoon in the Umgeni Estuary in Durban.

Petrik *et al.* (2017), Ojemaye and Petrik (2019), and Ojemaye and Petrik (2021) found acetaminophen in sediment and the tissue of various invertebrates and seaweeds sampled in the Green Point area and in False Bay, and in the tissues of several species of fish sold at a market in Kalk Bay Harbour in False Bay. The implication is acetaminophen has entered marine food webs in Cape Town. Ojemaye and Petrik (2021) concluded the acetaminophen poses a low hazard to the health of the biota studied in False Bay.

Hydrochlorothiazide

Hydrochlorothiazide is a diuretic used to treat high blood pressure and swelling due to fluid build-up, and to decrease the risk of kidney stones. It is the second most prescribed drug in the combined private and public health care sectors in South Africa (Osunmakinde *et al.*, 2013). In this study it was the 14th most often found compound in winter (at nine [or 26%] of the 35 sites) and 12th most often found compound in summer (at 15 [or 43%] sites) (Figure

4). Hydrochlorothiazide is often found in wastewater at high concentrations (Al Aukidiy *et al.*, 2012; Verlicchi *et al.*, 2012; Biel-Maeso *et al.*, 2018). It has a variable degradation and removal rate in wastewater treatment works (Gros *et al.*, 2010; Biel-Maeso *et al.*, 2018). Despite having a half-life of ~60 days (Čelić *et al.*, 2019) and the potential for long-range transport by coastal currents, hydrochlorothiazide was found most often at sites with a strong direct or indirect wastewater influence, most notably in the Diep River, at the Salt River mouth, near the point where the Athlone wastewater treatment works discharges into the Black River, at Lifebox23 Beach and Macassar Beach, and near the Gordon's Bay canal mouth (Figure 11). The concentration in water at Macassar Beach in summer is considerably higher than the highest concentration reported in comparison studies. The concentration in water at Lagoon Beach, Lifebox23 Beach, Mitchells Plain Beach, and near the Gordon's Bay canal mouth in one or both surveys is at or near the higher end of the range for comparison studies (Figure 11). The 90th percentile of the concentration distribution in both surveys, and the 75th percentile in summer is higher than for comparison studies, but not the 50th percentile.

There appears to be no information on hydrochlorothiazide in coastal waters in Cape Town or elsewhere in South Africa. No comparison can thus be made to concentrations in local coastal waters.

Ofloxacin

Ofloxacin is an antibiotic used to treat bacterial infections, including pneumonia and infections of the skin, bladder, reproductive organs, and prostate gland. In South Africa it is also used to treat multi drug resistant tuberculosis (Osunmakinde *et al.*, 2013). Ofloxacin was the 4th most often found compound in winter (at 21 [or 60%] of the 35 sites, tied with valsartan) and 3rd most often found in summer (at 22 [or 63%] sites) (Figure 4). Ofloxacin is commonly found in wastewater, including in South Africa (Gros *et al.*, 2010; Kostich *et al.*, 2014; Biel-Maeso *et al.*, 2018; Faleye *et al.*, 2019). It has a variable degradation and removal rate in wastewater treatment works (Gros *et al.*, 2010), with a half-life of ~60 days (Čelić *et al.*, 2019).

In this study, the highest ofloxacin concentrations

found in coastal water was at sites with a strong direct or indirect wastewater influence, namely at (not in order) Lagoon Beach, Lifebox23 Beach, and Macassar Beach (Figure 12). In summer, high concentrations were also found in the Diep River and near the point where the Athlone wastewater treatment works discharges into the Black River. Ofloxacin concentrations at many sites were in fact higher in summer than in winter. The highest ofloxacin concentration found in this study is well below the highest concentration reported in comparison studies (Figure 12). Most concentrations are near the lower end of the concentration range for comparison studies. Consequently, the 50th, 75th and 90th percentiles of the concentration distribution are comparable to, or lower than for the comparison studies.

There appears to be no other information on ofloxacin in coastal waters in Cape Town or elsewhere in South Africa. No comparison can thus be made to concentrations in local coastal waters.

Valsartan

Valsartan is an antihypertensive drug used to treat high blood pressure, heart failure, and diabetic kidney disease. It was the 3rd most often found compound in winter (at 21 [or 60%] of the 35 sites, tied with ofloxacin) and the 3rd most often found compound in summer (at 23 [or 66%] sites) (Figure 4). It is estimated humans excrete >96% of an ingested valsartan dose as the active compound in their urine and faeces (Brunton *et al.*, 2012). Valsartan is often found at a high concentration in the influent and effluent of wastewater treatment works (Kostich *et al.*, 2014). It has a half-life of ~15 days (Čelić *et al.*, 2019).

The highest valsartan concentrations were found in water at sites with a strong direct or indirect wastewater influence, such as Lagoon Beach, in the Diep River, in the Salt River mouth, near the point where the Athlone wastewater treatment works discharges into the Black River, at Lifebox23 and Macassar Beaches, and near the Gordon's Bay canal mouth (Figure 13). Valsartan was found at a high concentration in stormwater at Three Anchor Bay, especially in summer, but at a far lower concentration in stormwater at Fish Hoek Beach (although also in each survey). It was also found at

some of the more remote sites, such as Bloubergstrand in both surveys and at Kogel Bay in winter, but never at coastal sites between Camps Bay and Diaz Beach on the Atlantic Seaboard and rarely between Diaz Beach and Fish Hoek Beach in False Bay.

The valsartan concentration in water at Lifebox23 Beach in summer is very slightly higher than the highest concentration reported in comparison studies. The 50th and 90th percentiles of the concentration distribution are higher than for comparison studies, but not the 75th percentile (Figure 13).

There appears to be no other information on valsartan in coastal waters in Cape Town or elsewhere in South Africa. No comparison can thus be made to concentrations in local coastal waters.

Sulfamethoxazole

Sulfamethoxazole is an antibiotic used to treat bacterial infections, including ear and urinary tract infections, and bronchitis. It is also used as a prophylactic to prevent opportunistic infections in HIV infected persons (Archer *et al.*, 2021). Sulfamethoxazole, in combination with trimethoprim, is the 5th most prescribed pharmaceutical compound by the combined private and public health care sectors in South Africa (Osunmakinde *et al.*, 2013). Sulfamethoxazole is often found at a high concentration in the influent and effluent of wastewater treatment works, including in South Africa (Gros *et al.*, 2010; Al Aukidiy *et al.*, 2012; Hendricks and Pool, 2012; Verlicchi *et al.*, 2012; Kostich *et al.*, 2014; Matongo *et al.*, 2015; Agunbiade and Moodley, 2016; Archer *et al.*, 2017; Madikizela and Chimuka, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Faleye *et al.*, 2019; Nyamukamba *et al.*, 2019; Archer *et al.*, 2021). It has a variable but generally high degradation and removal rate in conventional wastewater treatment works (Gros *et al.*, 2010; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019). It has a generally reported half-life of 20.3 - 37.5 days (Lam *et al.*, 2004; Čelić *et al.*, 2019), but Benotti and Brownawell (2009) provide a half of 85 - >100 days.

Its wide use probably accounts, at least partly, for sulfamethoxazole being the 5th most often found

compound in winter (at 20 [or 57%] of the 35 sites, tied with bezafibrate) and 7th most often found compound in summer (at 16 [or 46%] sites, tied with four other compounds) (Figure 4). The highest concentrations were found in water at sites with a strong direct or indirect wastewater influence, such as Lagoon Beach, in the Diep River, in the Salt River mouth, near the point where the Athlone wastewater treatment works discharges into the Black River, in Hout Bay River, at Lifebox 23 Beach and Macassar Beach, and near the Gordon's Bay canal mouth (Figure 14). Sulfamethoxazole was found in stormwater at Three Anchor Bay in winter and summer and at Fish Hoek Beach in winter. It was also found at a low concentration at some of the more remote sites in winter, such as Bloubergstrand and Kogel Bay, but not in summer (Figure 14).

The sulfamethoxazole concentration in water at Lifebox23 Beach in summer is far higher than the highest concentration reported in comparison studies. The concentration at several other sites was near the higher end of the range for comparison studies (Figure 14). The 75th and 90th percentiles of the concentration distribution are higher than for the comparison studies.

Most quantifiable sulfamethoxazole concentrations found in this study exceed those found in seawater sampled in the Green Point area by Petrik *et al.* (2017) and in False Bay by Ojemaye and Petrik (2021). The highest concentration found in coastal waters in this study (1549.3 ng.l⁻¹) is ~337 times greater than the highest concentration reported by Petrik *et al.* (2017) and Ojemaye and Petrik (2021) (4.79 ng.l⁻¹). The lowest quantified concentration found in this study (4.6 ng.l⁻¹) is in fact only slightly lower than the highest concentration reported by Petrik *et al.* (2017) and Ojemaye and Petrik (2021). Petrik *et al.* (2017) and Ojemaye and Petrik (2021) found sulfamethoxazole in each of the seawater samples they analysed compared to a 57% detection frequency in winter and 46% frequency in summer in this study. The sulfamethoxazole concentrations found in seawater sampled in False Bay by Ojemaye and Petrik (2021) showed no pronounced spatial trend relative to wastewater treatment works discharges, in clear contrast to this study. Matongo *et al.* (2015) did not record sulfamethoxazole in water sampled at Blue Lagoon in the Umgeni Estuary

in Durban.

Petrik *et al.* (2017), Ojemaye and Petrik (2019), and Ojemaye and Petrik (2021) found sulfamethoxazole in sediment and the tissue of various invertebrates and seaweeds sampled in the Green Point area and in False Bay, and in various tissues of several species of fish sold at a market in Kalk Bay Harbour in False Bay. The implication is that sulfamethoxazole has entered marine food webs in Cape Town. Ojemaye and Petrik (2021) concluded sulfamethoxazole poses a low hazard to the biota studied in False Bay.

Trimethoprim

Trimethoprim is an antibiotic used mainly for the treatment of urinary tract infections, but also middle ear infections and travellers' diarrhoea. In South Africa it is also used as a prophylactic to prevent opportunistic infections in HIV infected persons (Archer *et al.*, 2021). Trimethoprim, in combination with sulfamethoxazole, is the 5th most prescribed pharmaceutical compound by the combined private and public health care sectors in South Africa (Osunmakinde *et al.*, 2013). In this study, trimethoprim was the 8th most often found compound (at 13 [or 37%] of the 35 sites, tied with irbesartan) in winter and 4th most often found compound in summer (at 20 [or 57%] sites) (Figure 4). Trimethoprim is often found in the influent and effluent of wastewater treatment works, including in South Africa (Gros *et al.*, 2010; Al Aukidiy *et al.*, 2012; Verlicchi *et al.*, 2012; Archer *et al.*, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Faleye *et al.*, 2019). It is not effectively removed or degraded in conventional wastewater treatment works (Ternes and Hirsch, 2000). It has a moderately long half-life of ~60 days (Čelić *et al.*, 2019). In this study, the highest trimethoprim concentrations were found in water at sites with a strong direct or indirect wastewater influence, such as Macassar Beach, in Hout Bay River, at Lifebox23 Beach, in the Salt River mouth, and near the point where the Athlone wastewater treatment works discharges into the Black River (Figure 20). It was found in stormwater at Three Anchor Bay in each survey, but not at Fish Hoek Beach.

Trimethoprim and sulfamethoxazole are often co-administered to enhance the treatment of bacterial infections. This may account for their cooccurrence

at many sites. It might also account for the strong correlation ($r = 0.976$, $p < 0.001$) between their concentrations if the results for two sites (Macassar Beach and Hout Bay River) are considered outliers in the winter survey. However, no correlation of note between their concentrations was evident in summer.

The highest trimethoprim concentrations found in this study are well below the highest concentrations reported in comparison studies (Figure 20). The 50th percentile of the concentration distribution is lower, while the 75th percentile is about the same and the 90th percentile is higher than for comparison studies. Some trimethoprim concentrations found in summer are higher than the average concentration of 200 ng.l⁻¹ reported by Matongo *et al.* (2015) for water sampled at Blue Lagoon in the Umgeni Estuary in Durban.

Bezafibrate

Bezafibrate is a lipid regulator used to lower cholesterol (mainly triglyceride) levels in the blood. It was the 6th most often found compound in winter (at 20 [or 57%] of the 35 sites, tied with sulfamethoxazole) and 8th most often found compound in summer (at 16 [or 46%] sites) (Figure 4). The highest concentrations were found in water at sites with a strong direct or indirect wastewater influence, such as the Diep River, Lagoon Beach, in the Salt River mouth, near the point where the Athlone wastewater treatment works discharges into the Black River, at Lifebox23 Beach and Macassar Beach, and near the Gordon's Bay canal mouth (Figure 15). It was interestingly not found in the Hout Bay River. Bezafibrate was found in stormwater at Three Anchor Bay and Fish Hoek Beach. It was also found at the remote Kogel Bay site in winter, but never at Diaz Beach.

Bezafibrate is common in wastewater, often at high concentrations, including in South Africa (Gros *et al.*, 2010; Al Aukidiy *et al.*, 2012; Verlicchi *et al.*, 2012; Agunbiade and Moodley, 2016; CSIR, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Archer *et al.*, 2021). It has a variable degradation and removal rate in wastewater treatment works (Gros *et al.*, 2010; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019). Bezafibrate was always found in wastewater discharged through marine outfalls at Green Point,

Camps Bay and Hout Bay, at concentrations between 0.35 - 4.30 $\mu\text{g.l}^{-1}$ (CSIR, 2017).

The bezafibrate concentrations at numerous sites in this study are at the upper end of the range for comparison studies (Figure 13). The 50th, 75th and 90th percentiles of the concentration distribution are higher than for comparison studies.

There appears to be no other information on bezafibrate in coastal waters in Cape Town or elsewhere in South Africa. No comparison to concentrations in local coastal waters is thus possible.

Codeine

Codeine is an analgesic and anti-inflammatory used to treat mild to moderate pain that is not relieved by non-opiate analgesics. Codeine is one of the most prescribed pharmaceutical compounds by the combined private and public health care sectors in South Africa (Osunmakinde *et al.*, 2013). Codeine was the 6th most often found compound in winter (at 15 [or 43%] of the 35 sites) and 6th most often found compound in summer (at 17 [or 49%] sites) (Figure 4). The highest concentrations were found in water sampled at sites with a strong direct or indirect wastewater influence, such as the Diep River, Lagoon Beach, in the Salt River mouth, and Lifebox23 Beach (Figure 13). This is consistent with the fact that codeine has been recorded at a high concentration in the influent and effluent of wastewater treatment works in parts of Cape Town (Archer *et al.*, 2021). Codeine was found in stormwater at Three Anchor Bay and at Fish Hoek Beach. The concentration in stormwater sampled at Three Anchor Bay in summer was particularly high.

The codeine concentration found in water at Lifebox23 Beach in summer was far higher than the highest concentration reported in comparison studies. The concentrations at numerous other sites were also higher than in comparison studies (Figure 14). The 75th and 90th percentiles of the concentration distribution are also higher than for comparison studies, but not the 50th percentile.

There appears to be no other information on codeine in coastal waters in Cape Town or elsewhere in South Africa. No comparison can thus be made to concentrations in local coastal waters.

Carbamazepine

Carbamazepine is an anticonvulsant used primarily for the treatment of epilepsy and neuropathic pain, but also to treat psychiatric disorders such as bipolar disorder. Carbamazepine was the 11th most often found compound in winter (at 11 [or 31%] of the 25 sites) and 10th most often found compound in summer (at 16 [or 46%] sites) (Figure 4). Carbamazepine is often found at high concentrations in the influent and effluent of wastewater treatment works, including in South Africa (Gros *et al.*, 2010; Al Aukidiy *et al.*, 2012; Verlicchi *et al.*, 2012; Osunmakinde *et al.*, 2013; Kostich *et al.*, 2014; Matongo *et al.*, 2015; Archer *et al.*, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Archer *et al.*, 2021) even though only an estimated <3 - 5% of the parent compound is excreted by humans. Carbamazepine was always found in wastewater discharged through marine outfalls at Green Point, Camps Bay and Hout Bay by the CSIR (CSIR, 2017), at concentrations between 0.19 - 0.60 $\mu\text{g.l}^{-1}$. It is not effectively removed by conventional wastewater treatment processes (Yang *et al.*, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Archer *et al.*, 2020) and is resistant to degradation in surface waters (Kahle *et al.*, 2009; Kasprzyk-Hordern *et al.*, 2009), with the result it is often found in a high proportion of surface water samples. This characteristic has led to its recommendation as an effective tracer of wastewater in surface waters (Clara *et al.*, 2004; Kasprzyk-Hordern *et al.*, 2009; Tran *et al.*, 2014). It has a half-life of ~37.5 days (Čelić *et al.*, 2019).

It is thus surprising that carbamazepine was found in water at only 11 of the 35 sites in winter and at 16 sites summer in this study (Figure 17), although it was at a concentration between the Limit of Detection and Limit of Quantification in water at a further 11 sites in winter and 13 sites in summer. The highest concentrations were found in water at sites with a strong direct or indirect wastewater influence, such as Diep River, Lagoon Beach, in the Salt River mouth, near the point where the Athlone wastewater treatment works discharges into the Black River, at Lifebox23 Beach and Macassar Beach, and near the Gordon's Bay canal mouth (Figure 17). It was found at a low concentration in stormwater at Three Anchor Bay and at Fish Hoek Beach.

The carbamazepine concentrations in water

sampled at Macassar Beach and Lifebox23 Beach in summer was considerably higher than the highest concentration reported in comparison studies. The concentrations at several other sites were at the higher end of the range for comparison studies (Figure 17). The 90th percentiles of the concentration distribution are higher than for comparison studies.

All quantifiable carbamazepine concentrations found in this study exceed those found in seawater sampled in the Green Point area by Petrik *et al.* (2017) and in False Bay by Ojemaye and Petrik (2021). The highest concentration found in this study (1001.0 ng.l⁻¹) is ~640 times greater than the highest concentration reported by Petrik *et al.* (2017) and Ojemaye and Petrik (2021) (1.56 ng.l⁻¹). In fact, the lowest quantifiable concentration found in this study (3.2 ng.l⁻¹) is about twice the highest concentration reported by Petrik *et al.* (2017) and Ojemaye and Petrik (2021). Petrik *et al.* (2017) and Ojemaye and Petrik (2021) found carbamazepine in each of the seawater samples they analysed compared to a 31% detection frequency in winter and 46% frequency in summer in this study. The carbamazepine concentrations found in False Bay by Ojemaye and Petrik (2021) showed no clear spatial trend relative to wastewater treatment works discharges, in contrast to this study. The highest concentrations recorded in this study are higher than the average concentration of 240 ng.l⁻¹ reported by Matongo *et al.* (2015) for water sampled at Blue Lagoon in the Umgeni Estuary in Durban.

Petrik *et al.* (2017), Ojemaye and Petrik (2019), and Ojemaye and Petrik (2021) found carbamazepine in sediment and the tissue of various invertebrates and seaweeds sampled in the Green Point area and in False Bay, and in various tissues of several species of fish sold at a market in Kalk Bay Harbour in False Bay. The implication is that carbamazepine has entered marine food webs in Cape Town. Ojemaye and Petrik (2021) concluded carbamazepine poses a low hazard to the biota studied in False Bay.

Ibuprofen

Ibuprofen is a nonsteroidal anti-inflammatory drug that is used to treat pain, fever, and inflammation, including painful menstrual periods, migraines, and rheumatoid arthritis. Ibuprofen was the 12th most often found compound in winter (at 10 [or 29%] of

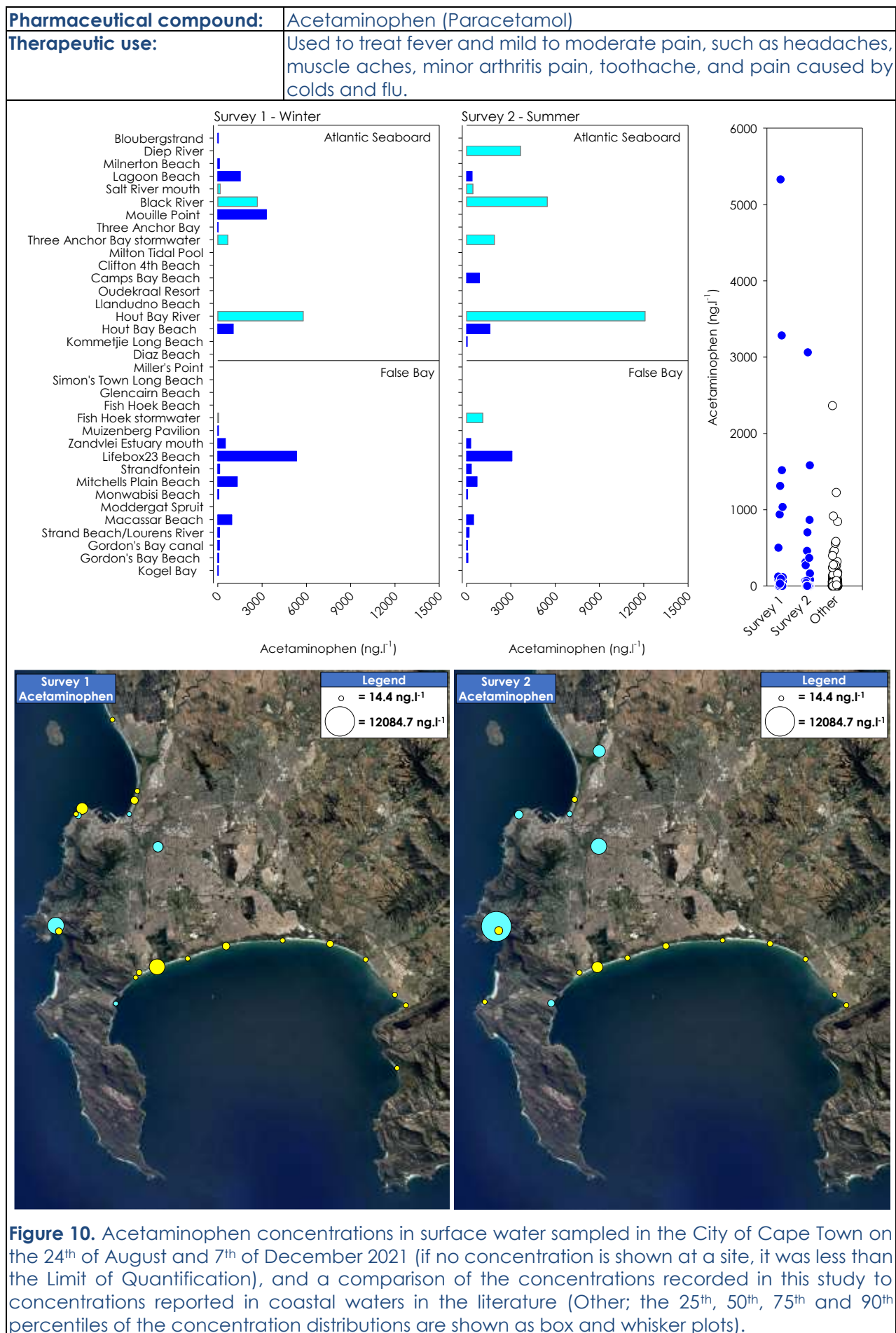
the 35 sites, tied with iopromide) and 23rd most often found compound in summer (at 8 [or 23%] sites) (Figure 4). Ibuprofen was found mainly at sites with a strong direct or indirect wastewater influence, such as the Diep River, Lifebox23 Beach, Macassar Beach, and Mitchells Plain Beach. Ibuprofen was found in stormwater at Three Anchor Bay, but not at Fish Hoek Beach (Figure 18). The concentrations found at sites in False Bay were, on average, considerably higher than at sites along the Atlantic Seaboard (Figure 18). Ibuprofen is one of the most common pharmaceutical compounds found in wastewater, including in South Africa, and is often present at high concentrations in the influent and effluent of wastewater treatment works (Gros *et al.*, 2010; Amdany *et al.*, 2014; Kostich *et al.*, 2014; Pereira *et al.*, 2015; Matongo *et al.*, 2015; Agunbiade and Moodley, 2016; Madikizela and Chimuka, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019; Archer *et al.*, 2021), reflecting its wide use and that it is used in drugs that can be purchased over the counter without a medical prescription. It is effectively, but not entirely removed in conventional wastewater treatment works (Gros *et al.*, 2010; Yang *et al.*, 2017; Biel-Maeso *et al.*, 2018; Čelić *et al.*, 2019). It has a half-life of ~15 days (Čelić *et al.*, 2019).

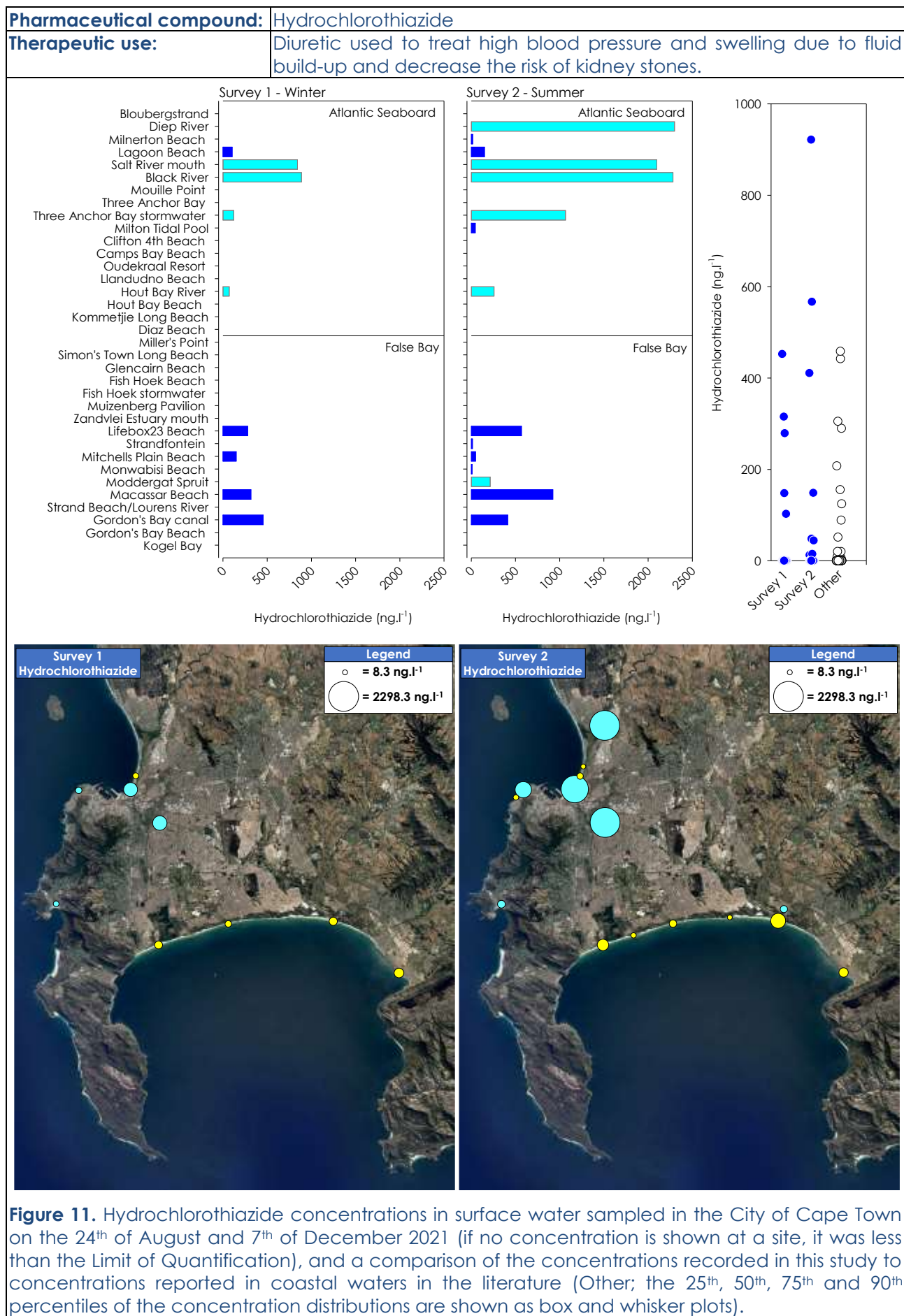
The highest concentrations found in this study are well below the highest concentration reported in comparison studies (Figure 18). The 50th, 75th and 90th percentiles of the concentration distribution are also lower than in comparison studies.

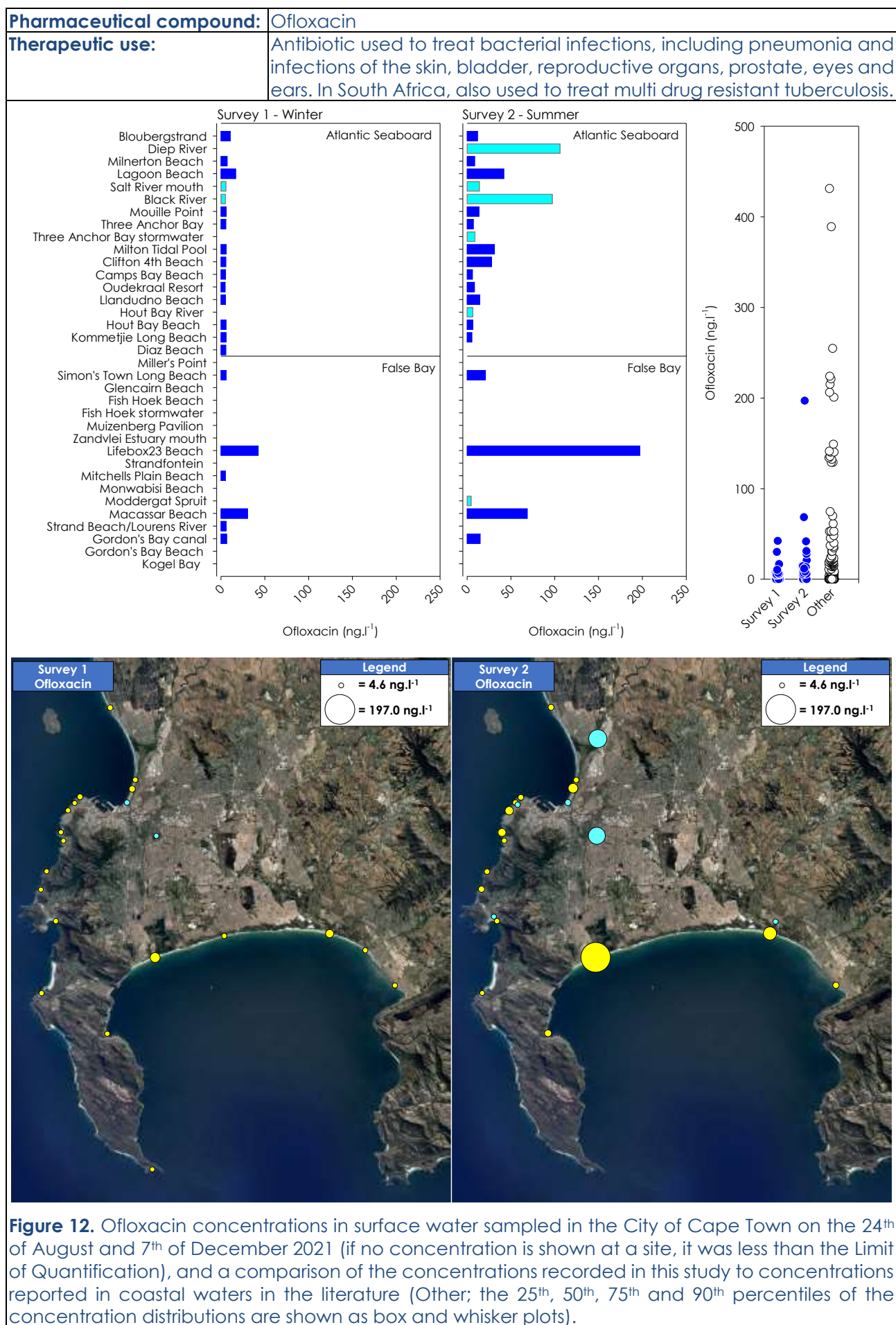
The highest concentration found in this study (408.2 ng.l⁻¹) is somewhat lower than the average concentration of 529 ng.l⁻¹ reported by Matongo *et al.* (2015) for water sampled at Blue Lagoon in the Umgeni Estuary in Durban, but the concentrations are broadly comparable to concentrations (<Limit of Detection - 261 ng.l⁻¹) reported for water sampled at different times in the Umgeni Estuary and at Blue Lagoon and Glen Ashley Beaches in Durban by Ngubane *et al.* (2019).

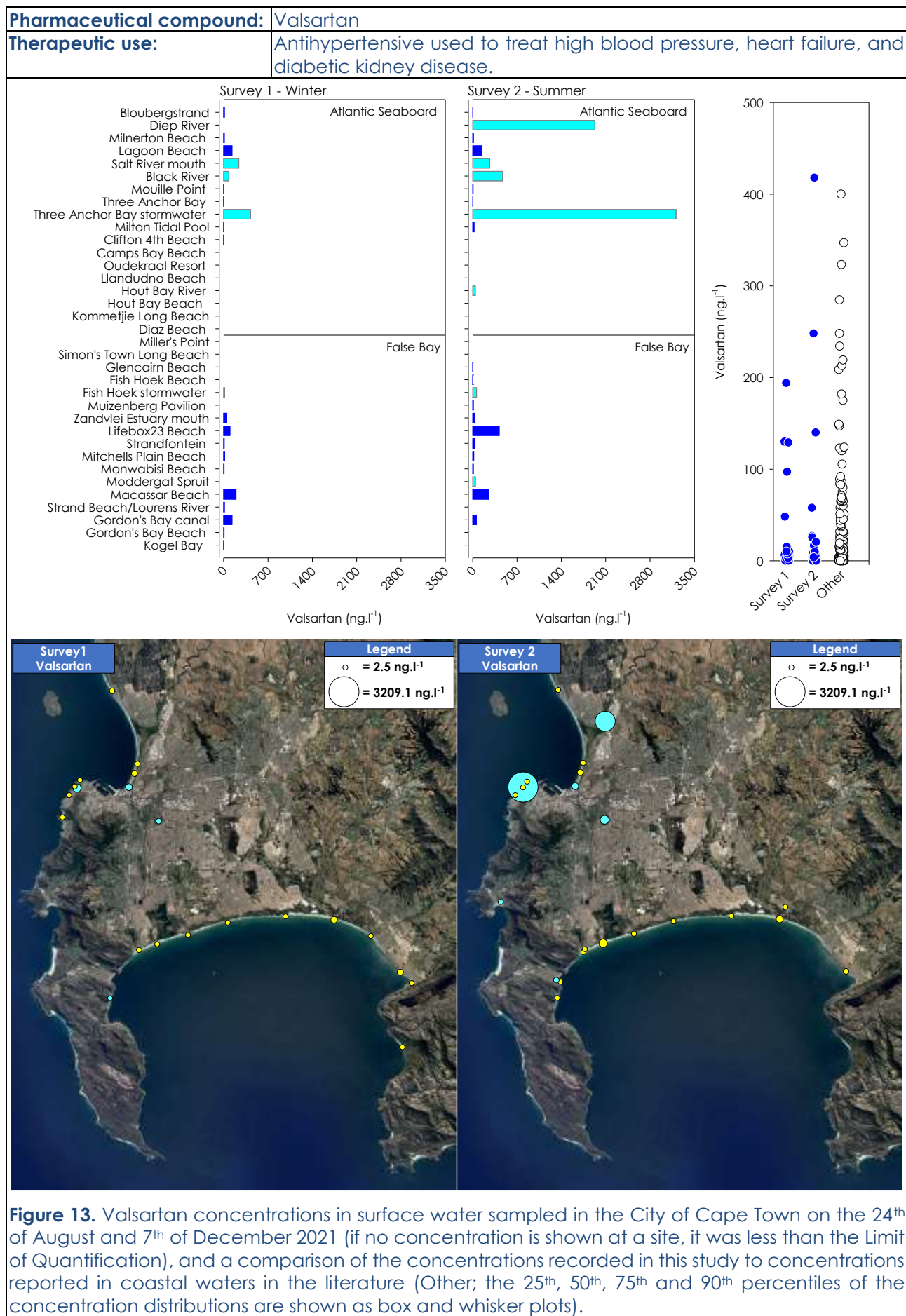
Iopromide

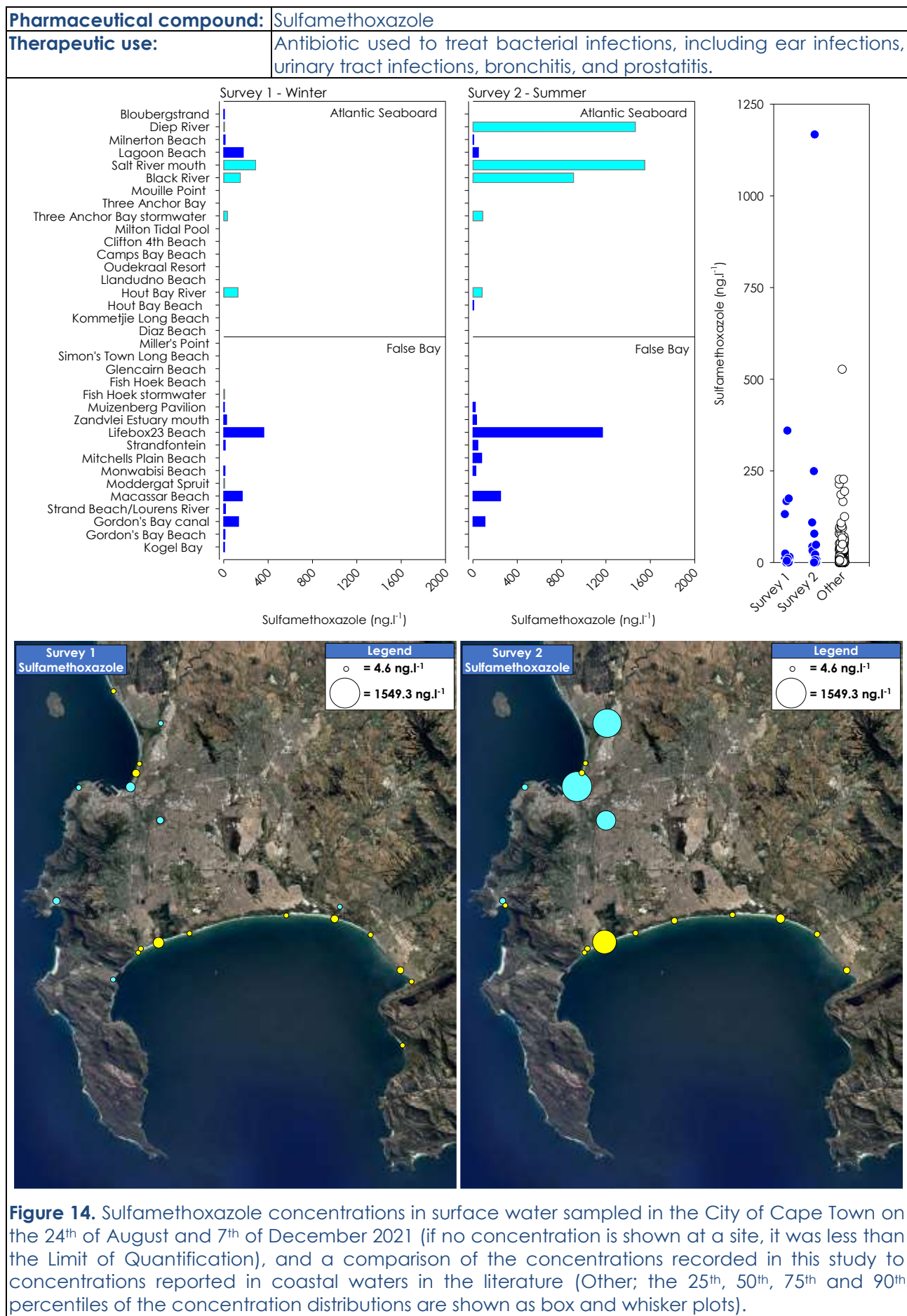
Iopromide is an x-ray contrast agent used during various types of imaging tests, such as angiographs and contrast computed tomography (CT) imaging. Iopromide is not metabolised in the human body











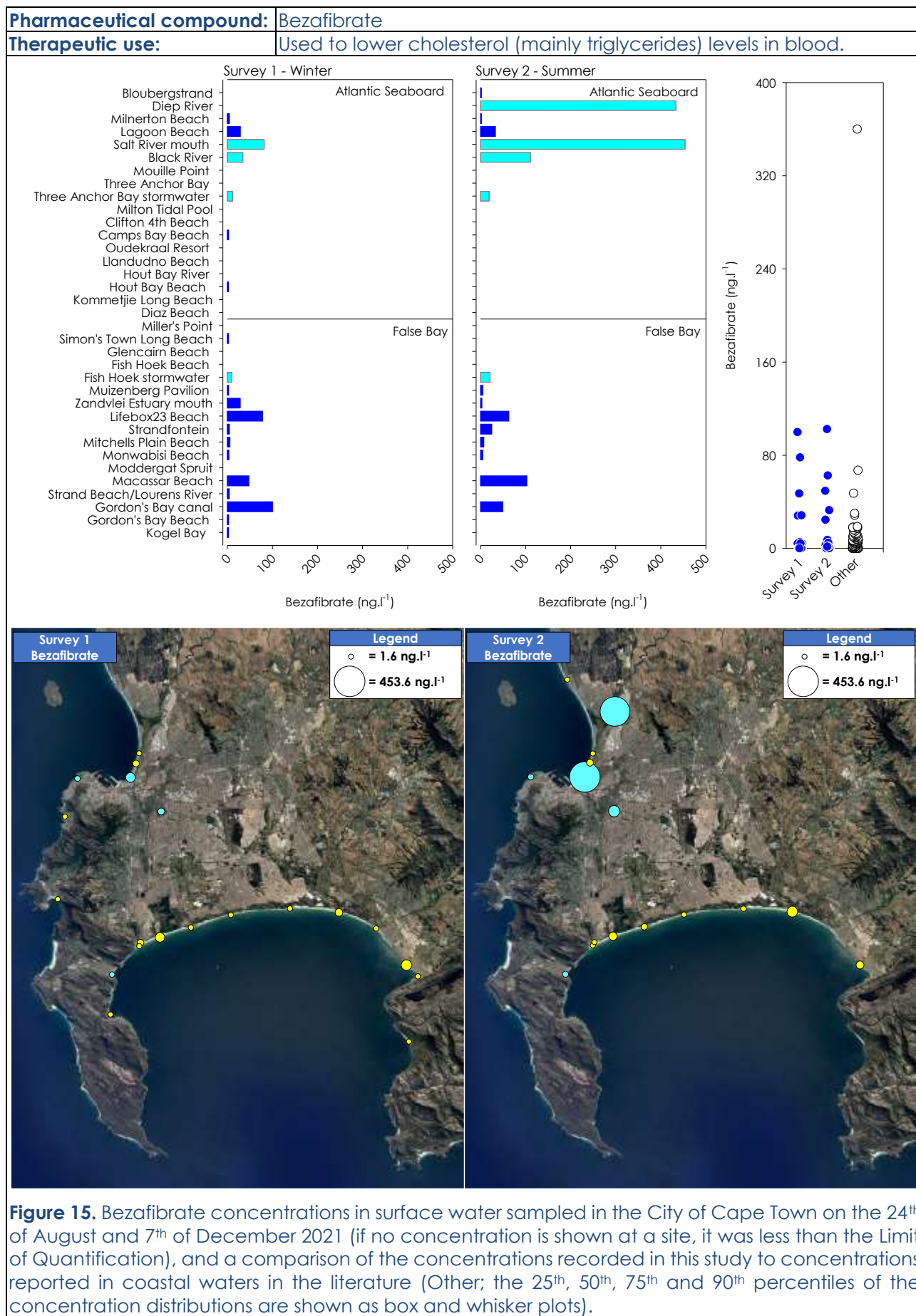
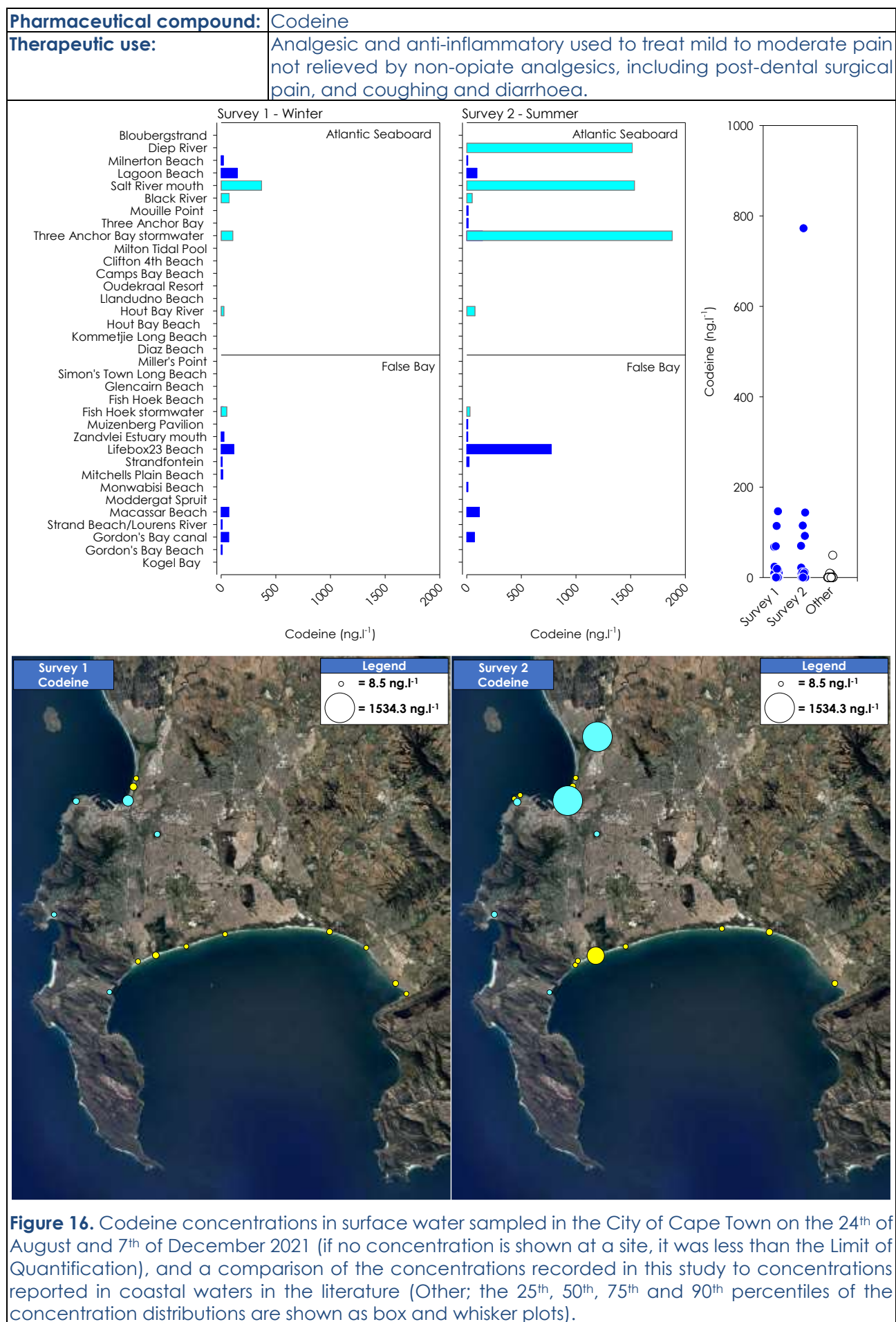
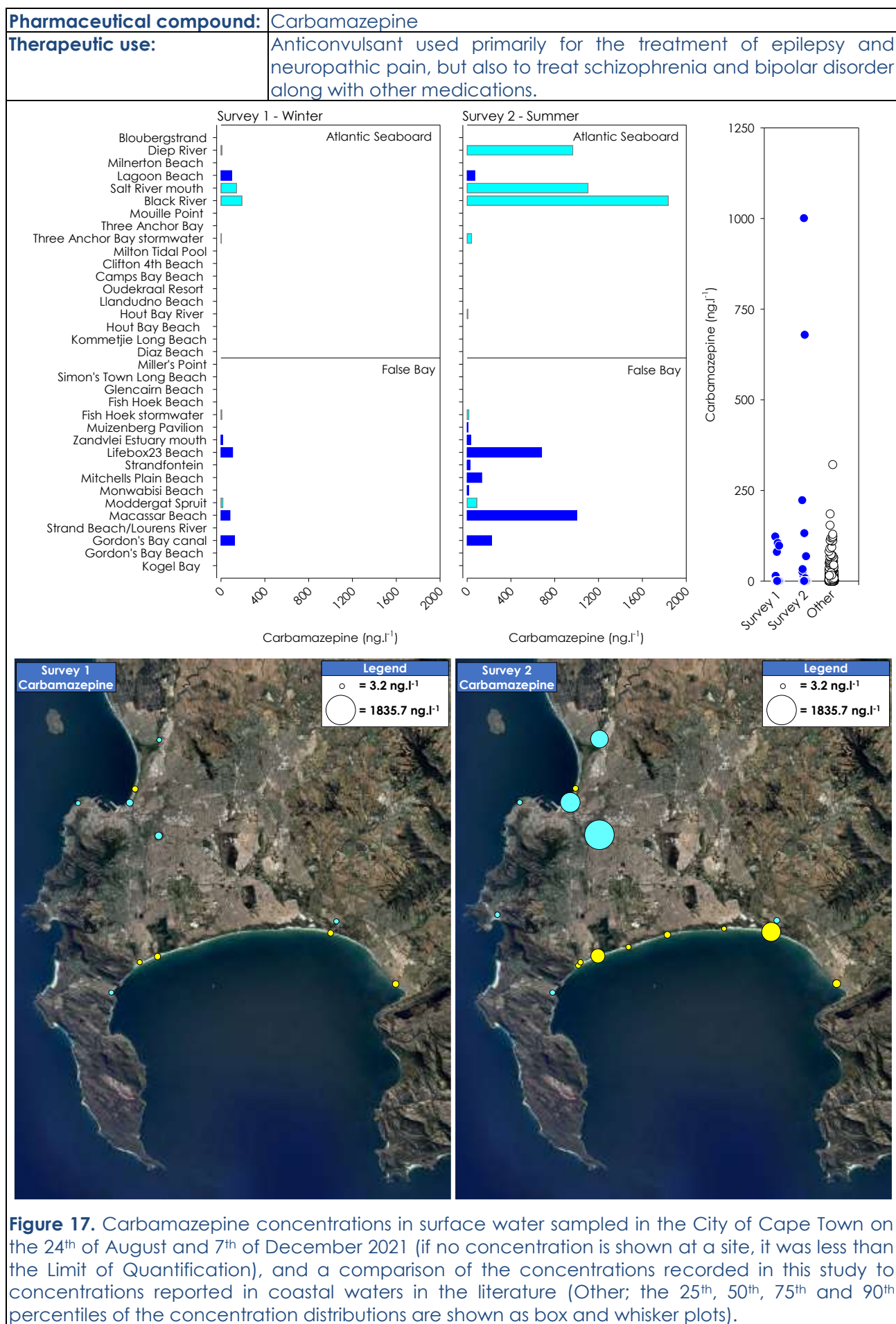
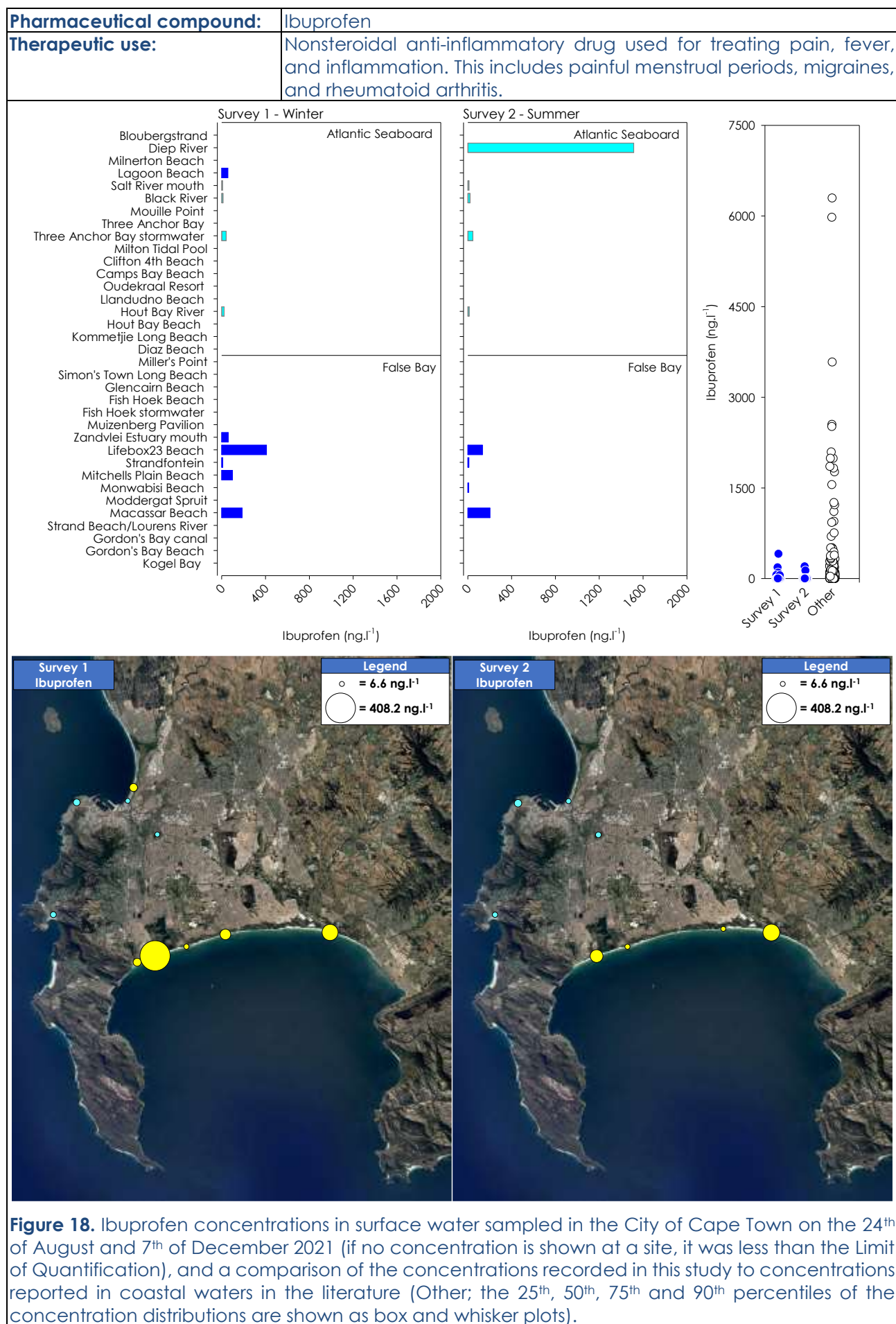
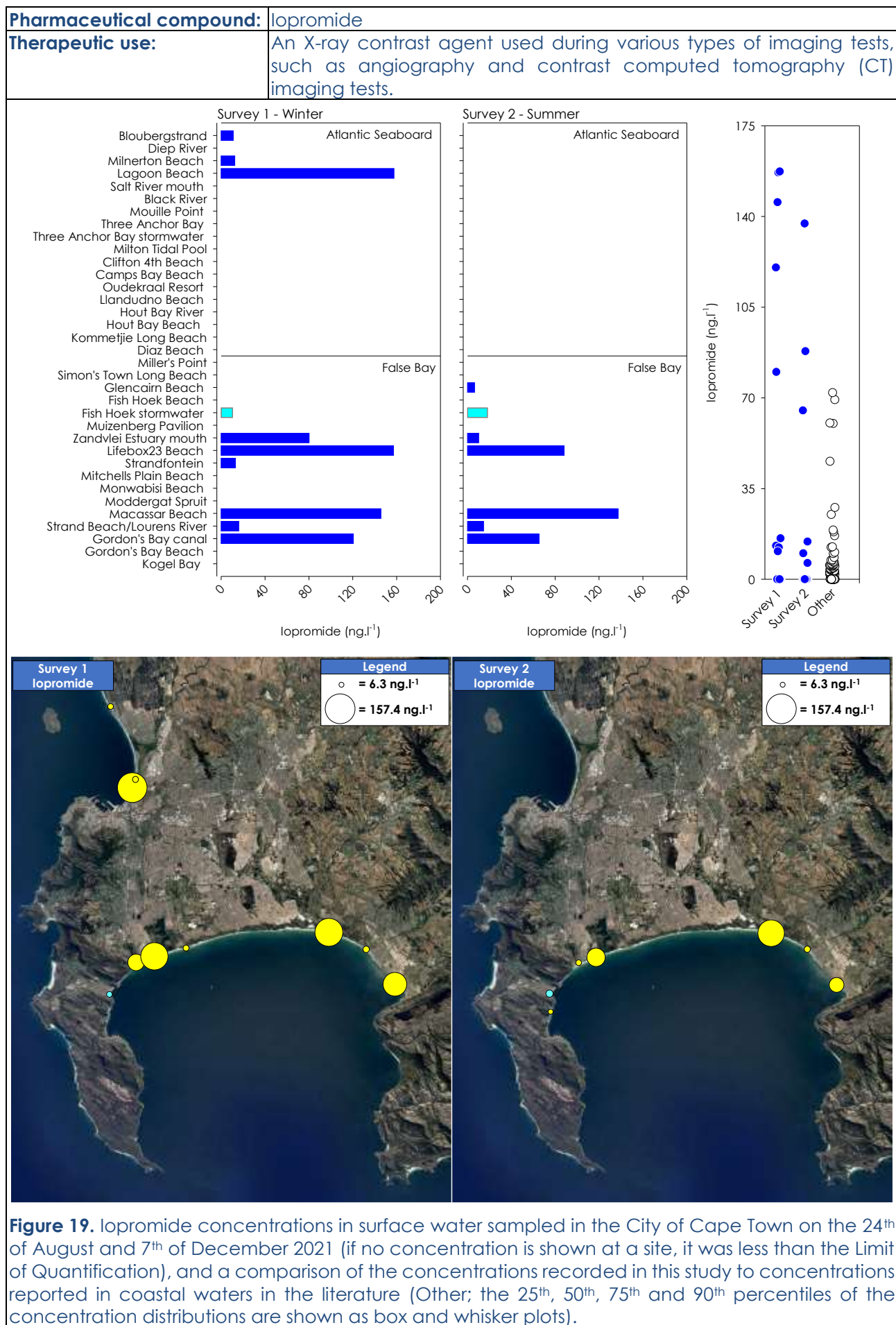


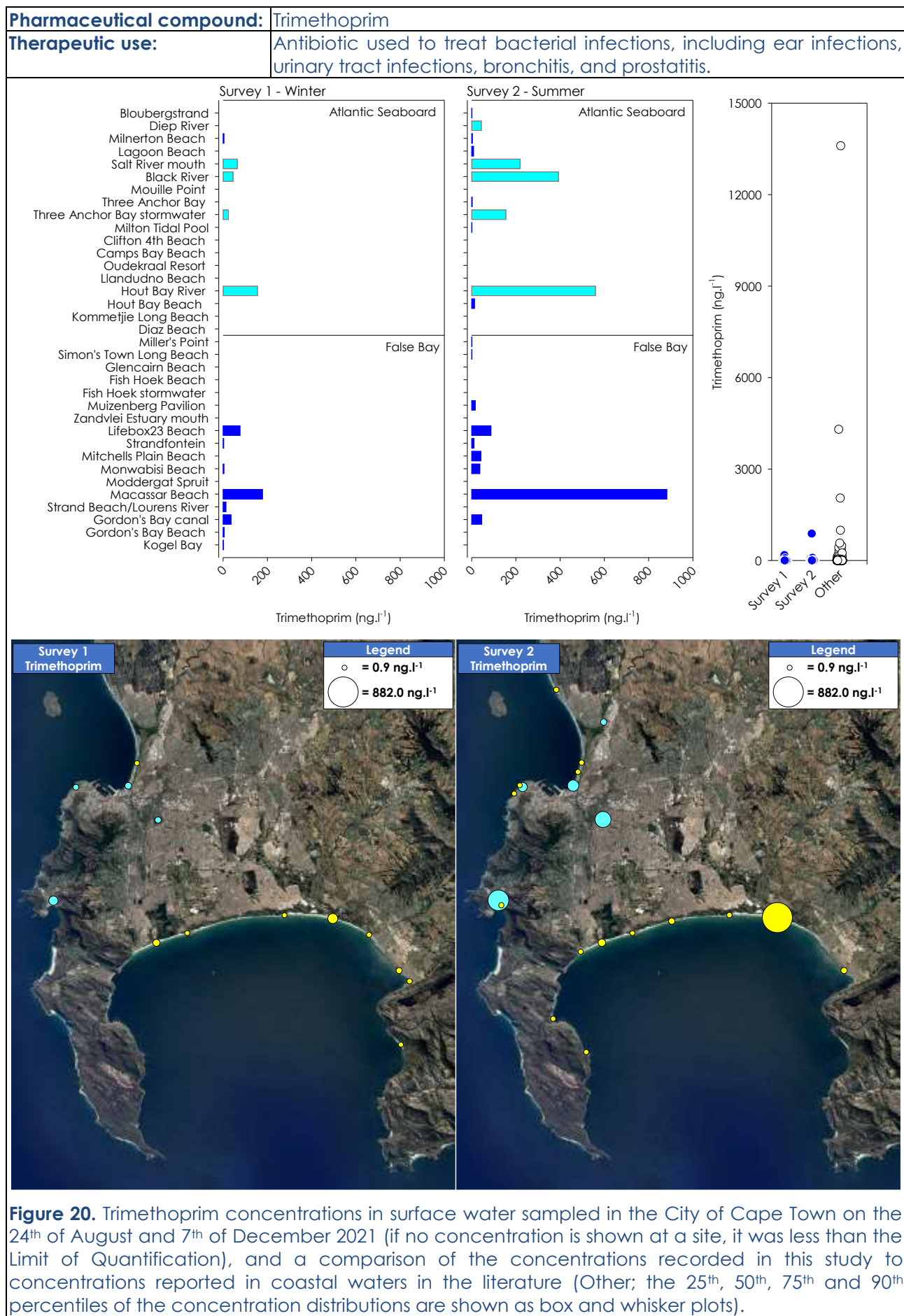
Figure 15. Bezafibrate concentrations in surface water sampled in the City of Cape Town on the 24th of August and 7th of December 2021 (if no concentration is shown at a site, it was less than the Limit of Quantification), and a comparison of the concentrations recorded in this study to concentrations reported in coastal waters in the literature (Other; the 25th, 50th, 75th and 90th percentiles of the concentration distributions are shown as box and whisker plots).

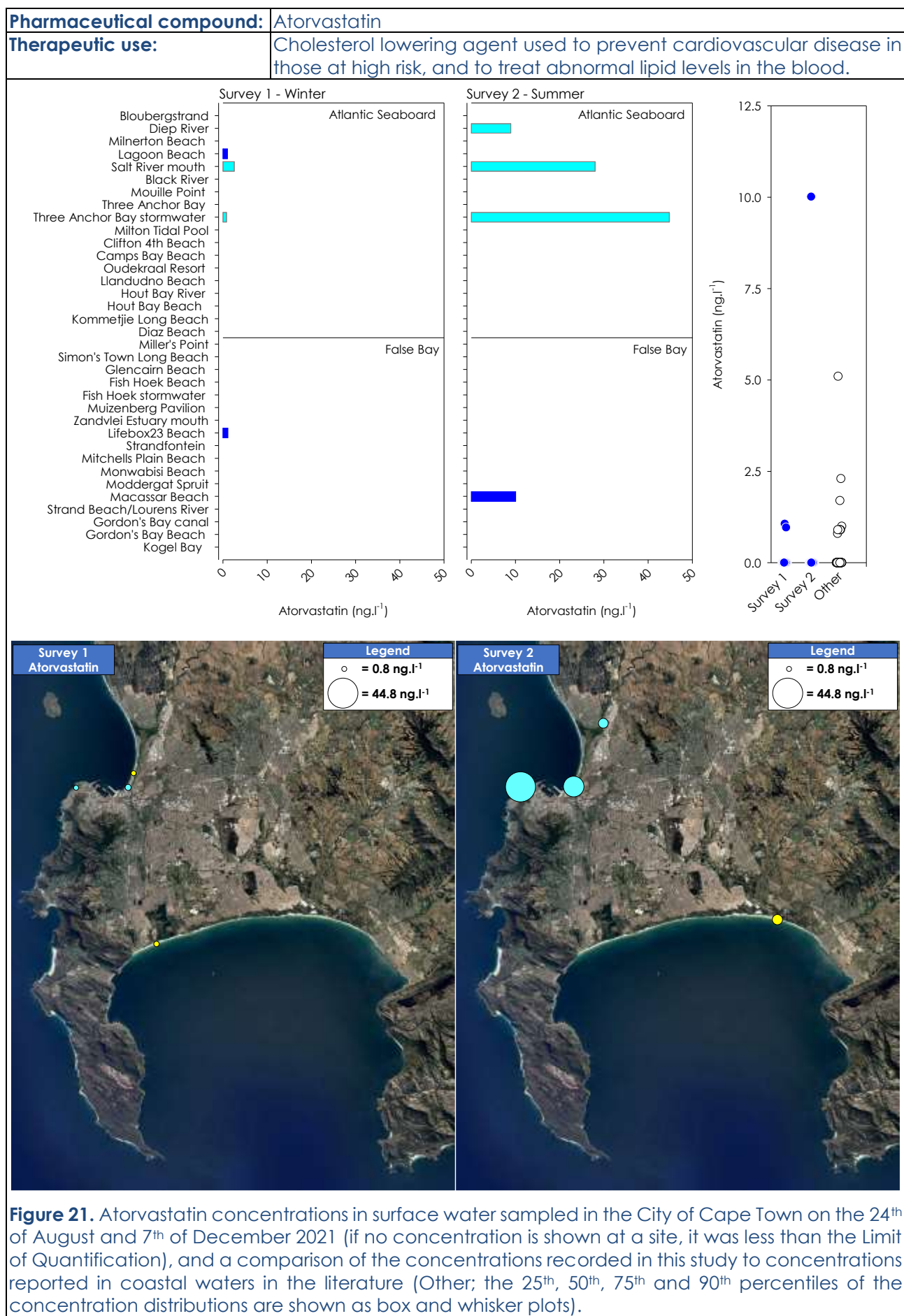


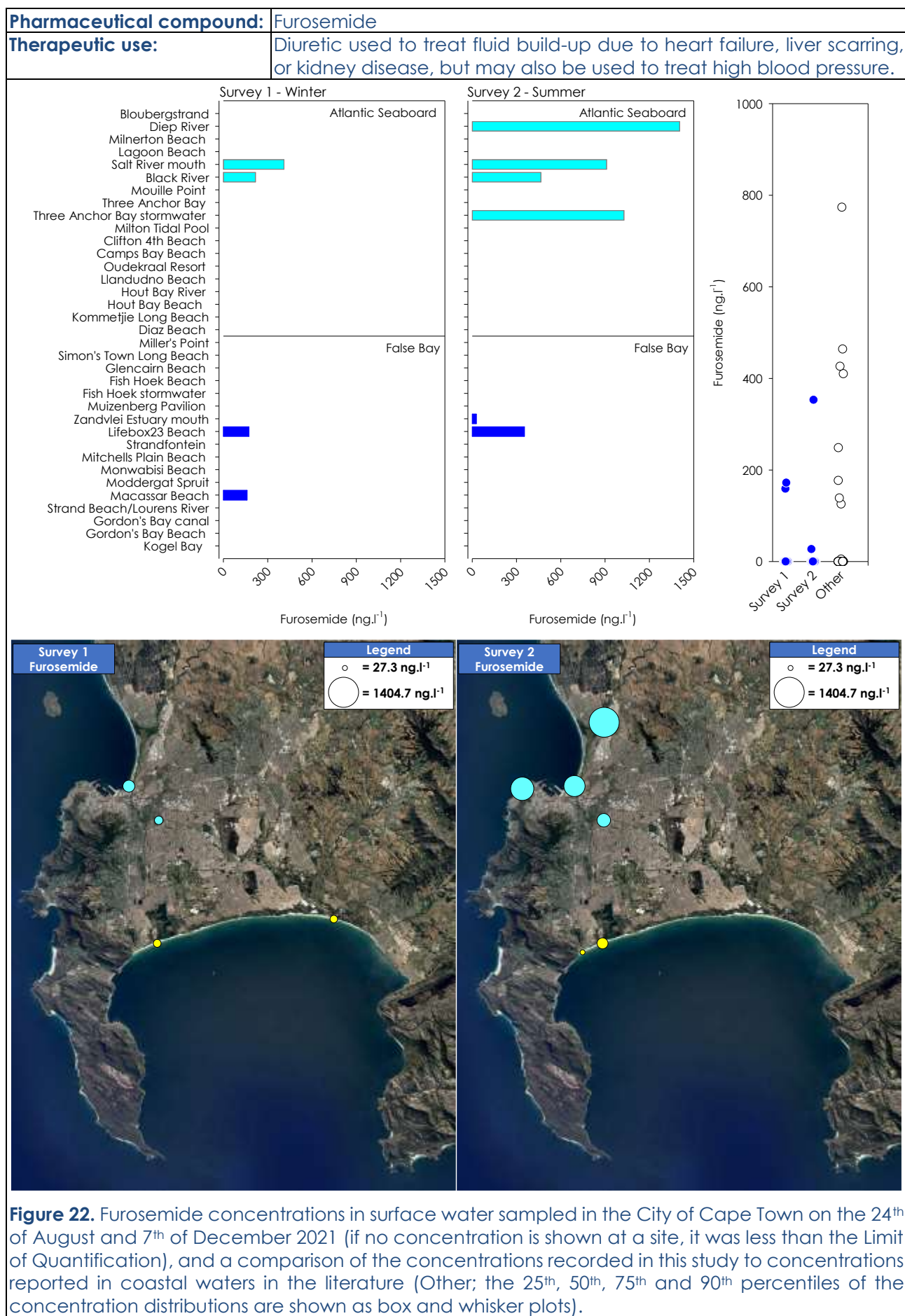


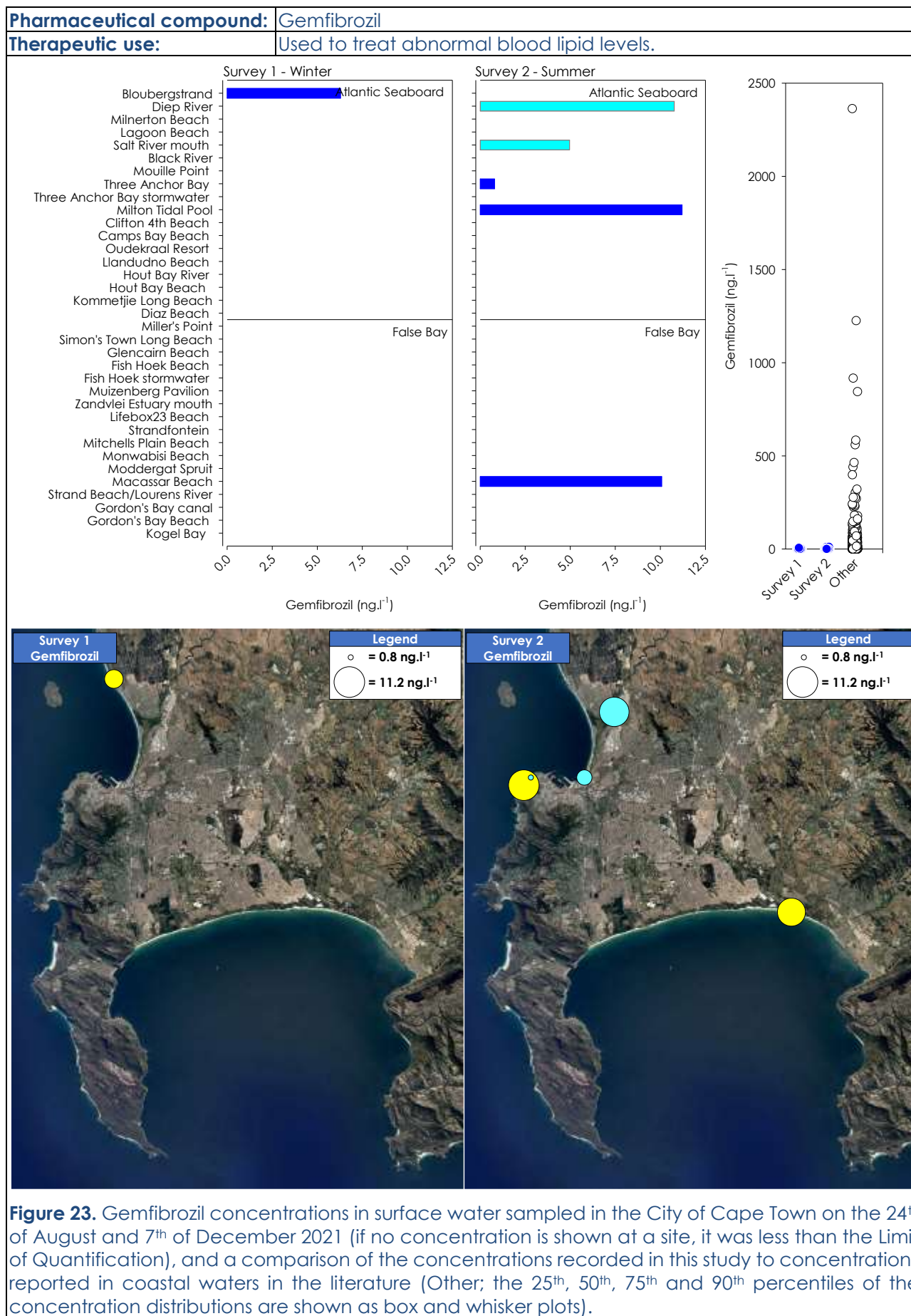


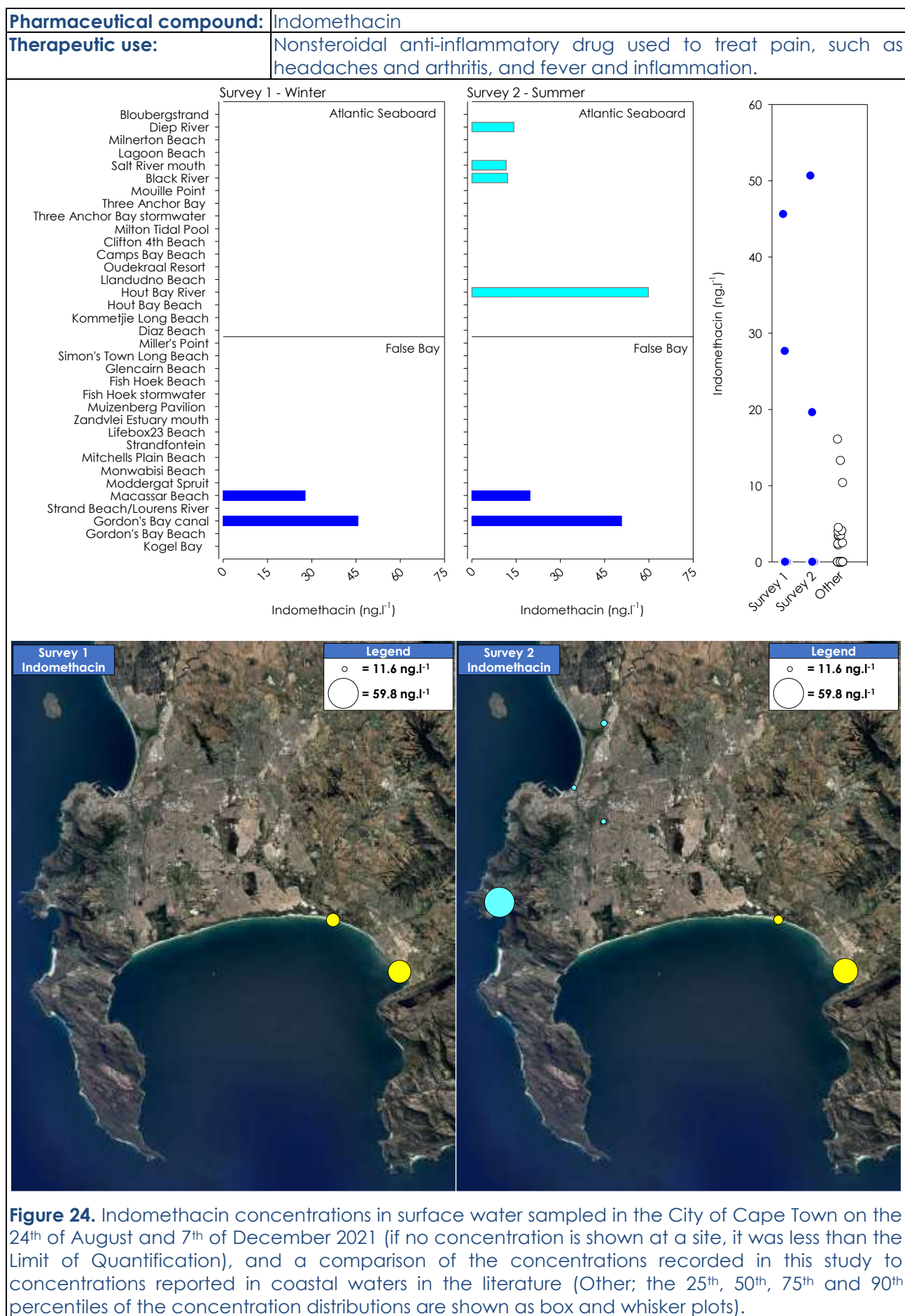


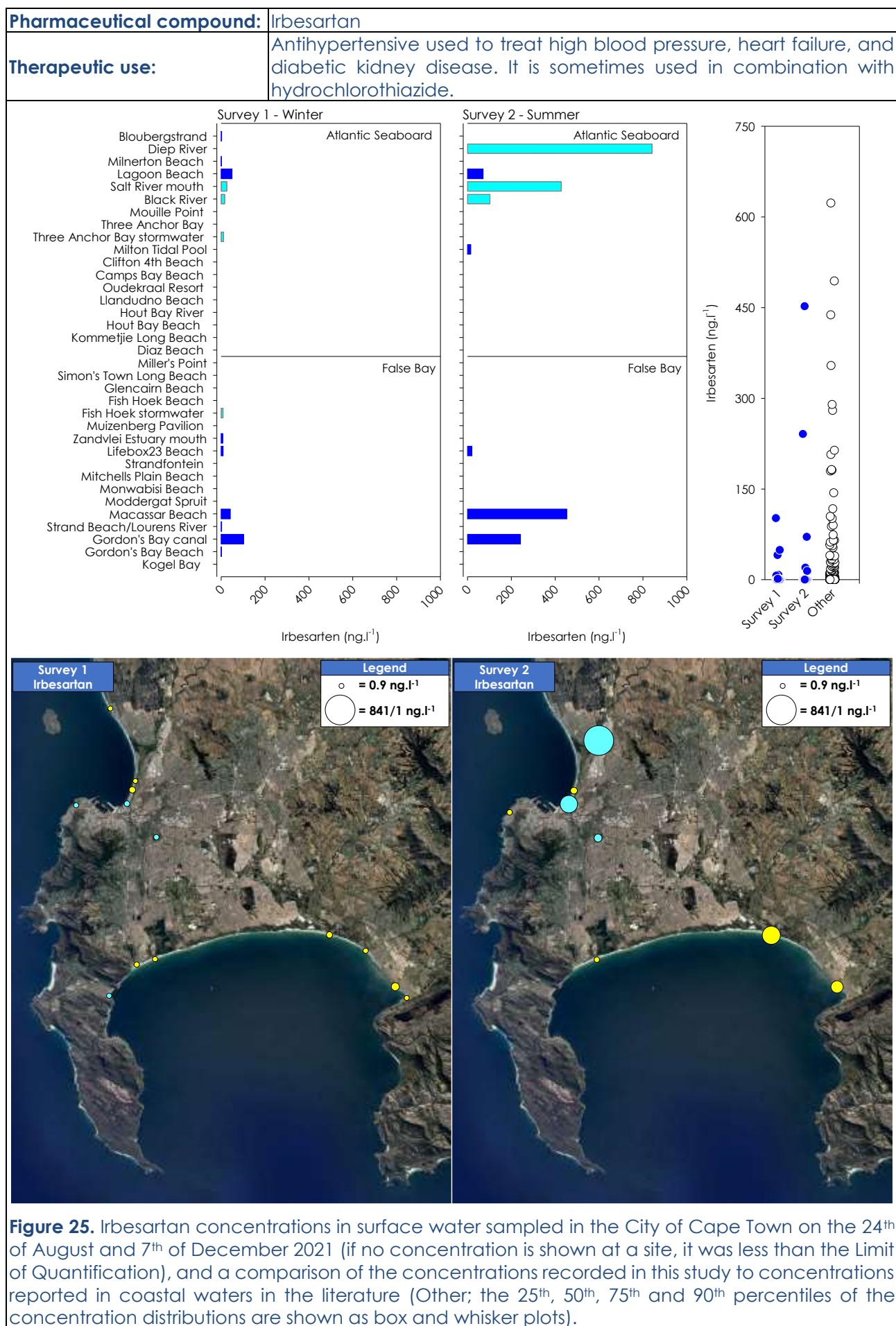


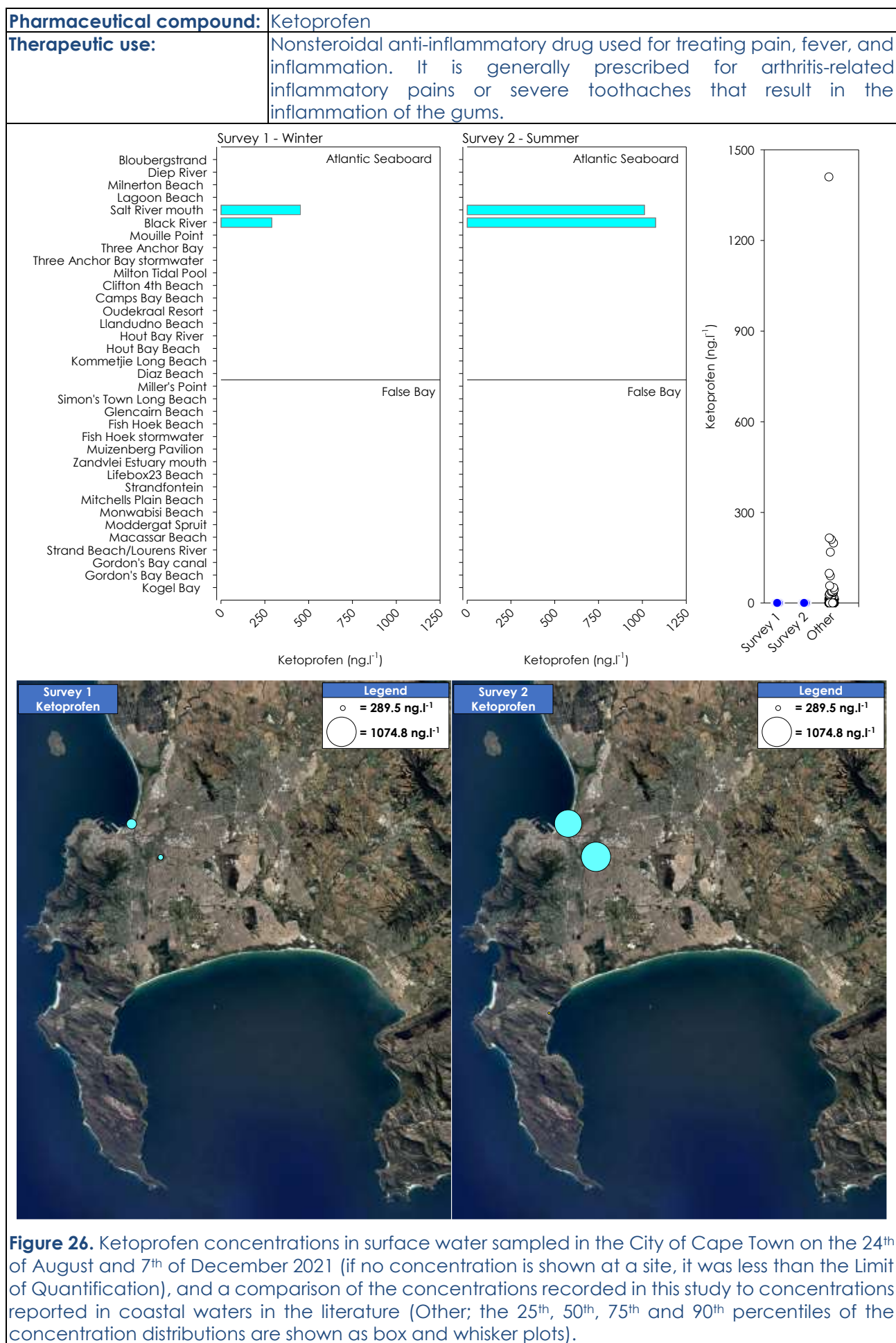


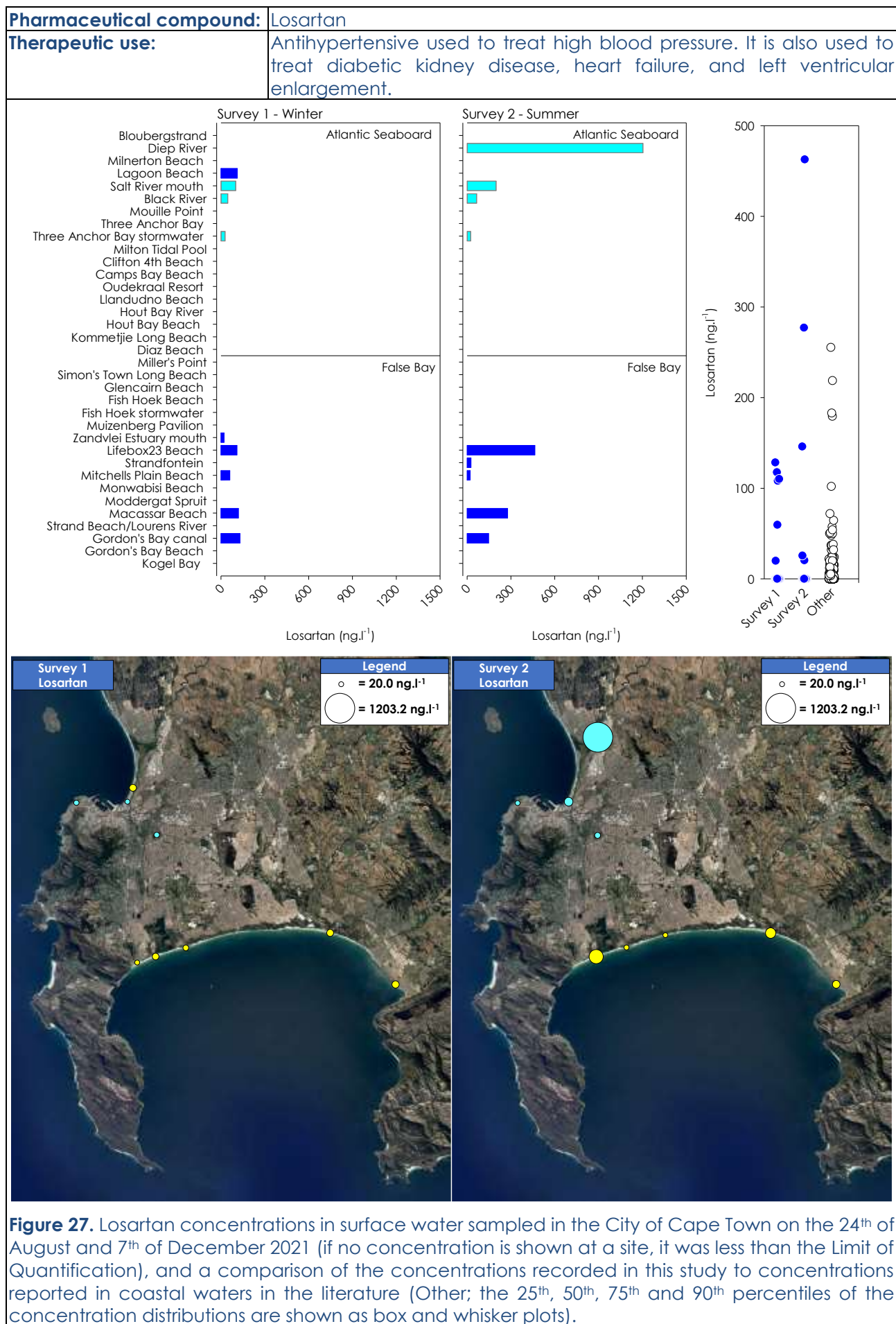


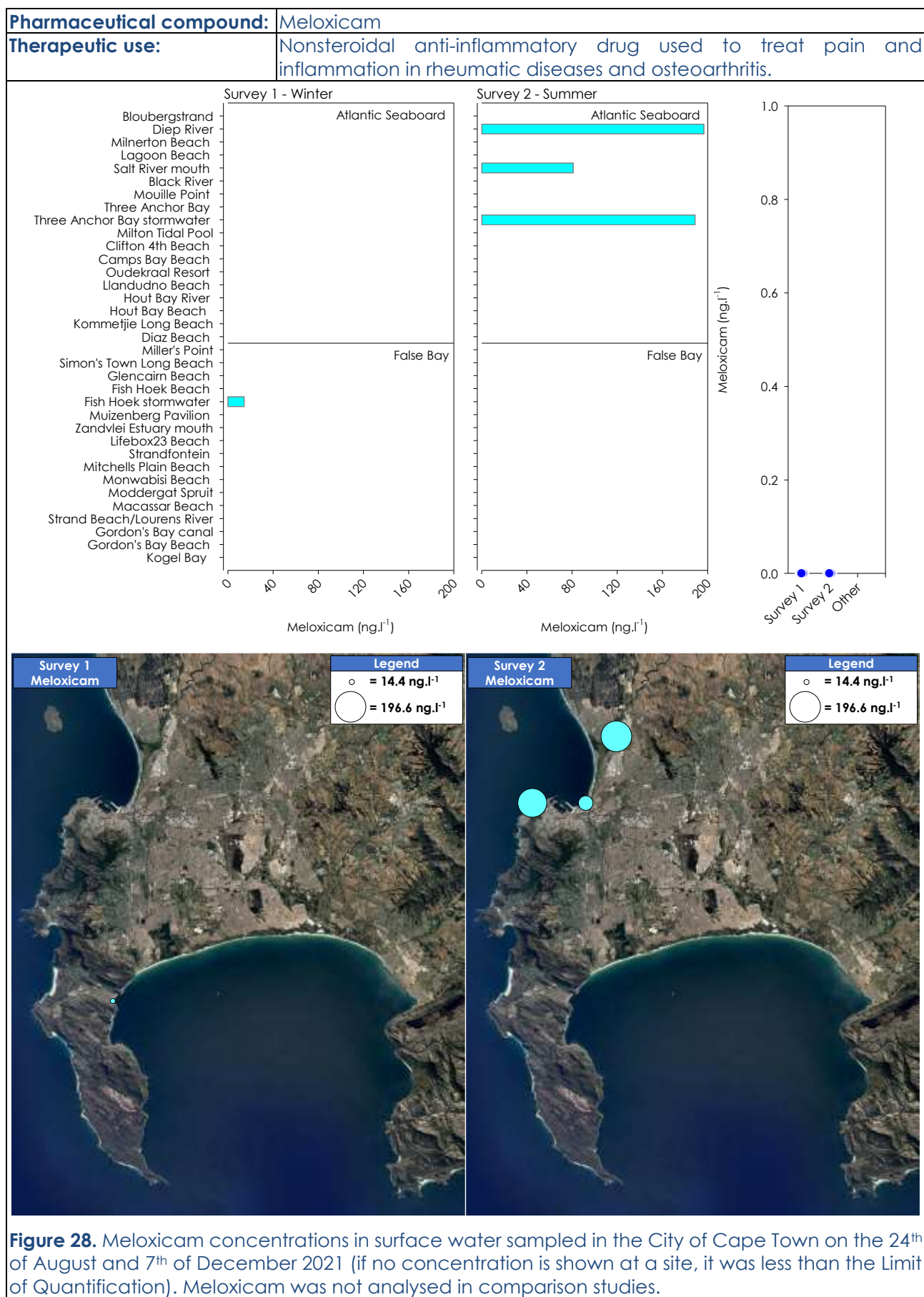


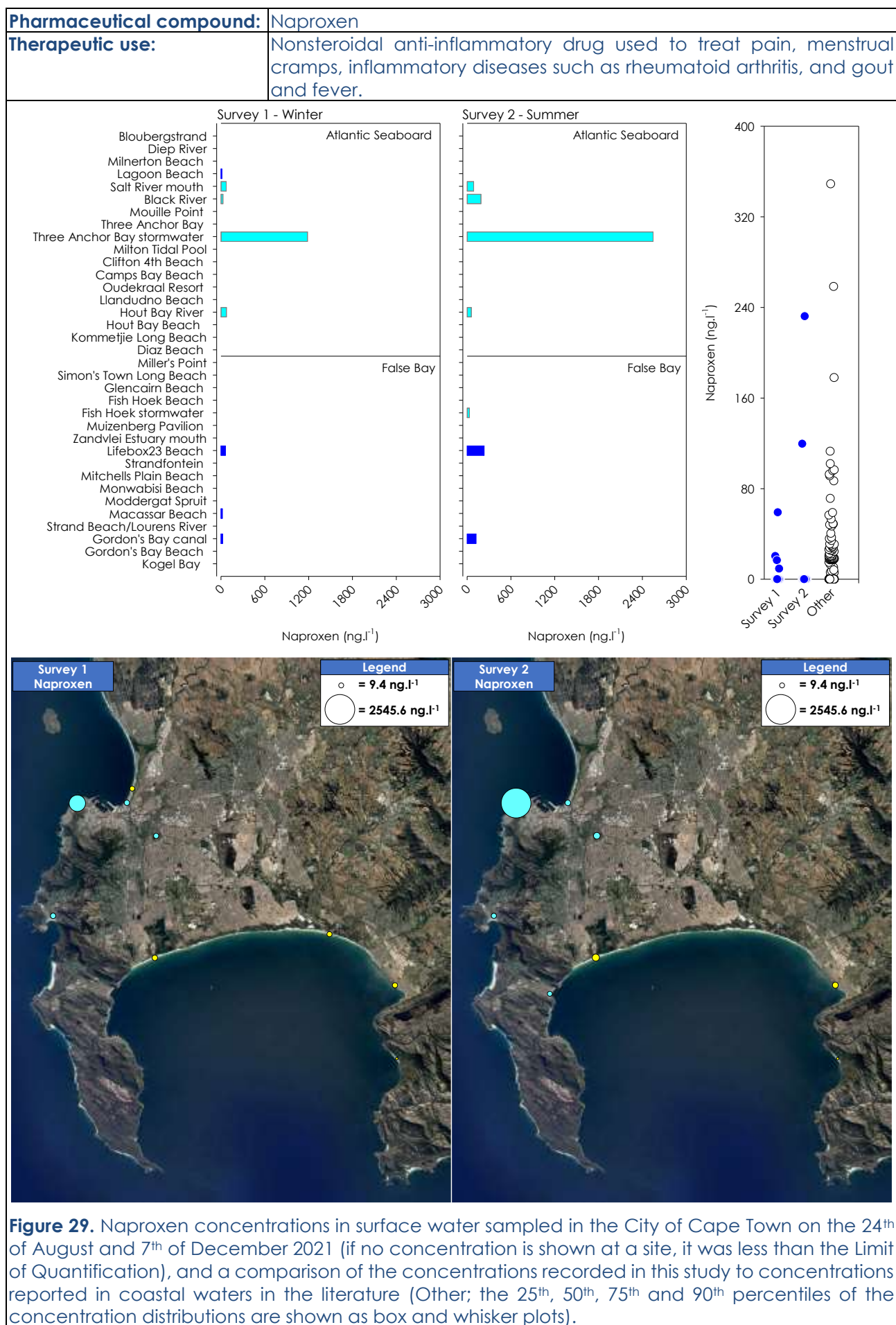


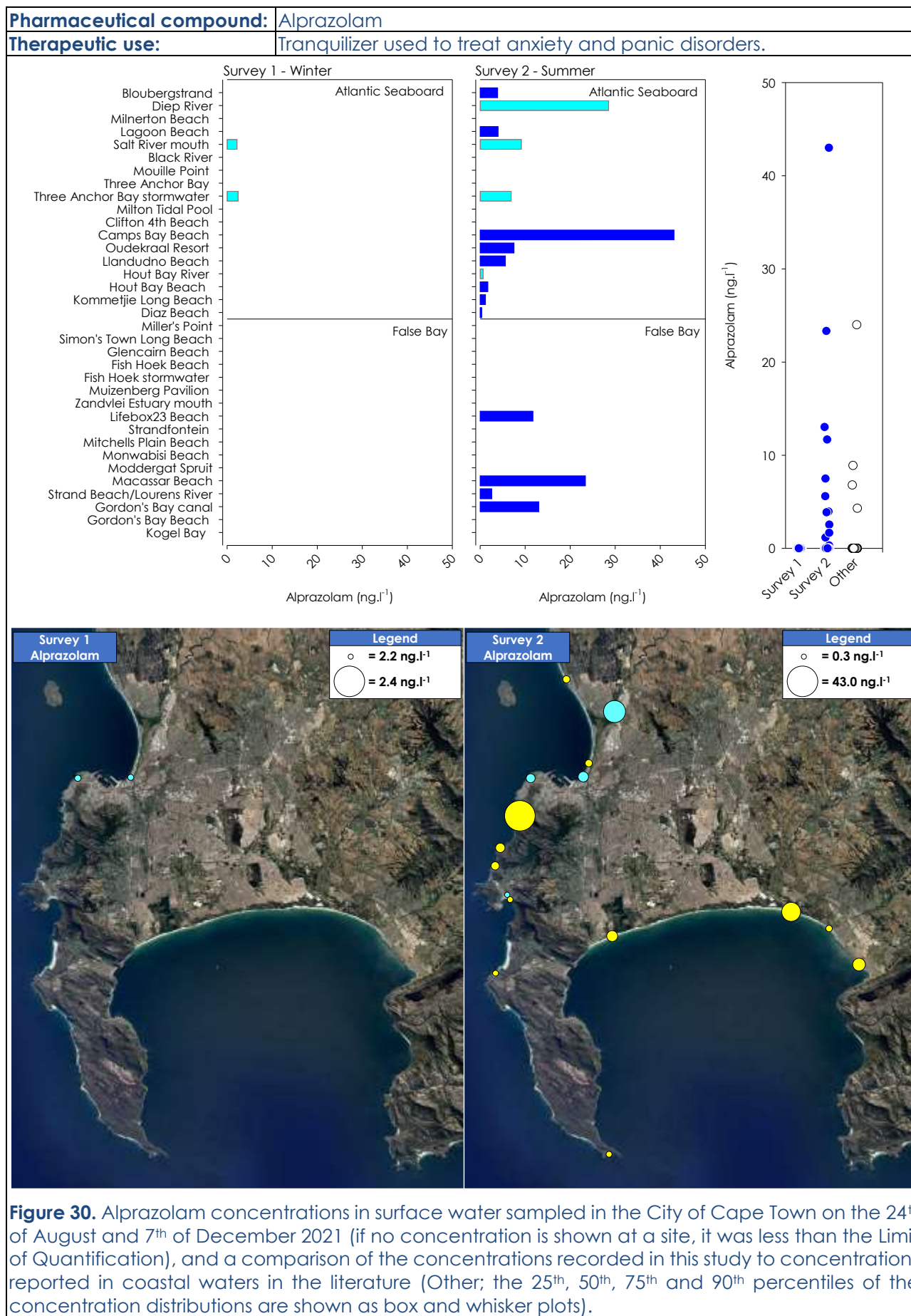


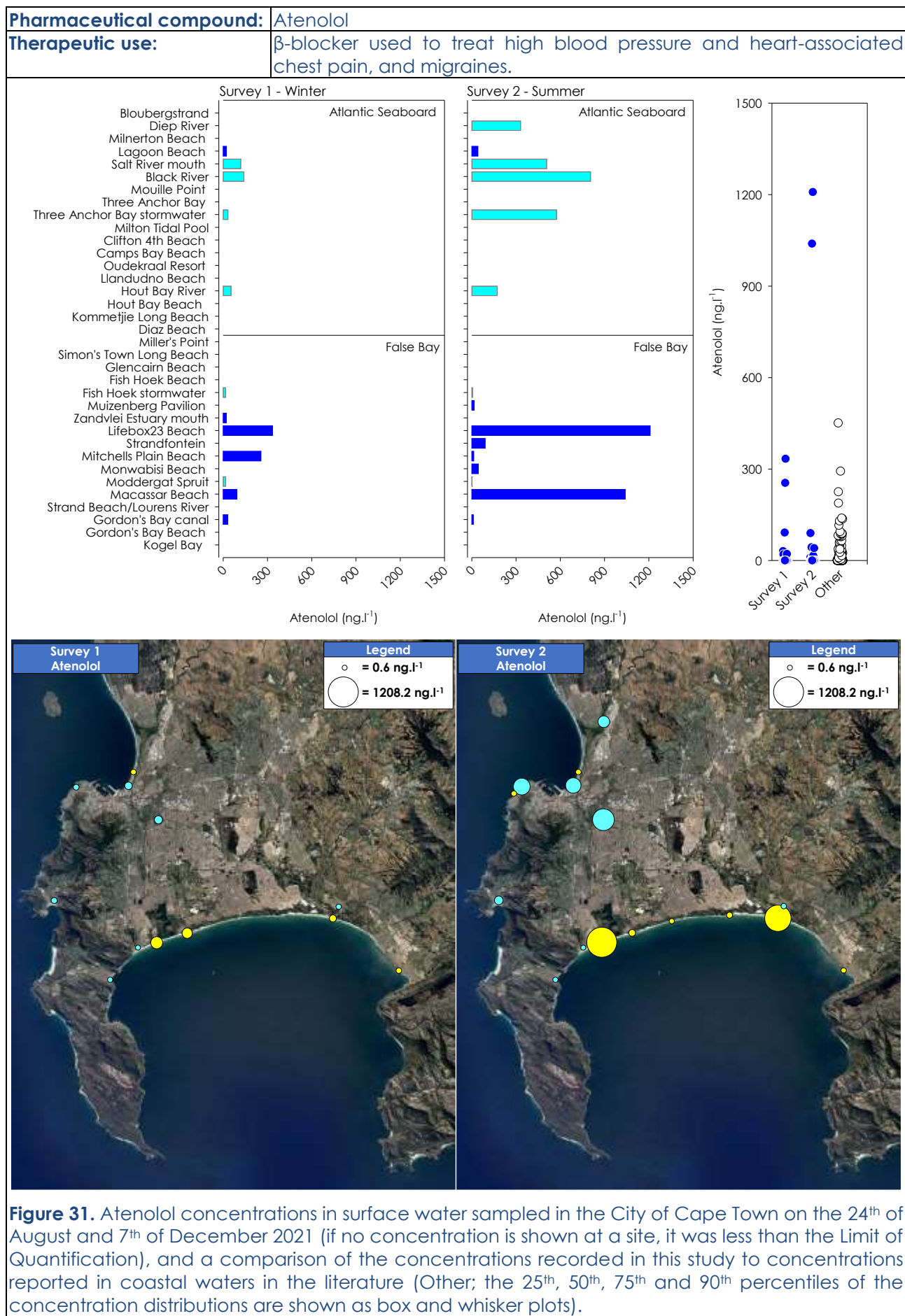


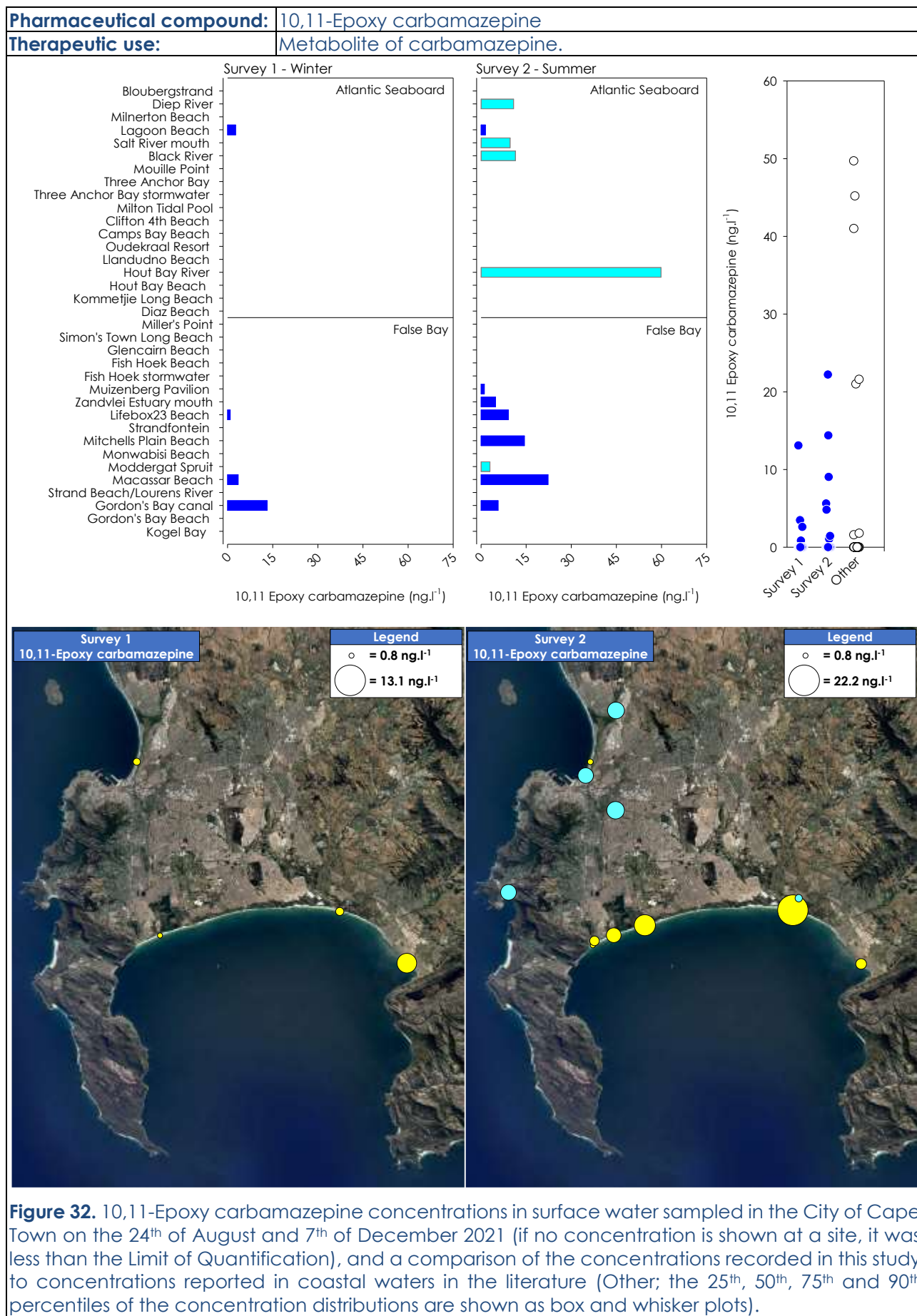


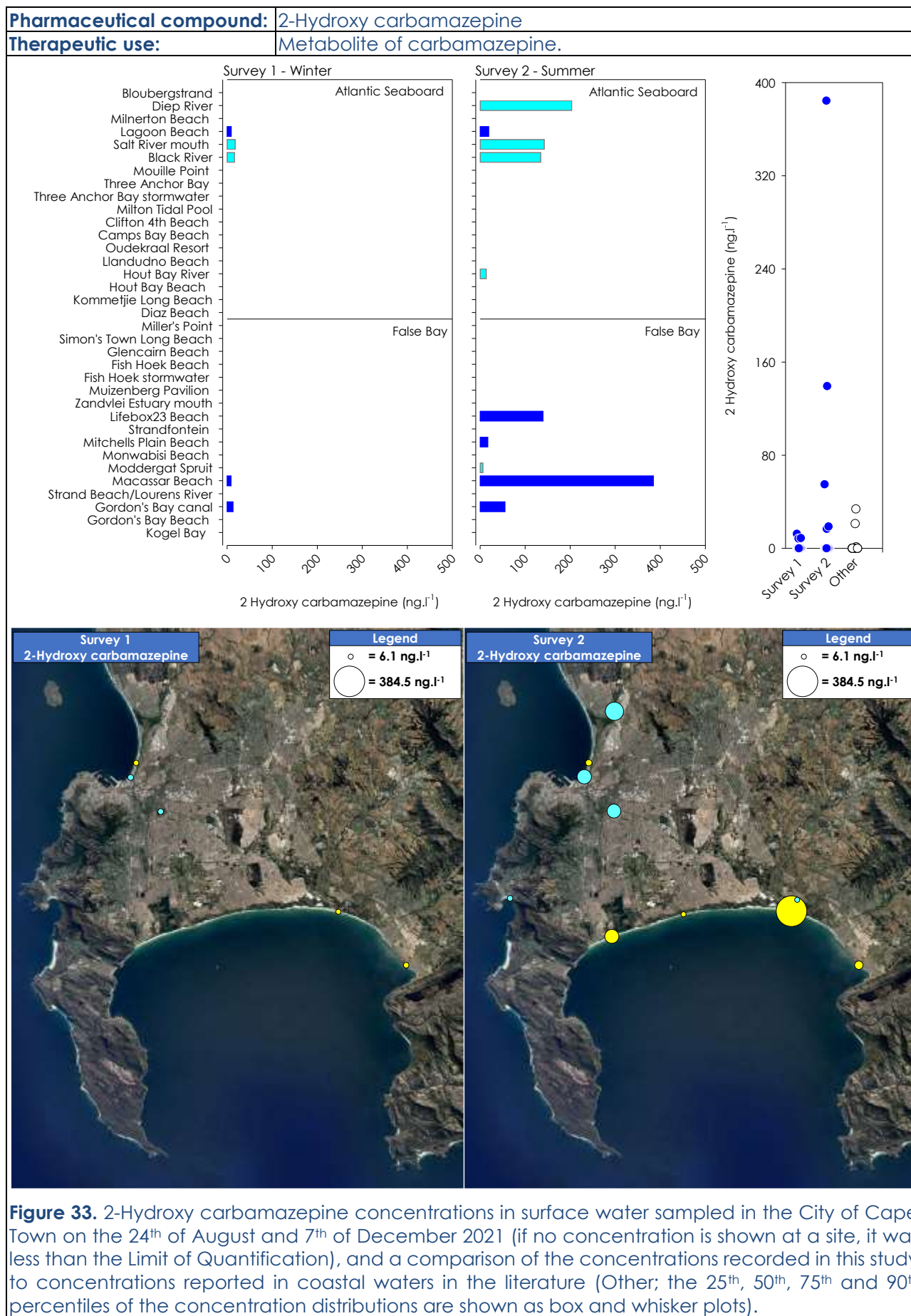


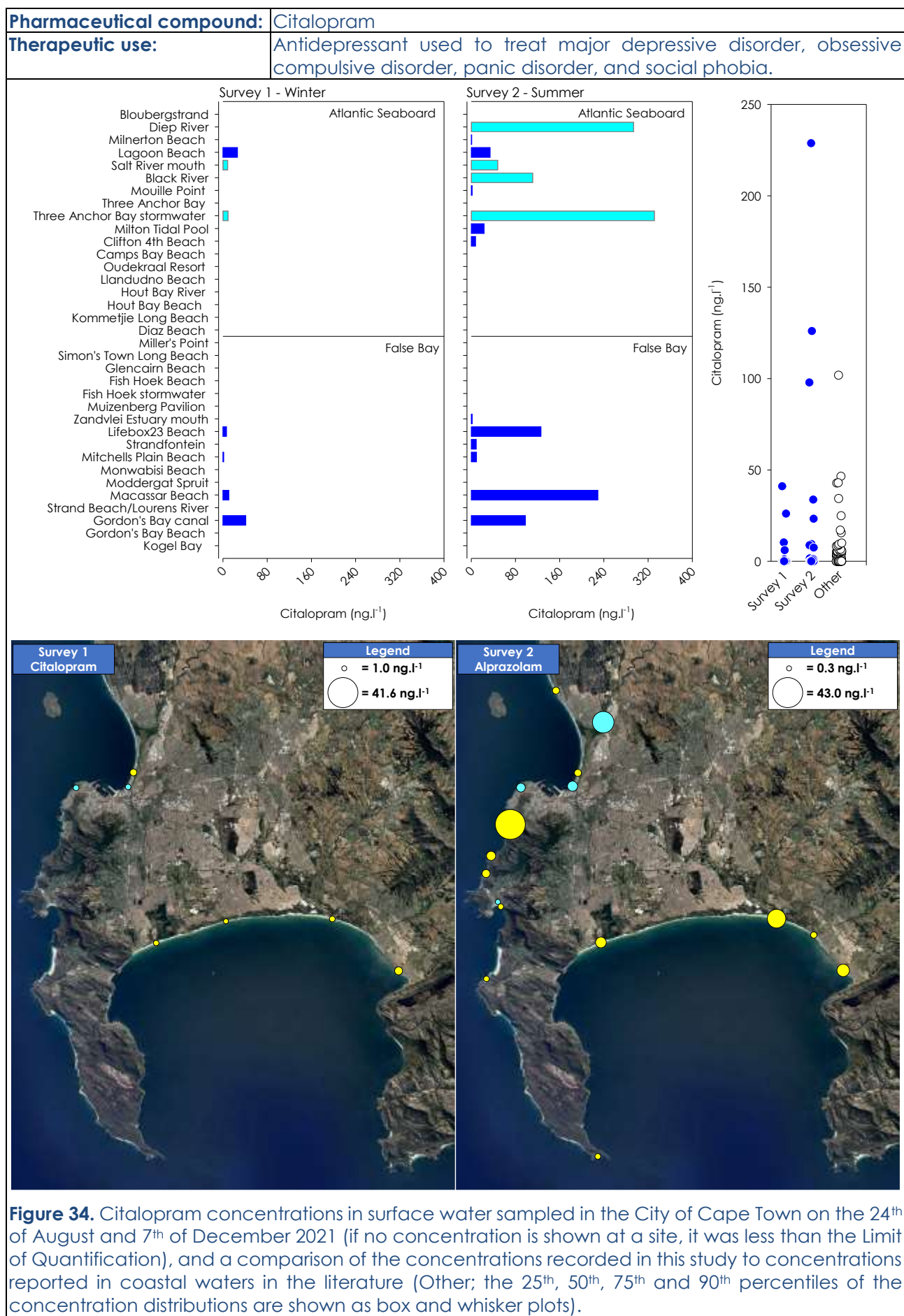


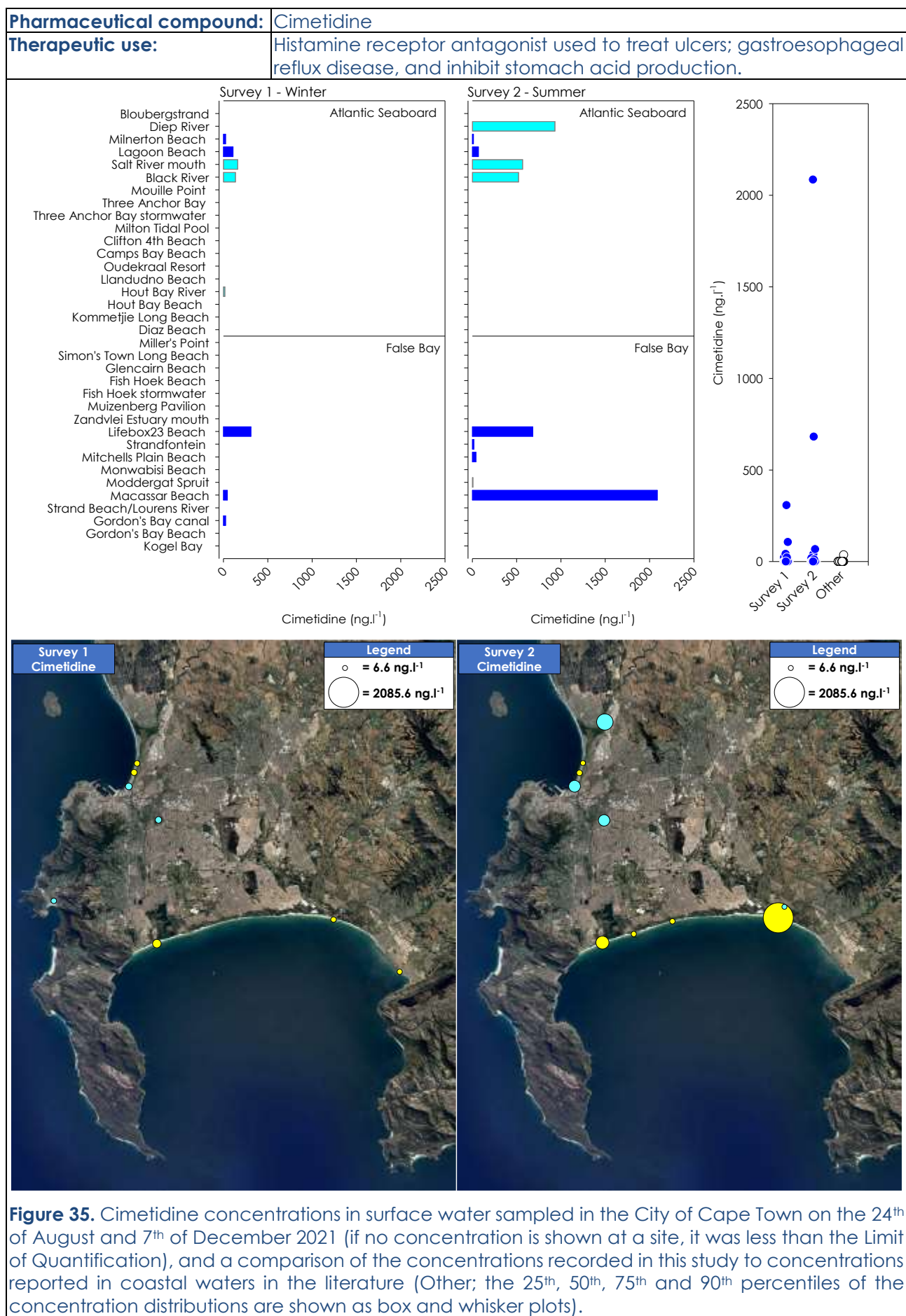


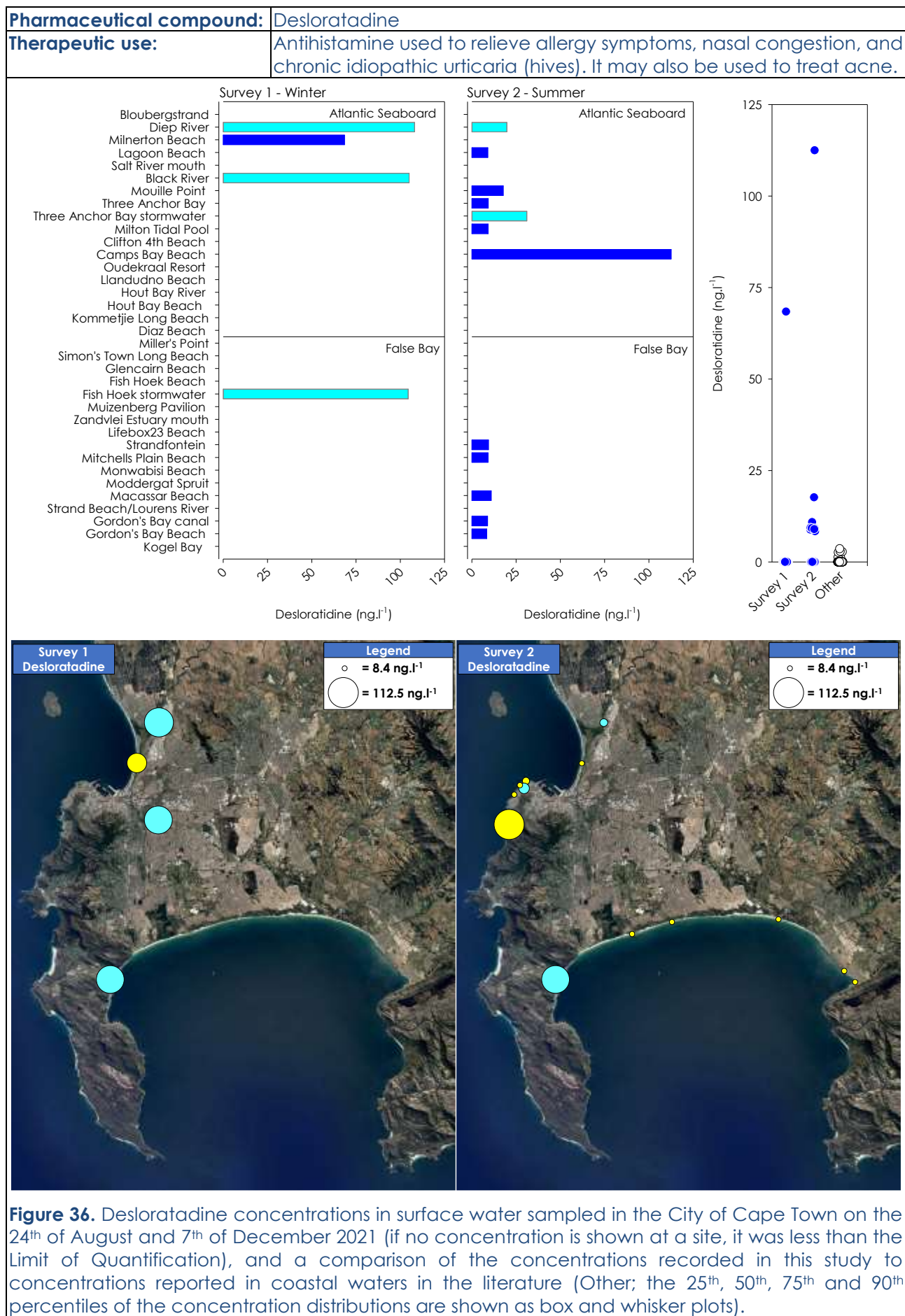


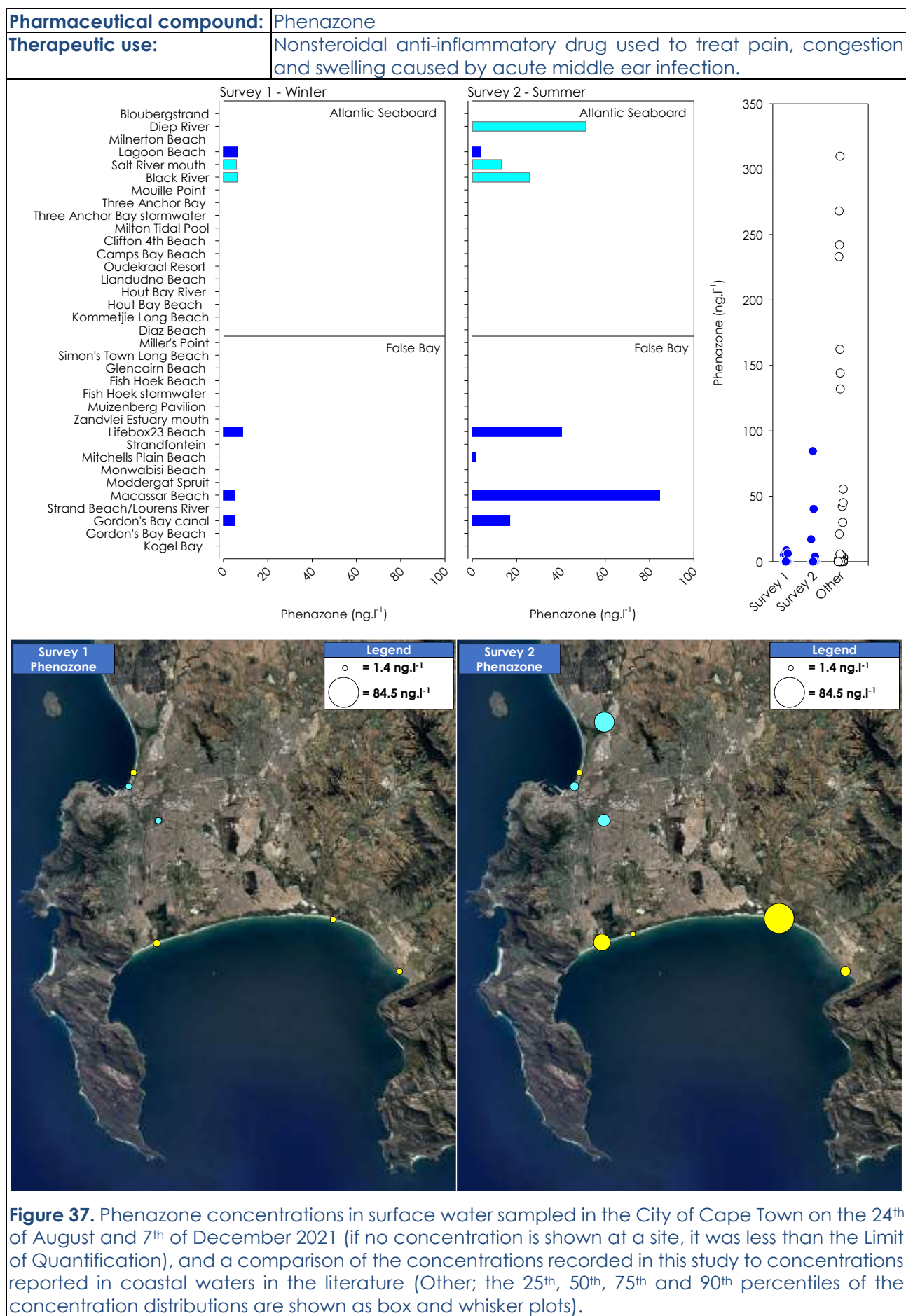


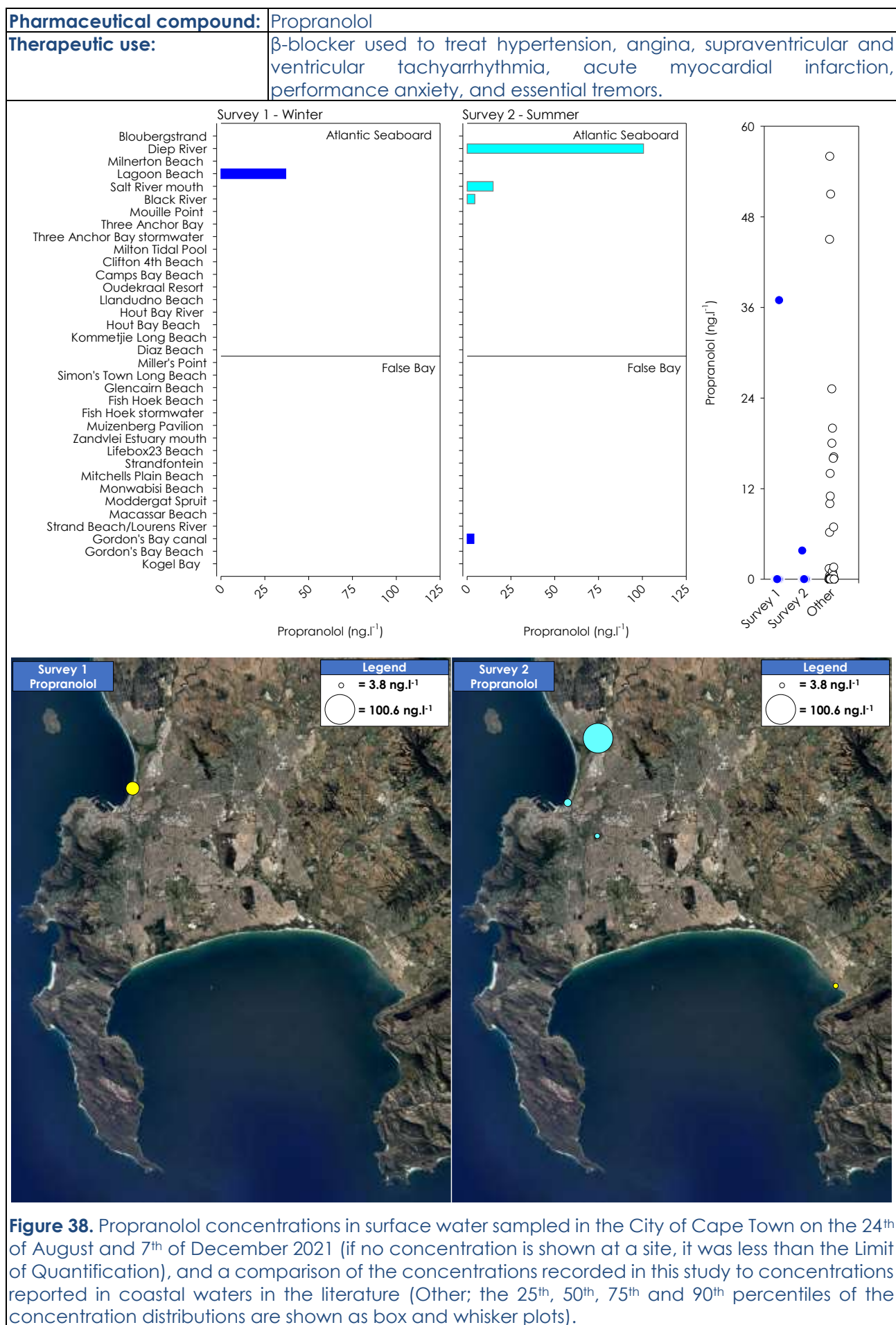


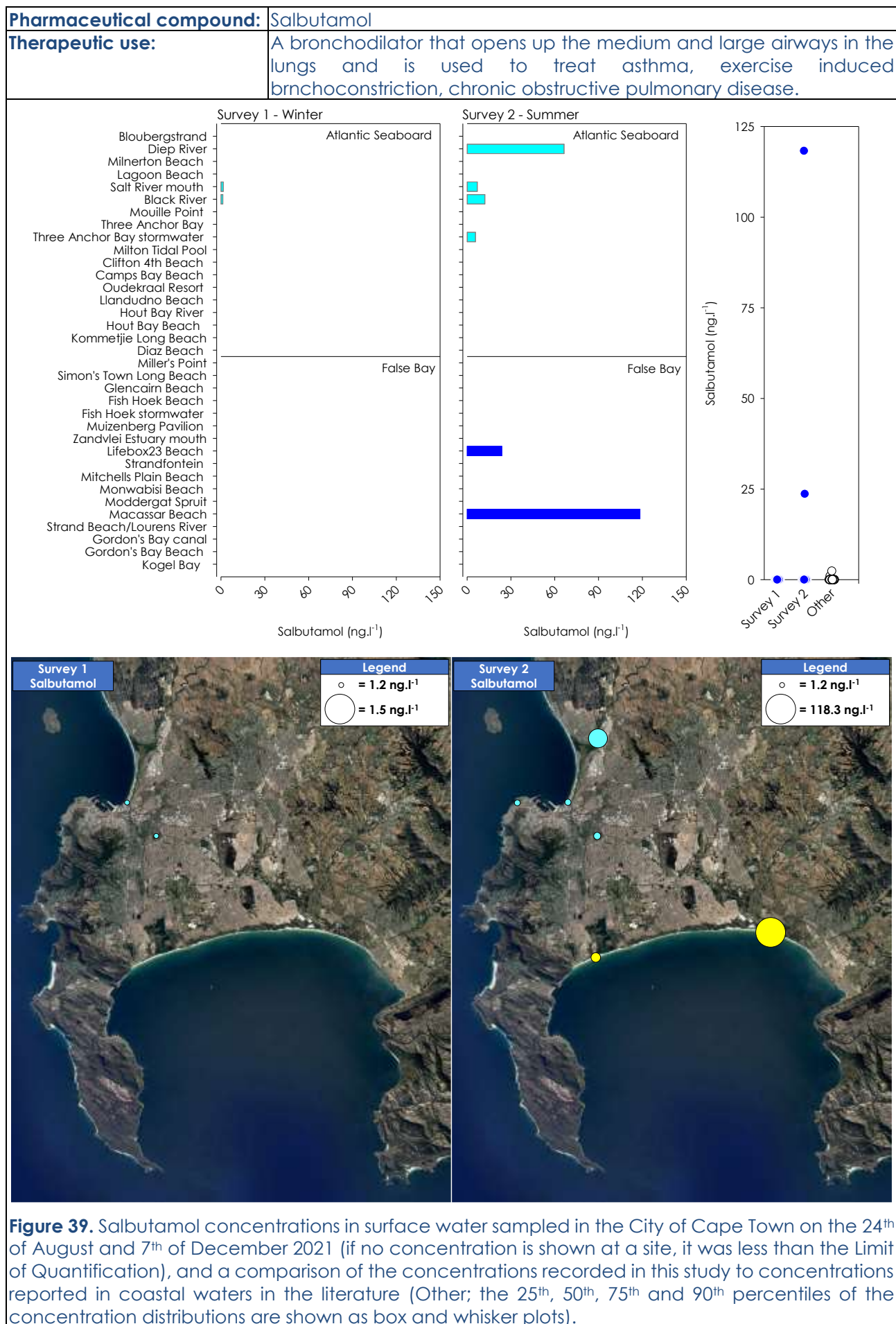


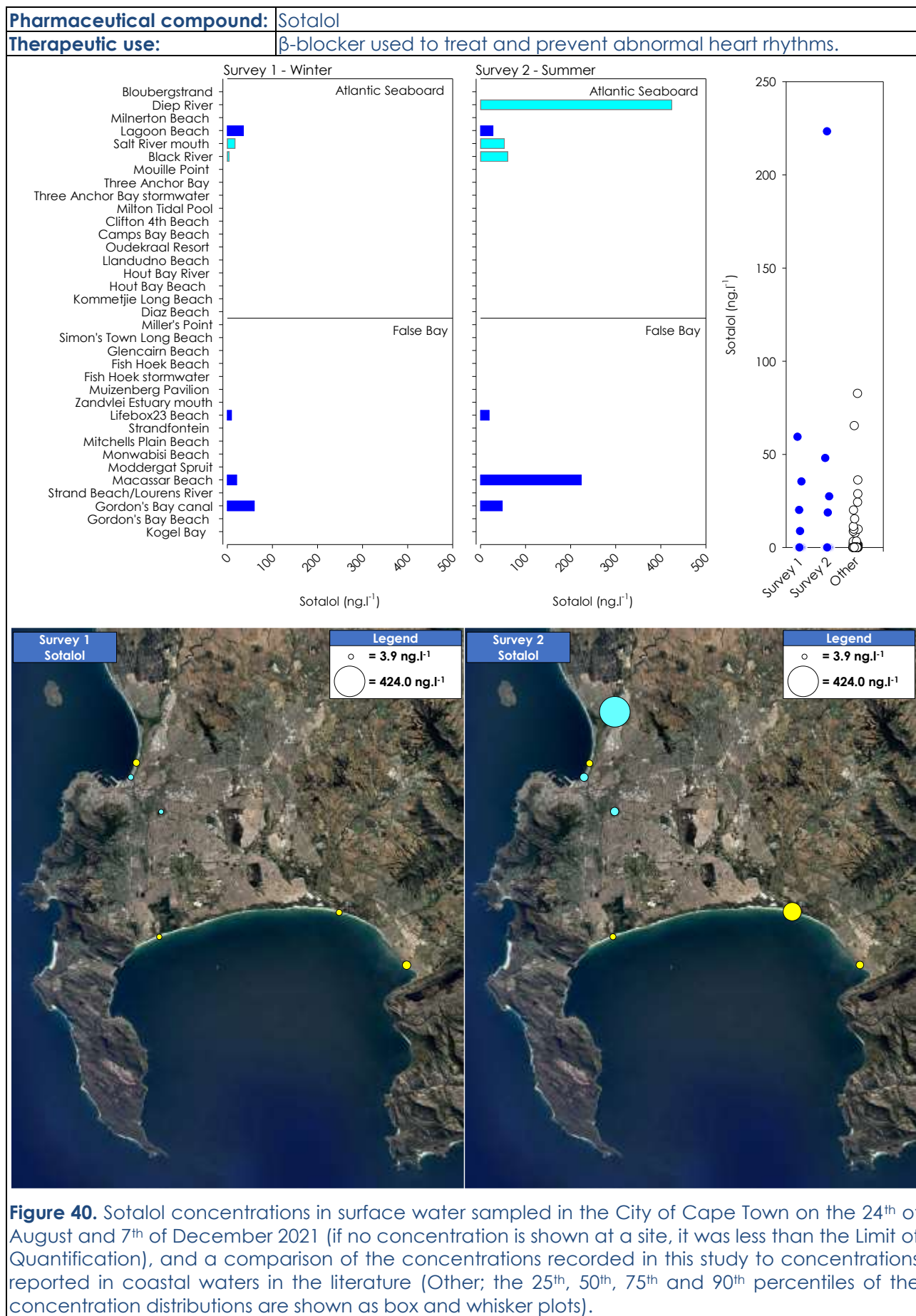


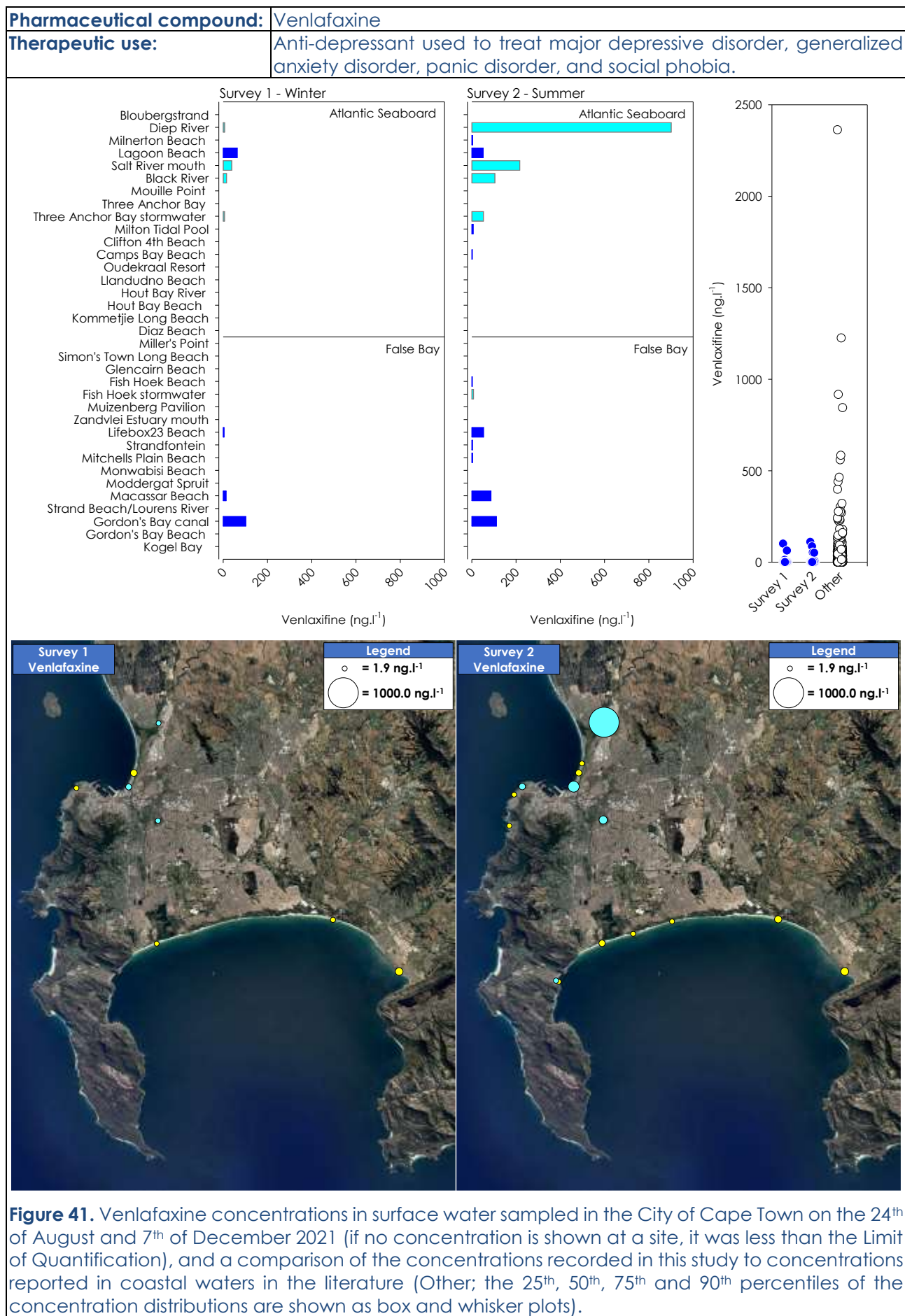


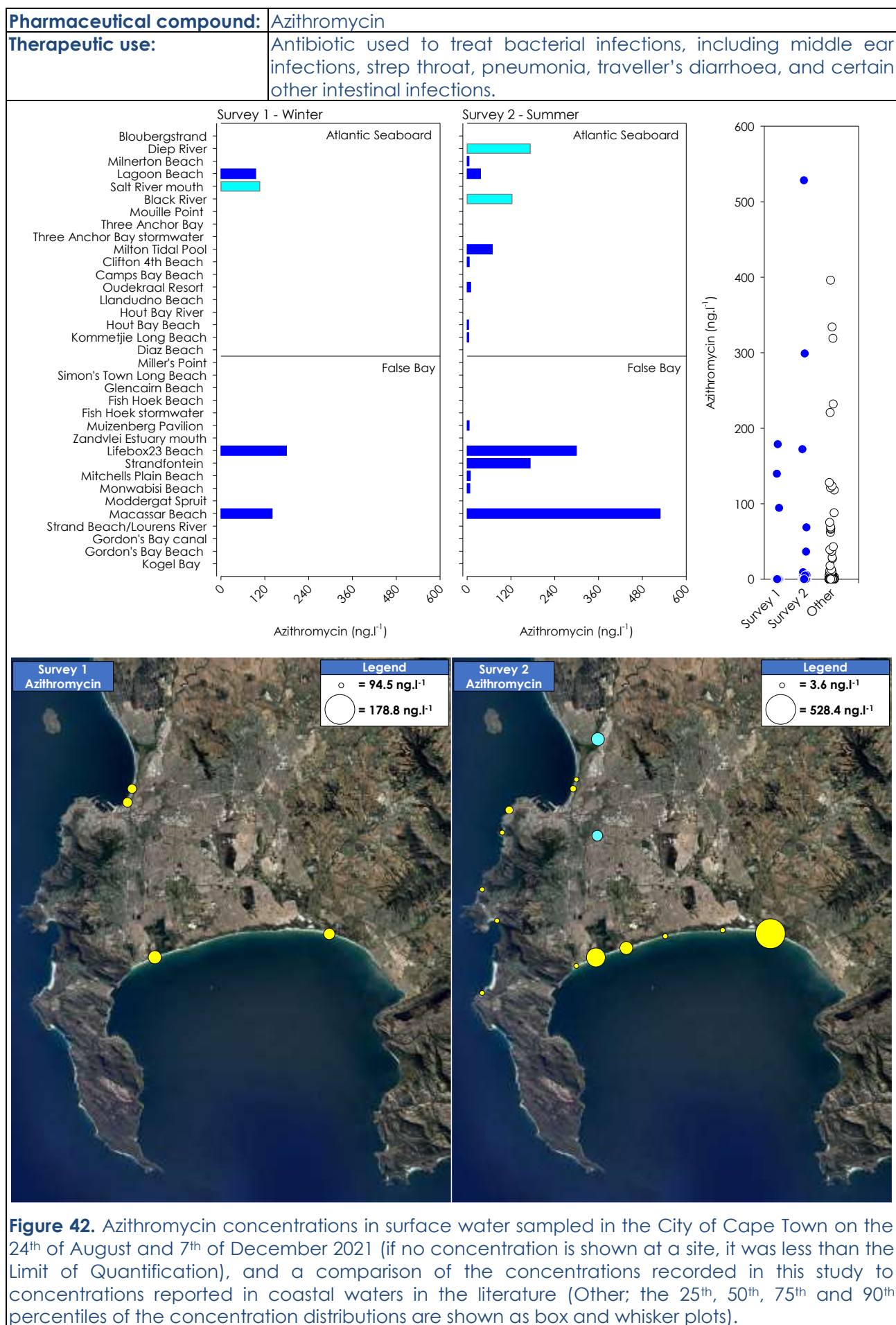


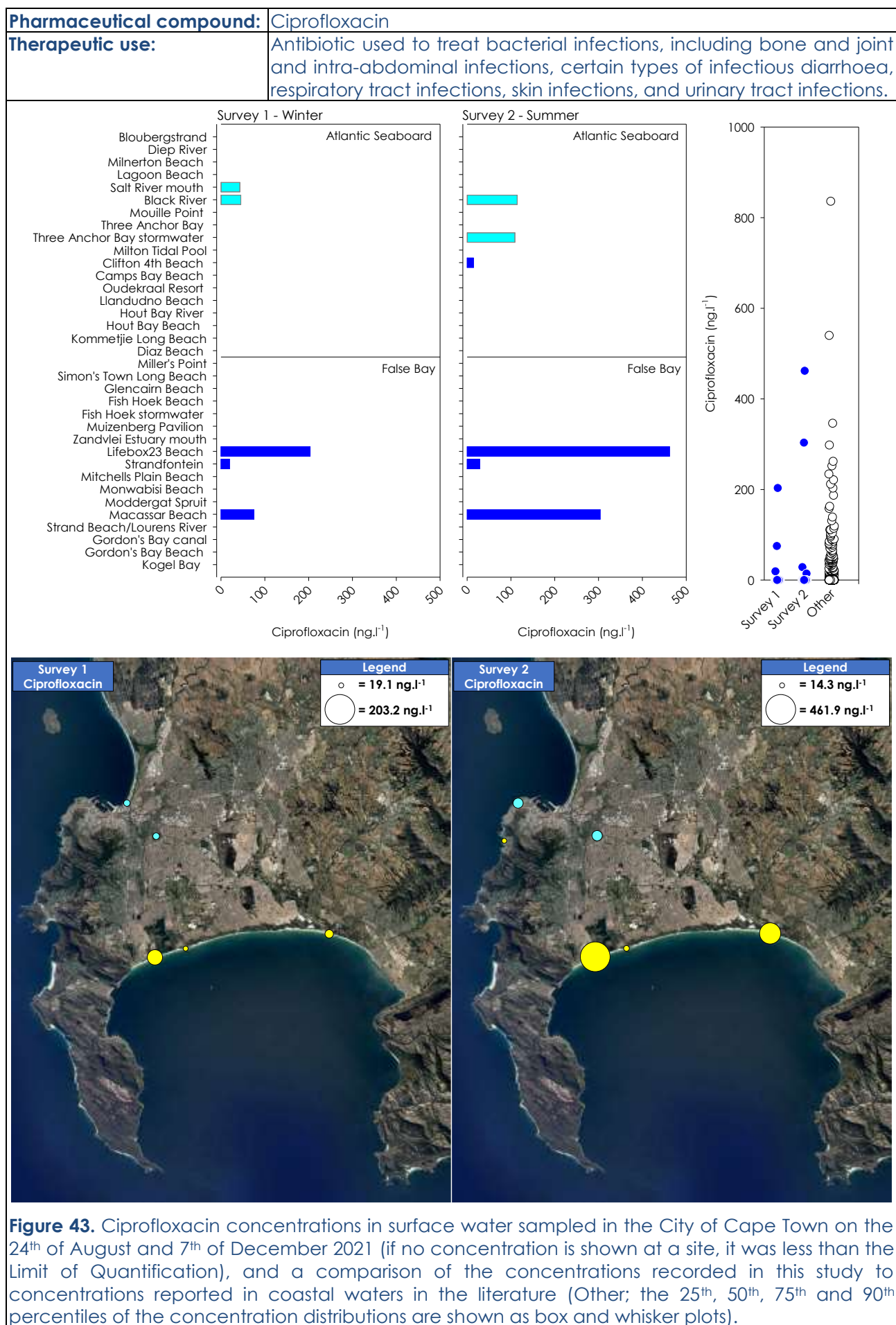


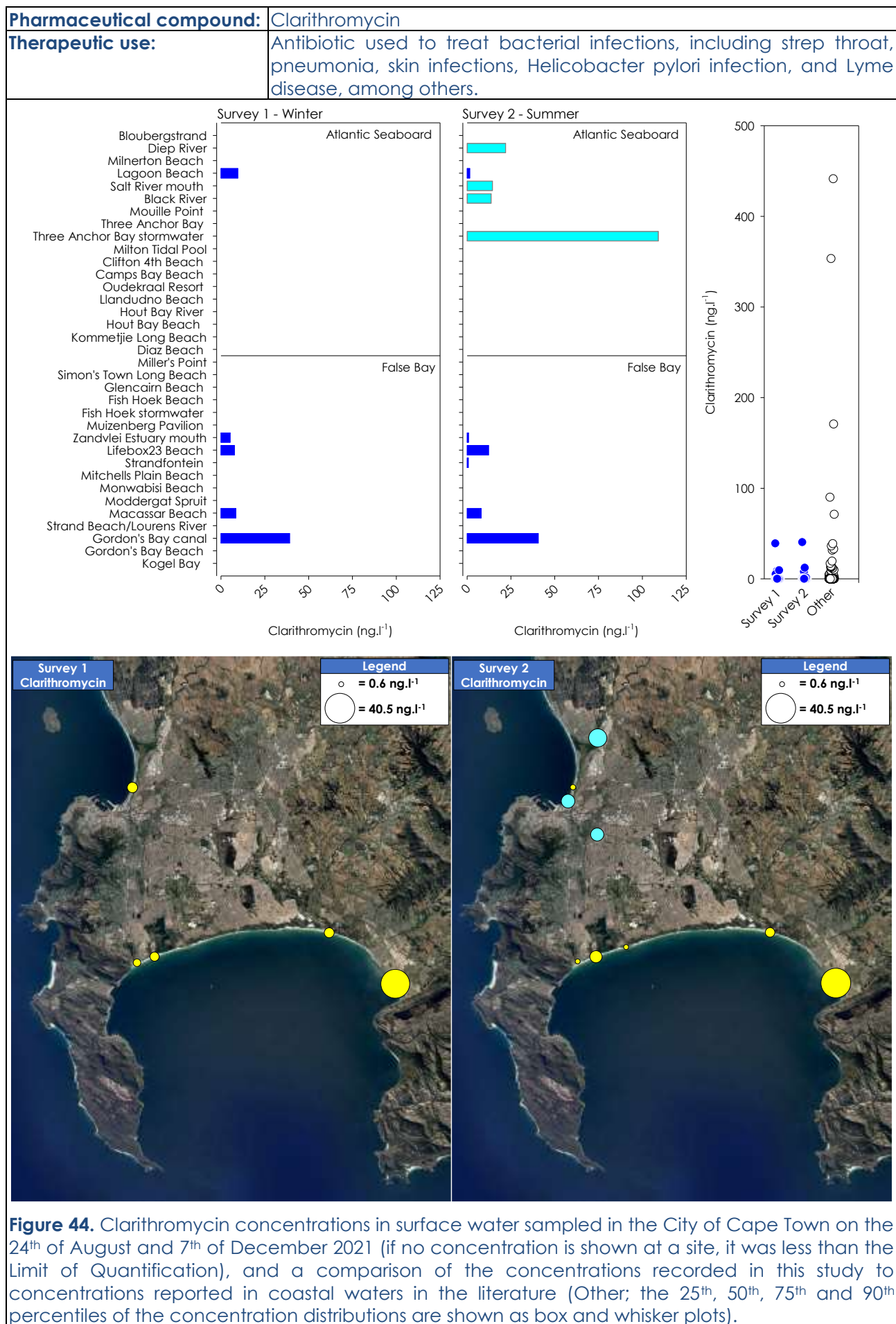


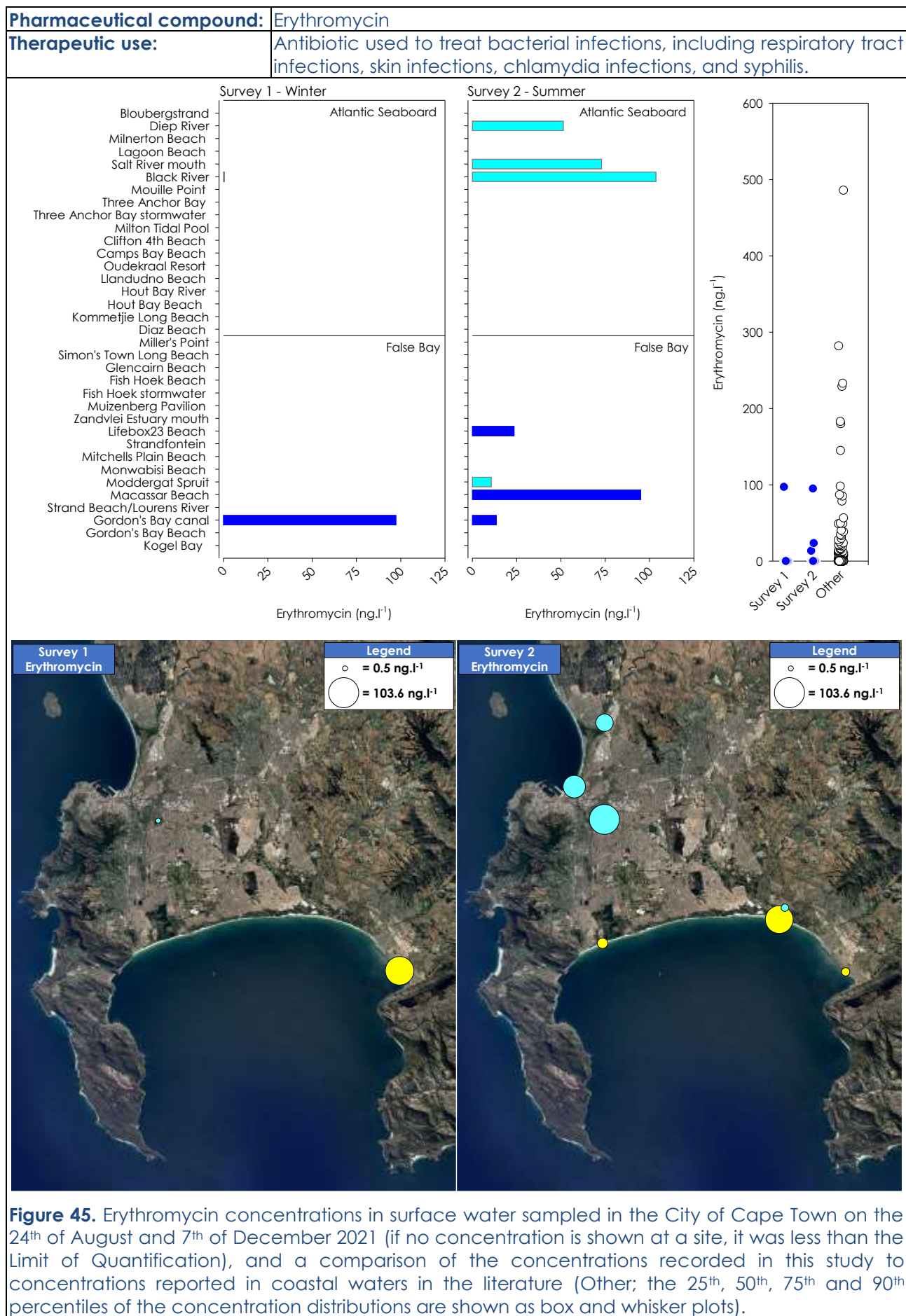


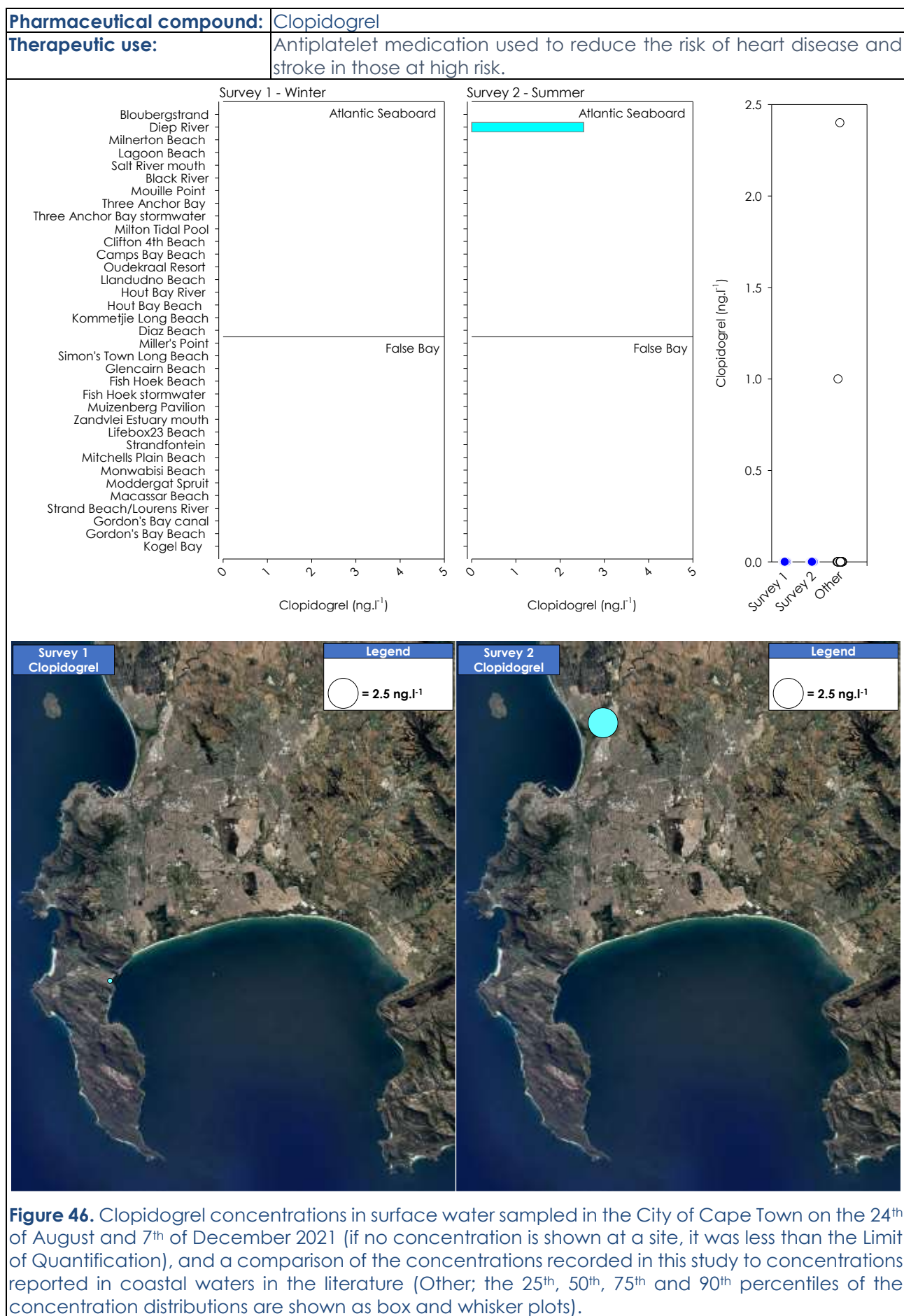


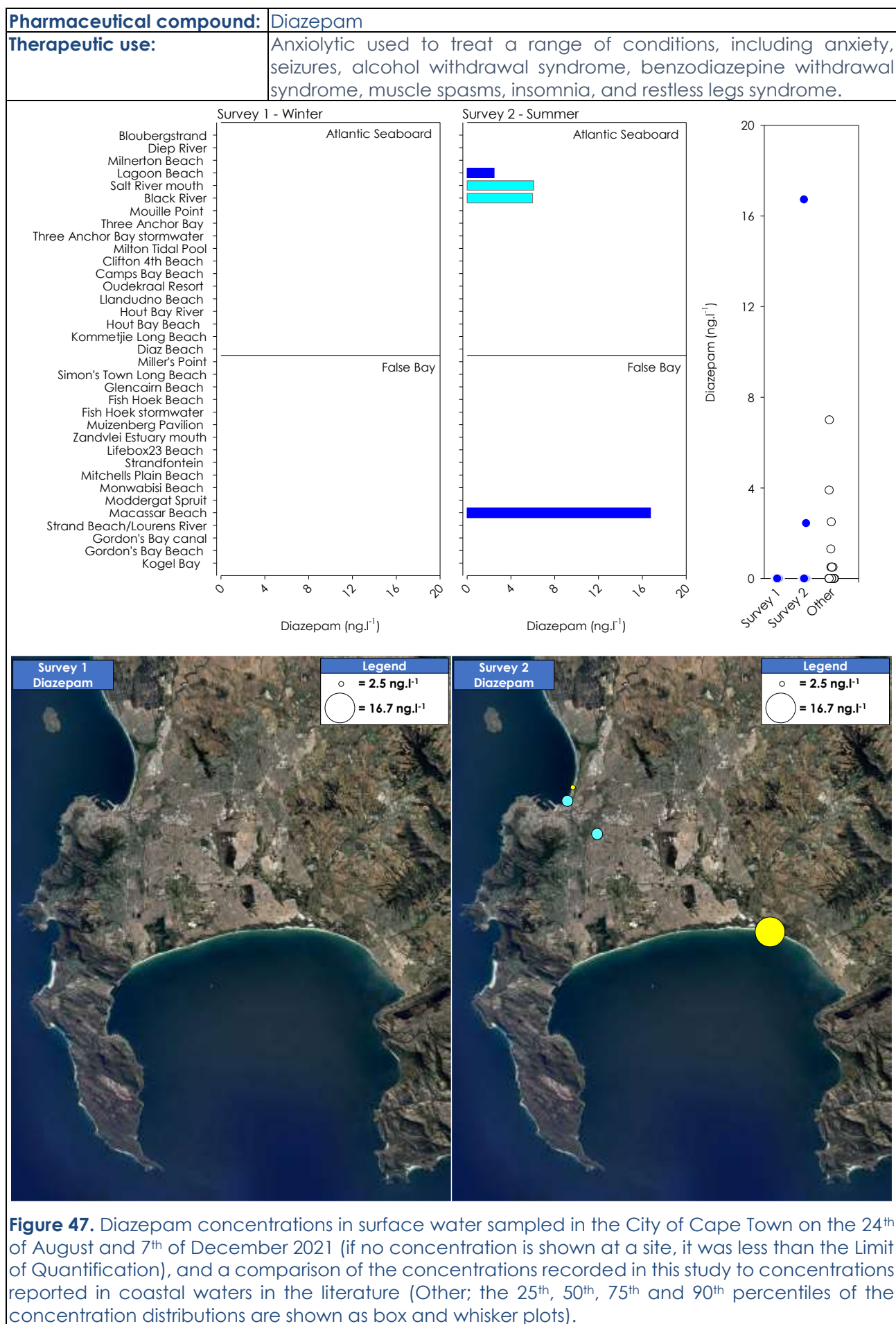


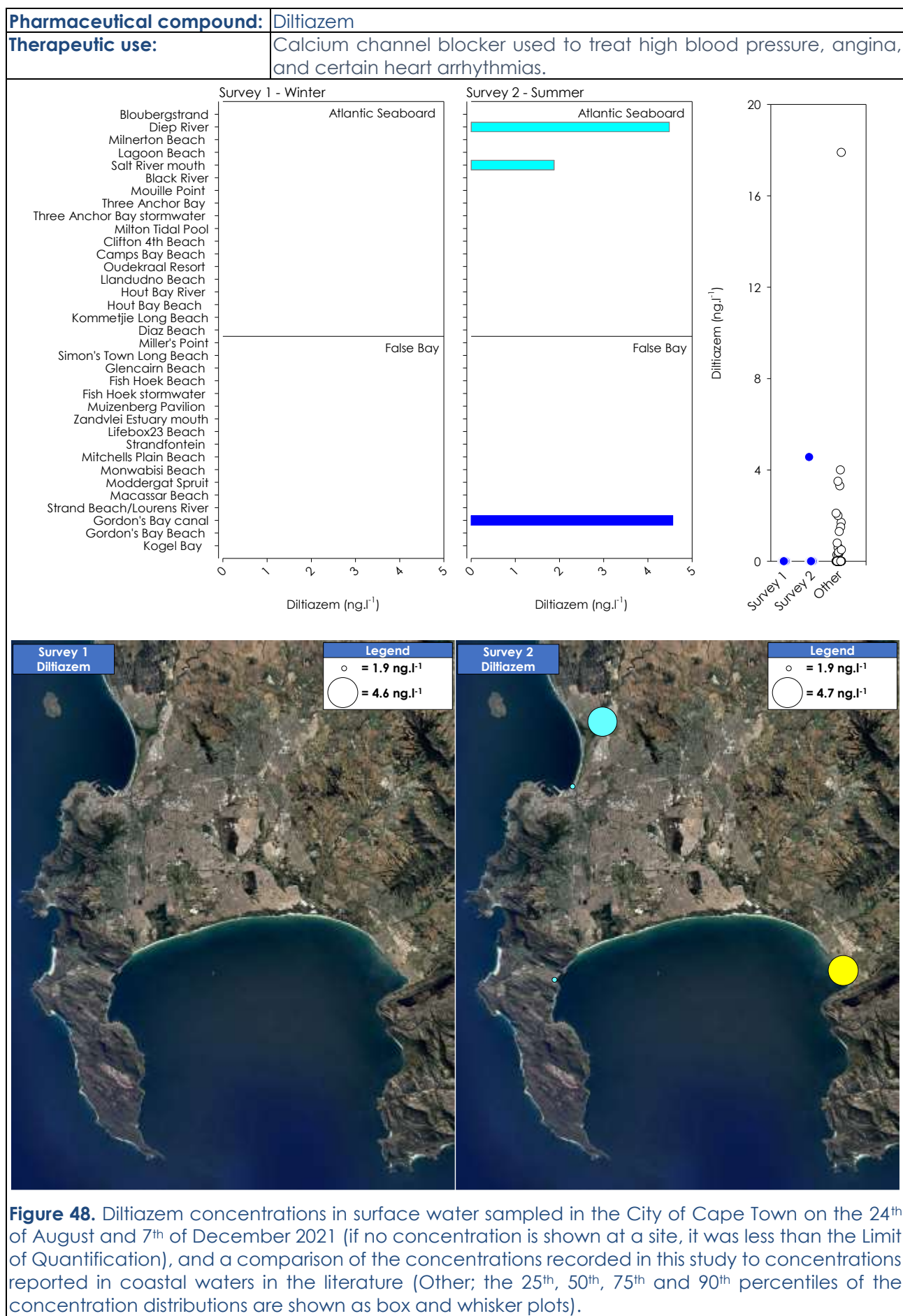


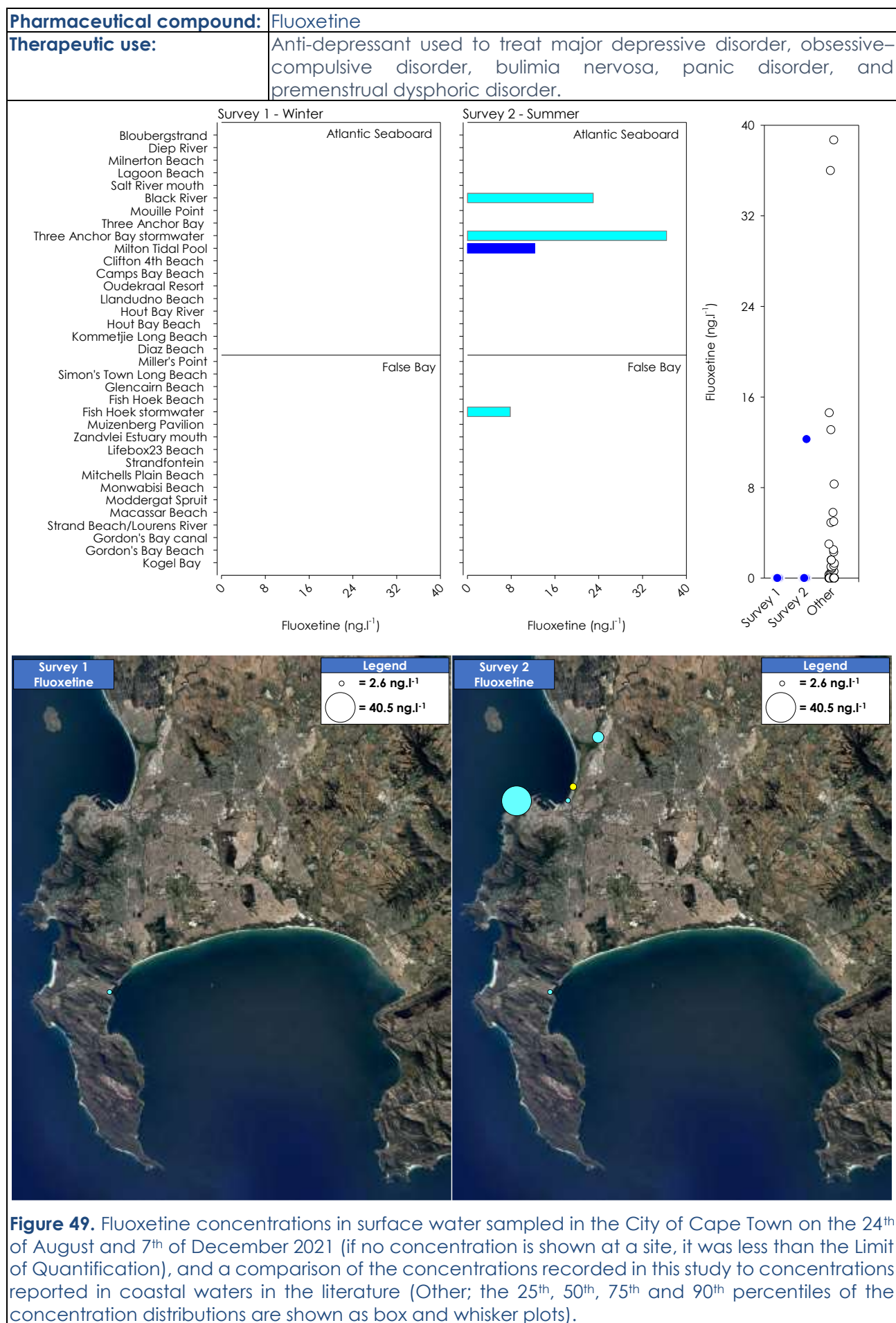












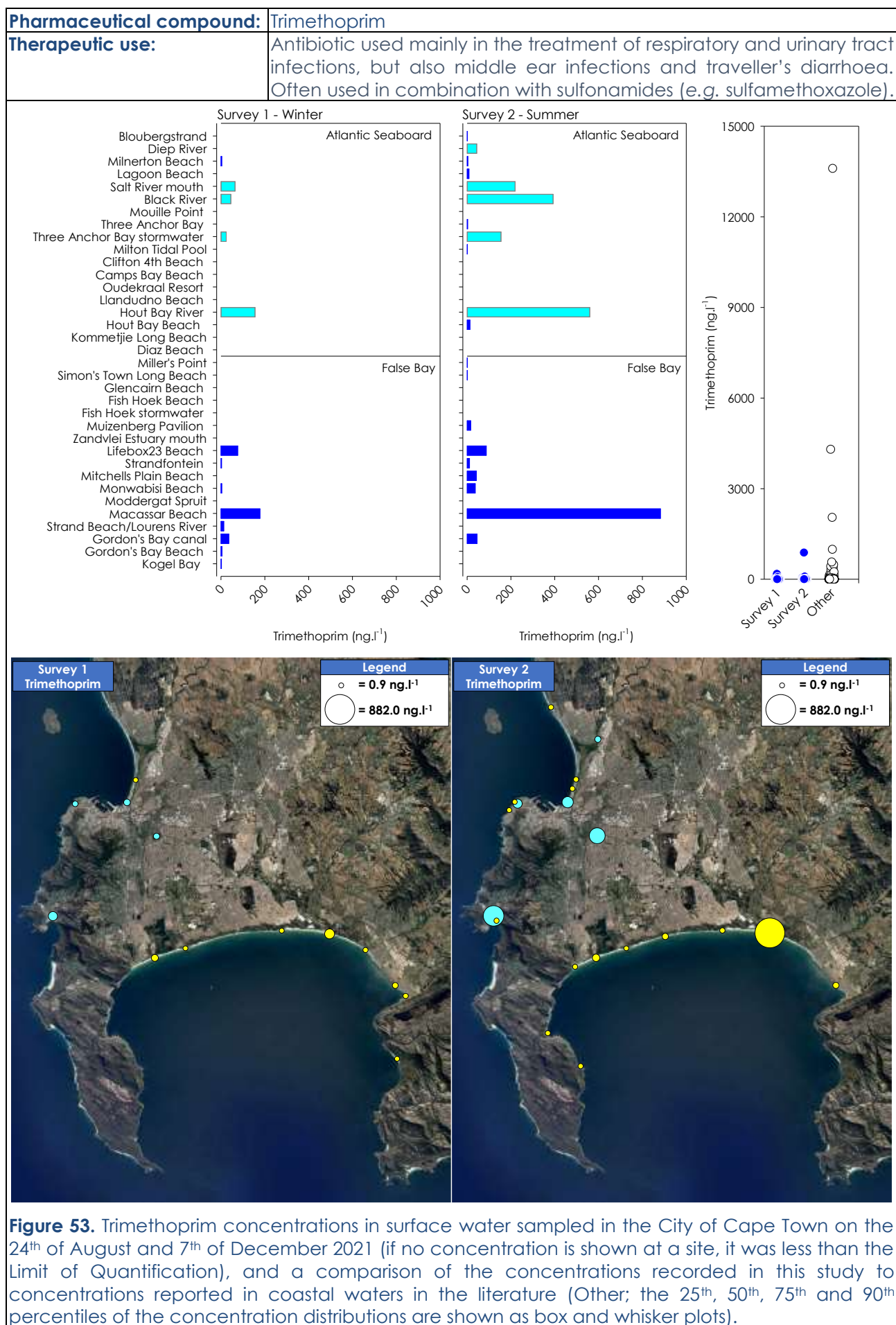


Figure 53. Trimethoprim concentrations in surface water sampled in the City of Cape Town on the 24th of August and 7th of December 2021 (if no concentration is shown at a site, it was less than the Limit of Quantification), and a comparison of the concentrations recorded in this study to concentrations reported in coastal waters in the literature (Other; the 25th, 50th, 75th and 90th percentiles of the concentration distributions are shown as box and whisker plots).

and does not degrade appreciably in the natural environment (Kalsch, 1999; Cantwell *et al.*, 2019). It is not effectively removed by wastewater treatment works (Čelić *et al.*, 2019). In this study, iopromide was the 13th most often found compound in winter (at 10 [or 29%] of the 35 sites, tied with ibuprofen) and 35th most often found compound in summer (at 7 [or 20%] sites) (Figure 4). The highest iopromide concentrations were found in water at sites with a strong direct or indirect wastewater influence, but it was interestingly not found in the Diep River, in the Black River near the Athlone wastewater treatment works discharge, in the Salt River mouth, and in the Hout Bay River (Figure 19). Iopromide was in fact absent at all but three sites along the Atlantic Seaboard in winter. It was found in stormwater at Fish Hoek Beach in each survey, but not at Three Anchor Bay. The iopromide concentrations in water at several sites are slightly to considerably higher than the highest concentration reported in comparison studies (Figure 19).

There appears to be no other information on iopromide in coastal waters in Cape Town or elsewhere in South Africa. No comparison can thus be made to concentrations in local coastal waters.

4.3. Environmental hazard assessment

Pharmaceutical compounds are formulated to cause a physiological response in humans or animals, often at a very low concentration. This has led to concerns the compounds might cause similar responses in biota that have similar target organs, tissues, and biomolecules, or might pose other hazards to biota (Fent *et al.*, 2006; Fabbri and Franzellitti, 2016). Estimating the environmental hazard posed by pharmaceutical compounds in estuarine and marine environments is difficult because there is limited information on the toxicity of most compounds to biota in these environments (Gaw *et al.*, 2016). Furthermore, Predicted No Effect Concentrations, which are required to estimate the hazard through the computation of a Hazard Quotient, often vary widely amongst studies. Depending on the Predicted No Effect Concentrations used the estimated hazard will differ. In this study, three approaches were followed to estimate the environmental hazard posed by pharmaceutical compounds in water sampled in Cape Town, namely using toxicological information for freshwater biota (microalgae,

invertebrates represented by *Daphnia*, and fish) provided by Kuzmanović *et al.* (2015), using toxicological information for coastal and marine biota represented largely by microalgae provided by Minguez *et al.* (2016), and using the fish plasma model proposed by Huggett *et al.* (2003).

Hazard Quotients computed using Predicted No Effect Concentrations derived using toxicological information provided by Kuzmanović *et al.* (2015) for freshwater microalgae, invertebrates, and fish are provided for all pharmaceutical compounds at each site in Figure 55, and for individual compounds at all sites in Figure 56. The number of Hazard Quotients that fall into each hazard category at each site are provided in Figure 57. Fifteen Hazard Quotients are >1 for microalgae, one for invertebrates, but none for fish. The Hazard Quotients represent concentrations of six compounds, with ten of the 16 Hazard Quotients representing either the anti-hypertensive losartan or antibiotic erythromycin. All but one of the concentrations resulting in high Hazard Quotients were found in water sampled in summer. The concentrations of pharmaceutical compounds at most sites thus present a low (8.0% of concentrations) or negligible (87.7% of concentrations) hazard to microalgae (Figures 55 - 57). The Hazard Quotients for microalgae at some sites fall into the medium hazard category (3.5% of concentrations) (Figures 55 - 57). The highest hazards are for the Diep River, Black River, Lifebox23 Beach, Macassar Beach, and near Gordons Bay canal (Figures 55 and 57).

The concentrations of pharmaceutical compounds at most sites present a low (4.9% of concentrations) or negligible (93.8% of concentrations) hazard to invertebrates, but some (1.3%) present a medium hazard (mainly attributable to acetaminophen, citalopram, and losartan). The acetaminophen concentration found in the Hout Bay River in summer presents a high hazard (Figures 55 - 57). The highest hazards are for the Diep River, Black River, Hout Bay River, and Lifebox23 Beach (Figure 55). Some compounds present a low hazard to fish, but in most cases the hazard is negligible. No compounds present a medium or high hazard to fish (Figures 55 - 57).

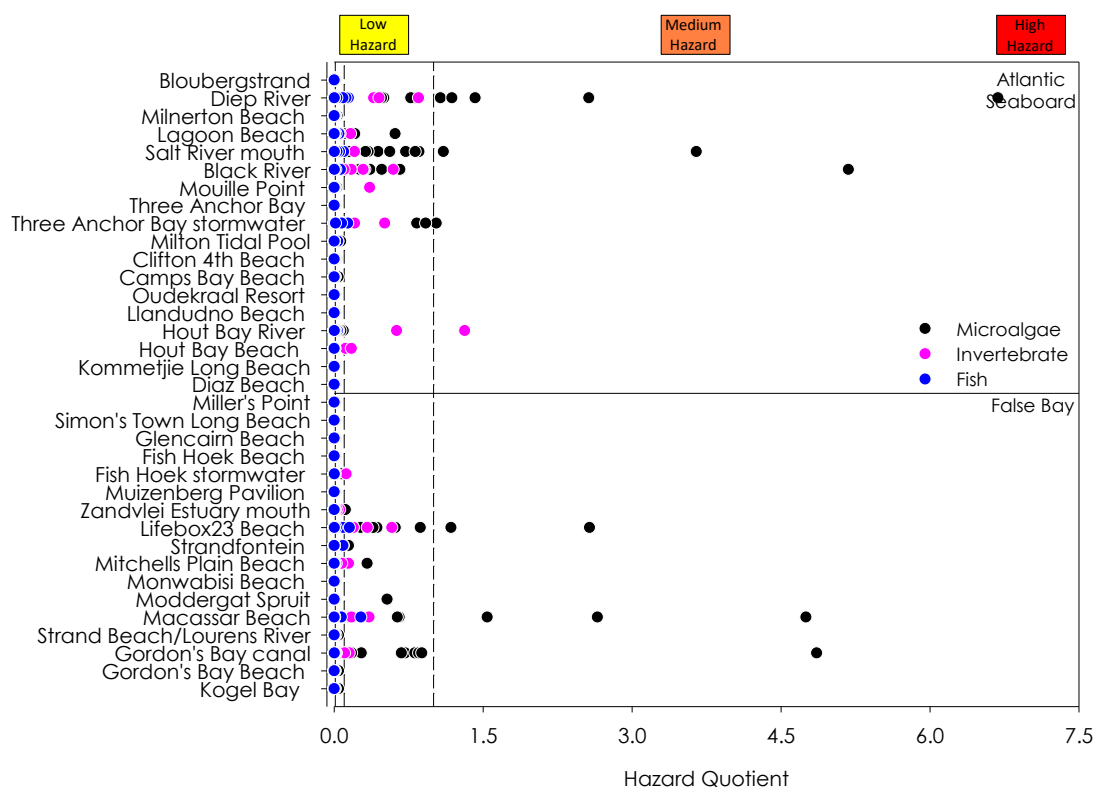


Figure 55. Hazard Quotients for pharmaceutical compound concentrations in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, as determined using toxicity information provided by Kuzmanović *et al.* (2015) for freshwater biota.

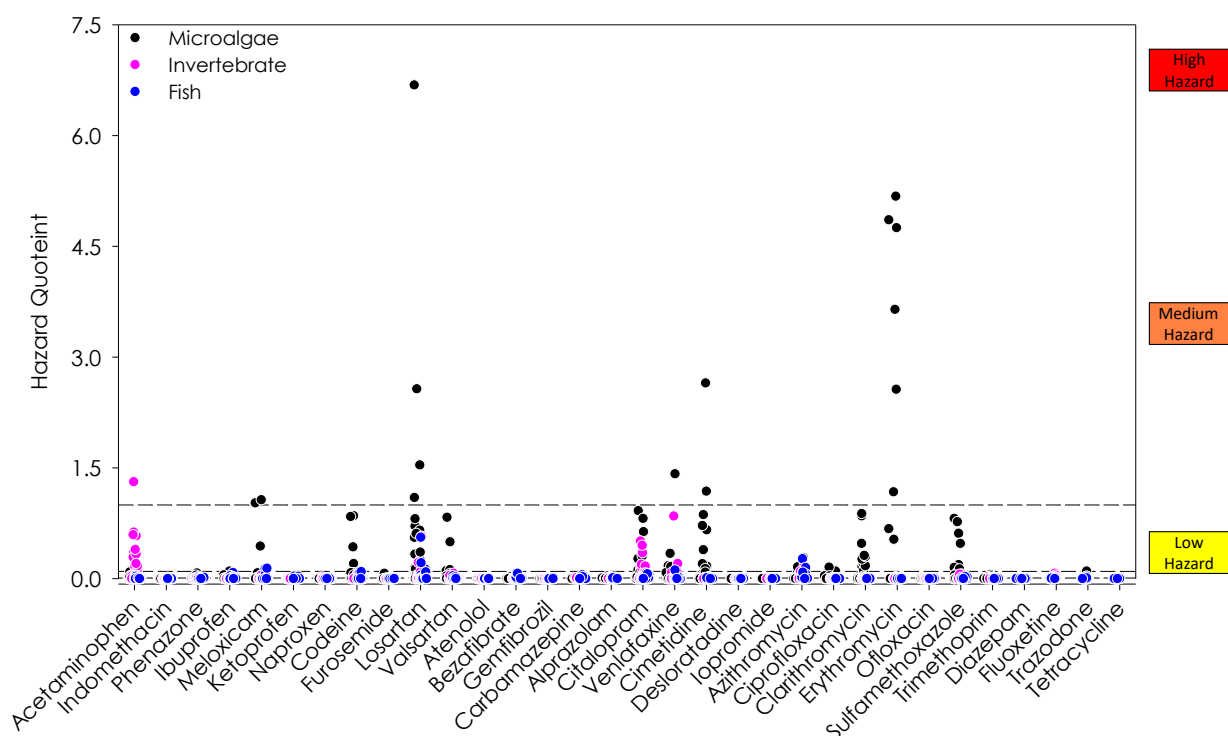


Figure 56. Hazard Quotients for pharmaceutical compounds in water samples collected in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Kuzmanović *et al.* (2015) for freshwater biota.

The highest environmental hazards to microalgae, invertebrates, and fish, regardless of the compounds causing the hazard, are thus evident (not in order as

the hazard varies amongst biota) in the Diep River, at Lagoon Beach, in the Salt River mouth, near the Athlone wastewater treatment works in the Black

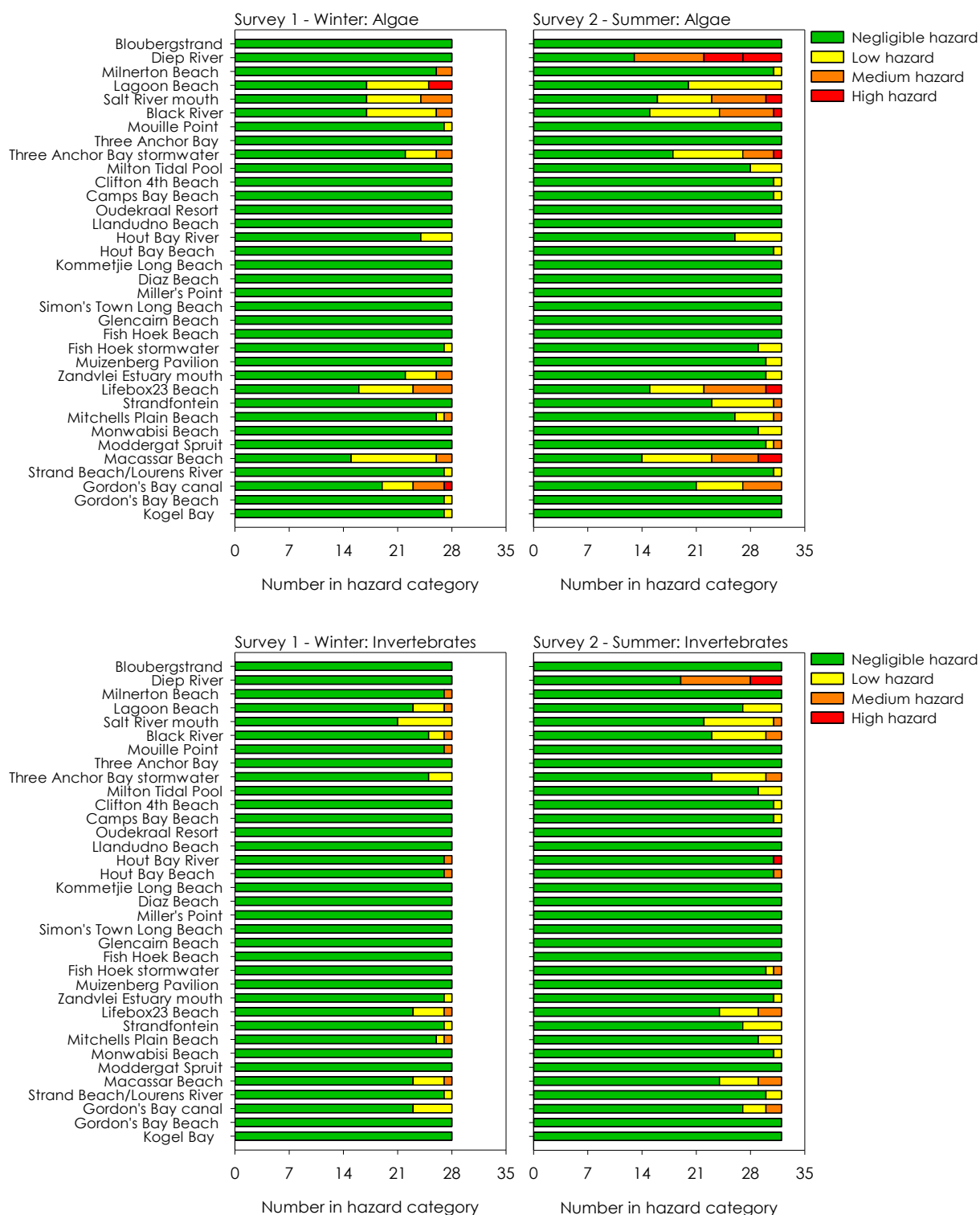


Figure 57. The number of Hazard Quotients (i.e. pharmaceutical compounds) falling into different hazard classes in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Kuzmanović *et al.* (2015) for freshwater biota. This figure continues on the following page.

River, in stormwater at Three Anchor Bay, in the Zandvlei Estuary mouth, at Lifebox23 Beach and Macassar Beach, and near the Gordon's Bay canal mouth. As stated above, however, the hazard is medium to usually low or negligible (Figures 55 - 57).

Pharmaceutical compounds usually are not found in water in isolation but as a mixture of compounds (see for example Figure 5). There is a poor understanding on the environmental hazard posed by mixtures of compounds, but they could interact in such a way to increase the hazard posed by



Figure 57 continued. The number of Hazard Quotients (i.e. pharmaceutical compounds) falling into different hazard classes in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Kuzmanović *et al.* (2015) for freshwater biota.

individual compounds. To provide an estimate of the potential environmental hazard posed by mixtures of pharmaceutical compounds analysed in water for this study a cumulative Hazard Quotient was computed. This is the sum of the Hazard Quotients for individual compounds at a site. The same ranking used to assess Hazard Quotients for individual compounds were also used to assess the cumulative Hazard Quotient. The cumulative Hazard Quotient was >1 for microalgae at several sites, reaching a maximum of 16.7 for the Diep River site in summer. The cumulative Hazard Quotient for few coastal sites was >1, most notably at Lifebox23 Beach, Macassar Beach, and near the Gordons Bay canal. The cumulative Hazard Quotient for invertebrates and fish was >1 for far fewer sites and was restricted to sites in freshwater sites.

The situation is different if Hazard Quotients are computed using Predicted No Effect Concentrations provided by Minguez *et al.* (2016), which as stated above are largely for marine microalgae. The Hazard Quotient for acetaminophen, azithromycin, clarithromycin, sulfamethoxazole, trimethoprim, and citalopram at numerous sites is >1, in some cases considerably so (Figures 59 - 61). For example,

the Hazard Quotient for clarithromycin at five sites in winter was between 336.9 - 2571.7 and at six sites in summer was between 525.6 - 2666.7 (Figure 58). The Predicted No Effect Concentration for clarithromycin is very low and this accounts for almost all the very high Hazard Quotients. To place this into perspective, the Predicted No Effect Concentration computed for freshwater microalgae using clarithromycin toxicological information provided by Kuzmanović *et al.* (2015) is 0.850 ng.l⁻¹, compared to a Predicted No Effect Concentration of 0.0152 ng.l⁻¹ provided by Minguez *et al.* (2016) for marine microalgae (a 56 fold difference). The Predicted No Effect Concentration provided by Minguez *et al.* (2016) is so low clarithromycin concentrations reported as one-half the Limit of Quantification return a Hazard Quotient of 14.2 for freshwater and 53.4 for seawater samples. The low Predicted No Effect Concentration is partly a consequence of the fact that Minguez *et al.* (2016) used an Assessment Factor of 10 000 rather than the traditional 1 000 to compute Predicted No Effects Concentrations for the marine environment. However, even if an Assessment Factor of 1 000 is used to compute a Predicted No Effect Concentration for marine microalgae all quantifiable

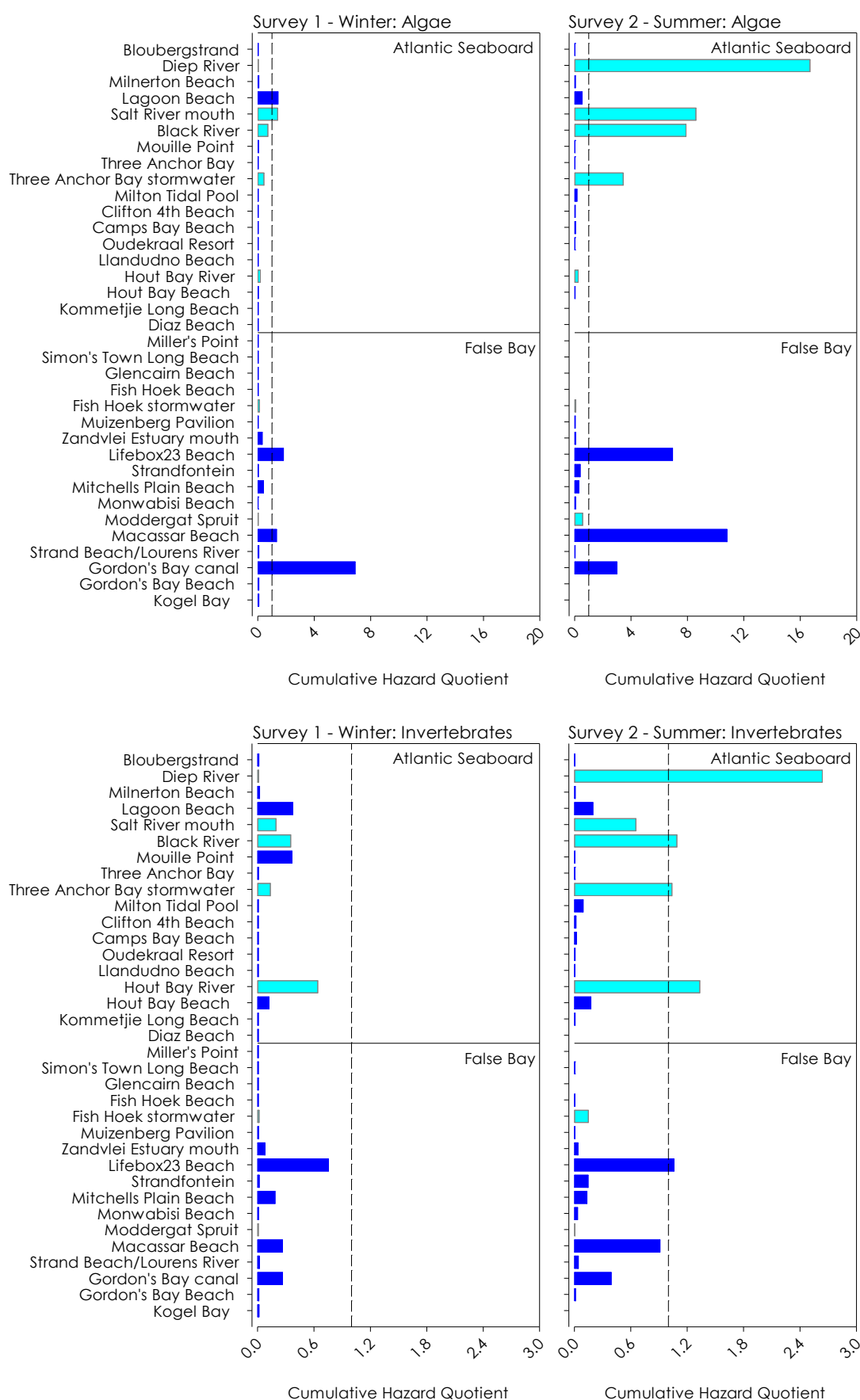


Figure 58. The cumulative Hazard Quotient for pharmaceutical compounds in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Kuzmanović *et al.* (2015) for freshwater biota.

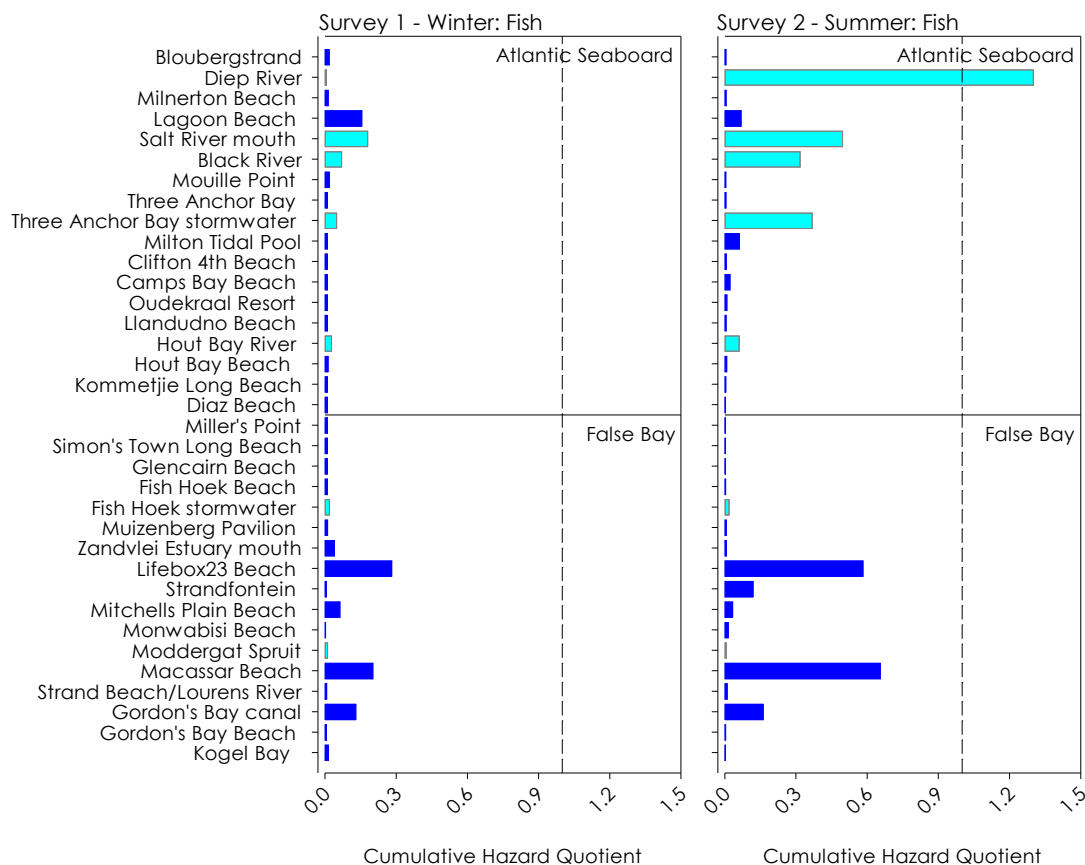


Figure 58 continued. The cumulative Hazard Quotient for pharmaceutical compounds in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Kuzmanović *et al.* (2015) for freshwater biota.

clarithromycin concentrations still present a Hazard Quotient >1. The acetaminophen concentrations at four sites present a Hazard Quotient ranging between 1.1 - 71.0 in winter and 1.1 - 148.5 in summer, but here many of the highest Hazard Quotients are for sites in rivers (Figure 60). The concentrations of acetaminophen, azithromycin, venlafaxine, sulfamethoxazole, trimethoprim, and citalopram at numerous sites, and ketoprofen, valsartan, propranolol, carbamazepine, and naproxen concentrations at one to a few sites present a medium hazard. Most compound concentrations present a low or negligible hazard (Figures 60 and 61).

The highest environmental hazards, regardless of the compounds causing the hazard, are evident at (not in order) Diep River, Lagoon Beach, in the Salt River mouth, near the point where the Athlone wastewater treatment works discharges into the Black River, at Mouille Point, in stormwater at Three Anchor Bay, in the Hout Bay River, in the Zandvlei Estuary mouth, at Lifebox23 Beach, Mitchells Plain Beach and Macassar Beach, and near the Gordon's

Bay canal mouth (Figure 60).

The cumulative Hazard Quotient was far >1 at numerous sites, being highest near the Gordons Bay canal in winter and summer (Figure 62). Once again, the high cumulative Hazard Quotients largely reflect the high Hazard Quotients for clarithromycin.

Not surprisingly the sites presenting the highest acute environmental hazard using toxicological information provided by Kuzmanović *et al.* (2015) and Minguez *et al.* (2016) are generally those that are most strongly influenced directly or indirectly by discharges from wastewater treatment works.

Based on the fish plasma model, in winter only the irbesartan concentration in water sampled near the Gordon's Bay canal mouth exceeded the Critical Environmental Concentration. In other words, this is the only pharmaceutical compound concentration with a high likelihood of causing a pharmacological response in fish. The Concentration Ratio for irbesartan, desloratadine, citalopram, and azithromycin at a few sites was between 1 - 10,

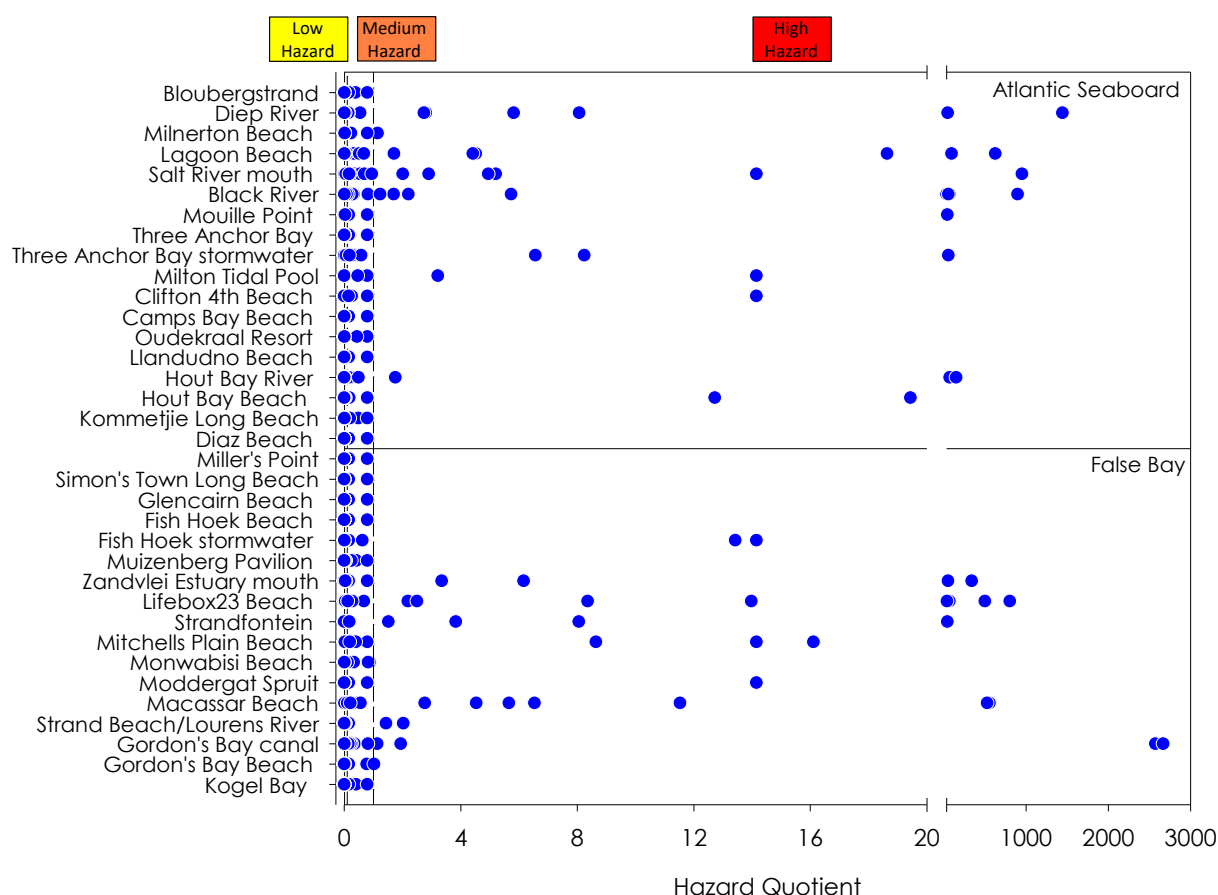


Figure 59. Hazard Quotients for pharmaceutical compound concentrations in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Minguez *et al.* (2016). Note that the Negligible Hazard area is not denoted by a name for space reasons but is situated to the left of the Low Hazard classification.

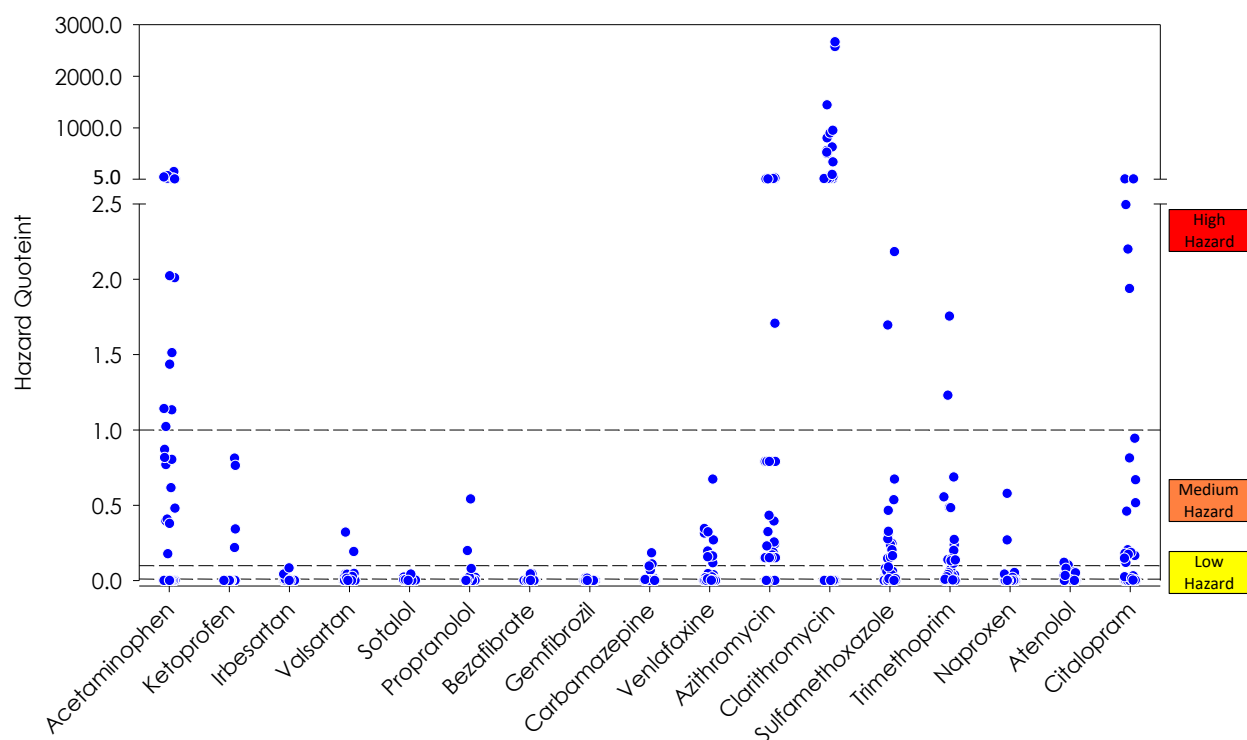


Figure 60. Hazard Quotients for pharmaceutical compounds in water samples collected in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Minguez *et al.* (2016).

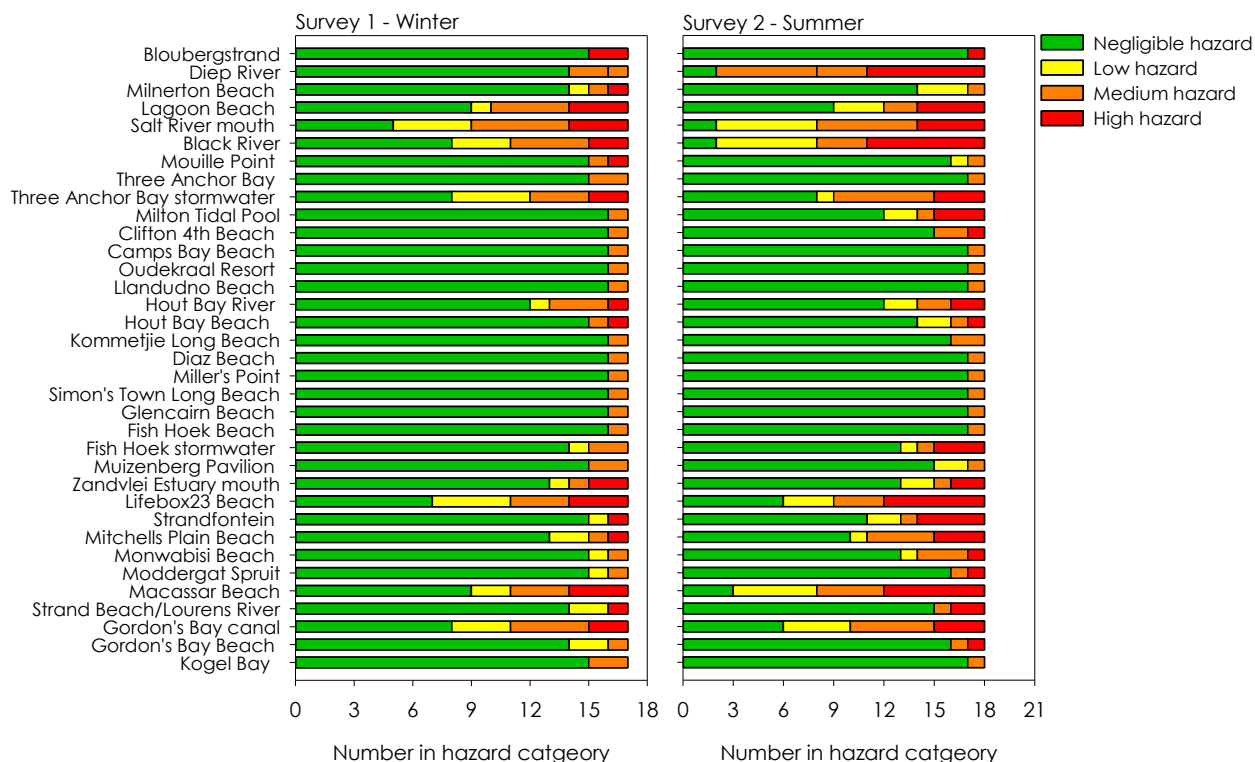


Figure 61. The number of Hazard Quotients (i.e. pharmaceutical compounds) falling into different hazard classes in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Minguéz *et al.* (2016).

presenting a medium hazard. The concentrations of other pharmaceutical compounds present a low to negligible hazard. In summer, the irbesartan concentration in water at six sites and citalopram concentration at three sites exceeded the Critical Environmental Concentration. The Concentration Ratio for losartan, irbesartan, valsartan, venlafaxine, desloratadine, citalopram, alprazolam, and azithromycin at a few sites was between 1 - 10, presenting a medium hazard.

Most of the sites where a medium or high hazard is possible are strongly directly or indirectly influenced by discharges from wastewater treatment works (Figure 64).

Based on the combined outcome of the above hazard assessments, the potential for a high hazard is largely limited to microalgae. Ojemaye and Petrik (2021) report a similar trend for pharmaceutical compounds in seawater in False Bay. Although the potential hazard to microalgae was limited to relatively few coastal sites, since microalgae constitute the base of the food web in coastal ecosystems the hazards could, if realised, lead to impacts through food webs (i.e. at ecosystem scale).

5. Conclusions

The aim of this study was to perform a preliminary assessment of the prevalence and concentrations of pharmaceutical compounds in coastal and some possible source waters along the Atlantic Seaboard and False Bay coast in Cape Town. Water was sampled in the winter and summer of 2021 at 28 coastal (surf zone) sites, at five sites in rivers, and at two stormwater discharge points. In winter, 37 of the 58 pharmaceutical compounds analysed were found at a quantifiable concentration in water at one or more of the 35 sites, compared to 45 in summer. These are the first records for many of the pharmaceutical compounds in South African coastal and/or fresh waters. At least one pharmaceutical compound was found at each site, but not necessarily in each survey. The highest number of compounds found at a site was 28 in winter and 36 in summer. The highest concentrations for most compounds were found in water in rivers that are strongly directly influenced, and at coastal sites that are strongly indirectly influenced via catchment flows by discharges from wastewater treatment works. The implication is wastewater is the main

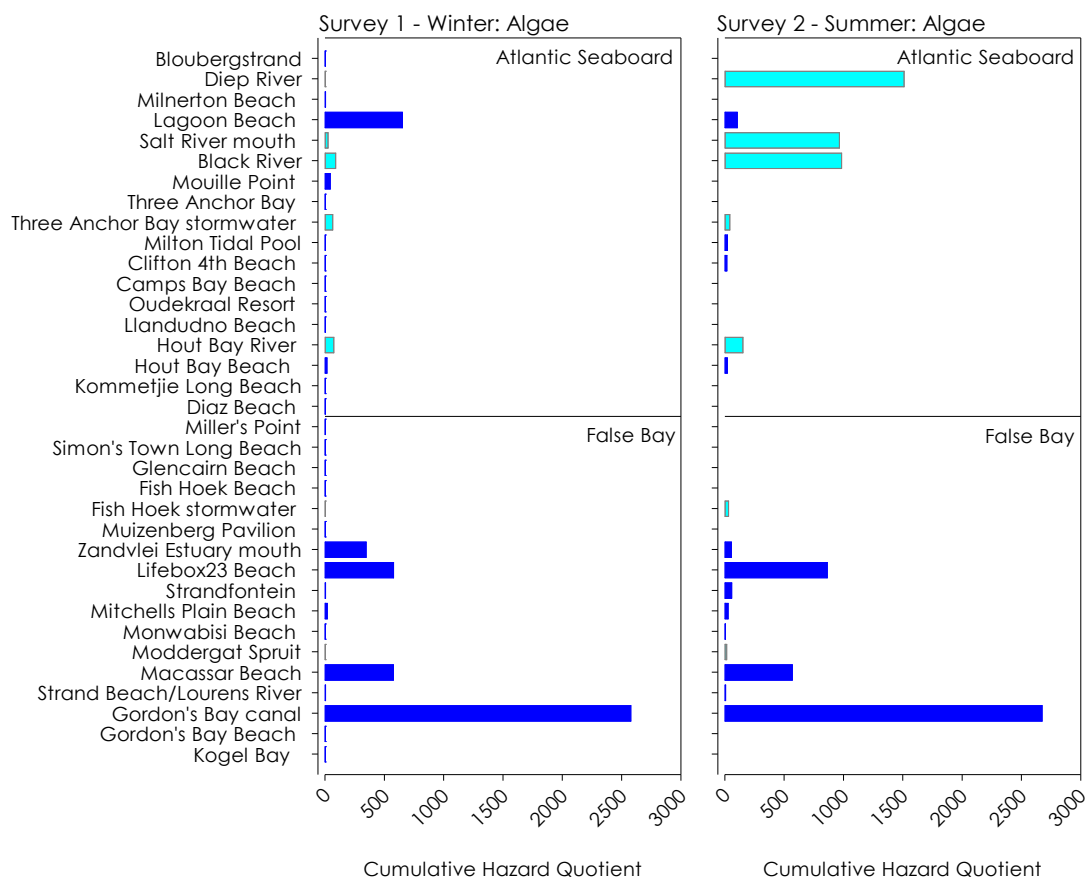


Figure 62. The cumulative Hazard Quotient for pharmaceutical compounds in water samples collected at different sites in the City of Cape Town on the 24th of August and 7th of December 2021, determined using toxicological information provided by Mínguez *et al.* (2016).

source of the pharmaceutical compounds found in Cape Town coastal waters.

Some pharmaceutical compounds analysed in this study are effectively degraded and removed, but not eliminated by processes in conventional wastewater treatment works and have relatively short half-lives in the aquatic environment. Despite this the compounds were found at high concentrations in water at some coastal sites. This probably reflects the high concentrations of these compounds remaining in treated or partially treated wastewater that is discharged continuously into the coastal environment and into catchments that flow into the sea. Other possible routes for the entry of these compounds into aquatic ecosystems, such as leaks in the sewer infrastructure, sewer overflows that enter the stormwater infrastructure, and untreated wastewater arising from informal settlements with inadequate or absent sewerage infrastructure, undoubtedly contribute to their presence in Cape Town's coastal waters. However, these sources are likely to be less important in terms of loads than discharges from wastewater treatment works.

Some coastal sites where pharmaceutical compounds were found are quite far from areas where a strong wastewater influence is expected. This implies chemicals, such as pharmaceutical compounds, that originate in wastewater may be transported along the coast far from their source, or there are unidentified sources near the sites. The number of pharmaceutical compounds found, and their total concentration varied widely amongst the sites surveyed, being low at many of the more remote sites but also at some sites in more populated areas near potential sources.

The findings of this study are consistent with the findings of other studies in Cape Town and with studies elsewhere in South Africa and the world, which have shown pharmaceutical compounds to be common and often ubiquitous contaminants of coastal and freshwater systems in coastal cities. Ojemaye and Petrik (2021), for example, found pharmaceutical compounds in each water sample they collected at eight sites between Millers Point and Rooi Els in False Bay. The concentrations of numerous compounds found in this study were, in

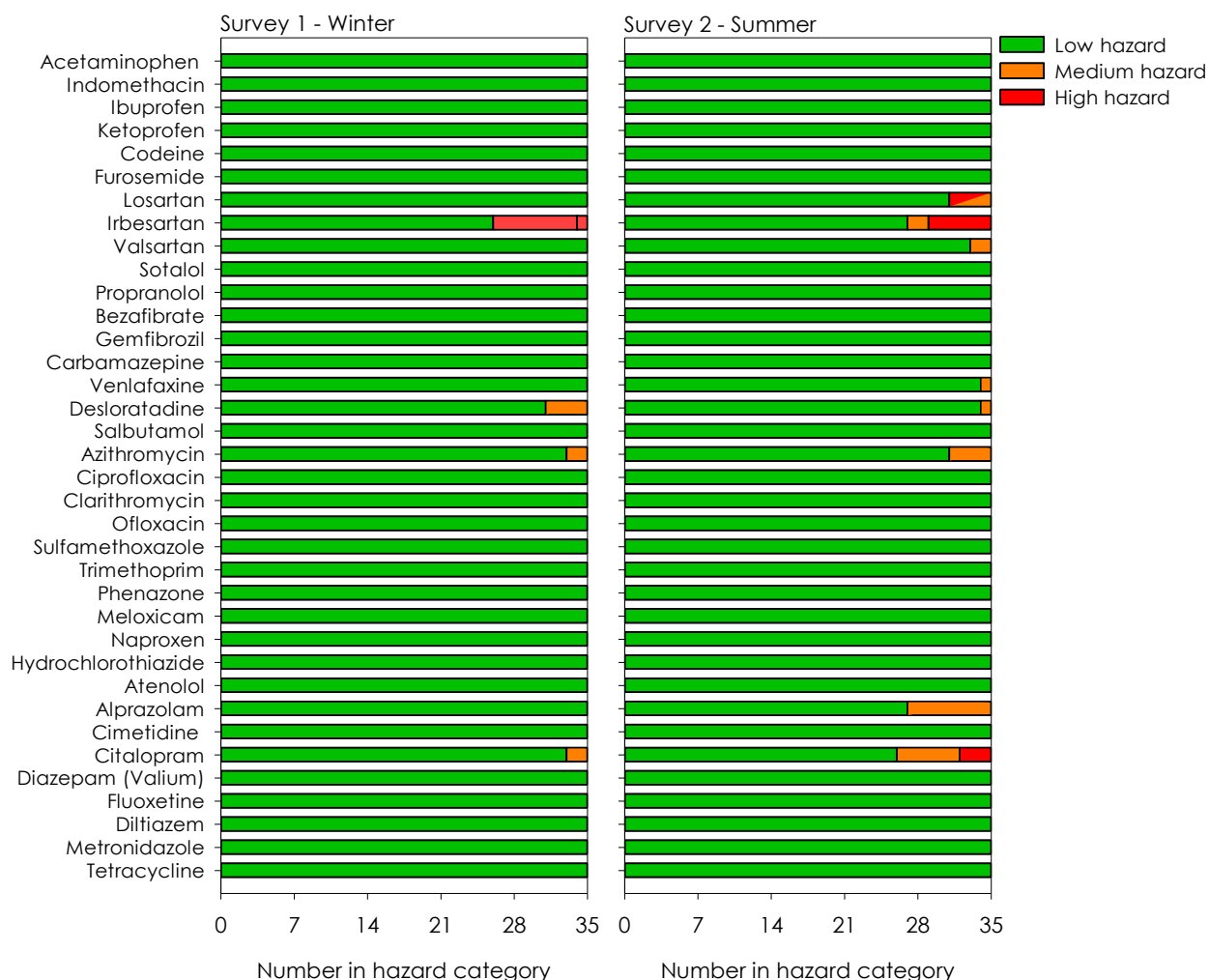


Figure 63. The number of Concentration Ratios for different pharmaceutical compounds falling into different hazard classes in water samples collected at different sites in the City of Cape Town on the 24th of August 2021, determined using Critical Environmental Concentrations provided by Fick *et al.* (2010).

some cases considerably higher than concentrations reported previously in coastal waters in Cape Town and elsewhere in South Africa and the world, while others were at comparable or lower concentrations.

The types and concentrations of pharmaceutical compounds found will vary from one area to another depending on local prescription and use patterns, the positions of study sites relative to wastewater treatment works discharges or other important human sources of these compounds, and prevailing meteorological, hydrological, and oceanographic conditions amongst other factors. Infrequent water sampling, as was done for this study, has limitations, including that the time when water is sampled may or may not coincide with episodic pollution events or hydrological and oceanographic conditions that concentrate or disperse chemicals at a site. It should not, therefore, be concluded that pharmaceutical compounds will always be largely absent at sites

where they were rarely found in this study, or that they will always be present at low concentrations if this was the case. Sampling at other times may reveal their presence, including at higher concentrations. The opposite of course also holds true. The trends at sites where high numbers and concentrations of pharmaceutical compounds were found in winter and summer do, however, probably reflect that this is often or consistently the case.

The pharmaceutical compounds common to this and recent studies in Cape Town by Petrik *et al.* (2017) in the Green Point area and Ojemaye and Petrik (2021) in False Bay were found less often amongst sites in this study, but usually at a considerably higher concentration. The positions where Ojemaye and Petrik (2021) sampled water in False Bay are near some positions where water was sampled for this study, the smallest separation between sites being ~100 m and largest ~2.15 km. The survey by

Ojemaye and Petrik (2021) was performed ~3 years prior to the surveys discussed in this report. The difference in the frequency that pharmaceutical

they are usually found in coastal waters, or that toxic effects are likely to be limited to certain situations (Brain, 2006; Miege, 2006; Leinert, 2007). There is,

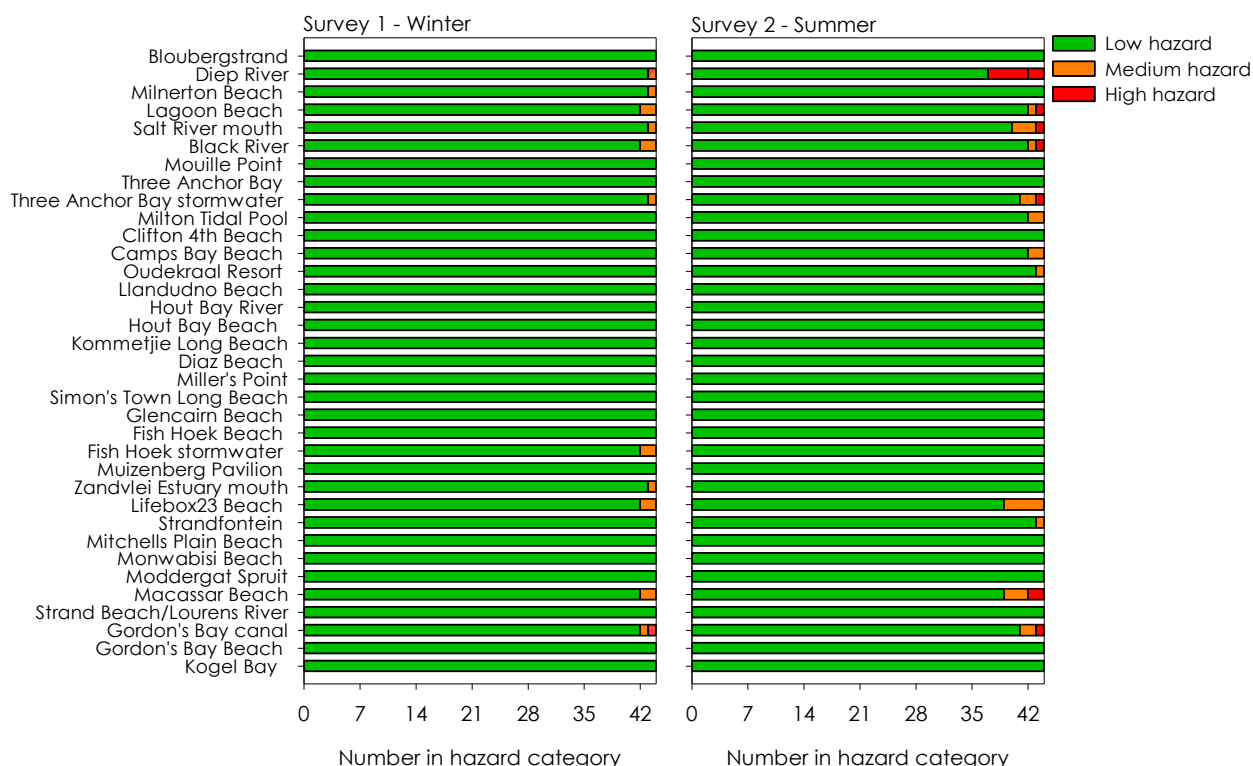


Figure 64. The number of Concentration Ratios (i.e. pharmaceutical compounds) falling into different hazard classes in water samples collected at different sites in the City of Cape Town on the 24th of August 2021, determined using Critical Environmental Concentrations provided by Fick *et al.* (2010).

compounds were found and their concentrations between these studies might reflect a difference in the loading of compounds from sources or hydrological and oceanographic conditions prevailing at the time of the surveys. Regardless of the cause, the differences allude to large changes in pharmaceutical compound concentrations at any position in False Bay over time. The pharmaceutical compound concentrations reported by Ojemaye and Petrik (2021) do not show spatial trends as strongly linked to wastewater sources as the trends evident in this study. Amongst the highest concentrations of some compounds reported by Ojemaye and Petrik (2021) were in fact found at the remote Kogel Bay and Rooi Els sites on the eastern shore of False Bay.

It is not easy to determine if pharmaceutical compounds in coastal waters in Cape Town are posing an environmental hazard because there is limited information on their toxicity to coastal biota. Some investigators are of the opinion most pharmaceutical compounds are unlikely to pose an acutely toxic hazard to biota at the concentrations

however, clear evidence that some compounds do adversely affect biota, such as the hormones found in female contraceptives that cause feminisation in the males of some fish (e.g. Jobling *et al.*, 2003) and citalopram that alters the behaviour of some fish (e.g. Kellner *et al.*, 2015). Chronic (usually sub-lethal and longer-term) impacts have been documented for many compounds in the laboratory, but usually not at concentrations common in fresh and marine waters. The environmental hazard posed by most pharmaceutical compounds found in this study to biota is estimated to be low or negligible, but some may pose a moderate hazard and a few a high hazard. The highest hazards are estimated for microalgae, and the lowest for fish. Not surprisingly, the highest hazards are estimated at sites strongly directly or indirectly influenced by discharges from wastewater treatment works.

6. Recommendations

A major advantage in monitoring pharmaceutical compounds in coastal (and any other) waters is their presence provides incontrovertible evidence for an

anthropogenic impact, and more specifically usually an impact attributable to wastewater discharge (including from agriculture). Pharmaceutical compounds are thus effective tracers of wastewater in aquatic environments and there is merit in monitoring these compounds in coastal (and other) waters in Cape Town if the aim is to identify and rank areas impacted by wastewater (whether directly or indirectly). This includes areas that may be in the transport and dispersion trajectory of wastewater from distant sources. Pharmaceutical compounds are also useful indicators for identifying stormwater flows contaminated by wastewater because of sewer leaks into or illegal sewer connections to stormwater infrastructure. In this study, the presence of pharmaceutical compounds in stormwater at Three Anchor Bay and Fish Hoek Beach provide clear evidence for sewage ingress into the catchments for this stormwater infrastructure. The sources of the ingress need to be identified.

A drawback is that the analysis of pharmaceutical compounds is expensive. Other compounds that are also effective tracers of wastewater and can be analysed more cost effectively must thus also be considered depending on the study aims. As stated above, a major challenge is the limited information on the toxicity for most pharmaceutical compounds, especially to estuarine and marine biota, and consequent difficulty in estimating their hazard (the 'so what' question). If pharmaceutical compounds are monitored in Cape Town's coastal waters, it will not be possible to conclude with a high level of confidence if measured concentrations are posing an environmental hazard until our understanding on their toxicity improves, or if direct toxicity testing specifically aimed at these compounds is implemented.

The monitoring of pharmaceutical compounds in coastal (and other) waters by the City of Cape Town thus requires careful consideration and must have clear aims. If such studies are implemented, they should be performed periodically rather than as an annual compliance monitoring tool. If the city identifies a need to use pharmaceutical compounds as a tool to identify spatial trends in wastewater loading and to trace the dispersion of wastewater in coastal waters, or to identify stormwater that is contaminated by wastewater, a narrower suite of

compounds can be analysed compared to this study in the interests of cost effectiveness. Based on the findings of this study the targeted compounds should include acetaminophen, ofloxacin, valsartan, sulfamethoxazole, carbamazepine, and bezafibrate. Indeed, the analysis could be restricted to acetaminophen and one or two other compounds. These compounds are identified based on their frequency of detection and/or concentrations found in this study and because they are known to be present in the effluent of wastewater treatment works at elevated concentrations, leading to their pseudo-persistence in surface waters. The above list of compounds is not exhaustive in the context of monitoring. Targeted compounds in future studies should be finalised based on the findings of other studies provided in the scientific literature, including in Cape Town. For example, Petrik *et al.* (2017), Ojemaye and Petrik (2019), and Ojemaye and Petrik (2021) report the ubiquity of diclofenac in seawater collected in Cape Town. In this study, however, diclofenac was not found at a quantifiable concentration in any sample despite using different methods for its analysis. Persistent interferences precluded its quantification. Diclofenac is often detected at high frequency in studies elsewhere and this has led to being recommended as an effective wastewater tracer. As new toxicological information becomes available this information should also be used to identify and prioritise compounds for monitoring, focussing on those likely to pose the greatest hazard.

There are other compounds, including sucralose (artificial sweetener) and caffeine, that have proved to be more effective wastewater tracers than pharmaceutical compounds in some circumstances (*e.g.* Yang *et al.*, 2017; Cantwell *et al.*, 2019; White *et al.*, 2019). These compounds should thus also be considered, including potentially in preference to pharmaceutical compounds from an analytical cost effectiveness perspective. The current use of faecal indicator bacteria as water quality indicators by the City of Cape Town should not be discounted. There is, however, sometimes uncertainty on the specific sources of these bacteria (*i.e.* human versus animal) in coastal waters and this drives the need to identify more specific tracers of wastewater depending on the study objectives. However, in the case of the Cape Town it is probable microbiological impairment

of coastal and freshwater quality has a predominantly human sewage/wastewater source. The findings of this study show, however, that faecal indicator bacteria numbers and pharmaceutical compound concentrations were not strongly linked, and pharmaceutical compounds appear to provide a more effective tracer of wastewater than faecal indicator bacteria at many sites.

Pharmaceutical compounds have had such a profound impact on society it is inevitable they will continue to be produced and used by man for the foreseeable future. The only way of reducing their entry to, and impacts in the environment is to control their uses and emissions from anthropogenic sources. Improving treatment processes at wastewater treatment works in Cape Town will reduce, but not eliminate pharmaceutical compounds reaching coastal waters as conventional treatment process are ineffective at removing many of these compounds from wastewater. The required improvements in wastewater treatment might not be possible in the short- or medium-term since the technologies needed to deal effectively with pharmaceutical compounds are expensive and none is effective in removing all compounds. Some technologies (*e.g.* reverse osmosis) also come with their own environmental costs (*e.g.* higher energy use). Nevertheless, reducing the load of pharmaceutical compounds in effluent discharged from wastewater treatment works should be a key goal of the City of Cape Town, and indeed of municipalities across South Africa. The load of pharmaceutical compounds reaching surface waters from informal settlements is unknown but is potentially high due to the poor or non-existent sanitation infrastructure in most settlements. Providing and improving sanitation infrastructure in informal settlements should also be a key goal, in addition to improving the dignity and health of these communities.

The City of Cape Town might consider a programme to educate the public on the hazards posed by human and veterinary pharmaceutical compounds in the environment, to change personal behaviour in terms of their use and disposal. This could include sensitising and educating the medical and veterinary fraternities, so they do not over-prescribe drugs, and where alternative drugs that have the same efficacy

for the same therapeutic use are available they prescribe drugs that pose the least environmental hazard. Many persons reading this report can probably attest to not using the full prescription of drugs due to feeling better before the prescription is used. The drugs will thus have been discarded down the drain or into landfills. The significance of down the drain drug disposal compared to other sources of pharmaceutical compounds to wastewater treatment works is unknown but is probably significant. Education initiatives might thus recommend the disposal of expired or unused drugs with household solid waste rather than down the drain if they cannot be returned to the producer, for example.

The medical and veterinary fraternities can only prescribe drugs with the least environmental hazard if this information is easily available, which is not the case for many compounds. The reality is the toxicity, particularly chronic toxicity, of most pharmaceutical compounds is poorly documented or unknown. This type of educational programme will thus need to involve the sharing of information by the pharmaceutical industry. Sweden has implemented a programme in this context and insights from the programme will be helpful. However, whether the responsibility for such a programme should fall onto the City of Cape Town rather than a national government department is debatable.

Ideally, a mechanism should be in place for the collection and proper disposal of unused or expired drugs from the public, such as in British Columbia in Canada (BC Pharmacy, 2019) and Australia (Bergen *et al.*, 2013). However, the scientists that prepared this report could find few comparable schemes in other countries, which might reflect the difficulty in their implementation or simply a lack of will or knowledge on the benefits of initiating such programmes. Pharmaceutical producers and pharmacies could take the initiative in this regard but will probably not be inclined to do so unless the South African government provides a financial incentive for doing so, since this will come at a cost.

There is a need to increase our understanding on the hazard posed by pharmaceutical compounds to estuarine and marine biota though laboratory-based testing at environmentally relevant concentrations.

However, this research is not necessarily the responsibility of the City of Cape Town (or any other municipality) but should rather be funded by research agencies (e.g. National Research Foundation, Water Research Commission) and the pharmaceutical industry. The point is made here as a call to the broader scientific community, research funding agencies, and pharmaceutical companies in South Africa to pursue and support this research, rather than to the City of Cape Town to do so. The City of Cape Town could of course fund this research should it identify an advantage in generating this knowledge.

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8. Appendices

Appendix 1. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 24th of August 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		<i>E. coli</i>	Faecal enterococci	Aceta-minophen	Indomethacin	Ibuprofen	Ketoprofen	Codeine	Furosemide	Losartan	Irbesartan
Site	Site description	(cfu/100ml)	(cfu/100ml)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	23	6	30.8	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	1.4
CT2	Diep River	46	20	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT3	Milnerton Beach	44	10	92.9	<LOD	<LOD	<LOD	19.1	<LOD	<LOD	1.2
CT4	Lagoon Beach	3100	280	1517.0	<LOD	54.6	<LOD	146.5	<LOD	110.2	49.0
CT5	Salt River mouth	16000	1400	163.6	<LOD	6.6	452.8	368.2	409.9	100.5	25.1
CT6	Black River	50000	4000	2672.2	<LOD	11.4	289.5	72.0	216.4	45.9	15.4
CT7	Mouille Point	143	23	3282.2	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOQ
CT8	Three Anchor Bay	20	15	14.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ
CT9	Three Anchor Bay stormwater	2500	2200	670.2	<LOD	39.5	<LOD	105.4	<LOD	27.4	10.4
CT10	Milton Tidal Pool	1	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ
CT11	Clifton 4 th Beach	25	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ
CT12	Camps Bay Beach	9	<1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ
CT13	Oudekraal Resort	1	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ
CT14	Llandudno Beach	2	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	20000	2000	5781.5	<LOD	21.7	<LOD	23.8	<LOD	<LOD	<LOD
CT16	Hout Bay Beach	<1	<1	1035.3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	2	<1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	1	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<1	<1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	26	151	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	14	60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	93	12	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	135	50	50.2	<LOD	<LOQ	<LOD	17.6	<LOD	<LOD	8.0
CT24	Muizenberg Pavilion	5	3	33.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	1100	142	501.0	<LOD	57.9	<LOD	23.8	<LOD	20.0	6.6
CT26	Lifebox23 Beach	20000	1500	5327.3	<LOD	408.2	<LOD	113.9	172.2	108.2	7.9
CT27	Strandfontein	44	48	123.1	<LOD	9.4	<LOD	9.2	<LOD	<LOD	<LOD
CT28	Mitchells Plain Beach	590	1000	1311.5	<LOD	97.9	<LOD	12.5	<LOD	59.6	<LOD
CT29	Monwabisi Beach	5	2	70.9	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT30	Eerste River	294	126	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT31	Macassar Beach	1000	260	938.0	27.7	185.7	<LOD	69.1	159.0	117.7	40.7
CT32	Strand Beach/Lourens River	108	34	116.8	<LOD	<LOD	<LOD	9.6	<LOD	<LOQ	1.4
CT33	Gordon's Bay canal	900	188	92.2	45.6	<LOD	<LOD	67.8	<LOD	128.4	101.7
CT34	Gordon's Bay Beach	22	63	62.6	<LOD	<LOD	<LOD	8.5	<LOD	<LOQ	0.8
CT35	Kogel Bay	<1	<1	32.2	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOQ	<LOQ

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 24th of August 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Valsartan	Sotalol	Propranolol	Atorvastatin	Bezafibrate	Gemfibrozil	Carbamazepine	Venlafaxine	Desloratadine	Salbutamol
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	10.2	<LOD	<LOD	<LOD	<LOD	6.3	<LOQ	<LOD	<LOQ	<LOD
CT2	Diep River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	8.6	6.0	108.0	<LOQ
CT3	Milnerton Beach	7.7	<LOD	<LOD	<LOD	4.2	<LOD	<LOQ	<LOD	68.4	<LOD
CT4	Lagoon Beach	129.0	35.4	36.9	1.0	28.4	<LOD	97.4	63.0	<LOD	<LOD
CT5	Salt River mouth	238.5	16.8	<LOD	2.5	81.6	<LOD	141.3	37.8	<LOD	1.5
CT6	Black River	80.9	3.9	<LOD	<LOD	34.4	<LOD	190.0	14.7	105.0	1.2
CT7	Mouille Point	3.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	3.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	423.2	<LOD	<LOD	0.8	11.2	<LOD	3.2	5.3	<LOD	<LOQ
CT10	Milton Tidal Pool	3.6	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD
CT11	Clifton 4 th Beach	3.3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOD	<LOD	<LOD	2.4	<LOD	<LOD	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ
CT16	Hout Bay Beach	<LOD	<LOD	<LOD	<LOD	2.2	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	2.1	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	13.9	<LOD	<LOD	<LOQ	9.9	<LOD	5.4	<LOD	104.4	<LOQ
CT24	Muizenberg Pavilion	<LOD	<LOD	<LOD	<LOD	2.6	<LOD	<LOQ	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	48.3	<LOD	<LOD	<LOD	28.1	<LOD	14.0	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	97.1	8.8	<LOQ	1.1	78.1	<LOD	105.0	3.4	<LOD	<LOQ
CT27	Strandfontein	6.4	<LOD	<LOD	<LOD	4.2	<LOD	<LOQ	<LOD	<LOD	<LOD
CT28	Mitchells Plain Beach	15.2	<LOQ	<LOD	<LOD	5.5	<LOD	<LOQ	<LOD	<LOD	<LOD
CT29	Monwabisi Beach	5.2	<LOD	<LOD	<LOD	2.9	<LOQ	<LOQ	<LOD	<LOD	<LOD
CT30	Eerste River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	16.4	<LOD	<LOD	<LOQ
CT31	Macassar Beach	194.0	20.1	<LOD	<LOQ	47.1	<LOQ	80.3	12.4	<LOD	<LOQ
CT32	Strand Beach/Lourens River	10.2	<LOQ	<LOD	<LOD	4.0	<LOD	<LOQ	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	130.0	59.4	<LOQ	<LOQ	99.8	<LOQ	122.7	101.3	<LOD	<LOQ
CT34	Gordon's Bay Beach	5.3	<LOD	<LOD	<LOD	2.6	<LOD	<LOQ	<LOD	<LOD	<LOD
CT35	Kogel Bay	4.3	<LOD	<LOD	<LOD	2.3	<LOD	<LOQ	<LOD	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 24th of August 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Iopromide	Azithromycin	Ciprofloxacin	Clarithromycin	Erythromycin	Ofloxacin	Sulfa-methoxazole	Trimethoprim	Phenazone	Meloxicam
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	10.8	<LOQ	<LOD	<LOD	<LOD	10.3	4.6	<LOQ	<LOD	<LOD
CT2	Diep River	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOQ	6.8	<LOD	<LOD	<LOD
CT3	Milnerton Beach	12.3	<LOQ	<LOD	<LOD	<LOD	6.8	10.8	2.7	<LOD	<LOD
CT4	Lagoon Beach	157.4	94.5	<LOD	9.5	<LOD	16.6	174.6	<LOD	6.2	<LOD
CT5	Salt River mouth	<LOD	105.7	42.7	<LOQ	<LOQ	5.4	286.5	63.7	5.8	<LOD
CT6	Black River	<LOQ	<LOQ	45.1	<LOQ	0.5	5.0	148.1	44.3	6.2	<LOD
CT7	Mouille Point	<LOD	<LOQ	<LOD	<LOD	<LOD	5.8	<LOQ	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<LOD	<LOQ	<LOD	<LOD	<LOD	5.4	<LOQ	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	<LOD	<LOQ	<LOD	<LOQ	<LOD	<LOQ	32.8	23.5	<LOD	<LOD
CT10	Milton Tidal Pool	<LOD	<LOQ	<LOD	<LOD	<LOD	5.9	<LOD	<LOD	<LOD	<LOD
CT11	Clifton 4 th Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	5.3	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	5.1	<LOQ	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	<LOD	<LOQ	<LOD	<LOD	<LOD	4.6	<LOQ	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	5.0	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOQ	<LOQ	<LOD	<LOD	<LOQ	127.4	154.7	<LOD	<LOD
CT16	Hout Bay Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	5.5	<LOQ	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	5.7	<LOQ	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	5.3	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	5.6	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	10.2	<LOQ	<LOQ	<LOD	<LOD	<LOQ	7.6	<LOD	<LOQ	14.3
CT24	Muizenberg Pavilion	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	4.9	<LOQ	<LOD	<LOD
CT25	Zandvlei Estuary mouth	80.0	<LOQ	<LOD	5.1	<LOD	<LOD	24.1	<LOD	<LOQ	<LOD
CT26	Lifebox23 Beach	157.0	178.8	203.2	7.6	<LOQ	42.3	359.8	75.4	8.6	<LOD
CT27	Strandfontein	13.0	<LOD	19.1	<LOD	<LOD	<LOD	11.5	2.2	<LOD	<LOD
CT28	Mitchells Plain Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	4.9	<LOD	<LOD	<LOD	<LOD
CT29	Monwabisi Beach	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	10.2	2.9	<LOD	<LOD
CT30	Eerste River	<LOQ	<LOQ	<LOQ	<LOD	<LOD	<LOQ	8.4	<LOD	<LOQ	<LOD
CT31	Macassar Beach	145.5	139.7	75.0	8.4	<LOQ	30.2	167.2	177.1	5.0	<LOD
CT32	Strand Beach/Lourens River	15.8	<LOD	<LOD	<LOD	<LOD	5.8	15.6	12.0	<LOD	<LOD
CT33	Gordon's Bay canal	120.3	<LOD	<LOD	39.1	97.2	6.3	131.8	34.7	5.0	<LOD
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	10.1	3.8	<LOD	<LOD
CT35	Kogel Bay	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	5.3	1.4	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 24th of August 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Naproxen	Hydrochloro- thiazide	Atenolol	10,11-Epoxy- carbamazepine	2-Hydroxy carbamazepine	Alprazolam	Cimetidine	Citalopram	Diclofenac	Salicylic acid
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOD	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOQ	171.4
CT2	Diep River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOQ	<LOD
CT3	Milnerton Beach	<LOD	<LOQ	<LOQ	<LOD	<LOD	<LOD	22.6	<LOQ	<LOQ	129.0
CT4	Lagoon Beach	9.4	102.6	21.4	2.6	8.8	<LOQ	106.7	26.1	<LOQ	<LOD
CT5	Salt River mouth	70.2	841.1	117.8	<LOD	17.6	2.2	159.2	8.4	<LOQ	573.3
CT6	Black River	25.1	886.9	139.9	<LOD	16.1	<LOD	134.6	<LOQ	<LOQ	691.2
CT7	Mouille Point	<LOD	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	215.7
CT8	Three Anchor Bay	<LOD	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	227.2
CT9	Three Anchor Bay stormwater	1182.9	120.7	31.0	<LOD	<LOD	2.4	<LOD	9.1	<LOQ	479.0
CT10	Milton Tidal Pool	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	165.5
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	178.9
CT12	Camps Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	170.7
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	178.1
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	170.5
CT15	Hout Bay River	72.6	69.6	52.2	<LOD	<LOD	<LOD	14.3	<LOD	<LOQ	683.6
CT16	Hout Bay Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	163.9
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	160.9
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	202.3
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	166.7
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	166.9
CT21	Glencairn Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	81.1
CT22	Fish Hoek Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	157.0
CT23	Fish Hoek stormwater	<LOD	<LOD	15.3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	173.9
CT24	Muizenberg Pavilion	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	137.9
CT25	Zandvlei Estuary mouth	<LOQ	<LOQ	20.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	38.2
CT26	Lifebox23 Beach	59.0	279.2	333.6	0.8	<LOD	<LOD	308.0	6.1	<LOQ	1180.1
CT27	Strandfontein	<LOD	<LOQ	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOQ	184.4
CT28	Mitchells Plain Beach	<LOD	147.9	254.5	<LOD	<LOD	<LOD	<LOD	1.0	<LOQ	63.9
CT29	Monwabisi Beach	<LOD	<LOQ	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOQ	169.6
CT30	Eerste River	<LOD	<LOD	15.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD
CT31	Macassar Beach	16.8	315.2	91.5	3.5	8.4	<LOQ	41.8	10.3	<LOQ	117.4
CT32	Strand Beach/Lourens River	<LOD	<LOQ	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOQ	126.3
CT33	Gordon's Bay canal	20.4	452.6	30.8	13.1	12.5	<LOQ	22.1	41.1	<LOQ	42.4
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	163.2
CT35	Kogel Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	156.6

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 24th of August 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Piroxicam	Clopidogrel	Acridone	Diazepam	Fluoxetine	Lorazepam	Norfluoxetine	Paroxetine	Sertraline	Trazodone
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT2	Diep River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT3	Milnerton Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT4	Lagoon Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT5	Salt River mouth	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT6	Black River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT7	Mouille Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT10	Milton Tidal Pool	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT16	Hout Bay Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT24	Muizenberg Pavilion	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT27	Strandfontein	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT28	Mitchells Plain Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT29	Monwabisi Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT30	Eerste River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT31	Macassar Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT32	Strand Beach/Lourens River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT35	Kogel Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 24th of August 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Diltiazem	Pravastatin	Metoprolol	Nadolol	Ranitidine	Tamsulosin	Cefalexin	Metronidazole	Metronidazole_O H	Tetracycline
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT2	Diep River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT3	Milnerton Beach	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT4	Lagoon Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT5	Salt River mouth	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT6	Black River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT7	Mouille Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT10	Milton Tidal Pool	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT16	Hout Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT24	Muizenberg Pavilion	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT27	Strandfontein	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT28	Mitchells Plain Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT29	Monwabisi Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT30	Eerste River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT31	Macassar Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT32	Strand Beach/Lourens River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT35	Kogel Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Appendix 2. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 7th of December 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		<i>E. coli</i>	Faecal enterococci	Aceta-minophen	Indomethacin	Ibuprofen	Ketoprofen	Codeine	Furosemide	Losartan	Irbesartan
Site	Site description	(cfu/100ml)	(cfu/100ml)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	24	6	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOQ
CT2	Diep River	20000	1400	3647.0	14.3	<LOD	<LOD	1514.5	1404.7	1203.2	841.1
CT3	Milnerton Beach	40	21	<LOD	<LOD	<LOD	<LOD	9.0	<LOD	<LOD	<LOQ
CT4	Lagoon Beach	280	85	367.5	<LOD	<LOD	<LOD	92.0	<LOD	<LOQ	70.8
CT5	Salt River mouth	220000	9600	423.1	11.6	10.1	1011.5	1534.3	909.4	197.8	427.5
CT6	Black River	300000	10000	5462.2	12.1	19.7	1074.8	49.3	464.8	64.8	102.1
CT7	Mouille Point	188	20	<LOD	<LOD	<LOD	<LOD	11.8	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<1	<1	<LOD	<LOD	<LOD	<LOD	11.7	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	1200	800	1879.9	<LOD	45.9	<LOD	143.5	1027.1	24.1	<LOD
CT10	Milton Tidal Pool	15	80	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	14.4
CT11	Clifton 4 th Beach	5	<1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<1	<1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	50	82	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	1	2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	62000	3900	12084.7	59.8	12.2	<LOD	75.2	<LOD	<LOD	<LOD
CT16	Hout Bay Beach	13	11	1582.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	18	3	39.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	<1	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	2	10	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	22	11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	4	7	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	5	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	900	320	1092.4	<LOD	<LOD	<LOD	29.3	<LOD	<LOD	<LOQ
CT24	Muizenberg Pavilion	4	14	<LOD	<LOD	<LOD	<LOD	9.4	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	14	21	272.2	<LOD	<LOD	<LOD	8.8	27.3	<LOD	<LOQ
CT26	Lifebox23 Beach	26000	800	3062.0	<LOD	132.8	<LOD	772.6	353.1	462.8	19.7
CT27	Strandfontein	1	2	311.2	<LOD	8.8	<LOD	21.7	<LOD	25.7	<LOQ
CT28	Mitchells Plain Beach	3	22	703.0	<LOD	<LOD	<LOD	<LOD	<LOD	20.5	<LOQ
CT29	Monwabisi Beach	13	1	66.4	<LOD	6.6	<LOD	9.7	<LOD	<LOD	<LOQ
CT30	Eerste River	400	580	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOQ
CT31	Macassar Beach	3400	510	460.2	19.6	200.7	<LOD	114.9	<LOQ	277.2	452.3
CT32	Strand Beach/Lourens River	1	<1	164.6	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	3140	260	65.4	50.7	<LOD	<LOD	70.0	<LOD	146.0	240.9
CT34	Gordon's Bay Beach	7	8	83.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT35	Kogel Bay	<1	<1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 7th of December 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Valsartan	Sotalol	Propranolol	Atorvastatin	Bezafibrate	Gemfibrozil	Carbamazepine	Venlafaxine	Desloratadine	Salbutamol
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	3.7	<LOD	<LOD	<LOD	1.6	<LOD	<LOQ	<LOQ	<LOQ	<LOD
CT2	Diep River	1927.5	424.0	100.6	8.9	433.5	10.8	964.0	901.0	19.8	66.3
CT3	Milnerton Beach	9.7	<LOQ	<LOQ	<LOD	1.7	<LOD	<LOQ	3.5	<LOD	<LOD
CT4	Lagoon Beach	140.0	27.4	<LOQ	<LOD	32.8	<LOD	68.4	50.8	9.0	<LOQ
CT5	Salt River mouth	267.9	52.7	14.8	28.0	453.6	5.0	1103.4	216.6	<LOQ	7.0
CT6	Black River	471.4	60.3	4.4	<LOQ	110.4	<LOD	1835.7	104.2	<LOQ	12.1
CT7	Mouille Point	5.9	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOQ	17.7	<LOD
CT8	Three Anchor Bay	4.2	<LOD	<LOD	<LOD	<LOD	0.8	<LOD	<LOD	9.2	<LOD
CT9	Three Anchor Bay stormwater	3209.9	<LOD	<LOD	44.8	19.0	<LOD	40.3	52.3	31.0	5.7
CT10	Milton Tidal Pool	20.5	<LOD	<LOQ	<LOD	<LOD	11.2	<LOD	5.9	9.2	<LOD
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOQ	<LOD	2.1	112.5	<LOD
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT15	Hout Bay River	40.4	<LOD	<LOD	<LOD	<LOD	<LOD	6.1	<LOQ	<LOD	<LOD
CT16	Hout Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT21	Glencairn Beach	3.0	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	2.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	1.9	<LOD	<LOD
CT23	Fish Hoek stormwater	60.7	<LOQ	<LOQ	<LOD	21.0	<LOD	15.5	7.8	<LOD	<LOD
CT24	Muizenberg Pavilion	9.0	<LOD	<LOD	<LOD	4.7	<LOD	7.8	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	25.6	<LOD	<LOD	<LOD	2.8	<LOD	32.6	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	417.9	18.8	<LOD	<LOQ	62.6	<LOD	679.0	52.9	<LOD	23.7
CT27	Strandfontein	26.9	<LOD	<LOD	<LOD	24.6	<LOD	25.5	3.0	9.4	<LOQ
CT28	Mitchells Plain Beach	16.8	<LOD	<LOQ	<LOD	7.2	<LOD	131.9	3.1	9.1	<LOQ
CT29	Monwabisi Beach	8.4	<LOD	<LOD	<LOD	4.6	<LOD	13.5	<LOD	<LOD	<LOD
CT30	Eerste River	41.7	<LOD	<LOD	<LOD	<LOD	<LOD	88.2	<LOQ	<LOQ	<LOD
CT31	Macassar Beach	248.0	223.3	<LOQ	10.0	102.4	10.1	1001.0	86.6	10.9	118.3
CT32	Strand Beach/Lourens River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	57.8	48.0	3.8	<LOD	49.4	<LOD	222.9	111.0	8.8	<LOD
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	8.4	<LOD
CT35	Kogel Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 7th of December 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Iopromide	Azithromycin	Ciprofloxacin	Clarithromycin	Erythromycin	Ofloxacin	Sulfa-methoxazole	Trimethoprim	Phenazone	Meloxicam
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOQ	<LOQ	<LOQ	<LOD	<LOD	11.7	<LOD	1.0	<LOD	<LOD
CT2	Diep River	<LOQ	172.6	<LOD	21.9	51.3	106.0	1464.0	43.5	51.3	196.6
CT3	Milnerton Beach	<LOD	4.9	<LOD	<LOD	<LOD	8.5	6.5	2.7	<LOD	<LOD
CT4	Lagoon Beach	<LOQ	36.5	<LOQ	1.4	<LOQ	41.7	48.2	8.0	3.8	<LOD
CT5	Salt River mouth	<LOQ	<LOQ	<LOD	14.4	72.9	13.9	1549.3	218.9	13.2	80.9
CT6	Black River	<LOQ	122.5	114.2	13.6	103.6	97.2	907.1	392.1	25.8	<LOD
CT7	Mouille Point	<LOQ	<LOD	<LOD	<LOD	<LOD	13.4	<LOQ	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<LOQ	<LOQ	<LOD	<LOD	<LOD	6.9	<LOD	1.9	<LOD	<LOD
CT9	Three Anchor Bay stormwater	<LOD	<LOQ	109.0	<LOD	<LOD	8.9	88.2	154.3	<LOD	188.8
CT10	Milton Tidal Pool	<LOQ	68.7	<LOD	<LOQ	<LOQ	31.1	<LOD	1.2	<LOD	<LOD
CT11	Clifton 4 th Beach	<LOD	5.5	14.3	<LOQ	<LOD	27.9	<LOD	<LOQ	<LOQ	<LOD
CT12	Camps Bay Beach	<LOD	<LOQ	<LOQ	<LOD	<LOD	6.0	<LOD	<LOQ	<LOD	<LOD
CT13	Oudekraal Resort	<LOQ	9.3	<LOQ	<LOD	<LOD	8.2	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOQ	<LOQ	<LOD	<LOD	14.3	<LOD	<LOQ	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOQ	<LOD	<LOD	<LOQ	6.4	82.9	559.7	<LOD	<LOD
CT16	Hout Bay Beach	<LOD	3.6	<LOQ	<LOD	<LOD	6.5	6.4	12.6	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	4.0	<LOD	<LOD	<LOD	5.3	<LOD	<LOQ	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	0.9	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOQ	<LOQ	<LOQ	<LOD	<LOD	20.9	<LOD	1.2	<LOQ	<LOD
CT21	Glencairn Beach	6.3	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOQ	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOQ	<LOQ	<LOD
CT23	Fish Hoek stormwater	18.1	<LOQ	<LOD	<LOQ	<LOD	<LOQ	<LOD	<LOQ	<LOD	<LOD
CT24	Muizenberg Pavilion	<LOD	5.2	<LOD	<LOD	<LOQ	<LOQ	21.6	16.1	<LOD	<LOD
CT25	Zandvlei Estuary mouth	10.0	<LOQ	<LOD	0.8	<LOD	<LOQ	32.4	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	88.0	299.0	461.8	12.2	23.5	197.0	1167.4	86.8	40.2	<LOD
CT27	Strandfontein	<LOQ	172.2	28.6	0.6	<LOQ	<LOQ	43.4	10.7	<LOD	<LOD
CT28	Mitchells Plain Beach	<LOQ	8.4	<LOD	<LOQ	<LOQ	<LOD	78.4	41.7	1.4	<LOD
CT29	Monwabisi Beach	<LOQ	6.9	<LOD	<LOD	<LOQ	<LOQ	26.5	36.5	<LOD	<LOD
CT30	Eerste River	<LOQ	<LOQ	<LOD	<LOQ	10.6	4.6	<LOD	<LOD	<LOD	<LOD
CT31	Macassar Beach	137.3	528.4	303.3	8.0	95.0	68.4	249.2	881.9	84.5	<LOD
CT32	Strand Beach/Lourens River	14.5	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOQ	<LOD	<LOD
CT33	Gordon's Bay canal	65.1	<LOQ	<LOD	40.5	13.5	14.8	109.1	45.3	16.9	<LOD
CT34	Gordon's Bay Beach	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD
CT35	Kogel Bay	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 7th of December 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Naproxen	Hydrochloro- thiazide	Atenolol	10,11-Epoxy- carbamazepine	2-Hydroxy carbamazepine	Alprazolam	Cimetidine	Citalopram	Diclofenac	Salicylic acid
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOD	<LOQ	<LOQ	<LOD	<LOD	3.9	<LOD	<LOQ	<LOD	124.9
CT2	Diep River	<LOQ	2298.3	330.0	10.8	203.2	28.5	931.8	293.6	<LOD	61.0
CT3	Milnerton Beach	<LOD	14.9	<LOQ	<LOD	<LOD	<LOQ	11.1	0.7	<LOD	107.9
CT4	Lagoon Beach	<LOD	148.4	40.4	1.4	18.7	3.9	67.7	33.7	<LOD	104.4
CT5	Salt River mouth	88.9	2097.3	507.1	9.7	142.3	9.1	566.4	47.7	<LOD	98.3
CT6	Black River	188.8	2280.0	804.8	11.4	134.4	<LOQ	520.4	111.0	<LOD	148.4
CT7	Mouille Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.2	<LOD	109.7
CT8	Three Anchor Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	88.7
CT9	Three Anchor Bay stormwater	2545.6	1064.7	574.0	<LOD	<LOD	6.9	<LOQ	331.2	<LOD	1189.3
CT10	Milton Tidal Pool	<LOD	44.4	0.6	<LOD	<LOD	<LOD	<LOD	23.3	<LOD	118.2
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	7.5	<LOD	168.4
CT12	Camps Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	43.0	<LOD	<LOD	<LOD	121.2
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	7.5	<LOD	<LOQ	<LOD	100.1
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	5.6	<LOD	<LOD	<LOD	101.1
CT15	Hout Bay River	57.3	256.7	171.8	9.9	13.4	0.7	<LOQ	<LOD	<LOD	496.1
CT16	Hout Bay Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	1.7	<LOD	<LOD	<LOD	124.7
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	1.2	<LOD	<LOQ	<LOD	112.0
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	0.3	<LOD	<LOD	<LOD	109.2
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	110.4
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	108.5
CT21	Glencairn Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	101.1
CT22	Fish Hoek Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	157.2
CT23	Fish Hoek stormwater	31.2	<LOD	4.9	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	201.5
CT24	Muizenberg Pavilion	<LOD	<LOD	15.8	1.1	<LOD	<LOD	<LOD	<LOD	<LOD	98.9
CT25	Zandvlei Estuary mouth	<LOD	<LOD	<LOQ	4.8	<LOD	<LOD	<LOD	1.6	<LOD	47.1
CT26	Lifebox23 Beach	232.2	566.7	1208.2	9.0	139.3	11.7	682.1	126.0	<LOD	724.4
CT27	Strandfontein	<LOD	12.5	89.8	<LOQ	<LOQ	<LOD	18.4	8.8	<LOD	113.2
CT28	Mitchells Plain Beach	<LOD	48.1	12.4	14.4	16.7	<LOD	39.8	9.4	<LOD	97.2
CT29	Monwabisi Beach	<LOD	8.3	43.4	<LOQ	<LOQ	<LOD	<LOD	<LOQ	<LOD	137.1
CT30	Eerste River	<LOD	213.1	1.3	2.9	6.1	<LOD	6.6	<LOD	<LOD	130.7
CT31	Macassar Beach	<LOD	921.5	1039.1	22.2	384.5	23.3	2085.6	228.8	<LOD	22.8
CT32	Strand Beach/Lourens River	<LOD	<LOD	<LOD	<LOD	<LOD	2.5	<LOD	<LOD	<LOD	113.6
CT33	Gordon's Bay canal	119.6	410.7	9.3	5.6	55.0	13.0	<LOQ	97.8	<LOD	44.1
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	111.1
CT35	Kogel Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	109.2

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 7th of December 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Piroxicam	Clopidogrel	Acridone	Diazepam	Fluoxetine	Lorazepam	Norfluoxetine	Paroxetine	Sertraline	Trazodone
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT2	Diep River	<LOD	2.5	<LOD	<LOQ	<LOQ	<LOD	<LOD	<LOQ	<LOD	12.6
CT3	Milnerton Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT4	Lagoon Beach	<LOD	<LOQ	<LOD	2.4	<LOQ	<LOD	<LOD	<LOD	<LOD	5.7
CT5	Salt River mouth	<LOD	<LOQ	<LOD	6.1	<LOQ	<LOD	<LOD	<LOD	<LOD	2.6
CT6	Black River	<LOD	<LOQ	<LOD	6.0	23.0	<LOD	<LOD	<LOD	<LOD	<LOD
CT7	Mouille Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	<LOD	<LOQ	<LOD	<LOD	36.4	<LOD	<LOD	<LOD	<LOD	40.5
CT10	Milton Tidal Pool	<LOD	<LOD	<LOD	<LOD	12.3	<LOD	<LOD	<LOD	<LOD	<LOD
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT16	Hout Bay Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	<LOD	<LOD	<LOD	<LOD	7.8	<LOD	<LOD	<LOD	<LOD	<LOD
CT24	Muizenberg Pavilion	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	<LOD	<LOQ	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT27	Strandfontein	<LOD	<LOQ	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT28	Mitchells Plain Beach	<LOD	<LOQ	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT29	Monwabisi Beach	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT30	Eerste River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT31	Macassar Beach	<LOD	<LOQ	<LOD	16.7	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT32	Strand Beach/Lourens River	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	<LOD	<LOQ	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT35	Kogel Bay	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Appendix 1 continued. Faecal indicator bacteria colony forming unit counts and pharmaceutical compound concentrations in water sampled in the City of Cape Town on the 7th of December 2021. cfu = colony forming unit, LOD = Limit of Detection, LOQ = Limit of Quantification.

		Diltiazem	Pravastatin	Metoprolol	Nadolol	Ranitidine	Tamsulosin	Cefalexin	Metronidazole	Metronidazole_O H	Tetracycline
Site	Site description	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)	(ng.l ⁻¹)
CT1	Bloubergstrand	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT2	Diep River	4.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT3	Milnerton Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT4	Lagoon Beach	<LOQ	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT5	Salt River mouth	1.9	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD
CT6	Black River	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOQ	<LOD
CT7	Mouille Point	<LOQ	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT8	Three Anchor Bay	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT9	Three Anchor Bay stormwater	<LOQ	<LOD	<LOD	<LOQ	<LOD	12.2	<LOD	<LOQ	<LOD	6.4
CT10	Milton Tidal Pool	<LOQ	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT11	Clifton 4 th Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT12	Camps Bay Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT13	Oudekraal Resort	<LOQ	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT14	Llandudno Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT15	Hout Bay River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	9.5	<LOD
CT16	Hout Bay Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT17	Kommetjie Long Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT18	Diaz Beach	<LOQ	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT19	Miller's Point	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT20	Simon's Town Long Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT21	Glencairn Beach	<LOQ	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT22	Fish Hoek Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT23	Fish Hoek stormwater	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT24	Muizenberg Pavilion	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT25	Zandvlei Estuary mouth	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT26	Lifebox23 Beach	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT27	Strandfontein	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT28	Mitchells Plain Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT29	Monwabisi Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT30	Eerste River	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT31	Macassar Beach	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD
CT32	Strand Beach/Lourens River	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT33	Gordon's Bay canal	4.6	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT34	Gordon's Bay Beach	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
CT35	Kogel Bay	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Appendix 3. Recoveries and relative standard deviations (RSD) for spiked concentrations of pharmaceutical compounds in fresh and seawater matrices, and Limit of Detection (LOD) and Limit of Quantification (LOQ).

Compounds	Freshwater matrix				Seawater matrix			
	Recovery (%)	RSD (%)	LOD (ng.l ⁻¹)	LOQ (ng.l ⁻¹)	Recovery (%)	RSD (%)	LOD (ng.l ⁻¹)	LOQ (ng.l ⁻¹)
Acetaminophen	112.8	27.3	2.45	8.17	79.5	16.8	0.45	1.51
Atorvastatin	89.0	17.1	0.05	0.18	65.0	2.7	0.02	0.05
Bezafibrate	91.6	7.8	1.20	3.98	85.5	19.8	0.36	1.20
Furosemide	85.0	9.6	1.43	4.76	98.4	21.2	0.26	0.87
Gemfibrozil	63.9	3.9	0.17	0.58	42.2	6.3	0.02	0.08
Hydrochlorothiazide	25.1	2.4	0.01	0.03	70.0	30.9	1.14	3.79
Ibuprofen	71.4	9.2	0.82	2.74	70.7	17.1	1.14	3.81
Indomethacin	71.9	10.6	2.28	7.59	48.4	24.7	0.44	1.45
Irbesartan	54.8	2.5	0.30	1.00	69.1	20.0	0.08	0.27
Ketoprofen	123.8	12.3	1.20	4.01	50.7	41.8	6.90	23.00
Losartan	61.0	5.2	0.61	2.02	70.3	13.9	4.59	15.30
Meloxicam	74.4	3.9	2.33	7.78	41.9	29.3	1.11	3.70
Naproxen	71.6	5.6	2.99	9.95	45.2	42.0	2.02	6.73
Pravastatin	62.0	8.9	6.19	20.65	43.2	59.5	4.83	16.11
Salicylic acid	146.0	5.5	3.85	12.84	97.0	22.7	0.56	1.86
Valsartan	81.6	2.5	0.86	2.85	110.5	17.4	0.10	0.33
Piroxicam	56.0	2.5	1.58	5.25	102.3	40.1	0.99	3.29
Acridone	53.1	5.7	0.30	0.99	66.0	3.9	0.02	0.05
Alprazolam	66.8	4.3	0.08	0.27	43.2	25.9	0.04	0.14
Atenolol	79.4	13.5	0.28	0.92	77.9	28.2	0.11	0.36
Carbamazepine	94.1	5.6	0.39	1.29	106.8	21.4	1.01	3.37
epoxy CBZ	82.3	3.7	0.08	0.27	37.0	39.8	0.02	0.08
2-OH CBZ	83.9	5.0	0.10	0.35	41.2	40.2	0.02	0.05
Citalopram	57.9	33.8	0.09	0.29	49.7	28.9	0.03	0.09
Cimetidine	73.1	4.0	0.38	1.28	74.0	16.5	0.38	1.26
Clopidogrel	68.6	2.9	0.41	1.36	60.3	54.3	0.01	0.03
Codeine	98.7	5.3	0.64	2.13	63.8	30.7	0.07	0.24
Desloratadine	82.0	1.4	4.71	15.70	51.3	5.7	0.25	0.82
Diazepam	84.6	5.4	0.08	0.26	44.7	32.4	0.03	0.10
Diltiazem	110.3	3.8	0.03	0.11	60.4	33.9	0.01	0.04
Fluoxetine	93.0	2.7	0.39	1.30	81.0	17.7	3.01	10.04
Iopromide	56.5	5.0	1.77	5.89	90.9	23.6	1.88	6.26
Lorazepam	99.0	5.8	0.66	2.20	82.4	36.4	0.40	1.33
Metoprolol	55.9	6.2	0.27	0.92	90.0	23.1	0.50	1.60
Nadolol	69.8	7.5	0.04	0.13	71.0	32.5	0.01	0.03
Norfluoxetine	45.1	2.9	3.64	12.14	105.0	16.0	2.44	8.13
Paroxetine	65.8	1.1	0.16	0.52	48.0	2.5	1.50	5.00
Phenazone	79.3	5.3	0.20	0.66	46.7	36.5	0.14	0.47
Propranolol	55.2	5.8	0.14	0.48	52.6	15.3	0.08	0.28
Ranitidine	31.1	5.9	0.02	0.08	72.0	6.1	0.01	0.04
Salbutamol	94.4	12.3	0.11	0.36	22.9	2.7	0.09	0.28
Sertraline	58.5	9.5	1.44	4.82	53.9	5.1	1.77	5.91
Sotalol	82.5	3.8	0.52	1.72	80.3	25.2	0.87	2.89
Tamsulosin	62.6	3.6	0.10	0.32	40.8	28.0	0.01	0.04
Trazodone	107.2	6.8	0.11	0.35	30.0	6.7	0.03	0.10
Venlafaxine	87.3	4.1	0.92	3.08	101.9	20.6	0.39	1.30
Azithromycin	128.0	20.0	1.94	6.47	121.0	16.1	10.14	33.81
Cefalexin	79.5	3.2	1.53	5.10	40.2	40.7	2.24	7.47
Ciprofloxacin	113.0	9.1	2.82	9.41	109.9	59.4	4.27	14.24
Clarithromycin	116.0	7.8	0.49	1.62	96.0	12.9	0.13	0.43
Erythromycin	51.9	4.3	0.10	0.34	79.0	17.5	0.07	0.23
Metronidazole	93.6	8.9	0.85	2.83	55.0	36.3	3.91	13.03
Metronidazole OH	78.7	2.2	0.68	2.28	31.1	28.4	0.39	1.29
Ofloxacin	105.9	9.4	0.96	3.21	66.3	37.2	1.25	4.17
Sulfamethoxazole	92.6	1.8	1.53	5.10	97.9	13.8	0.99	3.32
Tetracycline	112.0	13.1	2.39	7.97	127.0	6.3	0.40	1.40
Trimethoprim	63.6	3.0	0.57	1.92	66.0	12.2	0.17	0.55