Final Report
Sunscreen Pollution Analysis in Jellyfish Lake
Coral Reef Research Foundation
Palau

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Study on the accumulation of sunscreen from tourists in the endemic jellyfish as well as in the lake water of Jellyfish Lake in the World Heritage property of Rock Islands Southern Lagoon

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United Nations
Educational, Scientific and
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Rock Islands
Southern Lagoon
inscribed on the World
Heritage List in 2012

SUMMARY

Jellyfish Lake in Palau is part of the Koror State Rock Island Southern Lagoon (RISL), a UNESCO World Heritage site and is famous for its Golden Jellyfish population. Palau has seen a dramatic increase in its visitors, now over 100,000 per year, and most of those visit Jellyfish Lake, causing concern for the continued health of the lake. Our preliminary sampling for sunscreen chemicals in 2014 indicated the presence of oxybenzone (BP-3), a compound that is extremely common in personal care products, including sunscreens. The present study builds on those results, using more rigorous sampling and analytical methods to look for sunscreen products in water, sediment and jellyfish samples in Jellyfish Lake (tourism site) and three other sites (non-tourism) for comparison.

Our results showed that sunscreen compounds or their transformation products (such as metabolites) are wide spread in Jellyfish Lake. They were also present in the sites presumed to be 'pristine' with little human use. In general, water samples had low levels of sunscreen compounds, while jellyfish tissues and sediment had relatively higher levels of these compounds and metabolites. This is an indication of bioaccumulation of these chemicals.

Comparing different lakes and ocean/lagoon sites, Jellyfish Lake had the highest levels of sunscreen compound concentrations. The levels of sunscreen compounds and their metabolites in Jellyfish Lake indicates that: 1) personal care product pollution is entering the environment through tourist use, i.e. sunscreen washing off, and 2) jellyfish are absorbing and metabolizing BP3. Compounds were also detected in Ngermeuangel Lake, i.e. what should have been a control and uncontaminated lake. These may be from effluent/sewer leaking from the nearby population center into the adjacent watersheds, indicating that there are more widespread issues with marine pollution from different sources.

The Golden Jellyfish medusa stage is relatively short lived, with a life span of about 6 months. The presence of sunscreen chemicals in the medusae and their presence in the sediment in Jellyfish Lake and other marine lakes is cause for concern. The medusae stage may not live long enough to be directly affected, but their benthic polyp stage, critical to their life cycle, could be. We feel in the short term the known presence of UV filters should be addressed in a practical manner to try to stabilize their levels in Jellyfish Lake and minimize additions of them to the system.

Based on these findings we would like to recommend the following:

- Promote the use of clothing for sun protection, such as rash guards, to minimize the application of ANY sunscreen.
- Require that only eco-friendly sunscreen is used in and around Jellyfish Lake. This includes brands that DO NOT contain chemicals listed in Appendix 5.
- Educate tour guides and tourists for the most responsible use of these eco-friendly sunscreens: apply at least 20 minutes before entering the lake.
- Promote the use of these eco-friendly brands throughout Palau, with the development of legislation to prohibit the use and importation of traditional sunscreen products.
- Improve the waste water runoff and seepage situation surrounding Nikko Bay, in an attempt to help 'clean up' this exceptionally important reef site.

INTRODUCTION

Jellyfish Lake (Ongeim'l Tketau) in Palau is part of the Koror State Rock Island Southern Lagoon (RISL), a UNESCO World Heritage site, world famous for its unique perennial population of Golden Jellyfish (Patris et al., 2012). The lake contributed significantly to a record peak in tourism in 2015, with over 160,000 tourists visiting this island nation. The purpose of this UNESCO International Assistance project was to investigate links between tourism use of marine lakes and the environmental health of the marine lake ecosystem. Following preliminary results in 2014 which showed low levels of one sunscreen (UV filter) compound in Jellyfish Lake it became imperative to conduct further studies on the accumulation of sunscreen from tourists in the lake. Specifically, we proposed to quantify the levels of sunscreen contamination in Jellyfish Lake and two control lakes, analyzing sunscreen chemical levels in the lake water, their adsorption capacity onto the bottom sediments, as well as the accumulation in jellyfish tissues and in micro-zooplantkon (the medusae's external food source).

PROJECT OBJECTIVES

The project had five objectives, to directly address the following two questions …

1. Are sunscreen compounds found in the lake water and in the endemic *Mastigias papua etpisoni* jellyfish in Jellyfish Lake (used by tourists) in reportable amounts?
2. Are sunscreen compounds found in the lake water and in the endemic *Mastigias papua salii* jellyfish in Clear Lake (not used by tourists), 2 km distant from Jellyfish Lake, in reportable amounts?

… and to infer answers to three additional questions:

3. Do sunscreen compounds originate from tourists?
4. Is the groundwater in Mecherchar Island contaminated with sunscreen?
5. Do the endemic *Mastigias* medusae bio-accumulate sunscreen?

METHODS

Water, jellyfish and sediment were sampled from three marine lakes and the nearby ocean in Palau, western Pacific. All samples were collected on 15/16 January, 2016, as summarized in Table 1. Figure 1 shows the general proximity of sites to each other and to the population center of Koror. Marine lakes are bodies of sea water entirely surrounded by land with various connections to the sea, resulting in limited water exchange through a daily diurnal tide (Colin, 2009). Appendix 1 has detailed maps (Figures 3 & 4) of each site and sampling locations within sites.

Table 1. List of samples collected and analyzed. See Appendix 1 for detailed site maps.

Sample Type	No. of Samples per site	Site Name			
Water- evenly spaced inside lake: Center	8	OTM	CLM	NLK	
Water- in front of inside dock: Dock	8	OTM			
Water - outside lakes and ocean: Lagoon/Ocean	4	OTM		NLK	OCEAN
Zooplankton	8			NLK	
Jellyfishes	8	OTM		NLK	
Sediment	8	OTM	CLM	NLK	
Lake Blanks	2	OTM	CLM	NLK	
Lagoon/Ocean Blanks	2	OTM		NLK	OCEAN
Equipment (bottle) Blanks	5	Lab			

OTM: Jellyfish Lake (Ongeim'l Tketau)-16Jan2016; CLM: Clear Lake-16Jan2016; NLK: Ngermeuangel Lake-15Jan2016; OCEAN-15Jan2016: 7^{o} 14.851N, 134^{o} 28.974E.

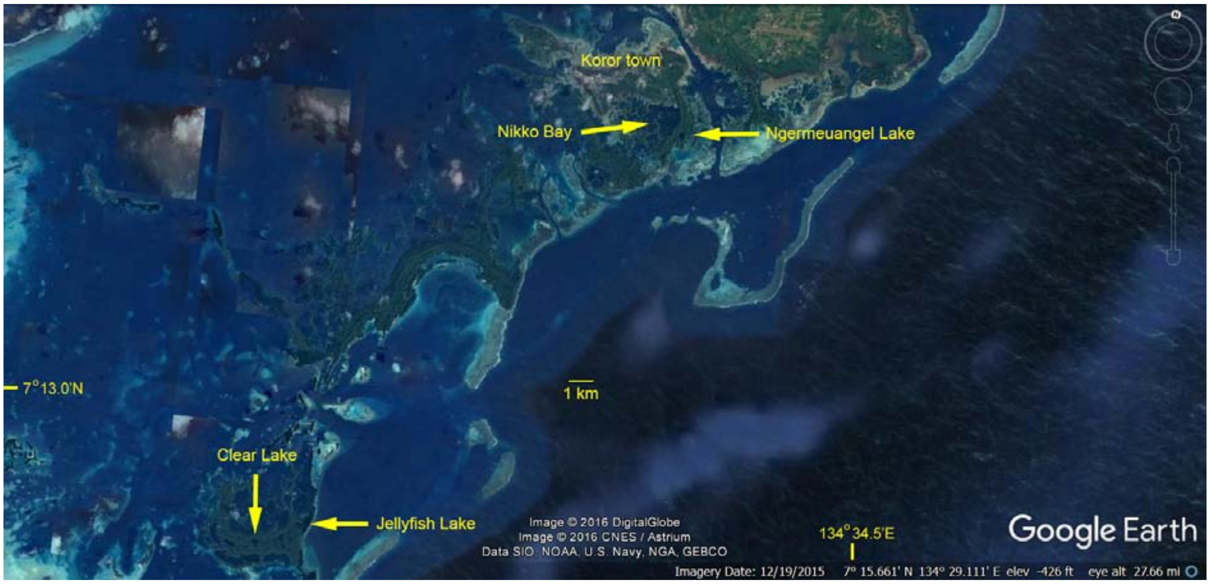

Figure 1. Map of main localities mentioned in the text, including sample locations detailed in Table 1. Jellyfish Lake (Ongeim'l Tketau; OTM); Clear Lake (CLM); Ngermeuangel Lake (NLK).

All containers were certified to U.S. EPA standards (I-Chem 340-0060 and 341-0060). The personnel involved in the sampling campaign avoided using sunscreen or other beauty/hygiene products before and on the sampling days. Clothing, the boat and devices used during sampling were extensively cleaned to avoid the contamination of the samples. Disposable nitrile exam gloves were worn by collectors and changed between each collected sample. All water samples (including blanks) were 40 ml volume collected in 60 ml jars. Each capped sample bottle was held 0.5 m below the water surface, cap removed, filled with water and recapped before bringing back to the surface. Jellyfish oral arms were removed using dissecting scissors from ~8 cm diameter golden jellies (*Mastigias papua*) to fill 60 ml wide mouth jars about 2/3 full. Sediment from the lake's slope was scooped directly into 60 ml wide mouth jars from 1-2 m depth. Bottles were opened underwater, sample collected then recapped, brought to the surface, settled, water was decanted and bottles recapped. Micro-zooplankton were sampled only in NLK with a 20 cm diameter 80 µm mesh plankton net, making multiple tows to 18m depth. The cod-end mesh was scraped into the open sample jar after each tow. About 5 net hauls were made at each of 8 sites, as zooplankton abundance was quite low; ultimately the quantity of zooplankton was not enough for analysis. Zooplankton in OTM and CLM was not abundant enough to sample. Collectors in the lakes sampled while either in a rubber boat (for water) or in the water (for jellies, sediment). Blank samples, a measure of field or laboratory contamination, were also collected. Nanopure water (HiPerSolv CHROMANORM for HPLC, VWR Scientific) was used for all blanks; 1 liter bottles were carried to field sites and field blanks filled either when inside the lake or outside the lake. Lagoon, ocean water and blank samples were taken, as above, from a paddleboard. CRRF bottle blanks were filled at the start of each day at the lab and not transported to the field. Matrix water (750 ml) for preparation of standards was collected in certified clean 1 liter bottles from the geographic center of each lake and the ocean site, following procedures above.

All samples were chilled upon collection and during transport to the lab, then frozen at -20 ^oC. Samples were labeled with random blind numbers before shipping so that the sample origin was not known during analysis. Frozen samples were transported to California (18 Jan 2016) in 50mm thick styrofoam boxes (24 hrs) with gel ice. Samples were then stored on dry ice until they were received by

IDAEA-CSIC in Barcelona, Spain (9 Feb 2016). Upon receipt, samples were kept frozen in the dark at -20ºC.

Samples were analyzed for 22 compounds in water and 23 compounds in jellyfish and sediment (Table 2). These chemicals are either directly found in sunscreen formulations or are products that the body makes (metabolites) from one of the sunscreen chemicals.

Table 2: Name, acronym and CAS Nº of the organic UV filters investigated in the water samples. Starred acronyms (**) are chemical metabolites that are not directly present in sunscreen.

Compound	Acronym	CAS Nº	Sample*
Benzophenone 1	BP1**	92092-63-2	W/J/S
Benzophenone 2	BP2	131-55-5	W/J/S
Benzophenone 3 (oxybenzone)	BP3	131-57-7	W/J/S
4-Hydroxybenzophenone (p-benzoylphenol)	4HB**	1137-42-4	W/J/S
4,4'-Dihydroxybenzophenone	4DHB**	611-99-4	J/S
2,2'-Dihydroxy-4-methoxybenzophenone (Benzophenone 8, dioxybenzone)	BP8, DHMB**	131-53-3	W/J/S
2,4,4'-Trihydroxybenzophenone	THB**	1470-79-7	W/J/S
2-Ethylhexyl-*p*-metoxycinnamate	EHMC	5466-77-3	W/J/S
3-(4-Methyl)benzyliden camphor	4MBC	36861-47-9	W/J/S
Octocrylene	OC	6197-30-4	W/J/S
Ethyl-PABA (benzocaine)	Et-PABA	94-09-7	W/J/S
2-Ethylhexyl-4-Dimethyil-PABA	OD-PABA	21245-02-3	W/J/S
1,2,3-Benzotriazole	1HBT	95-14-7	W/J/S
5-Methyl-1-H-benzotriazole	MeBT	136-85-6	W/J/S
2-(5-tert-butyl-2-hydroxyphenyl)benzotriazole	TBHPBT	3147-76-0	W/J/S
2-(2-Hydroxy-5-methylphenyl) benzotriazole	UVP	2440-22-4	W/J/S
2-(2'-Hydroxy-3',5'-di-tert-butylphenyl)benzotriazole	UV320	3846-71-7	W/J/S
2-Tert-butyl-6-(5-chlor-2H-benzotriazol-2-yl)-4-methylphenol (bumetrizole)	UV326	3896-11-5	W/J/S
2,4-Di-tert-butyl-6-(5-clor-2H-benzotriazol-2-yl)phenol	UV327	3864-99-1	W/J/S
2-(2H-Benzotriazol-2-yl)-4,6-di-tert-pentylphenol	UV328	25973-55-1	W/J/S
2-(2H-Benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol (octrizole)	UV329	3147-75-9	W/J/S
2-(2H-Benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol	UV234	70321-86-72	W/J/S
2,2′-methanediylbis[6-(2H-benzotriazol-2-yl)-4-(2,4,4-trimethylpentan-2-yl)phenol]	UV360	103597-45-1	W/J/S
Benzophenone-d10 as Surrogate Standard	BP-d10	22583-75-1	W/J/S

* W=water, J=jellyfish, S=sediment; **metabolites

Quality Assurance and Quality Control:

Background contamination in the laboratory can be a problem in the determination of UV filters at environmental trace levels. Thus, several measures were taken in the current study in order to prevent this problem. All glassware used in the lab was washed and heated overnight at 380 ºC, and further sequentially rinsed with acetonitrile, methanol (MeOH) and HPLC grade water. Furthermore, gloves were worn during sample preparation; separate solvents and only previously unopened packages of solvents, chemicals and other supplies, and glassware were used. Since many of the compounds analyzed undergo photodegradation, and the samples and standard solutions at all stages of the analysis may suffer the exposure to light during the procedure, all solutions were always covered with aluminium foil and stored in the dark to avoid photodegradation.

For every batch of samples analyzed, a procedural blank, a control standards mixture solution to check for instrumental drift in response factors, and two pure MeOH blank solutions, indicators of instrument contamination, were measured. Because procedural blanks followed the same steps as the samples, these controls underwent all potential contamination sources and events that the samples experienced. All solvent blanks were free of contamination.

Analytical Methodology:

Water samples were analyzed by on-line solid-phase extraction coupled to high performance liquid chromatography coupled to tandem mass spectrometry (on-line SPE-HPLC-QqLIT-MS/MS). Operational blanks along with standard solutions were included in the sequenced analysis of the water samples from Palau. Detailed information on the methodology applied can be found in Gago-Ferero et al., 2013.

Jellyfish samples were thawed and weighed, and then extracted by ultrasound extraction (USE) using MeOH as the extracting solvent. The extracts were further purified by solid phase extraction (SPE) eluting with ethyl acetate and dichloromethane. The analyses of the extracts were carried out by high performance liquid chromatography coupled to tandem mass spectrometry (HPLC-QqLIT-MS/MS). Operational blanks along with standard solutions were included into the sequenced analysis of the jellyfish extracts. The method applied was optimized from the methodology that can be found in Valle-Sistac et al. (2016).

Zooplankton samples were defrosted and weighted, and then extracted by ultrasounds extraction (USE) using MeOH as extracting solvent. The extracts were further purified by solid phase extraction (SPE) eluting with ethyl acetate and dichloromethane. The analyses of the extracts were carried out by high performance liquid chromatography coupled to tandem mass spectrometry (HPLC-QqLIT-MS/MS). Operational blanks along with standard solutions were included into the sequenced analysis of the zooplankton extracts. Zooplankton samples from NLK were all under 1 gm each, providing insufficient mass for quantitative results.

Sediment samples were defrosted and weighed, and then extracted by pressurized liquid extraction (PLE) using MeOH and HPLC-grade water as extracting solvents. The analyses of the extracts were carried out by high performance liquid chromatography coupled to tandem mass spectrometry (HPLC-QqLIT-MS/MS). For detailed method description see Gago-Ferrero et al. (2011). Operational blanks along with standard solutions were included into the sequenced analysis of the sediment extracts.

Results were reported as follows: nanograms per milliliter (ng/ml) for liquid, nanograms per gram (ng/g) wet weight for jellyfish tissue; nanograms per gram (ng/g) dry weight for sediment samples. Numerous sample results were near the method limit of quantification, LOQ, the lowest concentration at which the chemical can be reliably measured and quantified. The method limit of detection, LOD, is the lowest concentration at which a chemical can be reliably detected, differentiated from the noise of the measure, but cannot be quantified. Test results below the LOD are considered to be the same as a zero value. LOD and LOQ were calculated following the IUPAC Guidelines; the limits of detection, as the lowest analyte concentration with a signal to noise ratio (S/N) of 3, and the limit of quantification, as the concentration with S/N ratio of 10.

RESULTS

In order to better understand each lake as a whole, the results below are presented for each individual lake. The complete set of results for all samples, grouped by sample type (water, jellyfish and sediment) can be found in Appendices 2-4.

Jellyfish Lake (OTM)-

Five (62%) of the water samples collected from evenly-spaced sites within the lake had detectable levels of at least one of the surveyed chemicals (Table 3). Six (75%) of the water samples taken near the dock inside Jellyfish Lake also had detectable levels of at least one surveyed chemical. BP3, OC and BZT were the most commonly-detected chemicals in lake water. Additionally, UV327 was detected in four out of the sixteen total water samples from inside the lake, some at very high levels.

Of the 4 water samples taken outside of Jellyfish Lake (Fig. 3c), only one was positive for one chemical (Table 3). Two water blanks (nanopure water) each were taken inside and outside of the lake. Both samples inside the lake were positive for at least one surveyed chemical.

All medusae from Jellyfish Lake were positive for BP3 at levels higher than found in the water samples (Table 3). Additionally, three different BP3 metabolites (chemicals converted by the animal from BP3 resulting in a new chemical) were also detected in medusae samples. Two other chemicals were found in jellies, EtPABA in all eight samples, and 4MBC in two.

Sediment samples showed a different pattern of contamination from water and jellyfish, where 4HB (a BP3 metabolite), EHMC and OC were present in 7 of the 8 samples (Table 3).

Clear Lake (CLM)-

Four (50%) of the water samples taken from evenly-spaced sites within Clear Lake were positive for at least one surveyed chemical (Table 4). Jellyfish were absent from Clear Lake and therefore not sampled. 100% of the sediment samples were positive for at least one chemical.

Table 3. Results of sunscreen chemicals in Jellyfish Lake (OTM) and the Ocean water samples. See Table 2 for UV filter acronyms. ΣUV F- the sum of all UV chemicals in one sample (ng/ml); NUV F- the number of samples positive for UV chemicals; OTM-W: water samples collected in Jellyfish Lake from evenly-spaced sites throughout the lake; OTM-DK: water samples collected in Jellyfish Lake from the inlet in front of the dock; OTM-LGN: water samples collected outside Jellyfish Lake from near the outside dock; OCEAN: water samples collected in the ocean outside Lighthouse Reef (7° 14.851N, 134° 28.974E); BLANKS: nano-pure water to detect possible contamination from sources other than the sample; OTM-J: medusae samples collected from evenly-spaced sites; OTM-S: bottom sediment samples collected from evenly-spaced sites; n.d.- not detected (below the limit of detection); LOQ- Limit of Quantification, lowest concentration at which the chemical can be reliably measured. Numbers in bold indicate positive results with reliable concentration values.

WATER — Units ng/ml water

Sample No	BP3	4HB	4DHB	DHMB	BP2	EHMC	4MBC	EtPABA	OC	BZT	UVP	UV320	UV327	ΣUV F	N UV F
OTM-W01	**0.004**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.004	1
OTM-W02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM-W03	**0.006**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.541**	n.d.	**0.216**	n.d.	n.d.	0.763	3
OTM-W04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM-W05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.473**	n.d.	n.d.	**0.513**	0.986	2
OTM-W06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.130**	n.d.	n.d.	n.d.	n.d.	0.130	1
OTM-W07	**0.010**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.400**	n.d.	n.d.	n.d.	n.d.	0.410	2
OTM-W08	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM-DK01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM-DK02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.027**	n.d.	n.d.	n.d.	n.d.	0.027	1
OTM-DK03	**0.005**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**1.200**	1.205	2
OTM-DK04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.085**	**0.011**	n.d.	n.d.	n.d.	0.097	2
OTM-DK05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM-DK06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.079**	n.d.	n.d.	n.d.	0.079	1
OTM-DK07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.515**	n.d.	n.d.	n.d.	0.515	1
OTM-DK08	**0.005**	n.d.	n.d.	**0.005**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.010	2
OTM LGN-01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.454**	n.d.	n.d.	n.d.	n.d.	0.454	1
OTM LGN-02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM LGN-03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM LGN-04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM BLANK 01	**0.002**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.212**	n.d.	n.d.	n.d.	**1.070**	1.284	3
OTM BLANK 02	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**1.060**	1.060	1
OTM LGN BLANK 01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
OTM LGN BLANK 02	**0.014**	n.d.	n.d.	n.d.	n.d.	n.d.	**0.057**	n.d.	**0.067**	n.d.	n.d.	n.d.	n.d.	0.137	3
OCEAN 01	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.016**	n.d.	0.016	1
OCEAN 02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OCEAN 03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OCEAN 04	n.d.	<LOQ	n.d.	n.d.	n.d.	**0.714**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.714	1
OCEAN BLANK 01	**0.009**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.083**	n.d.	n.d.	n.d.	n.d.	0.092	2
OCEAN BLANK 02	**0.004**	n.d.	n.d.	**0.010**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.014	2

JELLYFISH — Units ng/g wet weight jellyfish

Sample No	BP3	4HB	4DHB	DHMB	BP2	EHMC	4MBC	EtPABA	OC	BZT	UVP	UV320	UV327	ΣUV F	N UV F
OTM-J01	**4.04**	**1.10**	**1.92**	n.d.	**5.55**	n.d.	n.d.	**1.07**	n.d.	n.d.	n.d.	n.d.	n.d.	13.68	5
OTM-J02	**5.37**	**7.29**	**2.39**	n.d.	**0.67**	n.d.	n.d.	**0.68**	n.d.	n.d.	n.d.	n.d.	n.d.	16.40	5
OTM-J03	**2.55**	**15.44**	**3.78**	n.d.	**4.68**	n.d.	n.d.	**1.25**	n.d.	n.d.	n.d.	n.d.	n.d.	27.70	5
OTM-J04	**3.28**	**0.58**	**3.13**	n.d.	**3.36**	n.d.	n.d.	**0.68**	n.d.	n.d.	n.d.	n.d.	n.d.	11.04	5
OTM-J05	**4.80**	**1.75**	**1.21**	n.d.	**1.86**	n.d.	n.d.	**3.24**	n.d.	n.d.	n.d.	n.d.	n.d.	12.86	5
OTM-J06	**6.99**	**6.83**	**1.83**	n.d.	**7.34**	n.d.	**0.17**	**1.39**	n.d.	n.d.	n.d.	n.d.	n.d.	24.56	6
OTM-J07	**4.39**	**0.87**	n.d.	n.d.	**2.07**	n.d.	**0.49**	**1.02**	n.d.	n.d.	n.d.	n.d.	n.d.	8.84	5
OTM-J08	**3.87**	**4.24**	n.d.	n.d.	**2.45**	n.d.	n.d.	**1.19**	n.d.	n.d.	n.d.	n.d.	n.d.	11.75	4

SEDIMENT — Units ng/g dry weight sediment

Sample No	BP3	4HB	4DHB	DHMB	BP2	EHMC	4MBC	EtPABA	OC	BZT	UVP	UV320	UV327	ΣUV F	N UV F
OTM-S01	n.d.	**36**	n.d.	n.d.	n.d.	**44**	n.d.	n.d.	**59**	n.d.	n.d.	n.d.	n.d.	140	3
OTM-S02	n.d.	**313**	n.d.	n.d.	n.d.	**39**	n.d.	n.d.	**44**	n.d.	n.d.	n.d.	n.d.	396	3
OTM-S03	n.d.	**57**	n.d.	n.d.	n.d.	**36**	n.d.	n.d.	**47**	n.d.	n.d.	n.d.	n.d.	140	3
OTM-S04	**15**	**526**	n.d.	n.d.	n.d.	**57**	n.d.	n.d.	**58**	n.d.	n.d.	n.d.	n.d.	660	4
OTM-S05	n.d.	**75**	n.d.	n.d.	n.d.	**7**	n.d.	n.d.	**7**	n.d.	n.d.	n.d.	n.d.	89	3
OTM-S06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM-S07	n.d.	**58**	n.d.	n.d.	n.d.	**59**	n.d.	n.d.	**222**	n.d.	n.d.	n.d.	n.d.	340	3
OTM-S08	n.d.	**362**	n.d.	n.d.	n.d.	**45**	n.d.	n.d.	**81**	n.d.	n.d.	n.d.	n.d.	487	3

Table 4. Results of sunscreen chemicals in Clear Lake (CLM). See Table 2 for UV filter acronyms. ΣUV F- the sum of all UV chemicals in one sample (ng/ml); NUV F- the number of samples positive for UV chemicals; CLM-W: water samples collected in Clear Lake from evenly-spaced sites throughout the lake; BLANKS: nano-pure water to detect possible contamination from sources other than the sample; CLM-S: bottom sediment samples collected from evenly-spaced sites; n.d.- not detected (below the limit of detection); LOQ- Limit of Quantification, lowest concentration at which the chemical can be reliably measured. Numbers in bold indicate positive results with reliable concentration values.

WATER		Units	ng/ml	water			
Sample No	**BP3**	**4HB**	**OC**	**UVP**	**UV327**	**ΣUV F**	**N UVF**
CLM-W01	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
CLM-W02	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
CLM-W03	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
CLM-W04	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
CLM-W05	**0.012**	n.d.	n.d.	n.d.	n.d.	0.012	1
CLM-W06	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
CLM-W07	n.d.	n.d.	**0.010**	n.d.	**0.735**	0.745	2
CLM-W08	**0.005**	n.d.	**0.241**	**0.022**	n.d.	0.268	3
CLM BLANK 01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
CLM BLANK 02	**0.004**	n.d.	n.d.	n.d.	**0.796**	n.d.	n.d.

SEDIMENT		Units	ng/g dry weight sediment				
Sample No	**BP3**	**4HB**	**OC**	**UVP**	**UV327**	**ΣUV F**	**N UVF**
CLM-S01	n.d.	**292**	n.d.	n.d.	n.d.	292	1
CLM-S02	n.d.	**363**	n.d.	n.d.	n.d.	363	1
CLM-S03	n.d.	**19**	n.d.	n.d.	n.d.	19	1
CLM-S04	n.d.	**12**	**14**	n.d.	n.d.	26	2
CLM-S05	n.d.	**475**	n.d.	n.d.	n.d.	475	1
CLM-S06	n.d.	**290**	n.d.	n.d.	n.d.	290	1
CLM-S07	n.d.	**452**	**28**	n.d.	n.d.	480	2
CLM-S08	n.d.	**225**	n.d.	n.d.	n.d.	225	1

Ngermeuangel Lake (NLK)-

Six (75%) of the water samples taken from evenly-spaced sites within the lake had detectable levels of at least one surveyed chemical (Table 5). Three (75%) of the water samples taken in the bay outside of the lake were positive for at least one surveyed chemical. Positive tests were obtained for nine different chemicals in the NLK lake and lagoon samples. Two water blanks (nanopure water) each were taken inside and outside of the lake. All four blanks were positive for at least one surveyed chemical, with a total of 8 different positive chemicals.

All medusae from Ngermeuangel Lake were positive for BP3 at levels higher than concentrations found in the water samples (Table 5). Additionally, three different BP3 metabolites (chemicals converted by the animal from BP3 resulting in a new chemical) were also detected in medusae samples. Two other chemicals were found in jellies, EtPABA in all eight samples, and 4MBC in one.

As the zooplankton samples were well under 1 gram, we were only able to obtain semi-quantative results. Seven out of the 23 UV filters investigated were measured above the LOQ in at least one sample. This included BP3 and its metabolites BP1, HB and 4DHB. Additionally, 4MBC, EtPABA and ODPABA were detected. Because the results were semi-quantiative, they are not listed in Table 5.

As in Jellyfish Lake, sediment samples showed a different pattern of contamination from water and jellyfish, where 4HB (a BP3 metabolite) was present in all 8 samples, and OC in one (Table 5).

Table 5. Results of sunscreen chemicals in Ngermeuangel Lake (NLK). See Table 2 for UV filter acronyms. ΣUV F- the sum of all UV chemicals in one sample (ng/ml); NUV F- the number of samples positive for UV chemicals; NLK-W: water samples collected in Ngermeuangel Lake from evenly-spaced sites throughout the lake; NLK-LGN: water samples collected outside NLK near the trial entrance; BLANKS: nano-pure water to detect possible contamination from sources other than the sample; NLK-J: medusae samples collected from evenly-spaced sites; NLK-S: bottom sediment samples collected from evenly-spaced sites; n.d.- not detected (below the limit of detection); LOQ- Limit of Quantification, lowest concentration at which the chemical can be reliably measured. Numbers in bold indicate positive results with reliable concentration values.

WATER — **Units ng/ml water**

Sample No	BP3	4HB	4DHB	DHMB	BP2	EHMC	4MBC	EtPABA	OC	BZT	TBHPBT	UVP	UV320	UV327	DMBZT	ΣUV F	N UVF
NLK-W01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.303**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.303	1
NLK-W02	0.019	<LOQ	n.d.	n.d.	n.d.	**1.800**	0.009	n.d.	n.d.	n.d.	n.d.	0.029	n.d.	n.d.	n.d.	1.856	4
NLK-W03	0.004	n.d.	n.d.	0.008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**1.160**	n.d.	1.173	3
NLK-W04	0.000	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.015	n.d.	n.d.	0.015	1
NLK-W05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
NLK-W06	0.008	n.d.	n.d.	0.030	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.038	2
NLK-W07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.022	n.d.	0.042	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.064	2
NLK-W08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
NLK LNG-01	n.d.	<LOQ	n.d.	n.d.	n.d.	0.044	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.008	n.d.	0.052	2
NLK LNG-02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.023	n.d.	n.d.	n.d.	n.d.	n.d.	0.023	1
NLK LNG-03	n.d.	<LOQ	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.015	n.d.	n.d.	0.015	1
NLK LNG-04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	0
NLK BLANK 01	**0.009**	n.d.	n.d.	**0.024**	n.d.	n.d.	n.d.	n.d.	**0.200**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.232	3
NLK BLANK 02	**0.028**	n.d.	n.d.	**0.017**	n.d.	n.d.	n.d.	n.d.	**0.410**	n.d.	n.d.	**0.090**	n.d.	n.d.	n.d.	0.545	4
NLK LGN BLANK 01	n.d.	<LOQ	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	0.006	n.d.	**0.015**	0.011	<LOQ	0.032	3
NLK LGN BLANK 02	**0.012**	n.d.	n.d.	**0.019**	n.d.	n.d.	n.d.	n.d.	**0.219**	n.d.	n.d.	n.d.	n.d.	<LOQ	**0.010**	0.259	4

JELLYFISH — **Units ng/g wet weight jellyfish**

Sample No	BP3	4HB	4DHB	DHMB	BP2	EHMC	4MBC	EtPABA	OC	BZT	TBHPBT	UVP	UV320	UV327	DMBZT	ΣUV F	N UVF
NLK-J01	**1.20**	**1.36**	n.d.	n.d.	<LOQ	n.d.	n.d.	**4.05**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	6.61	3
NLK-J02	**1.56**	**2.02**	**1.59**	n.d.	**3.33**	n.d.	n.d.	**1.21**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9.71	5
NLK-J03	**0.76**	**0.93**	**4.71**	n.d.	**0.53**	n.d.	n.d.	**1.20**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	8.14	5
NLK-J04	**1.00**	**2.82**	**1.48**	n.d.	**1.11**	n.d.	n.d.	**1.85**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	8.26	5
NLK-J05	**2.42**	**0.78**	**2.93**	n.d.	n.d.	n.d.	n.d.	**0.87**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7.00	4
NLK-J06	**1.11**	**3.54**	**2.26**	n.d.	**1.71**	n.d.	n.d.	**1.15**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9.78	5
NLK-J07	**2.33**	**0.84**	**1.31**	n.d.	**0.25**	n.d.	n.d.	**0.67**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	5.41	5
NLK-J08	**2.63**	**0.83**	**3.54**	n.d.	**0.48**	n.d.	**0.20**	**1.58**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9.26	6

SEDIMENT — **Units ng/g dry weight sediment**

Sample No	BP3	4HB	4DHB	DHMB	BP2	EHMC	4MBC	EtPABA	OC	BZT	TBHPBT	UVP	UV320	UV327	DMBZT	ΣUV F	N UVF
NLK-S01	n.d.	**28**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	28	1
NLK-S02	n.d.	**44**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	44	1
NLK-S03	n.d.	**203**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	203	1
NLK-S04	n.d.	**202**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	202	1
NLK-S05	n.d.	**136**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	136	1
NLK-S06	n.d.	**241**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**5**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	246	2
NLK-S07	n.d.	**43**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	43	1
NLK-S08	n.d.	**156**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	156	1

Open ocean-

Ocean water samples were collected on the east side of the archipelago, outside of Lighthouse Reef, 4 km from the Palau lagoon (Fig. 4). Of the 4 water samples taken in the open ocean outside the eastern reef, two (50%) were positive for one sunscreen chemical each (Table 3). Two ocean blanks (nano-pure water) were also taken at the same time; both were positive for two different chemicals.

Bottle Blanks in laboratory-

Five bottle blank samples, a measure of laboratory contamination, taken at the CRRF laboratory were positive for 3 of the 22 chemicals tested in water (see Appendix 1). Four of the five blanks tested were positive for at least one of these chemicals.

DISCUSSION

Results of the sunscreen chemicals in water, jellyfish, zooplankton and sediment from the marine lakes in Palau indicate that the compounds or their metabolites are wide spread, even in locations we assumed to be 'pristine.' Our results indicate that Jellyfish Lake appears to have consistently higher levels of most chemicals in both in medusae and sediment than the other two lakes sampled. Table 6 below summarizes the average values of important sunscreen compounds detected in jellyfish and sediment in the three study lakes. These chemicals enter the environment in two ways: 1) waste water effluent or 2) direct washing off of chemicals while in contact with the body of water. Because Jellyfish Lake is >20 km from the nearest populated town, it is assumed that sunscreen chemicals enter the environment through #2.

The most striking example of unexpected contamination is Ngermeuangel Lake (NLK) in Koror, our ‘control’ lake, distant from the tourist Jellyfish Lake visited yearly by tens of thousands of people, and located on a different island with a different watershed. The detection of UV filter chemicals in Ngermeuangel Lake is unexpected, as the lake is closed to the public and has minimal use by humans. Our original study design was reliant on using NLK as the unaffected control, a lake with little human use or visits. Its apparent contamination may be due to its proximity to the population center of Koror which is lined with multiple hamlets containing septic systems and leaky sewer lines. As such, the study has ended up having no pristine lake, but it still has comparative control sites when considering levels of human use and visits.

Table 6. A comparison of average values of 5 chemicals in jellyfish and 3 chemicals in sediment among the three lakes tested. Jellies were not present in Clear Lake and so no results are shown.

	Jellyfish ng/g wet weight					Sediment ng/g dry weight		
Lake	**BP3**	**4HB**	**4DHB**	**BP2**	**EtPABA**	**4HB**	**EHMC**	**OC**
Jellyfish Lake-OTM								
average (±sd)	4.41 (1.36)	4.76 (5.07)	1.78 (1.36)	3.5 (2.21)	1.31 (0.82)	178.38 (194.45)	35.88 (21.58)	64.75 (69.02)
median	4.21	3.00	1.88	2.91	1.13	66.50	41.50	52.50
range	2.55-6.99	0.58-15.44	0-3.78	0.67-7.34	0.68-3.24	0-526	0-59	0-222
# positive/total number	(n=8/8)	(n=8/8)	(n=6/8)	(n=8/8)	(n=8/8)	(n=7/8)	(n=7/8)	(n=7/8)
Ngermeuangel Lake-NLK								
average (±sd)	1.63 (0.73)	1.64 (1.05)	2.23 (1.47)	0.93 (1.13)	1.57 (1.07)	131.63 (83.58)	0	0.63(1.77)
median	1.38	1.15	1.92	0.50	1.21	146.00	0	0.00
range	0.76-2.63	0.78-3.54	0-4.71	0-3.33	0.67-4.05	28-241	0	0-5
# positive/total number	(n=8/8)	(n=8/8)	(n=7/8)	(n=6/8)	(n=8/8)	(n=8/8)	(n=0/8)	(n=1/8)
Clear Lake-CLM								
average (±sd)	--	--	--	--	--	266.00 (164.37)		5.25 (9.74)
median	--	--	--	--	--	290.00	0	0.00
range	--	--	--	--	--	12-475	0	0-28
# positive/total number	--	--	--	--	--	(n=8/8)	(n=0/8)	(n=2/8)

Another useful way to examine the data is by considering those chemicals that are metabolites- compounds that result when a living organism converts a sunscreen compound (or any other xenobiotic chemical) into a different chemical by a detoxification process, by improving its excretion rate (via urine or feces). The presence of metabolites strengthens the inference that the original chemical was present and also indicates that it is biologically relevant. The starred (**) compounds in Table 1 are metabolites converted from BP3. Figure 2 shows the pathways for production of these metabolites from BP3.

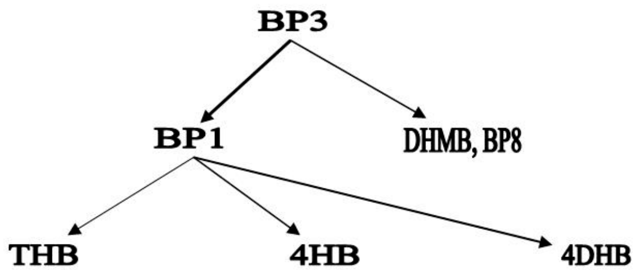

Figure 2. Path of metabolite production from BP3 in rats and humans.

Blank water samples: Blanks are an important part of the experimental design to help control for contamination from sources other than the actual sample. The incidence of positive detections of various chemicals in our blanks was surprising and worrisome. It implies there may be either some false positives among the blanks or an unexplained source of contamination, and requires that the results patterns seen from other samples be carefully evaluated. Personal care products (PCP's), such as sun screen, body lotion, shampoo and many others, often contain BP3. This compound, or its metabolites, was the most commonly found chemical in the samples in this study. BP3 is difficult to reliably test because it is thought to be 'everywhere' and contamination by humans and equipment used for collecting the samples cannot be ruled out, despite the measures of contamination control taken and explained in previous sections.

Jellyfish Lake: Water from Jellyfish Lake (OTM) was positive for UV filter compounds that occur in sunscreen and one metabolite in 62% of the open lake and 75% of the nearby dock samples. The slightly higher levels of these near the dock in OTM, where humans enter the water and often apply sunscreen, compared to the rest of the lake, is not surprising.

Medusae from OTM were positive for sunscreen chemicals and metabolites at concentrations higher than those found in water samples. All jellyfish had BP3, in the range 2.55-6.99 ng/g wet weight and contained 4HB, one of the known BP3 metabolites, at even higher concentrations than the parent compound (up to 15.44 ng/g ww). The BP3 metabolite 4DHB was also observed in 81% of the jellyfish, generally at lower concentrations than BP3 and 4HB. 4HB and 4DHB are both metoblites from BP3, i.e. they are biochemically converted from BP3 (see Figure 2). They are not chemicals used in personal care products and could not have come from anywhere else other than the metabolism of BP3. Jellies were also consistently positive for sun screen products BP2 and EtPABA.

The occurrence of these metabolites suggests that the jellyfish may have a mechanism for detoxification of BP3 as both 4DHB and 4HB have been previously identified as metabolism products of BP3 in rats and humans. We cannot rule out that these compounds were not present in the water and subsequently absorbed by the jellyfish. However, the levels of concentrations measured in the jellyfish are high, and cannot be explained only by the adsorption of the traces of these metabolites measured in the water samples.Because the intermediate metabolite BP1 (Figure 2) in the rat/human pathway was not detected, it suggests that a different metabolism pathway may occur in these jellyfish.

Sediment samples also showed consistent amounts of the BP3 metabolite 4HB. Sediments are known to adsorb these organic chemicals to their surface, ie. form an ultra-thin layer on the sediment surface, where they collect and remain. The persistent presence in sediments also suggests that biota (living organisms) in the lake may be accumulating and metabolizing these compounds.

The source of the contamination in OTM is most likely from human visitors to the lake, since the island of Mecherchar is distant from any human population center and associated direct or indirect pollution. The visitors typically apply sunscreen before making the short walk to the lake and then enter the water without removing it. Of the 16 "spaced" and "near dock" water samples from OTM, 11 (69%) had detectable levels of 6 different UV filter chemicals, while only 1 (25%) of those taken outside OTM in the lagoon had detectable levels of just one chemical.

Clear Lake: Clear Lake (CLM) was not as contaminated as OTM, which was expected, but 38% of the water samples were still positive. The absolute amount of UV chemicals was also lower in CLM, relative to OTM. Unfortunately jellyfish are not always present in CLM, and at the time of sampling the lake no *Mastigias* medusae were present (we have not recorded them in CLM since 2014). Results from sediments indicate the presence of the BP3 metabolite, 4HB, similar to results from OTM.

CLM is 2 km west of OTM, but both lakes are connected at some level via the water table under the island of Mecherchar. We believe because so few people go into Clear Lake (probably 3 researchers per year) the likely source of contamination in CLM is from the water table under the island. Both lakes rise and fall with the tides, although the tidal range is dampened by the island. These is no direct transport of water between lagoon and lake, it is all mediated through the ground water lens. The tidal forcing of ground water movement would also cause mixing and some net transport within the ground water lens, but such has not been quantified at any level. It is reasonable to assume the water from the lake with chemical contaminates would gradually disperse into the ground water lens and eventually some of these would arrive at both the lagoon shore and nearby marine lakes.

Ngermeuangel Lake: Ngermeuangel Lake (NLK) was expected to be relatively 'clean' and serve as an uncontaminated control lake for the study. But, in fact, eight chemicals were detected in NLK water samples (Table 6), and jellyfish and sediment showed consistent levels of BP3 metabolites. All jellyfish had BP3, in the range 0.76-2.42 ng/g ww. In addition, they all also contained 4HB, one of the known BP3 metabolites, at higher concentrations than the parent compound (up to 3.54 ng/g ww). One other BP3 metabolite, 4DHB, was also frequently observed in 88% of the jellyfish, though in general the levels in NLK were lower than in OTM (Table 6). Additionally, despite the semi-quantitative results, it is clear that zooplankton also do bioaccumulate these compounds.

The source of the contamination in NLK is most likely its close proximity and connections to the surrounding Koror hamlets. The populated areas of Koror town are on basalt rock with only limited ground water capacity, and most rainfall moves rapidly near the surface to the lagoon. Similarly, sewage leaks and septic tanks are common in Koror and also have their water flow towards the lagoon. The outflow of these sources for UV filter chemicals (common in personal care products) would quickly reach the lagoon. The nearby rock structure of the rock islands, where the lakes occur, is porous reef limestone into which lagoon water is forced on every tidal cycle. Consequently, contaminated lagoon water could constantly enter the ground water beneath the island where NLK is found. NLK Lagoon samples were taken for reference from the east side of Ngermeuangel island (Figure 4) in the cove at the trail head to NLK, and 75% of these were positive. These positive samples are not surprising in light of the connection between this site and Nikko Bay via tidal flow. It is unfortunate we did not collect 'Lagoon' water samples specifically from Nikko Bay, to the west of NLK, as these would be more likely to carry much higher levels of pollutants from the human habitation of Koror town.

Sunscreen use by tourists is extremely common and, in many cases, visitors to Palau have little experience dealing with conditions in tropical marine environments. Personal observations indicate tourists tend to apply much more sunscreen than is effective and consequently much of this excess quickly sloughs off in the water once submerged. The likely presence of sunscreen compounds in ground water is concerning, since the volume of such beneath the porous rock islands is large and would take potentially many years to flush out, even if sunscreen use was totally stopped. The overall environmental effects on the marine lakes of Palau from sunscreen is still uncertain.

Jellyfish are the draw to the iconic Jellyfish Lake in Palau. As jellies are closely related to corals we would be remiss not to mention that recent studies show that BP2 and BP3 have toxic effects on corals and their larvae (Downs et al., 2014; Downs et al, 2016) and can cause coral bleaching by promoting viral infections (Danovaro et al., 2008). While our results do not indicate any negative effects at present on marine lake organisms, it would be valuable to use the precautionary principle to reduce or eliminate sunscreen use, switch to more biologically friendly products, and educate the tourism sector of the need to reduce or eliminate sunscreens. Additionally, the potential toxicity effect of these low levels of UV filters currently observed after long-term exposure (chronic toxicity) are yet unknown. Moreover, as many different ingredients in personal care products were detected, the mixture-toxicity (due to the simultaneous occurrence) should be another issue to take into account in the risk assessment.

Notes on other UV Filter chemicals detected:

Some of the other compounds detected in the samples raise individual concerns about their presence. These include the following:

1- Et-PABA (benzocaine) was also ubiquitous in the jellyfish samples, but at lower concentrations, generally below 1.5 ng/g ww. This compound is used in cosmetics and sunscreen, and for many other purposes. The source of this compound is diverse, and, without doubt, comes from the swimmers in the lake.

2- BP2, another sunscreen from the benzophenones group, was very frequently observed (88%) in the jellies, but generally at lower concentrations than the rest of the benzophenones detected. This compound is used as a fragrance ingredient and as sunscreen. It is not approved for use in United States sunscreens formulations because of the concerns about hormone disruption.

3 - EHMC was not frequently observed in the water samples, but its presence and high concentration in a few samples should be highlighted because this UV filter was included in the “Watch list” for European Union-wide monitoring in 2015. It is an endocrine disruptor and known to be a bioaccumulating compound.

4 -The presence of UV327 at such high concentrations in water samples and frequency is of concern. This compound is not intended for use in products for which prolonged contact with mucous

membranes or skin is expected. This UV filter is used in technical products such as plastics, coatings, adhesives and construction materials to prevent their deterioration. UV327 is so persistent and bioaccumulative that in 2015 it was included in the list of SVHC, Substances of Very High Concern through Decision ED/79/2015 of the European Chemicals Agency (ECHA).

A plastic tourist dock has been in place in Jellyfish Lake, in various forms, since the late 1990's. It is not known if this could be a source of UV327 contamination, but it should not be discounted.

Conclusions & Recommendations:

The *Mastigias* medusa stage is relatively short lived, with a life span of about 6 months. The presence of sunscreen chemicals in them and their presence in the sediment in Jellyfish Lake and other marine lakes is cause for concern. The medusae stage may not live long enough to be directly affected, but their benthic polyp stage, critical to their life cycle, is much longer lived and could be. The chemical analysis for sunscreen compouds and metabolites is expensive and require shipping samples overseas in a frozen condition. We feel in the short term there is little need to further monitor sunscreen compound levels in Jellyfish Lake. We know they are there and will be for some time. Their presence should be addressed by the scientists and managers working in Jellyfish Lake in a practical manner to try to stabilize the levels of UV filters in Jellyfish Lake and minimize additions of them to the system.

To help accomplish this, we recommend the following:

- Promote the use of clothing for sun protection, such as rash guards, to minimize the application of ANY sunscreen.
- Require that only eco-friendly sunscreen is used in and around Jellyfish Lake. This includes brands that DO NOT contain chemicals listed in Appendix 5.
- Educate tour guides and tourists for the most responsible use of these eco-friendly sunscreens: apply at least 20 minutes before entering the lake.
- Promote the use of these eco-friendly brands throughout Palau, with the development of legislation to prohibit the use and importation of traditional sunscreen products.
- Improve the waste water runoff and seepage situation surrounding Nikko Bay, in an attempt to help 'clean up' this exceptionally important reef site.

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Appendix 1. Maps showing details of collection sites and sampling locations at each site.

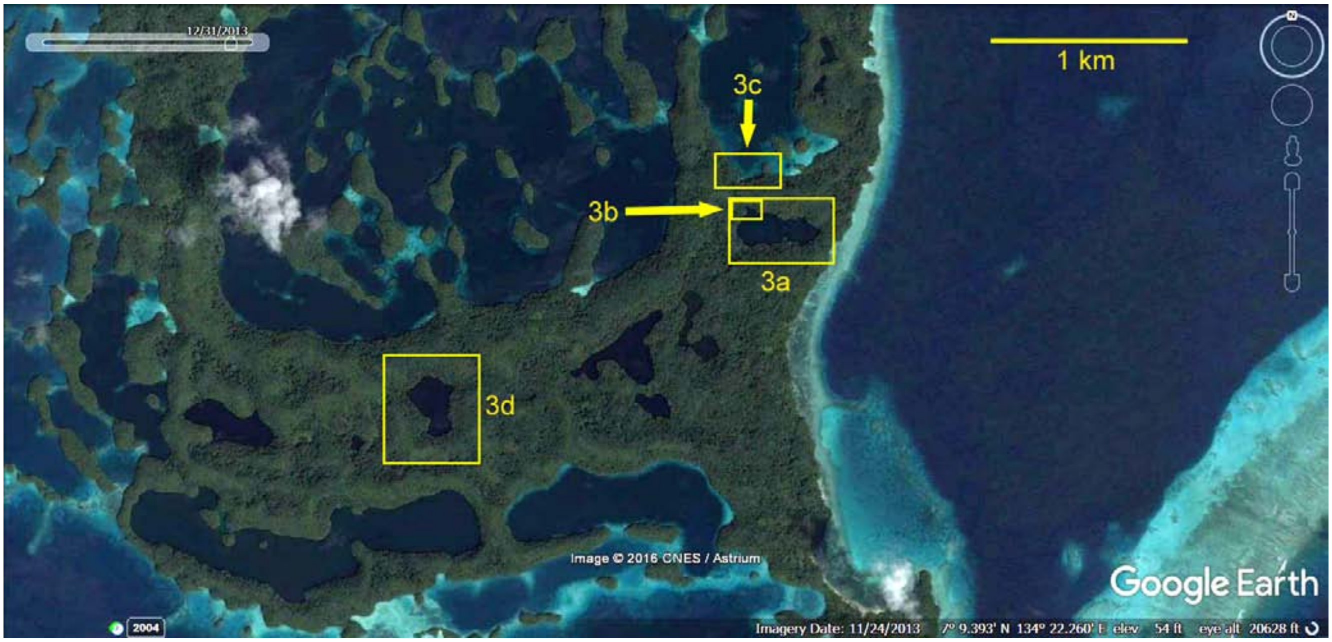

Figure 3. Mecherchar Island in the southern rock islands is ~20km distant from Koror and harbor two marine lakes that were sampled: Jellyfish Lake (3a) and Clear Lake (3d).

Figure 3a. Sampling sites inside of Jellyfish Lake on Mecherchar Island. JW indicates points that water and medusae jellyfish samples were collected; numbers 1-8 around the perimeter of the lake are sediment sampling locations. The concentrated points in the upper left of the photo are detailed in Figure 3b.

Figure 3b. Sampling sites for water inside of Jellyfish Lake near the tourist dock are labeled DK01-DK08.

Figure 3c. Sampling sites for water in the lagoon outside of Jellyfish Lake, near the tourist dock are labeled OTMLGN 1-4.

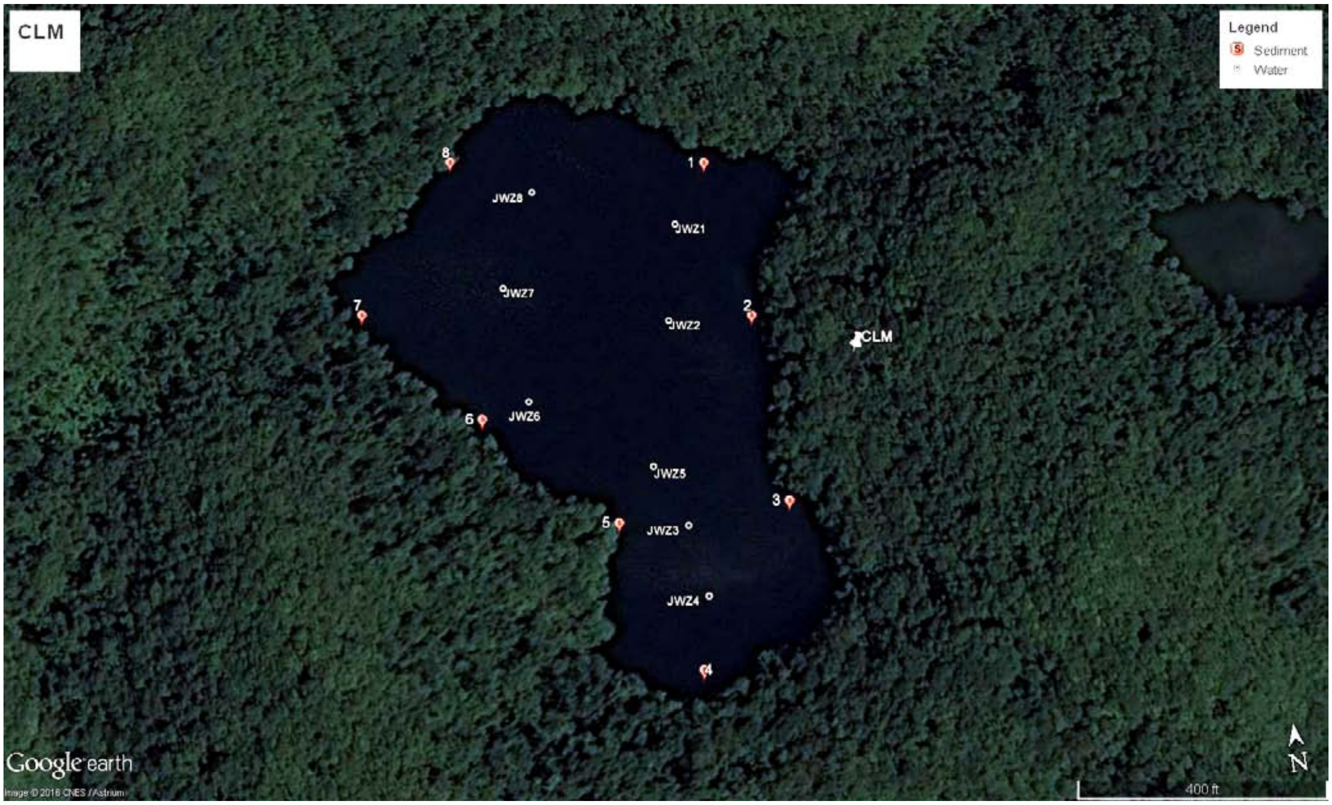

Figure 3d. Sampling sites inside of Clear Lake at the center of Mecherchar Island. W indicates points that water samples were collected; numbers 1-8 around the perimeter of the lake are sediment sampling locations.

Figure 4. Northern part of Koror showing Ngermeuangel Lake, detailed in Figure 4a. and its proximity to the Ocean site where 4 comparative samples were collected, labeled OCEAN 01-04.

Figure 4a. Ngermeuangel Lake (above): JW indicates sites where medusae jellyfish and water samples were collected. Numbers 1-8 around the lake's perimeter are sediment sampling sites. NLKLGN 01-04 sites (below) are the 4 lagoon comparative sites taken outside of Ngermeuangel Lake.

Appendix 2. Testing results of water samples from marine lakes in Palau analyzed for UV filter chemicals. See Table 1 for UV filter acronyms. OTM-W: water samples collected in Jellyfish Lake (Ongeim'l Tketau) from evenly-spaced sites throughout the lake; OTM-DK: water samples collected in Jellyfish Lake from the inlet in front of the dock; OTM-LGN: water samples collected outside Jellyfish Lake from near the outside dock; CLM-W: water samples collected in Clear Lake from evenly-spaced sites throughout the lake; NLK-W: water samples collected in Ngermeuangel Lake from evenly-spaced sites throughout the lake; NLK-LGN: water samples collected in the lagoon outside of the hiking entrance to Ngermeuangel Lake; OCEAN: water samples collected in the ocean outside Lighthouse Reef (7^{o} 14.851N, 134^{o} 28.974E) (see Figures 3 & 4 for site details); BLANKS: nano-pure water to detect possible contamination from sources other than the sample; n.d.: not detected; LOD- Limit of Detection, lowest quantity of a substance that can be distinguished from the absence of that substance within a stated confidence limit of 1%; LOQ- Limit of Quantification, lowest concentration at which the chemical can be reliably detected.

	Sunscreen Chemical (UV Filter)														
Sample No.	**BP3**	**4HB**	**DHMB**	**EHMC**	**4MBC**	**ODPABA**	**OC**	**BZT**	**TBHPBT**	**UVP**	**UV320**	**UV327**	**DMBZT**	**ΣUV F**	**N UV F**
OTM-W01	4.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.12	1
OTM-W02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM-W03	6.45	n.d.	n.d.	n.d.	n.d.	n.d.	541	n.d.	n.d.	216	n.d.	n.d.	n.d.	763.45	3
OTM-W04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM-W05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	473	n.d.	n.d.	n.d.	513	n.d.	986	2
OTM-W06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	130	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	130	1
OTM-W07	10.2	n.d.	n.d.	n.d.	n.d.	n.d.	400	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	410.2	2
OTM-W08	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM-DK01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM-DK02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	27.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	27.4	1
OTM-DK03	5.36	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1200	n.d.	1205.36	2
OTM-DK04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	85.3	11.4	n.d.	n.d.	n.d.	n.d.	n.d.	96.7	2
OTM-DK05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM-DK06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	79.1	n.d.	n.d.	n.d.	n.d.	n.d.	79.1	1
OTM-DK07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	515	n.d.	n.d.	n.d.	n.d.	n.d.	515	1
OTM-DK08	4.99	n.d.	4.56	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9.55	2
OTM LGN-01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	454	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	454	1
OTM LGN-02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM LGN-03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM LGN-04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0

Appendix 2. (cont.)

Sample No.	BP3	4HB	DHMB	EHMC	4MBC	ODPABA	OC	BZT	TBHPBT	UVP	UV320	UV327	DMBZT	ΣUV F	N UV F
CLM-W01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
CLM-W02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
CLM-W03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
CLM-W04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
CLM-W05	12.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	12.1	1
CLM-W06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
CLM-W07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9.53	n.d.	n.d.	n.d.	n.d.	735	n.d.	744.53	1
CLM-W08	4.9	n.d.	n.d.	n.d.	n.d.	n.d.	241	n.d.	n.d.	21.6	n.d.	n.d.	n.d.	267.5	3
NLK-W01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	303	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	303	1
NLK-W02	18.5	<LOQ	n.d.	1800	8.8	<LOQ	n.d.	n.d.	n.d.	29	n.d.	n.d.	n.d.	1856.3	4
NLK-W03	4.4	n.d.	8.2	n.d.	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	1160	n.d.	1172.6	3
NLK-W04	n.d.	<LOQ	n.d.	n.d.	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	15.3	n.d.	n.d.	15.3	1
NLK-W05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	< 0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
NLK-W06	8.44	n.d.	29.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	38.24	2
NLK-W07	n.d.	n.d.	n.d.	n.d.	21.6	n.d.	41.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	63.5	2
NLK-W08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
NLK LNG-01	n.d.	<LOQ	n.d.	43.8	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	8.07	n.d.	51.87	2
NLK LNG-02	n.d.	n.d.	n.d.	n.d.	n.d.	<LOQ	n.d.	23.3	n.d.	n.d.	n.d.	n.d.	n.d.	23.3	1
NLK LNG-03	n.d.	<LOQ	<LOQ	n.d.	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	14.6	n.d.	n.d.	14.6	1
NLK LNG-04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OCEAN 01	n.d.	<LOQ	n.d.	n.d.	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	16.2	n.d.	n.d.	16.2	1
OCEAN 02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OCEAN 03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OCEAN 04	n.d.	<LOQ	n.d.	714	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	714	1
OTM BLANK 01	2.48	n.d.	n.d.	n.d.	n.d.	n.d.	212	n.d.	n.d.	n.d.	n.d.	1070	n.d.	1284.48	3
OTM BLANK 02	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1060	n.d.	1060	1
OTM LGN BLANK 01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
OTM LGN BLANK 02	13.5	n.d.	n.d.	n.d.	57.1	n.d.	66.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	137.2	3
CLM BLANK 01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
CLM BLANK 02	3.76	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	796	n.d.	799.76	2

Appendix 2. (cont.)

Sample No.	BP3	4HB	DHMB	EHMC	4MBC	ODPABA	OC	BZT	TBHPBT	UVP	UV320	UV327	DMBZT	ΣUV F	N UV F
NLK BLANK 01	8.93	n.d.	23.5	n.d.	n.d.	n.d.	200	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	232.43	3
NLK BLANK 02	28.4	n.d.	17.1	n.d.	n.d.	n.d.	410	n.d.	n.d.	89.7	n.d.	n.d.	n.d.	545.2	4
NLK LGN BLANK 01	n.d.	<LOQ	<LOQ	n.d.	n.d.	<LOQ	n.d.	n.d.	6.32	n.d.	14.9	11	n.d.	32.22	3
NLK LGN BLANK 02	11.8	n.d.	19	n.d.	n.d.	n.d.	219	n.d.	n.d.	n.d.	n.d.	n.d.	9.67	259.47	4
OCEAN BLANK 01	9.47	n.d.	n.d.	n.d.	n.d.	n.d.	82.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	92.07	2
OCEAN BLANK 02	4.34	n.d.	9.94	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	14.28	2
BOTTLE BLANK 01	9.99	n.d.	12.5	n.d.	n.d.	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	22.49	2
BOTTLE BLANK 02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	520	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	520	1
BOTTLE BLANK 03	<LOQ	n.d.	n.d.	n.d.	n.d.	n.d.	270	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	270	1
BOTTLE BLANK 04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	0
BOTTLE BLANK 05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	230	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	230	1
Limit of Detection (ng/L)	1.09	1.1	0.6	1.1	0.6	1.0	1.3	0.2	0.6	1.4	3.7	2.5	0.2		
Limit of Quantification (ng/L)	3.6	3.5	2.0	3.8	2.0	3.3	4.3	0.6	1.9	4.8	12.3	8.3	0.8		
All Field Samples (including field blanks)															
Count (>LOQ)	13	0	6	3	3	0	10	1	1	3	4	7	1		
Frequency %	23.2	0.0	10.7	5.4	5.4	0.0	17.9	1.8	1.8	5.4	7.1	12.5	1.8		
Inside the Lake															
Count (>LOQ)	5	0	2	1	2	0	4	0	0	2	1	2	0		
Frequency %	11.4	0.0	4.5	2.3	4.5	0.0	9.1	0.0	0.0	4.5	2.3	4.5	0.0		
Outside the Lake															
Count (>LOQ)	6	0	4	0	0	0	4	0	1	1	1	2	1		
Frequency %	50.0	0.0	33.3	0.0	0.0	0.0	33.3	0.0	8.3	8.3	8.3	16.7	8.3		

Appendix 3. Testing results of *Mastigias* jellyfish samples from marine lakes in Palau analyzed for UV filter chemicals. See Table 1 for UV filter acronyms. OTM-J: jellyfish samples collected in Jellyfish Lake from evenly-spaced sites throughout the lake; NLK-J: jellyfish samples collected in Ngermeuangel Lake from evenly-spaced sites throughout the lake (see Figures 3 & 4 for site details). Concentrations expressed in nanograms/gram wet weight. n.d.: not detected; LOQ- Limit of Quantification, lowest concentration at which the chemical can be reliably detected.

JELLYFISH — **Concentrations expressed in ng/g ww**

Sample No.	BP3	4HB	4DHB	BP2	4MBC	EtPABA	Σ UV Fs
OTM-J01	4.04	1.10	1.92	5.55	n.d.	1.07	13.68
OTM-J02	5.37	7.29	2.39	0.67	n.d.	0.68	16.40
OTM-J03	2.55	15.44	3.78	4.68	n.d.	1.25	27.70
OTM-J04	3.28	0.58	3.13	3.36	n.d.	0.68	11.04
OTM-J05	4.80	1.75	1.21	1.86	n.d.	3.24	12.86
OTM-J06	6.99	6.83	1.83	7.34	0.17	1.39	24.56
OTM-J07	4.39	0.87	n.d.	2.07	0.49	1.02	8.84
OTM-J08	3.87	4.24	n.d.	2.45	n.d.	1.19	11.75
NLK-J01	1.20	1.36	n.d.	<LOQ	n.d.	4.05	6.61
NLK-J02	1.56	2.02	1.59	3.33	n.d.	1.21	9.71
NLK-J03	0.76	0.93	4.71	0.53	n.d.	1.20	8.14
NLK-J04	1.00	2.82	1.48	1.11	n.d.	1.85	8.26
NLK-J05	2.42	0.78	2.93	n.d.	n.d.	0.87	7.00
NLK-J06	1.11	3.54	2.26	1.71	n.d.	1.15	9.78
NLK-J07	2.33	0.84	1.31	0.25	n.d.	0.67	5.41
NLK-J08	2.63	0.83	3.54	0.48	0.20	1.58	9.26

Appendix 4. Testing results of sediment samples from marine lakes in Palau analyzed for UV filter chemicals. See Table 1 for UV filter acronyms. OTM-S: sediment samples collected in Jellyfish Lake from evenly-spaced sites throughout the lake; NLK-S: sediment samples collected in Ngermeuangel Lake from evenly-spaced sites throughout the lake (see Figures 3 & 4 for site details). Concentrations expressed in nanograms/gram sediment dry weight. n.d.: not detected.

SEDIMENT **Concentrations expressed in in ng/g dw**

Sample No.	BP3	4HB	EHMC	OC	ΣUVFs
OTM-S01	n.d.	36	44	59	140
OTM-S02	n.d.	313	39	44	396
OTM-S03	n.d.	57	36	47	140
OTM-S04	15	526	57	58	660
OTM-S05	n.d.	75	7	7	89
OTM-S06	n.d.	n.d.	n.d.	n.d.	0
OTM-S07	n.d.	58	59	222	340
OTM-S08	n.d.	362	45	81	487
CLM-S01	n.d.	292	n.d.	n.d.	292
CLM-S02	n.d.	363	n.d.	n.d.	363
CLM-S03	n.d.	19	n.d.	n.d.	19
CLM-S04	n.d.	12	n.d.	14	26
CLM-S05	n.d.	475	n.d.	n.d.	475
CLM-S06	n.d.	290	n.d.	n.d.	290
CLM-S07	n.d.	452	n.d.	28	480
CLM-S08	n.d.	225	n.d.	n.d.	225
NLK-S01	n.d.	28	n.d.	n.d.	28
NLK-S02	n.d.	44	n.d.	n.d.	44
NLK-S03	n.d.	203	n.d.	n.d.	203
NLK-S04	n.d.	202	n.d.	n.d.	202
NLK-S05	n.d.	136	n.d.	n.d.	136
NLK-S06	n.d.	241	n.d.	5	250
NLK-S07	n.d.	43	n.d.	n.d.	43
NLK-S08	n.d.	156	n.d.	n.d.	156

Appendix 5. Eco-friendly sunscreens DO NOT contain the following 10 chemicals:

1) Oxybenzone (BP3)
2) Octyl methoxycinnamate (EHMC)
3) Octocrylene (OC)
4) 4-methyl-benzylidene camphor (4MBC)
5) Triclosan
6) Methyl paraben
7) Ethyl paraben
8) Propyl paraben
9) Butyl paraben
10) Benzyl paraben
11) Phenoxyethanol