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TOP SCHOLAR

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2025
Statistics

Time allowed: Three hours
Total score: 32

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

Pull out Formulae and Tables Booklet S–STATF from the centre of this booklet.

Show ALL working.

Check that this booklet has pages 2–28 in the correct order and that none of these pages is blank.

Do not write in the margins. This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

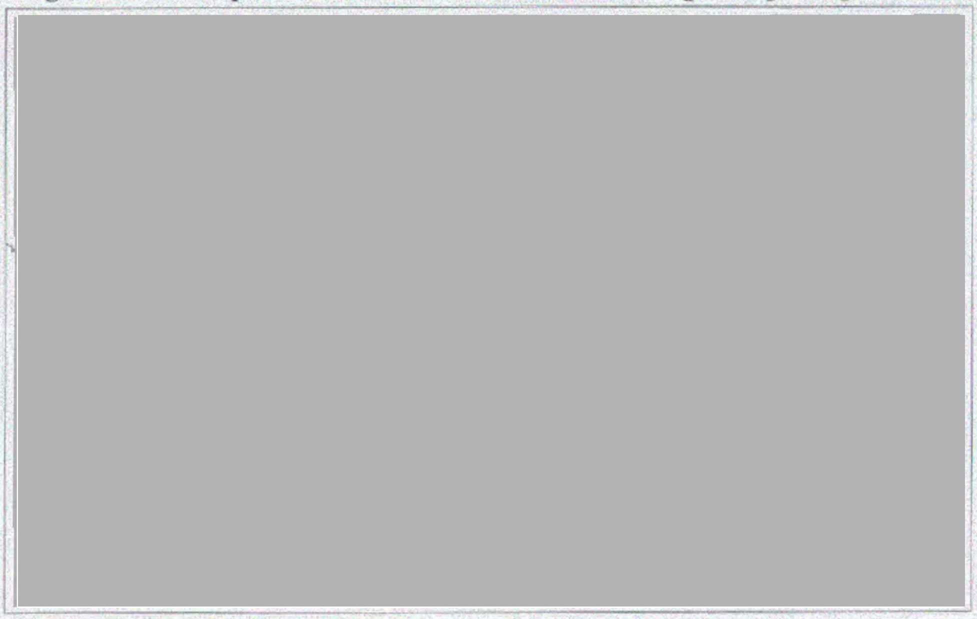
QUESTION ONE

(a) Plastics in our oceans pose a severe threat to marine ecosystems and human health. Plastic pollution damages coastal habitats, disrupts ecosystems, and contributes to the decline of endangered species. Most ocean plastic comes from land-based sources, with an estimated 70 – 80% carried to the sea via rivers or coastlines. Research shows that wealthier countries contribute very little to this plastic pollution, meaning domestic policies in these countries alone will do little to curb this pollution. Instead, wealthier countries can help by supporting waste management improvements in lower-income countries, which is seen as a key solution to reducing global plastic pollution.

Figure 1: Percentage of global plastic pollution emitted to the ocean by country, 2019

Source: https://ourworldindata.org/ocean-plastics

Figure 2: Plastic pollution emitted to the ocean in kilograms per capita, 2019



Source: https://ourworldindata.org/grapher/per-capita-ocean-plastic-waste

(i) Explain the graphical techniques that have been used to visualise the data.

The countries have been compared using a World map so as to best understand their location relative to each other and any trends in plastic pollution by location. The response variable of plastic pollution is shown using colour coding with darker colours indicating more pollution - this allows extreme values and the approximate amount of pollution to be compared more easily across countries, although precision in the data has been lost.

(ii) *Our World in Data* suggests that there are multiple factors which may increase a country's contribution of plastics to the ocean. One of these contributing factors is the location of most of the population in relation to the coast. For example, countries that consist of smaller islands may be more likely to contribute to ocean waste.

Using information from Figures 1 and 2, discuss whether the visualisations support this claim.

Figure 1 appears to neither support or refute the above claim, as although countries with the highest percentage of plastic pollution seem to all have a coastline the relationship between proximity to coast and percentage of global pollution is not especially strong - for example, New Zealand (an island country) has a very low percentage of pollution. However, Figure 2 examines a similar statistic per capita instead of as a whole. This seems to adjust for the lurking variable of population size in a countries plastic pollution, giving a more accurate picture of how much a country is contributing to ocean waste relative to size. In Figure 2 the relationship between proximity to ocean and pollution appears more strongly positive, with especially island countries in South-East Asia as well as coastal countries (especially poorer coastal countries) the highest polluters per capita. New Zealand is an example of this difference - despite being a low polluter overall, it is a much higher polluter per capita on par with populous countries such as China and India.

(b) Read the report below.

Report 1: The deep ocean contains a mountain of microplastic pollution

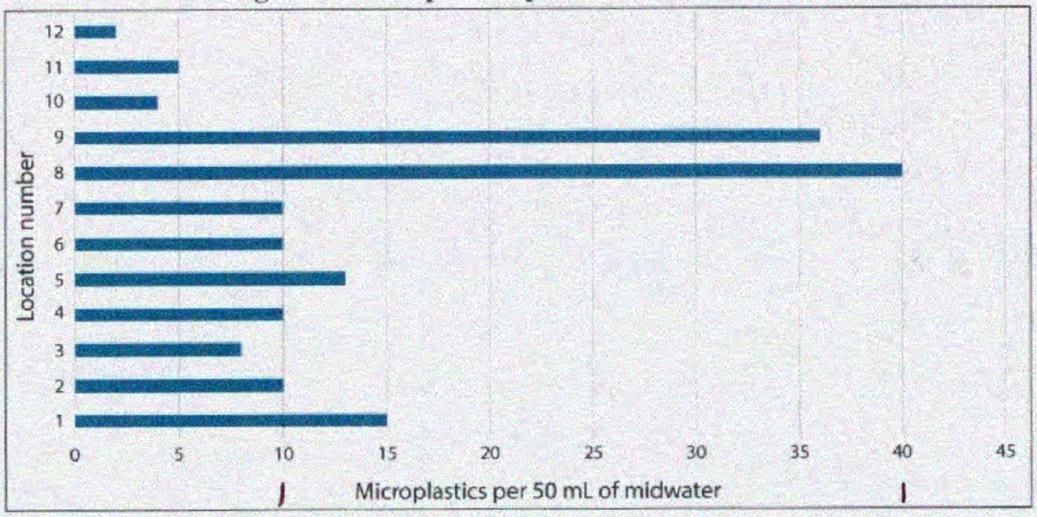
In the first study to systematically comb a section of ocean from top to bottom for microplastics, researchers have found that the midwater region (located 180–460 metres below the surface) contains significantly greater plastic pollutant loads than surface water does. They expected to find the greatest amount of plastic in surface water, because plastic is less dense than water. However, the surface water contained some of the lowest concentrations of microplastics. The highest concentrations of microplastics were found in the midwater region. Results from the study found that the midwater region generally contained four times as much microplastic waste as the surface water.

Source: www.scientificamerican.com/article/the-deep-ocean-harbors-a-mountain-of-microplastic-pollution/

A marine biologist is studying the presence of microplastics in samples of both surface water and midwater from around the world. 60% of the samples collected are surface water and 40% are midwater. For this study, high levels of microplastics are defined as 10 or more pieces of plastic per 50 mL. The results from the 12 midwater samples are shown in Figure 3.

Figure 3: Microplastics per 50 mL of midwater

$H = \frac{6}{12}$



Using information provided in Report 1 and Figure 3, answer the following questions.

(i) The biologist selects a sample at random from the midwater and surface water samples.

Given that a sample contains a high level of microplastics, estimate the probability that it is a midwater sample.

$P(H)$ = probability that sample contains a high level of microplastics

$P(M)$ = probability that sample is from midwater

$P(H \cap M) = 0.4 \times \frac{6}{12} = 0.2667 \quad (\frac{4}{15})$

$P(M|H) = \frac{P(H \cap M)}{P(H)}$

$P(H) = P(H \cap M) + P(H \cap \bar{M})$

$P(H \cap \bar{M}) = 0.6 \times \frac{1}{12} = 0.05$

$P(H) = \frac{4}{15} + 0.05 = 0.3167$

$P(M|H) = \frac{0.2667}{0.3167} = 0.84$ (2s.f.)

(ii) Discuss any assumptions you have made when calculating this estimate.

I assumed that the probability ~~that~~ of a ~~...~~ surface water sample containing a high number of microplastics was $\frac{1}{12}$. I based this assumption off of the distribution given in Figure 3, as well as the statistic in Report 1 that midwater region contained about 4 times as much microplastic waste as the surface water. By dividing the microplastics of each midwater location number ~~to~~ in the sample by 4, I gained an estimate for the value that ~~roughly~~ followed the distribution shown in Figure ~~4~~ 3 - this seemed more accurate than simply dividing the midwater probability by ~~4~~ 4, and simpler than coming up with a ~~...~~ model, but it could still be inaccurate.

(iii) The marine biologist also samples ocean water from 500 different deep water locations (defined as more than 460 metres below the surface) and counts the number of microplastic pieces per 50 mL. They model the distribution of microplastics using a Poisson distribution with an average of 2 pieces per 50 mL. The marine biologist finds that 98 of the 500 deep water samples contain exactly 1 microplastic piece.

Comment on whether the Poisson distribution is an appropriate model for this data.

Support your answer with calculations or numerical evidence.

~~Expected value from 500 samples~~

Using the information given, $\lambda = 2$, $P(X=1) = 0.2707$ with a Poisson distribution.

This would give an expected value of 135 out of 500 samples containing exactly 1 microplastic piece. The probability of 98 of less samples giving the result can be found with a binomial distribution where $\mu = 0.2707$, trials = 500 is 6.54×10^{-5} which is very unlikely, therefore the data doesn't seem to be modelled well by a Poisson distribution - it is significantly overpredicting the number of samples with exactly 1 microplastic piece, and so may vary more towards extreme values of 0 or >5 pieces due to samples not being independent of each other. This is because locations where samples are collected could be more or less prone to containing microplastics rather than each microplastic being randomly found in a location in the ocean (e.g. the Great Pacific Garbage Patch has a large concentration of microplastics due to ocean currents). So the assumptions that must be made in order to use Poisson distribution are invalid, causing the model to be a bad fit for the data.

(iv) In part (b)(iii) the distribution of microplastics was modelled using a Poisson distribution, with an average of 2 pieces per 50 mL.

Using this model, explain why the probability of finding 2 microplastic pieces in one 50 mL sample is equal to the probability of finding a total of 2 microplastic pieces in two independent 25 mL samples.

Use calculations to support your explanation.

$\lambda = 2$ (per 50 mL)

$P(X=2) = 0.2707$

A key feature of Poisson distribution is proportionality of the mean to the scope (in this case sample volume), so for a 25 mL sample the average number of microplastics found should be $\lambda = 1$.

$P(X=2) \times P(X=0) = 0.1839 \times 0.3679 = 0.0677$

$P(X=1) \times P(X=1) = 0.3679^2 = 0.1354$

$P(X=0) \times P(X=2) = 0.1839 \times 0.3679 = 0.0677$

P (2 microplastics from 2 samples) $= 0.0677 \times 2 + 0.1354 = 0.2707$

This makes sense ~~with~~ as 2 independent 25mL samples can be functionally treated as 1 50mL sample by Poisson distribution.

QUESTION TWO

(a) New Zealand participated in a global assessment to examine the recyclability of product packaging. Consumer organisations in 9 countries assessed packaging recyclability and labelling on 11 popular products.

Consumer NZ participated with organisations in Australia, Brazil, France, Hong Kong, India, Malaysia, Portugal, and the United Kingdom, coordinated by Consumers International. Combined, these consumer organisations represent 1.8 billion people.

In this assessment, a 'recyclable' product is 'recyclable in practice'. This means there is an existing collection, sorting, and recycling system in place that recycles the packaging which is readily accessible nationwide. In other words, the majority of consumers can actually recycle these products in their home countries – it is not just a theoretical possibility.

Table 1: Global recyclability of product packaging

Product	Approximate volume or weight*	Packaging recyclability in practice – New Zealand	Packaging recyclability in practice – international average
Coca-Cola mini 6 pack	200 ml x 6	100%	98%
Dove body wash	1 L	68%	82%
Heinz tomato ketchup	250 g	77%	81%
KitKat chocolate bar	50 g	0%	36%
M&M peanut chocolates	100 g	0%	33%
Nescafé original coffee	300 g	95%	88%
Nutella Ferrero hazelnut spread with cocoa	300 g	77%	84%
Pringles chips	200 g	0%	16%
San Pellegrino sparkling water	1 L	0%	77%
Toblerone chocolate bar	60 g	0%	64%
Whiskas mixed favourites 12 pack	85 g x 12	51%	60%

* *Sometimes the packaging volume varied between countries.*

Source: https://www.consumer.org.nz/articles/media-release-new-zealand-ranks-second-to-last-in-international-packaging-recyclability-trial

Use the information from Table 1 to evaluate the claim that 57% of the packaging used in New Zealand is not recyclable in practice.

Discuss any reservations you have about this claim.

Average percentage of recyclability in practice in NZ:

$(100 + 68 + 77 + 95 + 77 + 51)/11 = 43\%$

$100 - 43 = 57\%$ not recyclable in practice according to the table.

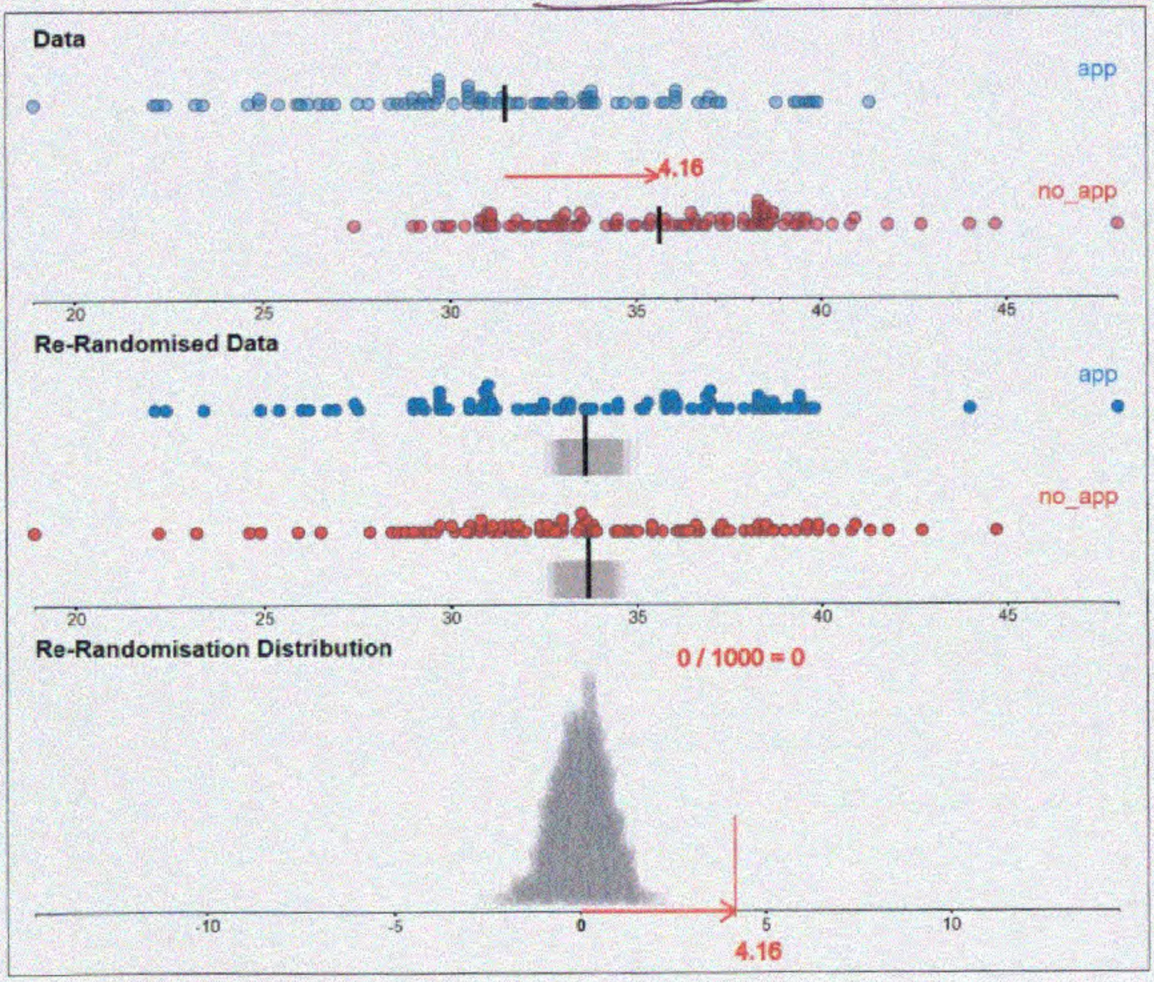
However, the sample size of products is 11 which is extremely small, and so a confidence interval for the population of product packaging in NZ should be calculated as $57 \pm \frac{100}{\sqrt{11}} = 57 \pm 30\%$. This creates an extremely wide interval of (27%, 87%) which shows the likely range that the overall percentage of recyclable packaging in NZ falls into - as this range contains such a large range we cannot reasonably make the call that there is any accuracy to the 57% claim - or even that it is above 50%.

(b) A student observed that many packaging products in New Zealand were only partially recyclable. For example, Dove body wash comes in a plastic bottle with a plastic plunger cap, but the plunger cap is non-recyclable and must be removed before recycling the bottle.

The student questioned whether partially recyclable packaging might reduce overall recycling rates, as consumers may not always know which parts of the packaging can be recycled.

The student developed an app that scans product barcodes and shows consumers which parts of the product's packaging are suitable for recycling. The student recruited 176 volunteer households from around New Zealand. These volunteer households agreed to separate their discarded packaging into recycling and landfill each week for three months. The households were randomly allocated into one of two groups: separating discarded packaging with the use of the app or without the use of the app. Participants' discarded packaging (both landfill and recycling) was collected and analysed and the percentage of recyclable packaging sent to landfill was recorded, with the mean percentage for each group calculated. The data was then used to create a re-randomisation distribution (Figure 4).

Figure 4: Test output for the percentage of recyclable packaging sent to landfill.



Discuss what can be concluded from both the features of the sample data distributions and the re-randomisation test output, including any reservations you may have about extending any findings from the results.

The mean percentage of recyclable packaging sent to landfill by participants who did not use the app was 35-36%, 4.16 percentage points higher than the mean for participants who used the app to sort packaging (~~with~~ of 31-32%).

Using a rerandomisation test to separate the participants into ~~[illegible]~~ new groups, ~~the~~ a difference in means of at least 4.16 percentage points occured 0 out of 1000 times. ~~[illegible]~~ From this, it can be concluded that the difference in means is highly unlikely to occur from chance alone - the treatment of the app can be ~~[illegible]~~ assumed to have an effect on ~~[illegible]~~ how participants sorted their packaging.

Although a causal claim can be made with reasonable confidence,* ~~[illegible]~~ the student's results are unable to be generalised to the wider population of New Zealand households due to the methods of ~~[illegible]~~ volunteering used to recruit participants. ~~By~~ This is because a non-response bias could be at play where those who volunteer for the experiment were more likely to ~~[illegible]~~ make use of the information given in the app, inflating the difference observed. Additionally, there may be differences in the group of participating households and wider population *A that could otherwise change the results of the experiment from a lurking variable

*due to the random allocation of ~~[illegible]~~ participants and subsequent significant difference in means.

*A (a non-representative sample)

(c) The Ministry for the Environment surveyed 1000 New Zealanders who were given a list of lifestyle 'tweaks' and asked to pick the three that they believed would have the biggest positive impact on the climate crisis.

Figure 5 shows the top 13 answers with the proportions below. The correct order of effectiveness is shown on the right of the figure.

Figure 5: Lifestyle 'tweaks' to improve the climate crisis

Source: https://www.nzgeo.com/stories/the-great-recycling-delusion/

(i) According to the Ministry for the Environment, buying products with less packaging will have more of an impact on reducing the effects of the climate crisis than recycling will.

Use the information provided in Figure 5 to construct a 95% confidence interval, and evaluate the claim that a higher proportion of New Zealanders consider recycling to be more effective at reducing the effects of the climate crisis than buying products with less packaging.

Difference in proportions = 33 - 28 = 5%
Sample size of 1000
Margin of error: $2 \times \frac{100}{\sqrt{1000}} = 6.32$
(↑ I used the rule-of-thumb for proportions in the same group ($2 \times \frac{1}{\sqrt{n}}$), although the respondents were able to pick 3 options which may reduce the margin of error slightly.)
Confidence interval = 5 ± 6.32 = (-1.32, 11.32)
It is a fairly safe bet that the proportion of New Zealanders who consider recycling to be more effective at reducing the effects of the climate crisis is between 1.32 percentage points lower and 6.32 percentage points higher than the proportion who believe buying products with less packaging to be more effective. As this interval includes a difference of 0%, we cannot make the call that a higher proportion believe in recycling than less packaging, as the claim does not have enough evidence supporting it.

(ii) When investigating the results shown in Figure 5, a student argues that the effect that renovating your house for efficiency will have on your environmental impact is dependent on a number of confounding variables, such as how energy efficient the house was in the first place, the types of renovations being made, or how effective the efficiencies are in different environments. The student also argues that efficient renovations may even result in less desirable changes in occupants' behaviour, such as spending more time indoors with air-conditioning during warmer weather or choosing not to purchase energy-efficient appliances because of the effect of the renovations on finances.

They suggest that the Ministry for the Environment conducts a study to see how effective energy-efficient house renovations are at reducing household energy usage. They suggest two methods for an investigation. These are outlined in Table 2 below.

Table 2: Two possible studies to investigate the effectiveness of energy-efficient house renovations

Study A	**Study B**
A sample of New Zealand households recently renovated for efficiency is selected at random. Each household is categorised based on the pre-renovation energy efficiency of their home, into 'energy efficient' and 'not energy efficient'. Each household is observed for a year; their energy usage is calculated and weighted to take into account the size of the house and the number of occupants living in it. The results of the study are analysed and a bootstrap confidence interval constructed.	Volunteer participants are randomly allocated into one of two groups: renovations and no renovations. The renovations group each undertake an energy-efficient renovation, the no renovations group do not renovate at all. Energy usage is calculated and weighted to take into account the size of the house and the number of occupants living in it. The results of the study are analysed and a re-randomisation test conducted.

Discuss the impact of each study design on any conclusions that could be made.

Study A is designed to be an observational study rather than an experiment, which means that a causal claim about the energy efficiency of renovation would not be able to be made. This is because the study is unable to control for lurking variables in those renovating their houses for efficiency - for example, the financial state of those already doing renovations might be such that it does not impact their ability to make other improvements, compared to that of a general population.

Study B is an experimental design with random allocation, which allows causal claims on the effect of renovation for energy efficiency to be made from any significant difference between groups. However, the fact that groups volunteer for the experiment means that it will not be a representative sample of New Zealand households and ~~[illegible]~~ any results cannot therefore be generalised to the population of NZ. Additionally, the study design of B is highly impractical as it requires a treatment of renovations, which would make it difficult to impossible to implement as an experiment rather than an observational study due to the ~~[illegible]~~ time and money involved.

QUESTION THREE

(a) Figure 6 shows a scatterplot comparing the gross domestic product (GDP) per capita (in international dollars at 2021 prices, adjusted for inflation and differences in living costs between countries) and the plastic waste generation per person per day (in kg). Additionally, colour has been used to indicate the continent each country belongs to, while size denotes the population size of each country.

Figure 6: Per capita plastic waste vs. GDP per capita

Adapted from: https://ourworldindata.org/grapher/per-capita-plastic-waste-vs-gdp-per-capita

Identify at least three key features of the scatterplot shown in Figure 6, including a brief discussion of how per capita plastic waste compares for two different **continents**.

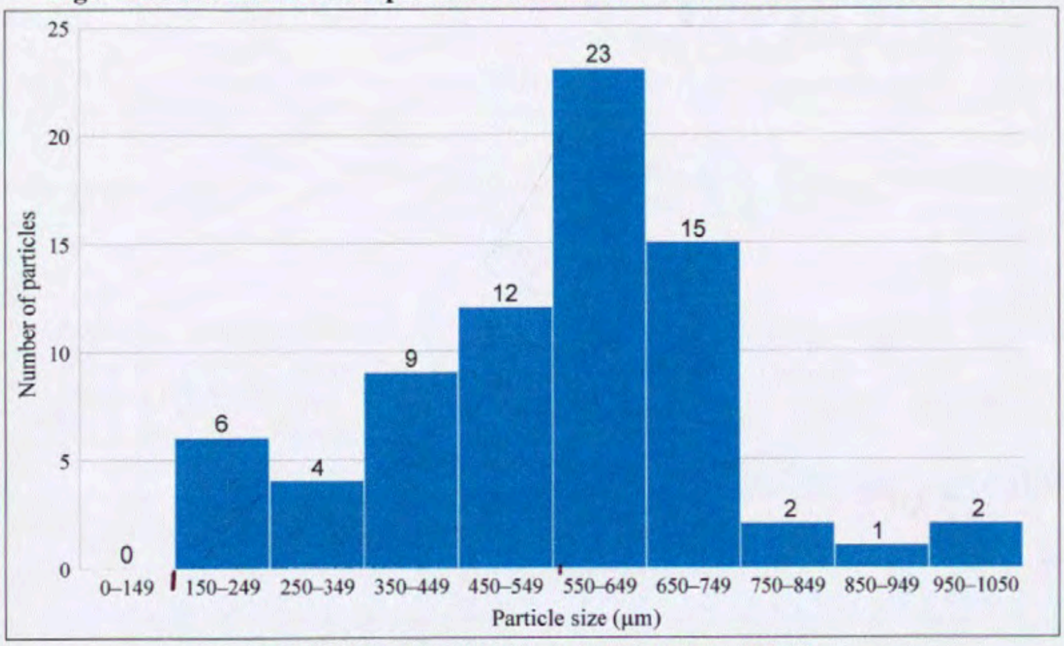
There is a weak positive linear relationship between GDP per capita and percapita plastic waste of countries. As the GDP per capita of ~~[illegible]~~ increases, the variation between plastic ~~p~~ waste created also increases with extremely wide scatter bands for high GDP countries, ~~which~~ while most low (<15000 per capita) GDP countries have a corresponding low plastic waste per capita of 0.2kg or less (Vanuatu being the exception with 0.3kg of waste for a B-4000 GDP). Large countries tend to have a stronger ~~and~~ positive relationship than smaller countries.

Per capita plastic waste for Europe has a high amount of variation, with amounts ~~varying~~ varying from Sweden's 0.05 kg to Germany's 0.5 kg* - this may be because of the relatively high GDP per capita European countries have, with all on the graph above $10 000. African countries, on the other hand, have a lower average amount of plastic waste (about 0.8 kg) and less variation from 0.01 kg to 0.35 kg. The GDP per capita of African countries is also lower on average with ~~the~~ the least wealthy also ~~were~~ showing the least waste. Both of these continents fit in with the general attributes on the graph, although they lie on different ends of the GDP scale.

* ~~with~~ and an average of about 0.25 kg per capita.

(b) The occurrence of microplastics in saltwater bodies is relatively well studied, but little is known about their presence in most of the commercial salts that are widely consumed by humans across the globe. Researchers extracted 74 microplastic particles larger than 149 μm (micrometres) from 17 salt brands, originating from 8 different countries.

Figure 7: Presence of microplastics in commercial salts from different countries



Adapted from: https://www.nature.com/articles/srep46173

(i) Using information from Figure 7 calculate the mean size of microplastic particles larger than 149 μm (micrometres) that were extracted from the 17 salt brands.

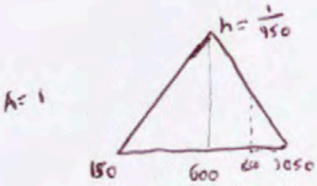
$\mu = (6 \times 200 + 4 \times 300 + 9 \times 400 + 12 \times 500 + 23 \times 600 + 15 \times 700 + 2 \times 800 + 900 + 2 \times 1000)/74$

$\mu = 551$ μm

(ii) Suggest two suitable probability distribution models, including any additional relevant parameters, to model the size of microplastics in commercial salts from different countries.

Normal distribution with $\mu = 551$, $s = 150$

Triangular distribution with $a = 150$, $b = 1050$, $c = 600$



(iii) Use probability calculations to evaluate the fit of each model you have suggested in (b)(ii).

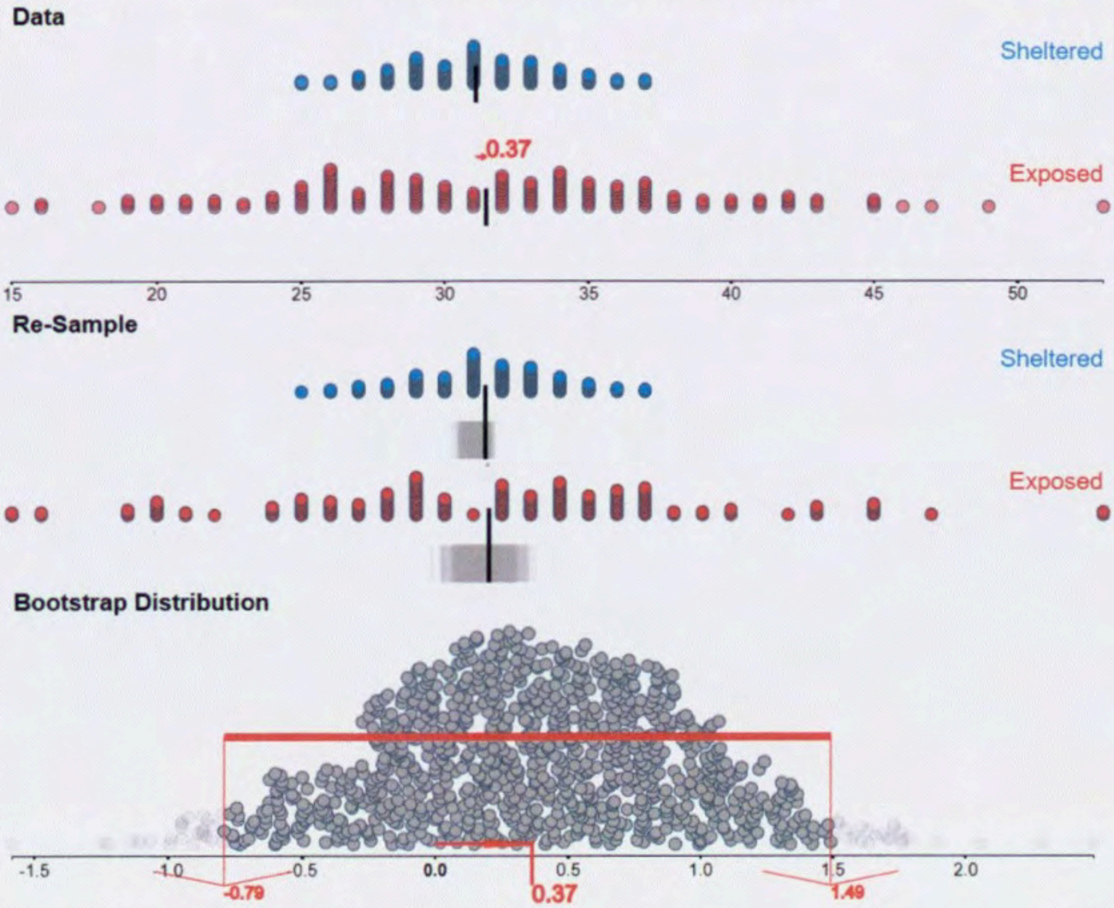
The ~~[illegible]~~ mean size of microplastics was calculated to be 151 μm and ~~[illegible]~~ the normal distribution would match that ~~at~~ with the parameters provided. The mean size from the triangular distribution would be 600 μm (from the approximate mode on the graph).
The actual proportion of plastics over 550 μm is $\frac{3}{74} = 0.0405$ whereas from a normal distribution it would be $0.5 - 0.4999984$ $= 1.6 \times 10^{-6}$ which is significantly underpredicting, while the triangular distribution ~~also~~ overpredicts it to be 0.2222.
Overall, the normal distribution is a poor fit due to the asymmetry and right skew of the data as well as too many extreme values for a standard deviation to work, while triangular distribution either over or under predicts the ~~frequency~~ number of macroplastics above 750 μm depending on where you place limits - this is due to the large ~~[illegible]~~ drop in number of plastics which then stays relatively steady as the size increases past 750 μm.
Neither model is a good fit due to being unsuitable for the distribution of data.

(c) Macroplastics are pieces of plastic that are over 5 mm in size. They may include waste such as bottles, bags, packaging materials, discarded fishing equipment, and other plastic items. Macroplastics are a major contributor to environmental pollution, particularly in marine and freshwater ecosystems, where they can break down into smaller microplastics over time.

An environmental group has been studying the prevalence of macroplastics on sheltered and exposed beaches on the Coromandel Peninsula. They use software to generate random points on these beaches where they survey a 20 m^2 area and count the number of macroplastics found. Their data has been used to construct a bootstrap confidence interval for the difference in the mean number of macroplastics found on sheltered beaches in comparison to exposed beaches.

The output from this analysis is shown in Figure 8.

Figure 8: Bootstrap distribution test output



Discuss the conclusions that can be made from both the sample data and the confidence interval constructed using the sample data.

The mean number of macroplastics found in sampled areas of both sheltered and exposed beaches in the Coromandel Peninsula was just above 30, with exposed beaches having a 0.37 higher mean than sheltered. Exposed beaches also seem to have more variation in the amount of macroplastic found on them, with a much larger range and spread than sample beaches.

The difference in sample means can be analysed using bootstrapping to gain an estimate for the difference in means in the population (across all beaches in the Coromandel). From the confidence interval constructed, we can be 95% confident that the mean number of macroplastics found in exposed beaches on the Coromandel is between 0.79 lower and 1.49 higher than the mean number ~~of~~ found in sheltered beaches. As this interval includes a difference of 0, the claim cannot be made that exposed beaches contain on average more macroplastics than sheltered beaches - the difference in means could have occurred from chance alone.

QUESTION FOUR

(a) In April 2025, a nationally representative sample of 122 respondents was asked questions about recycling and waste reduction. Respondents reported their age and the actions they took towards reducing their household recycling, including which bin they used when they were uncertain whether or not an item was recyclable, and whether or not they had kerbside recycling collection in their area. Figures 9–12 show four plots produced from this data.

Figure 9: Age in years by actively recycle

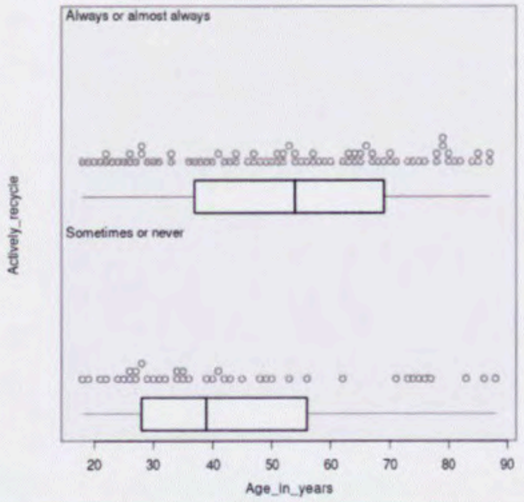


Figure 10: Age in years by which bin when uncertain about recyclability, subset by actively recycle

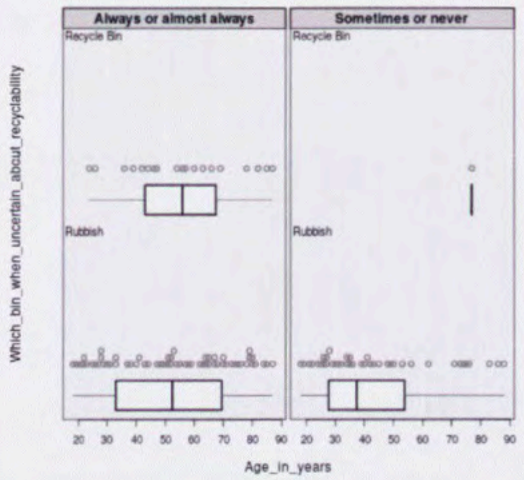


Figure 11: Which bin when uncertain about recyclability by actively recycle

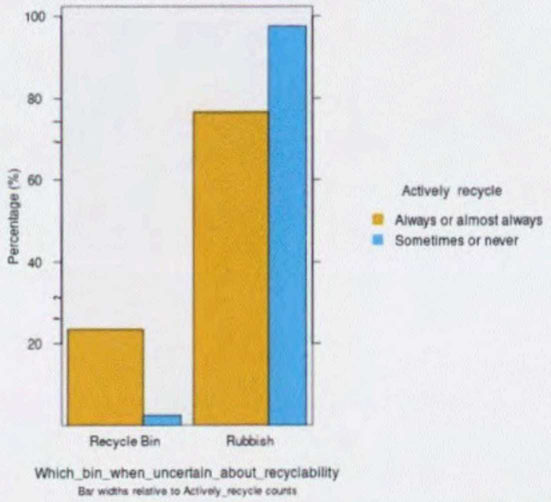
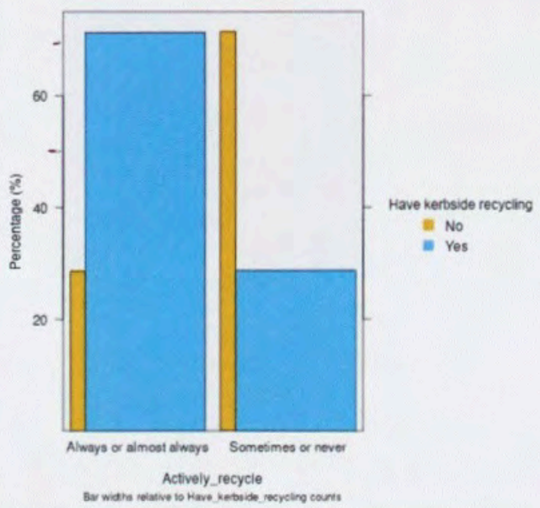


Figure 12: Actively recycle by have kerbside recycling



(i) Describe what the plots in Figures 9 – 12 reveal about respondents' recycling habits.

Figures 9-12 all show that the proportion of respondents who said they always or almost always recycled was higher ~~they~~ (about 2 times as large) as those who sometimes or never recycled. Those who

recycled more tended to be older on average than those who recycled less (mean of 54 ~~ ~~ compared to 38 years). Those who recycled less, with the exception of one respondent, said they would put items they were unsure about in the rubbish, which is expected. Of those who recycled more, figures ~~ ~~ 10 and 11 show that most still tended to use the rubbish bin when they were unsure (about 77% rubbish to 23% recycling), ~~although~~ and although those who used the recycling had a slightly older average age ~~ ~~ the difference in means is small enough to be insignificant.
Of those who have kerbside recycling, about 70% recycled more and 30% less, and for those who didn't have kerbside recycling the proportion flipped to 70% recycling less and 30% more. The number ~~proportion~~ of people with kerbside recycling seems to be much larger than those without, - judging from the width of the bars in figure 12 its close to 10 times as many.

(ii) Buller, Grey, and Westland district councils are exploring the introduction of kerbside collection for food and green waste. A councillor uses the information from Figure 12 to support their argument that the introduction of kerbside food and green waste collection will cause more people to appropriately discard their green waste.

Discuss the appropriateness of this extension of results.

As the sample of respondents in figure 12 was nationally representitive it is likely that it could be a good model of recycling behaviour ~~ ~~ with the introduction of kerbside collection - although the location of people by council could ~~ ~~ influence this statistic (i.e. urban vs. rural opinions on recycling lining up with kerbside collection). Additionally, the argument is being made for green waste and food collection as opposed to recycling which may have completely different results - extension of results in this case is not appropriate without further data on specifically green waste collection, as well as possibly data from the inhabitants of the district councils named.

Question Four continues on the following page.

(b) Christchurch City Council provides a kerbside waste collection service to all households. Each household has three bins: a red bin for general rubbish, a yellow bin for recycling, and a green bin for organic waste.

Table 3: Christchurch City Council waste statistics

	Collection frequency	% of bins presented at kerbside	Mean total weight of waste collected at each collection
Rubbish	Fortnightly	83%	1522 tonnes
Recycling	Fortnightly	73%	936.1 tonnes
Organics	Weekly	60%	92.7 tonnes

Christchurch City Council suggests that the mean weekly combined weight of all recycling, rubbish, and organics produced by individual households is 11.46 kg.

Using the information from Table 3 (and assuming that those households that do not present their bins at kerbside generate the same amount of waste as those that do) calculate an estimate for the number of households in the Christchurch City Council district.

~~mean total combined weight of waste each week~~ $\cancel{= \frac{1522}{2} + \frac{936.1}{2} + 92.7}$

$\cancel{= 1321.75}$ ~~per week~~

Approximate total rubbish weight per week $= \frac{1522}{0.83 \times 2} = 916.9$ tonnes

Approximate total recycling weight per week $= \frac{936.1}{0.73 \times 2} = 641.2$ tonnes

Approximate total organics weight per week $= \frac{92.7}{0.6} = 154.5$ tonnes

Weekly combined total weight of waste per week $= 916.9 + 641.2 + 154.5$

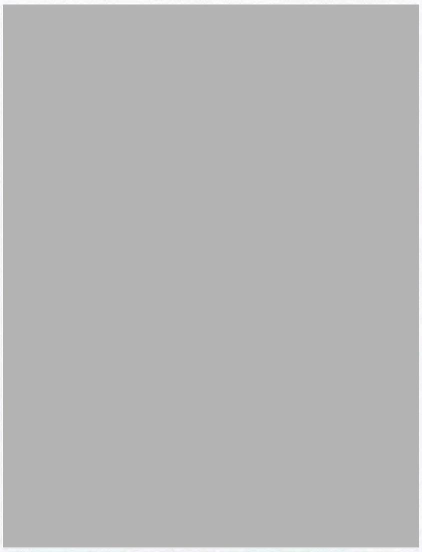
$= 1712.6$ tonnes.

No. of households in CCC district $\approx \frac{1712.6 \times 1000}{11.46} = 149.4 \times 10^3$

$\approx 150\ 000$ households

(c) At large events, recycling bins should be conveniently located to encourage recycling and reduce litter. As part of event planning, many city and district councils require recycling bins to be provided at set distances from each other. Current models of recycling bin location are mostly determined by distance – at one particular event in Hastings, event attendees were found to be on average 10.5 m from a recycling bin location, with a standard deviation of 2.75 m.

In general, a person will inappropriately discard their recyclable waste if the nearest recycling bin is more than 12 m away.



Source: https://www.hastingsdc.govt.nz/services/rubbish-and-recycling/waste-at-events/event-recycling-bins/

(i) Assuming that the variable 'distance from bin' is approximately normally distributed, estimate the probability that, out of 5 people attending this event in Hastings, all 5 people recycle their waste by using the recycling bin.

Normal

P(Recycles waste) = 0.7073 ($\mu = 10.5$, $s = 2.75$, $P = 0.5 + P(10.5 \leq x \leq 12)$)

Binomial distribution with $n = 0.7073$, trials = 5

$P(x = 5) = 0.1770$ or a 17.7% chance

(ii) Discuss any other assumptions you made when calculating your estimate in part (c)(i).

In order to use binomial distribution as a model for the number of recyclers, I assumed that the probability of each person discarding their recycling correctly was 0.7073 → so that the only factor for recyclers was bin distance and each person had an equal chance of being within 12 m of a bin. This may not be true if, for example, a bin was close but out of sight, or people could influence each other through societal pressure to recycle as a group (in which case each person's choice was not independent of each other).