2 Methods

2.1 Study site

The area that was researched comprises over 560,000 km^2 of the GoA, reaching from 135˚W to 148˚W and 47.5˚N and 56.7˚N. The Russian research vessel Professor Kaganovskiy performed the cruise in February and March 2019. In this area 56 neuston trawls samples were collected and a visual survey of floating plastics was performed at 20 locations as shown in Figure 3.
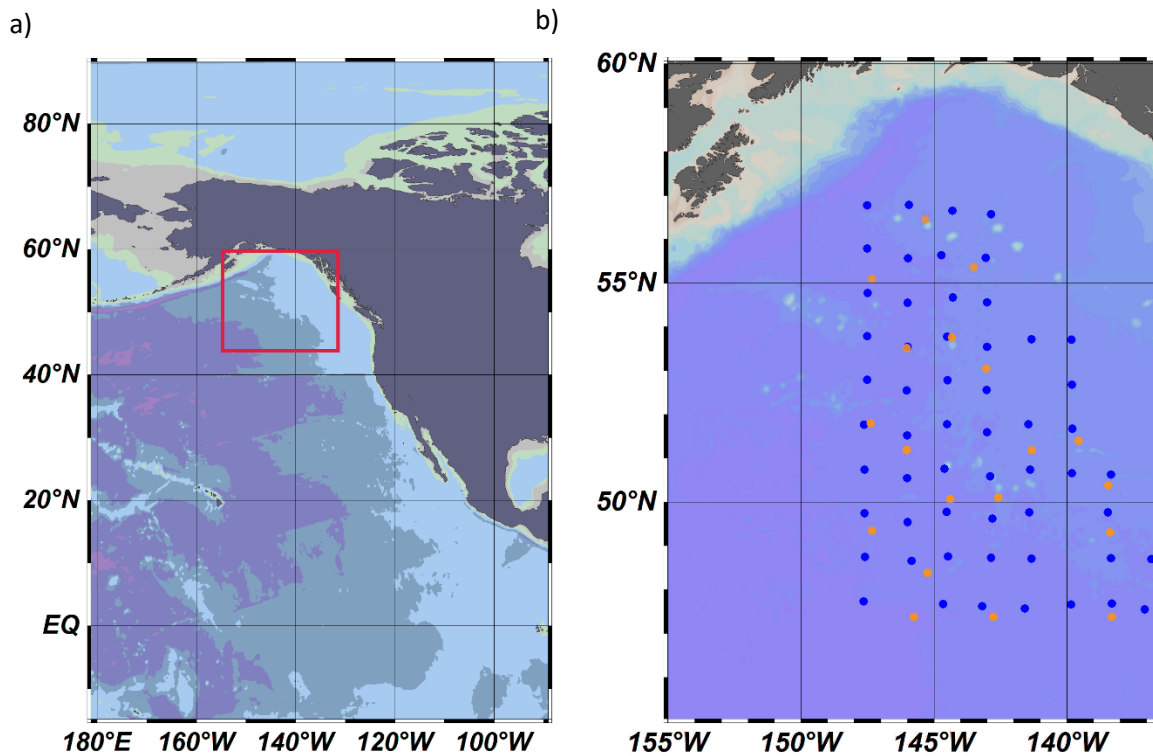

Figure 3 - The location of sampling within the GoA. Map a) shows the research area within the North Pacific indicated with the red square. Map b) is a zoom in of the GoA, showing the location of the 56 neuston sample stations (blue dots) and the 20 visual survey stations (orange dots). These maps were created with the ODV software, version 5.1.7 (available at https://odv.awi.de/).

2.2 Sampling

The sampling was done with a Hydro-Bios neuston trawl (mouth opening of 70 cm x 40 cm), with a 260 cm long sampling net with a mesh size of 300 µm. Prior to sampling, the sea state, date, time and coordinates of the position at the start of trawling were noted on a log sheet. The neuston trawl was deployed from a winch on the starboard side at vessel speeds < 2.5 knots. After 15 minutes of trawling the net was lifted out of the water in vertical position. The time and coordinates of the position at the end of trawling were noted on the log sheet. Still in upright position, the net was rinsed with seawater, to ensure that all the plastics and biomass was transferred into the cod-end. In the vessel's wet laboratory the cod-end was gently washed with sea water above a 250 µm sieve. The collected material was transferred into labelled bags (Whirl-Paks) together with 25 ml of formaldehyde to preserve the organic material.

2.3 Trawl sample processing

In the laboratory onshore, the samples were first washed into a sieve tower (0.05–0.15 cm, 0.15–0.5 cm, 0.5–1.5 cm, 1.5–5 cm, and >5 cm) using fresh water. Afterwards the sieves were placed in salt water and the material in the sieves was stirred multiple times to detach any possible biomass from the plastics particles. The buoyant particles were manually extracted using a forceps, measured with a ruler and sorted by size: Microplastic (0.05–0.5 cm) in two classes (0.05-0.15 cm and 0.15-0.5 cm) and

mesoplastic (0.5–5 cm) in two classes (0.5-1.5 cm and 1.5-5 cm). The collected plastic particles were separated into four main plastic types: H - including pieces of hard plastic; plastic sheet and film; N - encompassing plastic lines, ropes and fishing nets; P - being pre-production plastic pellets; F - being pieces made of foamed material. This separation was based on examination with the naked eye or with the help of a microscope (Hidalgo-Ruz et al., 2012). In case of uncertainty with the nature of the particle, the latter was picked and analysed with Raman spectroscopy. The picked plastics were counted and rinsed with distilled water to remove salt. Afterward the particles were placed in aluminium dishes and dried overnight for 3 hours at 65˚C. The dry mass was placed in zip-locks and weighed using an OHAUS Explorer EX324M (0.0001 g resolution). The particles were subsequently analysed using Raman spectroscopy to determine the polymer composition.

2.4 Visual survey

During the visual survey the observer first chose the side of the vessel (port or starboard) that provided the best sight given the visual conditions. During one hour the observer looked for debris within a 90˚ arc, encompassing the area ahead of the ship and on one side of the track-line. The observer was responsible to visually scan the water close to the vessel (0-50 m). The colours and plastics types (e.g. hard fragment, rope, miscellaneous household items) of all the identified objects were noted on a log sheet. Prior to and after the survey the log sheet was filled in for post processing purposes. The noted parameters include among other things the sea state, date, time and coordinates of the starting position (an example of the log sheet including most of the parameters is attached in appendix II).

2.5 Raman spectroscopy

Raman spectroscopy is commonly used in plastic analysis, to not only allow the discrimination of plastic and natural particles, but also to identify the different plastic polymers in a non-destructive way (Allen et al., 1999; Lenz et al., 2015; Peng et al., 2018; Van Cauwenberghe et al., 2013).

Raman spectroscopy uses a monochromatic laser that changes the energy state of a molecule from a ground state to a higher excited energy state. The sample will immediately recover to a lower energy state and during this recovery light is scattered (Smith et al., 2005). The energy loss during this reaction represents different characteristic vibrational modes (Lenz et al., 2015). The light is captured by a charge-coupled device (CCD) and its spectral signal is transferred to a computer. The signal is visualized in a spectrum showing the presence of characteristic frequency bands (Smith et al., 2005). The different polymers are defined by different frequency bands in the spectrum.

The Raman system used in this study was a PeakSeeker™ PEK-785, Agiltron Inc. with a 785 nm laser coupled to a RSM Video Raman Microscope with anp AmScope MU1000 digital camera. The microscope was equipped with 4 objectives, 10x, 20x, 40x and 60x. The integration time and the laser intensity were varied to optimize the signal intensity and the signal-to-noise ratio. The default settings used were an integration time of 20 s with a laser intensity of 70 mW and a 40x objective. The RSIQ software provided by Raman Systems, Agiltron Inc. was used to visualize the spectra.

With this instrument it was possible to identify PP, PE, PS, PVC, PET and cellulose acetate by comparing the obtained spectra to a library of reference spectra. Black or dark coloured particles were not analysed due to their strong infrared absorbance, which makes them unsuitable for analysis with Raman spectroscopy (Löder et al., 2015). Particles that do not clearly visually resemble plastic and that are not confirmed to be plastics by Raman spectroscopy were excluded from the data-set. Particles that do resemble plastic but lack confirmation by spectroscopy were labelled as unknown (NA).

2.6 Data analysis

With the trawl data the numerical and mass concentrations (particles or mass per km² of sea surface) of the plastics particles were calculated. These calculations were done for all the size classes and types. The towed area was calculated by multiplying the trawl width (0.7 m) by the tow length, determined by a flowmeter attached to the neuston trawl. However due to vertical mixing as a result of wind the concentrations of sampled plastics could be underestimated. For this reason 'depth-integrated' numerical and mass concentrations (C_i, in particles km⁻² or kg km⁻²) for all types and size classes at each sample locations were determined. These variables were combined in the following formulas as described by Kukulka et al., (2012).

$$Ci = \frac{Cs}{1 - e^{-d\,Wb - Ao^{-1}}}$$
(1.1)

The 'depth-integrated' concentrations depend on Wb, the ocean plastic terminal rising velocity, (in m s⁻¹), U, the wind speed (in m s⁻¹), d, the sample depth of the trawl (in m) and Cs, the plastic concentrations found in the cod-ends of the manta trawls per km² (in particles km⁻² or kg km⁻²). The values for Wb originate from rising velocity experiments described in Lebreton et al., (2018). The terminal rising velocity yields uncertainties (25th and 75th percentile) regarding the correction for vertical mixing formulating the confidence intervals.

$$Ao = 1.5 U *w\, k\, Hs$$
(1.2)

Were A_0 is the near surface turbulent exchange coefficient as described by formula 1.2, where U_{*w} is the frictional velocity of water (in m s⁻¹); K is the von Karman constant, equal to 0.4; H_s is the significant wave height (in m).

$$Hs = \frac{0.96}{g} \sigma^{\frac{3}{2}} U *a^2$$
(1.3)

The term H_s is defined in formula 1.3 by the g, the gravitational constant, equal to 9.81 (in m s⁻²); σ, the wave age, equal to 35, which assumes a fully developed state; u_{*a}, the frictional velocity of air (in m s⁻¹).

$$U *w = \sqrt{\frac{\rho a}{\rho w}\, Cd\, U^2}$$
(1.4)

U_{*w} is depending on the C_d the drag coefficient, equal to 1.2 10⁻³ and ρ_a, ρ_w respectively the density of air, equal to 1.225 kg dm⁻³, and the density of sea water respectively, equal to 1.024 kg dm⁻³.

$$U *a = \sqrt{Cd\, U^2}$$
(1.5)

By substituting the formulas 1.2 – 1.5 within formula 1.1, the final formula for the 'depth-integrated' numerical and mass concentration is stated in formula 1.6

$$Ci = \frac{Cs}{1 - e^{-d\,Wb - \left(1.5\sqrt{\frac{\rho a}{\rho w}}\,Cd\,U^2\,k\left(\frac{0.96}{g}\sigma^{\frac{3}{2}}\sqrt{Cd\,U^2}^2\right)^{-1}\right)}}$$

(1.6)

This data was visualized in maps using two programs; 1) Ocean Data Viewer (ODV) software, version 5.1.7 (available at https://odv.awi.de/) and 2) QGis software, version 3.4 (available at https://qgis.org).

2.7 Numerical and mass model

The observations within the GoA were compared to modelled concentrations of floating plastic debris derived from the model by Lebreton et al., (2018). This model consists of a global ocean circulation model coupled to a dispersal model based on Lagrangian particle trajectories. The model has defined sea surface currents, wind induced Stokes drift and wind as the drivers of the particles. Outcomes of the HYCOM + NCODA global 1/12° reanalysis (experiment 19.0 and 19.1) were used for global sea surface currents (Cummings, 2006; Cummings et al., 2013; Fox et al., 2002). Particles movement due to wind was simulated as a fraction of the wind speed at 10 m above sea level, which was sourced from NCEP/NCAR global reanalysis (Kalnay et al., 1996). The Stokes drift was determined by outcomes of wave characteristics from Wavewatch3 model (Tolman, 1989).

Particles were continuously released from 1993-2012 from both land- and sea based sources as described in the Supplementary Methods 4 of Lebreton et al., (2018). The model outcomes were calibrated with the depth integrated microplastic concentrations obtained by the extensive trawling effort in the GPGP (Lebreton et al., 2018). The model calculated the monthly average particle visits per day over 0.2° grid cells of the global water masses. The August 2015 projection was used. Plastic concentrations of the model outcome for the exact stations in the GoA were extracted using the Point Sampling Tool in the QGIS software.