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Analyzing Durability and Efficacy of Long-lasting Insecticide-treated Bed Nets: A Longitudinal Monitoring Study at Western Kenya

By

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Degree to be awarded: MSPH

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Science in Public Health in Biostatistics
2013

Abstract

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By Shaoman Yin

Malaria is a mosquito-borne disease caused by parasite infection. Long-lasting insecticide treated nets (LLIN) are becoming one of the primary malaria prevention strategies in many parts of sub Saharan Africa. However, the durability and efficacy of these nets in the field condition is not well known. To answer these questions, a mosquito bed net study with followed up surveys (rounds) has been carried out in Western Kenya to monitor physical conditions and maintenances of seven net brands. Here, we first performed descriptive summaries by bands and rounds in four aspects of the study: 1) net attrition and reasons of net loss; 2) physical integrity, such as net hole areas and counts; 3) net care and use, such as net wash, net use, and bed type; 4) side effects of net use. Next, general linear regression, logistic regression, Poisson regression and Negative Binomial regression were used to analyze associations of net hole areas or net hole counts with brands, rounds and practices of net use and care. Results show that net hole areas and net hole counts were significantly affected by net brands and time of collected rounds. Net hole counts were also significantly affected by net use conditions. LLIN brands Olyset and PermaNet2.0 may have a poor physical integrity compared to other brands. These results may have implications of understanding physical durability and efficacies of LLIN nets in the field conditions for malaria control and prevention.

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Analyzing Durability and Efficacy of Long-lasting Insecticide-treated Bed Nets: A Longitudinal Monitoring Study at Western Kenya

Shaoman Yin

Introduction

Malaria is a mosquito-borne disease caused by infection with one of 5 species of parasites within the genus *Plasmodium*. It is a leading cause of morbidity and mortality worldwide. An estimated 219 million cases of malaria occurred worldwide in 2010 and 660,000 people died, most (90%) in the African region[1]. Moreover, malaria has been shown to hinder economic and social development, especially for countries in sub Saharan Africa[2].

Insecticide-treated bed nets (ITNs) have become a major intervention for malaria control and prevention in many parts of sub Saharan Africa. A Cochrane review concluded that ITNs reduce overall child mortality by about 20% in Africa and that, for every 1,000 children aged 1-59 months with ITNs protection, about 6 lives are saved each year[3]. Based upon the encouraging results of community-wide trials, the Global Malaria Program (GMP) recommended ITNs as one of the four basic elements of the Global Strategy to reduce malaria burden by 50% by 2010[4]. However, a significant barrier to effective ITNs protection is that they require insecticide retreatment every 6-12 months. In programs with a cost recovery element, only 5% to 30% of nets are re-treated[5]. Even in programs where treatment was provided free of charge, retreatment rates remained low.

The solution to low retreatment rates was to develop long-lasting insecticidal nets. These are factory treated nets where the insecticide is designed to resist washing and remain on the nets for at least 3 years of routine use. To ensure that all nets are adequately treated with insecticide to provide maximum protection against malaria, long-lasting insecticide-treated nets (LLINs) are currently advocated over conventional ITNs by governments and NGOs[6].

Most LLINs are manufactured from polyester or polyethylene fibers that are coated or incorporated with pyrethroid insecticides (deltamethrin, permethrin or alphacypermethrin)[7]. Despite their potential most LLINs have only been evaluated under laboratory conditions or in short-term experimental hut studies. Whether these LLINs remain effective under field conditions over 3 or more years of routine use as claimed is unknown. Furthermore, early studies to estimate longevity under field conditions have focused primarily on the insecticidal activity. More recent studies suggest that physical durability may be the limiting factor for LLINs under field conditions[8]. For example, the actual washing practice in field and local climatic conditions could be critical factors in regulating LLIN efficacy and lifetime. Thus, there is a need to evaluate durability and efficacy of LLINs under the field condition in a variety of settings. This knowledge is of great importance for developing malaria control policy to determine the optimal type of LLIN to procure as well as how often to replace LLINs. The information is also valuable to LLINs manufacturers in developing improved, next generation LLINs.

The main goal of this thesis is to analyze the durability and efficacy of seven different LLIN net products from a field study conducted in western Kenya. Specific aims are: 1) to monitor LLIN attrition and reasons of net loss; 2) to assess differences in physical integrity of LLIN bed nets among different net brands, as measured by the number and size of holes; 3) to measure net use and care practices, such as frequency of net use and washing; and 4) to analyze how net brands and net use and care factors affect net physical integrity through regression analysis.

Methods

Data Sets

The data sets used in this thesis are from Dr. John Gimnig at Center of Global Health of CDC. There are five files: Masterlist file that lists all bed net ID and brand information; Net_Holes_Top file that records all net holes on the top of bed nets as well as brand and net ID; Net_Holes_Sides file that records all net holes on sides of bed nets as well as brand and net ID; Net_Main file that includes all hole summaries of both top and side holes; NetCollection file that records bed nets ID and their collected rounds; NetFollowups file that records all other variables that are related with net use and care reported during follow up surveys.

Descriptive Summary

Nets were distributed in December of 2009 to 16 villages in western Kenya. Seven different LLIN brands were distributed: DawaPlus, DuraNet, Interceptor, NetProtect, Olyset, PermaNet2.0 and PermaNet 3.0. At 6 month intervals (one round), all nets were visited to determine if they remained with the original owner and, if not, what happened to the nets. After each net census, 30 nets of each type were randomly selected for destructive sampling and replaced with new nets. Owners of sampled nets were then dropped from the study. Sampled nets were returned to the laboratory where they were examined for the number and size of holes. Data on net follow ups were available through the 5th follow up while data on the number and size of holes was available through the 4th follow up. Therefore, our durability analysis is limited up to 2 years of follow up.

To monitor and track the nets over time, net attritions and reasons of net loss were summarized by brands and by rounds. Net attrition is the percentage of net lost over total initial distributed bed nets. Because 30 bed nets for each brand were collected and replaced by new nets at each round, these collected nets were not included in the denominator during the net attrition calculation for subsequent rounds. To evaluate physical integrity of bed nets, net hole areas and size categories were described by brands and by rounds. Based on the WHO recommendations[7], net holes with diameter less than 2 cm are defined as "small holes"; net holes with diameter larger than 2 cm but less than 10 cm are defined as "medium holes"; net holes with diameter larger than 10 cm but less than 25 cm are defined as "large holes"; net holes with diameter larger than 25 cm are defined as "very large holes". The area of each individual hole was estimated assuming that each hole was approximately circular in shape. The holes size was then calculated as $A = \pi(\frac{d}{2})^2$, where d is net hole diameter. To measure net physical integrity, total net hole area for each net (Net Hole Areas) and total net hole counts (Net Hole Counts) are compared by brands and rounds. To evaluate net use and care, frequencies or related percentages of net use (Net Use), net use last night (Net Use Last Night), net wash (Net Wash), bed type (Net Type), and net location (Net Location) were summarized by brands and by rounds. To assess side effects and symptoms of net use, percentages of side effects (Side Effects) were summarized by brand and rounds. Symptoms of net use were summarized by brands. All variable names begin with a uppercase letter in this thesis.

Regression Analysis of Net Hole Areas

To analyze how net physical integrity is influenced by Brand and other covariates, such as Net Wash and Net Use Last Night, a linear regression model was used. Because Net Hole Area is highly skewed and not normally distributed, a logarithm transformation was performed for Net Hole Areas. Bed nets collected for each round in the NetCollection file was merged with NetFollowups file, which includes information about net use and care. Seven covariates (Brand, Round, Net Wash, Net Use, Net Type, Net Location and Net Use Last Night) and all possible interactions of Brand with other covariates were analyzed for the linear regression modeling. To select significant covariates or interaction terms, a stepwise selection was used. Type III SS (sum of squares) table is used to evaluate the overall marginal effects for each factor. LSMean (least squares means) is to measure the fixed effects or predicated population margins for each factor. Multiple pairwise comparisons were adjusted by Tukey method. The final model for the linear regression was: log(Net Hole Areas)=β_0+β_1(Brand)+ β_2(Round)+β_3(Brand*Round)+e, where e~N(0,1).

An alternative approach to analyze Net Hole Areas is to convert it to categorical variable and use logistic modeling analysis. A dichotomous variable Condition, with two levels "poor condition" (Net Hole Areas larger than 100 cm^2) and "good condition" (Net Hole Areas less than or equal to 100 cm^2), was used as the dependent variable. A total hole surface of 100 cm^2) corresponds to having no hole in the >5 cm diameter category and no more than 8 holes in the >2-5 cm diameter category, and considered to be a serviceable LLIN[9]. Data sets with Net Hole Areas were combined from round 1 to round 4. The 7 covariates and all possible interactions of Brand with other covariates were analyzed for the logistic modeling. A stepwise selection is used to select significant covariates or interaction terms. The final model for the logistic regression is: logit(Poor condition)=$\beta_0+\beta_1$(Brand)+ β_2(Round).

Regression Analysis of Net Hole Counts

To analyze how net hole counts is influenced by brands and other co-variables, such as Net Wash and Net Use Last Night, Poisson regression is used since the outcome is a "count" variable. A key assumption of Poisson regression is that the net hole count is not overdispersed and has a same value for variance and mean. To satisfy this assumption, a deviance adjustment is included in the SAS procedure. Type III SS table is used to evaluate the overall marginal effects for each factor. LSMean was used to measure the fixed effects or predicated population margins for each factor. Multiple pairwise comparisons were adjusted by Tukey method. The final model for the Poisson regression was: log(Net Hole Counts)=$\beta_0+\beta_1$(Brand)+β_2(Round)+β_3(Net Use)+β_4(Net Wash). We also tried Negative Binomial regression, which has more flexibility in accounting for overdispersed count data. The final model for the Poisson or Negative Binomial regression was: log(Net Hole Counts)=$\beta_0+\beta_1$(Brand)+ β_2(Round))+β_3(Net Use).

Results

<u>1. Net Attrition and Reasons of Net Loss</u>

1.1 Net Attrition

Net attrition is the percentage of LLINs lost compared to the number initially distributed. To monitor how the net users kept their bed nets over time, a survey on all distributed nets was conducted every six-month up to 2.5 years. **Figure 1** shows net attrition of 7 net brands over 5 rounds. Results suggest that net attrition of all 7 brands increased over time. From round 1 to round 4, cumulative net attrition ranged from 5%-15% for most brands. However, at round 5, cumulative net attrition for most brands was more than 20%. Net attrition for PermaNet2.0 (47%) was significantly higher than other brands. These results suggest that net attrition increased in a time- and brand- dependent manner.

1.2 Reasons of Net Loss

To understand why nets were lost, frequencies of net loss by brands at round 1-5 are shown in **Table 1a-e**. Results suggest that the most frequent reason for net loss (more than 30% of total nets) was “taken from house or moved”. The one exception was the Olyset net of which, more than 30% of the total nets were “sold or given away” in all rounds. These results indicate different destinations for LLIN nets by brands over time.

2. Net Physical Integrity

2.1 Percentage of Nets with Holes

To assess the overall quality of bed nets, percentages of nets with at least one hole or nets without any hole are presented by brands and by rounds (**Table 2a-d**). As expected, at round 1, there were few nets with holes. The proportion of nets with at least one hole increased by round for each brand. At round 4, NetProtect, Olyset and PermaNet2.0 each had a higher percentage of nets with at least one hole.

2.2 Net Hole Counts and Sizes

To further quantify net holes, four categories of net holes are used: small hole (hole diameter<=2cm), medium hole (2<hole diameter<=10), large hole (10<hole diameter<=25), and very large hole (hole diameter>25). **Figures 2a-e** summarize the frequency of net hole size and net hole counts of the collected nets for each brand and round. It should be noted that the number of collected nets per brand at certain rounds may not be exactly as 30 as shown in **Table 2**. Results suggest that the frequencies of each category of holes increased from round 1 to round 4 for each brand. At round 3 or round 4, the total net hole counts for Olyset, PermaNet2.0 and Netprotect were more than other brands. Olyset or PermaNet2.0 had relatively more medium-size holes, while Netprotect had more small-size holes at round 3 or round 4.

2.3 Net Hole Areas

To access the durability and integrity of nets, 30 nets for each brand were randomly selected from 7 villages in Kenya at each round. **Table 3a-d** summarizes the distributions of Net Hole Areas for all collected nets and for nets with at least one net hole by brands. Results show that Net Hole Areas for all brands had skewed distributions with large variation. Nets with at least one hole increased from round 1 to round 4. Results suggest that Net Hole Areas were significantly different among brands for most rounds. Net Hole Areas for DuraNet and Interceptor was lower than other brands from round 1 to round 4.

<u>3. Net Care and Use</u>

3.1 Frequency of Net Use

Types of Net Use over the week before each survey include “don’t know”, “every night”, “less than half of all nights”, “more than half of all nights” and “not used”. **Figures 3a-e** show the percentages of these Net Use by brands and rounds. Nets were used “every night” for each brand from round 1 to round 5. Percentages of nets not used decreased from round 1 to round 5. More than 20% of Olyset or PermaNet2.0 were not used from round 1 to round 5, which were significantly more than other brands.

3.2 Net Use Last Night (Whether Net Used or Not Last Night before Survey)

Figures 4a-e show that more than 50% of nets were used last night for each brand from round 1 to round 5. Compared to other brands, the percentage of nets that were not used the previous night was lower for the Olyset, PermaNet2.0 and NetProtect.

3.3 Net Wash (Whether Net Washed or Not)

Figures 5a-e show the percent of LLINs that were washed in the 6 months before each follow up for each brand. More than 50% of nets for each brand were not washed at round 1. From round 1 to round 5, percentages of nets washed increased. Interestingly, the percent of Interceptor washed (>80%) dramatically increased at round 2 and remained high through round 5. It is unclear that why Interceptor had such a high frequency of net wash. In the following results, we found that Interceptor had more side effects than other net brands. It is possible that these side effects may promote people to wash Interceptor net more often than others.

3.4 Bed Types

Types of BedTypes include five groups: “bed and mat”, “net not hung up”, “other”, “palm mat” and “reed mat”. **Figures 6a-e** show the percentages of bed nets for each brand from round 1 to round 5. Most of bed net types were “bed and mat” for each brand over all rounds.

3.5 Bed Net Locations

Bed net locations include five groups: “hanging in place, not tied up”, “hanging in place, tied up”, “net not seen” and “present in house, stored away”. **Figures 7a-e** show the percentages of bed net locations for each brand from round 1 to round 5. In later rounds, there were more nets “hanging in place, tied up”. Interestingly, the percentages of nets “present in house, stored away” for Olyset increased, particularly in later rounds.

4. Side Effects on Net Use

4.1 Presence of Side Effects

To monitor if there were any side effects associated with using nets, 7 net brands were followed up for 5 rounds (**Figures 8a-e).** Results indicate that the percentages of people having any side effect because of net use decreased from round 1 to round 5.

4.2 Symptoms of Side Effects

Specific symptoms considered as potential side effects due to using each net are compared in **Figure 9**. Results suggest that the main side effects were “sore eyes” and “itching/burning skin”, which happened most frequently for Interceptor, followed by DuraNet and PermaNet 3.0.

5. Effects of Brand, Round, Net Use and Net Care on Net Physical Integrity

To quantify the durability of net physical integrity, two kinds of measurement were used: Net Hole Areas and Net Hole Counts.

5.1 General Linear Regression Analysis of Net Hole Areas

To determine how Net Hole Area is affected by net brand and other covariates, we first performed generalized linear regression (GLM) analysis. Nets with at least one hole were used and a logarithm transformation of Net Hole Area was performed to get a normal distribution. Results showed that log Net Hole Areas were significantly explained by Brand, Round and their interaction (**Table 4**). **Table 5** showed the multiple pariwise comparisons of log Net Hole Areas among different net brands. These multiple comparisons were adjusted by the Tukey method. We found that Olyset and PermaNet2.0 had more large areas of net holes than other brands.

5.2 Logistic Regression Analysis of Net Condition

One limitation of the GLM analysis is that it did not include nets with no hole. To account for these nets, we further used logistic regression to analyze net Condition, which classified all nets into two groups: poor condition (Net Hole Areas>=100 cm^2) and good condition (Net Hole Areas<100 cm^2). Here the brand Interceptor was used as the reference group considering that it had relatively smaller Net Hole Areas. Results suggested that net Condition could be significantly explained by Brand and Round (**Table 6**). **Table 7** and **Figure 10** showed odds ratios for Brands or Rounds with poor condition v.s. with good condition compared with their reference groups. Odds ratios for Olyset and PermaNet2.0 with poor condition as the outcome were significantly larger than 1, while odds ratios for other Brands were not significantly different compared to the reference brand Interceptor. These findings suggest the Olyset and PermaNet2.0 were more likely to be in poor condition. Odds rations for Round 3 and 4 with poor conditions were significantly larger than 1, while odds ratio for Round 2 was not significant compared to the reference Round 1. These findings indicate that net condition deteriorates over time.

5.3 Poisson Regression Analysis of Net Hole Counts

To assess how Net Hole Counts were affected by Brand and other covariates, a Poisson regression was first used to analyze the count data. **Table 8** and **Figure 11** showed that Net Hole Counts were significantly affected by Brand, Round, Net Use and Net Wash. **Table 9** showed the relative log Net Hole Counts (coefficient estimate) of these variables compared to their reference groups. The coefficient of difference between the Olyset and Interceptor was 0.3339, indicating that there were 40% more net holes on an Olyset compared to an Interceptor net (relative difference $=e^{0.3339} = 1.40$). Similar interpretations apply to other coefficient differences. As expected, with the increase of Round, all nets were had more net holes compared to Round 1.

Different with the Net Hole Areas, we detected significant effects of Net Use or Net Wash on Net Hole Counts. Compared to the nets not used (the reference group for Net Use), nets that were used less than half of all nights had 66% ($1-e^{-1.0764}=1-0.34=0.66$) less of holes. Washed nets had 24% ($1-e^{-0.1505}=1-0.86=0.24$) less of hole than nets that were not washed. Also we noted that this Poisson regression had a scale of 2.2184 (larger than the ideal value 1), indicating some extent of overdispersion even after the deviance adjustment.

5.4 Negative Binomial Regression Analysis of Net Hole Counts

Next, we further tried a Negative Binomial regression, which is an alternative approach to account for the overdispersed count data. **Table 10** showed that Net Hole Counts were significantly affected by Brand, Round and Net Use. **Table 11** showed the relative log Net Hole Counts (coefficient estimate) of these variables compared to their reference groups. The coefficient of difference between the Olyset and Interceptor was 0.4345, indicating that there were 54% more net holes on an Olyset compared to an Interceptor net (relative difference $=e^{0.4345}=1.54$). In contrast, the Dawaplus (relative difference$=e^{-0.3892}=0.6776$) and the DuraNet (relative difference $e^{-0.3892}=0.57$) had lower Net Hole Counts compared to Interceptor. Similar to the Poisson regression, nets at Round 2, 3 and 4 had more holes compared to Round 1.

Compared to the Poisson regression, the Negative Binomial regression only detected the significant effect of Net Use but not Net Wash. Compared to the reference group that nets were not used, nets that were used every nights had 29% more net holes (relative difference $=e^{0.2574}=1.29$). Nets that used less than half of all nights had 50% ($1-e^{-0.6896}=1-0.50=0.50$) fewer holes than nets that were not used. The scale value from the Negative Binomial regression is 0.9193, which is close 1 indicating a good fit for the count data.

Discussion

Malaria is one of major diseases contributing to global health burden and disparity around the world, especially in the African region. LLIN net use is an effective tool for control and prevention of this mosquito-transmitted disease. Currently there are several

LLIN brands used in the field. However, there is little knowledge about how these nets are used and how durable they remain under routine use. Since most LLIN products have only been evaluated under laboratory conditions and short term experimental hut studies, field studies is essential to determining the most appropriate replacement schedule. Evaluating different net brands in the field condition over time is also needed to determine the most cost effective tool for malaria prevention and control and to spur new innovations in LLIN technology.

The main goal of this thesis is to analyze the attrition and physical durability of 7 different LLIN net products from a field study carried out in western Kenya. *First*, net attrition was estimated from the proportion of nets that remained at each follow up and, for nets that were lost, the reason for lost was assessed. *Next*, net physical integrity was described by percentage of net with holes, areas of net holes and net hole counts. Secondary analyses were done to estimate the frequency of minor side effects and to compare net use and care practices. Finally, effects of net Brand, Round and practices of net use and care on net physical conditions were analyzed by four statistical models including GLM analysis, logistic regression, Poisson regression and Negative Binomial regression.

Several findings from this study may have important implications for LLIN net use and care. *First*, Olyset and PermaNet2.0 seemed to have lower physical durability compared to other LLIN brands. From GLM and logistic regression analysis, Olyset and PermaNet2.0 had a larger value of net hole areas and a higher percentage in poor condition than other brands. It is possible that these durability indicators were due to overuse of these nets in the field but not because of intrinsic qualities. However, practices of net use and care suggest that Olyset and PermanNet 2.0 were not overused. More than 20% of Olyset or PermaNet2.0 were not used from round 1 to round 5, which is higher than other net brands. A high percentage of Olyset and PermaNet2.0 were stored away or not hung up. Because only a relative small sample size was collected at each Round for each Brand, it is possible that these nets may not be representative of their targeted population. Although we have investigated several factors of net use and care, some other factors, such as age, number of children, income and women's pregnancy in different villages may serve as possible confounders. *Second*, DuraNet may have a better physical durability. DuraNet had high percentages for net use last night and every night net use. The percentage of DuraNet without any hole was also higher than other brands. *Finally*, Interceptor had a higher percentage of Net Wash than other brands at all rounds. Interestingly, Interceptor also had a higher percentage of side effects than other brand. It would be interesting to further investigate whether the high frequency of side effects promote more net wash.

Four statistical models have been used to analyze net physical integrity in this study. The GLM analysis of Net Hole Areas provided explanations about how the total Net Hole Areas were affected by Brand and other factors. However, one limitation is that this model could not account for the nets with no holes due to the normality assumption. An alternative way is to classify nets into poor/good conditions based on Net Hole Areas and perform logistic regression. This approach allows more net use and care factors to be included in modeling analysis than GLM regression. Initially, a Poisson regression is used to analyze Net Hole Counts, which detected the significance of Brand, Round, Net Use and Net Wash. However, since the scale value (2.2148) was larger than 1, suggesting that the data was still overdispersed for the Poisson regression. Thus, the effects of covariates including Net Use and Net Wash may be inaccurate and questionable. Next, we tried a Negative Binomial model to analyze the count data. The scale value was very close to 1, indicating a good match of current model with the count data. In the Negative Binomial regression, the effect of Net Wash became not significant. Nets that used every nights had more net holes than unused nets, which is a reasonable expectation. Interestingly, nets that used less than half of all nights had less net holes than unused nets. It may be that unused nets acquired holes because of animal bites, fire, or other damage unrelated to use. Alternatively, nets with holes may not have been used by people who perceive them to be ineffective.

In summary, through basic descriptive summary and 4 regression analysis, we found some meaningful and interesting results about net attrition, net use, net wash, net hole areas, net hole counts and symptoms of side effects among different net brands. These findings may have important implications in terms of improving physical durability and biological efficacies of LLIN nets for malaria control and prevention.

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Figures and Tables

1. Net Attritions and Reasons of Net Loss

Figure 1 Net Attritions by Brands and Rounds

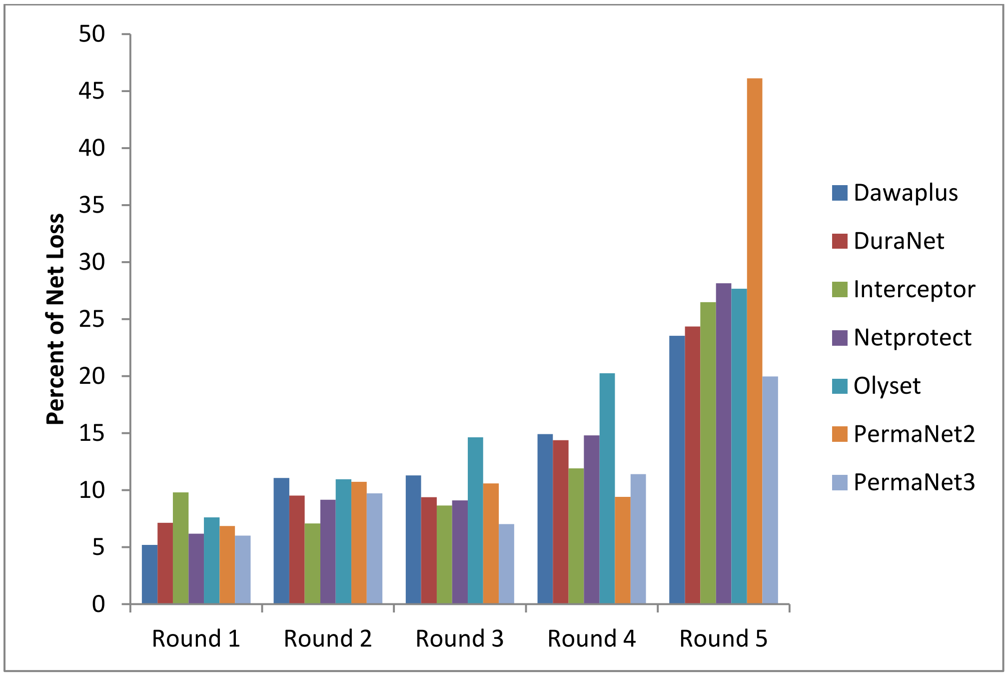


Table 1a Reasons of Net Loss at Round 1

Table of Reason Net Lost by Brand

ReasonNetLost	*Brand*						
Frequency	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Destroyed--Burned by fire	0	0	0	0	0	2	0
Discarded--Too torn up	0	0	0	0	0	0	1
Lost/Stolen	6	7	11	8	4	10	3
Other	3	4	4	7	15	1	0
Sold/Given away	4	0	4	11	12	6	4
Taken from house/Moved	18	45	49	15	13	20	29
Total	31	56	68	41	44	39	37

Table 1b Reasons of Net Loss at Round 2

Table of Reason Net Lost by Brand

ReasonNetLost	*Brand*						
Frequency	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Destroyed--Burned by fire	1	1	4	0	1	8	0
Discarded--Too torn up	9	1	0	0	0	0	1
Discarded-Not killing mosquito	1	0	0	0	0	0	0
Lost/Stolen	15	10	10	9	13	7	2
Other	1	0	6	2	6	0	0
Sold/Given away	15	1	3	12	28	9	9
Taken from house/Moved	21	59	24	35	12	34	45
Total	63	72	47	58	60	58	57

Table 1c Reasons of Net Loss at Round 3

Table of Reason Net Lost by Brand

ReasonNetLost	*Brand*						
Frequency	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Destroyed--Burned by fire	10	2	3	1	7	7	0
Discarded--Too torn up	6	0	0	0	1	7	1
Discarded-Not killing mosquito	1	0	0	0	0	0	0
Lost/Stolen	6	10	17	11	8	8	6
Other	1	0	1	0	9	1	0
Sold/Given away	9	4	12	17	42	3	6
Taken from house/Moved	28	52	22	26	9	28	26
Total	61	68	55	55	76	54	39

Table 1d Reasons of Net Loss at Round 4

Table of ReasonNetLost by Brand

ReasonNetLost / *Frequency*	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Destroyed--Burned by fire	16	19	6	6	8	8	1
Discarded--Too torn up	12	0	0	1	2	2	2
Discarded-Not killing mosquito	0	0	0	1	0	0	0
Lost/Stolen	10	19	15	13	23	5	14
Other	0	1	0	1	25	3	0
Sold/Given away	9	12	3	24	36	1	5
Taken from house/Moved	29	49	48	39	5	26	38
Total	76	100	72	85	99	45	60

Table 1e Reasons of Net Loss at Round 5

Table of ReasonNetLost by Brand

ReasonNetLost / *Frequency*	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Destroyed--Burned by fire	17	14	5	4	24	23	11
Discarded--Too torn up	12	2	4	0	2	34	5
Discarded-Not killing mosquito	2	0	0	2	0	0	0
Lost/Stolen	15	24	40	8	31	24	24
Other	6	3	4	2	10	12	1
Sold/Given away	14	1	1	25	47	1	12
Taken from house/Moved	47	118	98	112	13	113	46
Total	113	162	152	153	127	207	99

2. Physical Integrity

2.1 Net Hole Presence

Table 2a Net Hole Presence at Round 1

Table of Net Hole Presence by Brand

Net Hole Presence	*Brand*						
Col Pct	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Nets with at least one hole	14.29	6.90	30.00	17.24	32.26	26.67	23.33
Nets without any hole	85.71	93.10	70.00	82.76	67.74	73.33	76.67
Total	28	29	30	29	31	30	30

Table 2b Net Hole Presence at Round 2

Table of Net Hole Presence by Brand

Net Hole Presence	*Brand(Brand)*						
Col Pct	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Nets with at least one hole	40.00	32.26	41.38	26.67	44.83	43.33	40.00
Nets without any hole	60.00	67.74	58.62	73.33	55.17	56.67	60.00
Total	30	31	29	30	29	30	30

Table 2c Net Hole Presence at Round 3

Table of Net Hole Presence by Brand

Net Hole Presence	*Brand(Brand)*						
Col Pct	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Nets with at least one hole	46.67	53.33	53.33	53.33	63.33	64.52	36.67
Nets without any hole	53.33	46.67	46.67	46.67	36.67	35.48	63.33
Total	30	30	30	30	30	31	30

Table 2d Net Hole Presence at Round 4

Table of Net Hole Presence by Brand							
Net Hole Presence	*Brand(Brand)*						
Col Pct	*Dawaplus*	*DuraNet*	*Interceptor*	*Netprotect*	*Olyset*	*PermaNet2*	*PermaNet3*
Nets with at least one hole	53.33	60.00	61.29	80.00	73.33	60.00	40.00
Nets without any hole	46.67	40.00	38.71	20.00	26.67	40.00	60.00
Total	30	30	31	30	30	30	30

2.2 Hole Number and Hole Size

Figure 2a Hole Number and Hole Size by Brand at Round 1

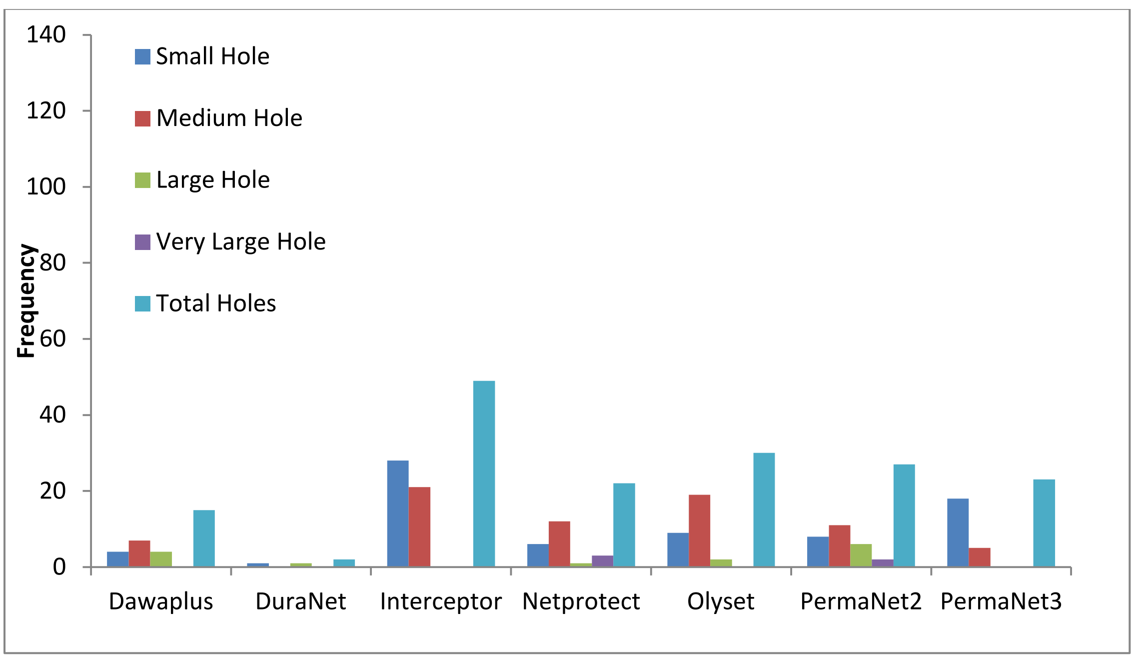


Figure 2b Hole Number and Hole Size by Brand at Round 2

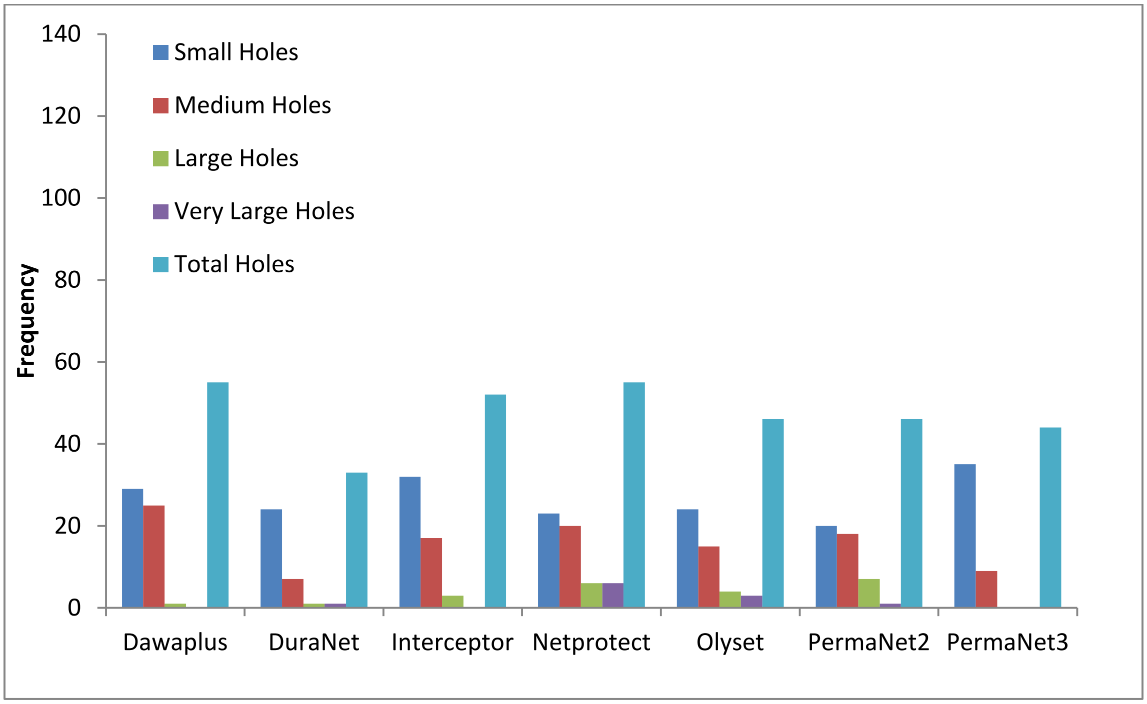


Figure 2c Net Hole Categories by Brand at Round 3

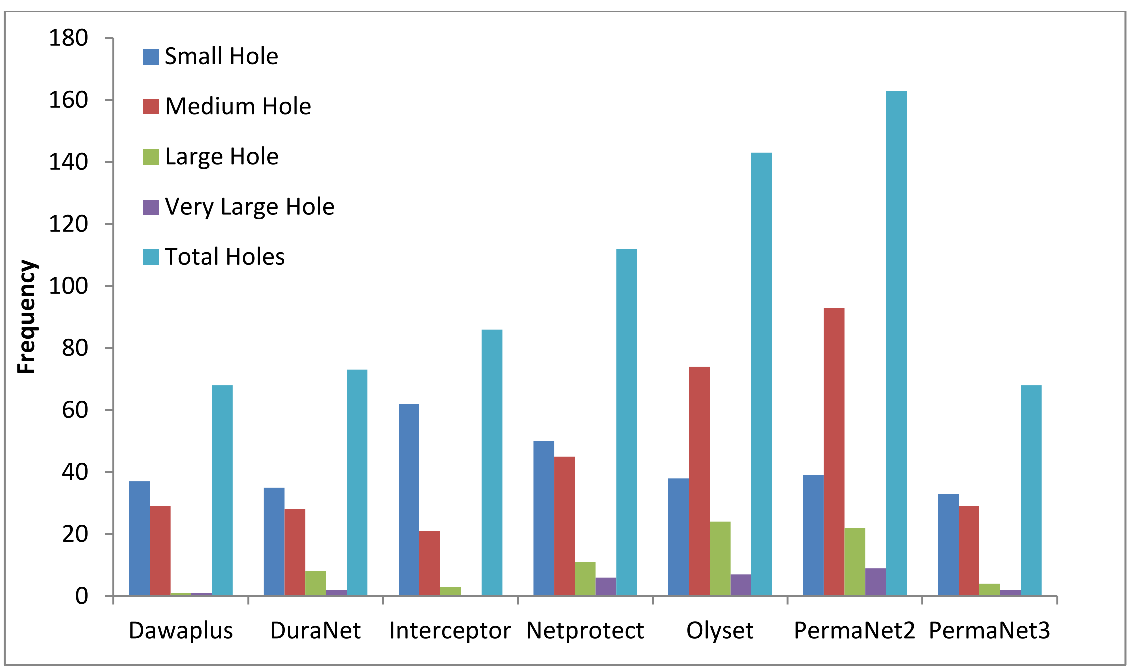
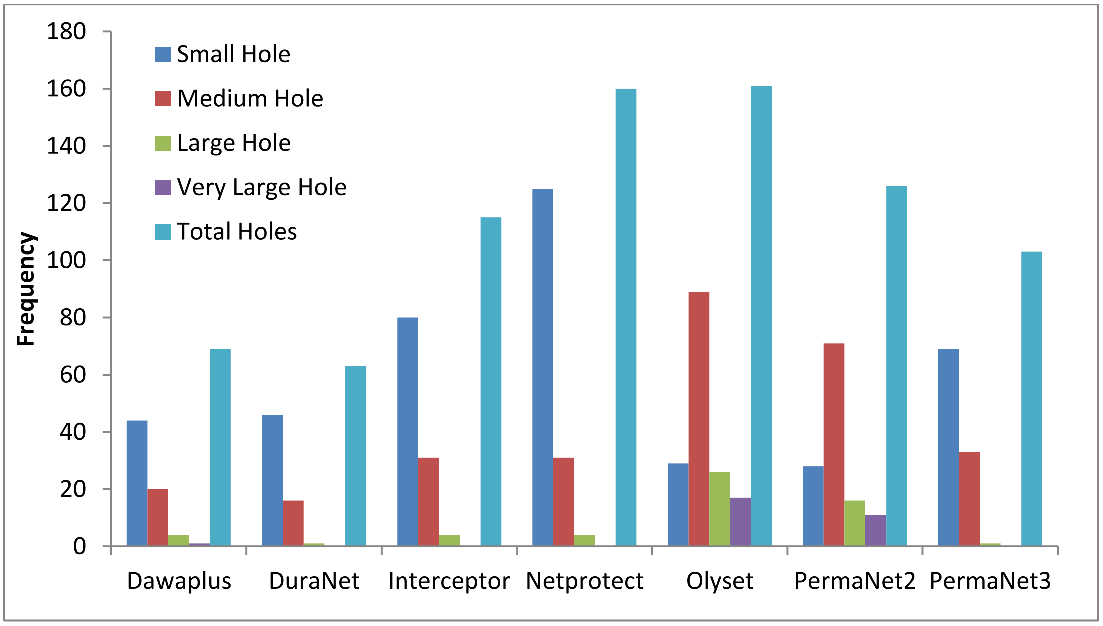


Figure 2d Net Hole Categories by Brand at Round 4



2.3 Net Hole Areas

Table 3a Net Hole Areas by Brand at Round 1

Analysis Variable : Areas

Brand	*N Obs*	*N*	*Mean*	*Median*	*Std Dev*	*Minimum*	*Maximum*
Dawaplus	28	28	45.30	0.00	167.13	0.00	762.62
DuraNet	29	29	4.01	0.00	20.99	0.00	113.10
Interceptor	30	30	16.21	0.00	42.29	0.00	164.15
Netprotect	29	29	173.98	0.00	717.09	0.00	3686.66
Olyset	31	31	22.22	0.00	65.77	0.00	322.80
PermaNet2	30	30	121.40	0.00	480.11	0.00	2605.95
PermaNet3	30	30	4.76	0.00	17.82	0.00	95.82

Table 3a Net Hole Areas by Brand at Round 1 (Nets with at least one hole)

Analysis Variable : Areas

Brand	*N Obs*	*N*	*Mean*	*Median*	*Std Dev*	*Minimum*	*Maximum*
Dawaplus	4	4	317.10	250.93	369.43	3.93	762.62
DuraNet	2	2	58.12	58.12	77.75	3.14	113.10
Interceptor	9	9	54.02	19.63	64.70	0.79	164.15
Netprotect	5	5	1009.08	55.76	1595.68	3.14	3686.66
Olyset	10	10	68.88	21.21	104.16	3.14	322.80
PermaNet2	8	8	455.24	122.13	883.89	3.14	2605.95
PermaNet3	7	7	20.42	6.28	34.08	0.79	95.82

Table 3b Net Hole Areas by Brand at Round 2

Analysis Variable : Areas							
Brand	*N Obs*	*N*	*Mean*	*Median*	*Std Dev*	*Minimum*	*Maximum*
Dawaplus	29	29	24.62	0.00	85.77	0.00	462.60
DuraNet	31	31	28.55	0.00	129.99	0.00	725.71
Interceptor	29	29	35.07	0.00	106.84	0.00	546.64
Netprotect	30	30	308.71	0.00	1049.05	0.00	4325.97
Olyset	29	29	166.94	0.00	482.22	0.00	2162.20
PermaNet2	30	30	85.53	0.00	279.53	0.00	1225.22
PermaNet3	30	30	7.54	0.00	22.33	0.00	96.60

Table 3b Net Hole Areas by Brand at Round 2 (Nets with at least one hole)

Analysis Variable : Areas							
Brand	*N Obs*	*N*	*Mean*	*Median*	*Std Dev*	*Minimum*	*Maximum*
Dawaplus	12	12	59.49	23.95	128.31	0.79	462.60
DuraNet	10	10	88.51	16.10	224.57	0.79	725.71
Interceptor	12	12	84.76	15.32	156.40	0.79	546.64
Netprotect	8	8	1157.68	122.52	1853.65	4.71	4325.97
Olyset	13	13	372.40	15.71	678.00	3.14	2162.20
PermaNet2	13	13	197.38	10.21	406.09	0.79	1225.22
PermaNet3	12	12	18.85	3.14	32.90	0.79	96.60

Table 3c Net Hole Areas by Brand at Round 3

Analysis Variable : Areas							
Brand	*N Obs*	*N*	*Mean*	*Median*	*Std Dev*	*Minimum*	*Maximum*
Dawaplus	30	30	109.17	0.00	435.82	0.00	2359.34
DuraNet	30	30	185.72	8.64	616.03	0.00	3356.79
Interceptor	30	30	37.02	2.36	102.33	0.00	546.64
Netprotect	30	30	452.26	3.53	1286.35	0.00	6208.57
Olyset	30	30	678.17	31.81	1479.13	0.00	6259.62
PermaNet2	30	30	614.05	31.02	1228.26	0.00	4194.81
PermaNet3	30	30	108.38	0.00	350.14	0.00	1475.76

Table 3c Net Hole Areas by Brand at Round 3 (Nets with at least one hole)

Analysis Variable : Areas							
Brand	*N Obs*	*N*	*Mean*	*Median*	*Std Dev*	*Minimum*	*Maximum*
Dawaplus	14	14	233.94	22.78	626.33	0.79	2359.34
DuraNet	16	16	348.23	52.62	820.57	6.28	3356.79
Interceptor	16	16	69.41	21.99	133.59	1.57	546.64
Netprotect	16	16	847.98	168.86	1685.57	3.14	6208.57
Olyset	19	19	1070.79	255.25	1755.30	6.28	6259.62
PermaNet2	20	20	921.08	225.02	1415.96	0.79	4194.81
PermaNet3	11	11	295.60	43.98	542.82	7.07	1475.76

Table 3d Net Hole Areas by Brand at Round 4

Analysis Variable : Areas

Brand	N Obs	N	Mean	Median	Std Dev	Minimum	Maximum
Dawaplus	30	30	74.90	0.79	224.09	0.00	1148.25
DuraNet	30	30	15.81	0.79	42.94	0.00	223.05
Interceptor	31	31	34.23	7.07	75.58	0.00	384.06
Netprotect	30	30	63.75	8.64	122.51	0.00	538.78
Olyset	30	30	1038.92	80.90	1693.47	0.00	5566.90
PermaNet2	29	29	503.58	24.35	903.13	0.00	3114.10
PermaNet3	30	30	30.47	0.00	79.52	0.00	371.49

Table 3d Net Hole Areas by Brand at Round 4 (Nets with at Least One Hole)

Analysis Variable : Areas

Brand	N Obs	N	Mean	Median	Std Dev	Minimum	Maximum
Dawaplus	16	16	140.44	24.35	295.41	0.79	1148.25
DuraNet	18	18	26.35	5.50	53.39	0.79	223.05
Interceptor	19	19	55.85	16.49	90.80	0.79	384.06
Netprotect	24	24	79.69	24.74	132.66	3.14	538.78
Olyset	22	22	1416.72	150.40	1843.81	7.07	5566.90
PermaNet2	18	18	811.32	179.46	1038.77	12.57	3114.10
PermaNet3	12	12	76.18	14.14	113.45	0.79	371.49

3. Net Use and Care

3.1 Frequency of Net Use

Figure 3a Net Use by Brand at Round 1

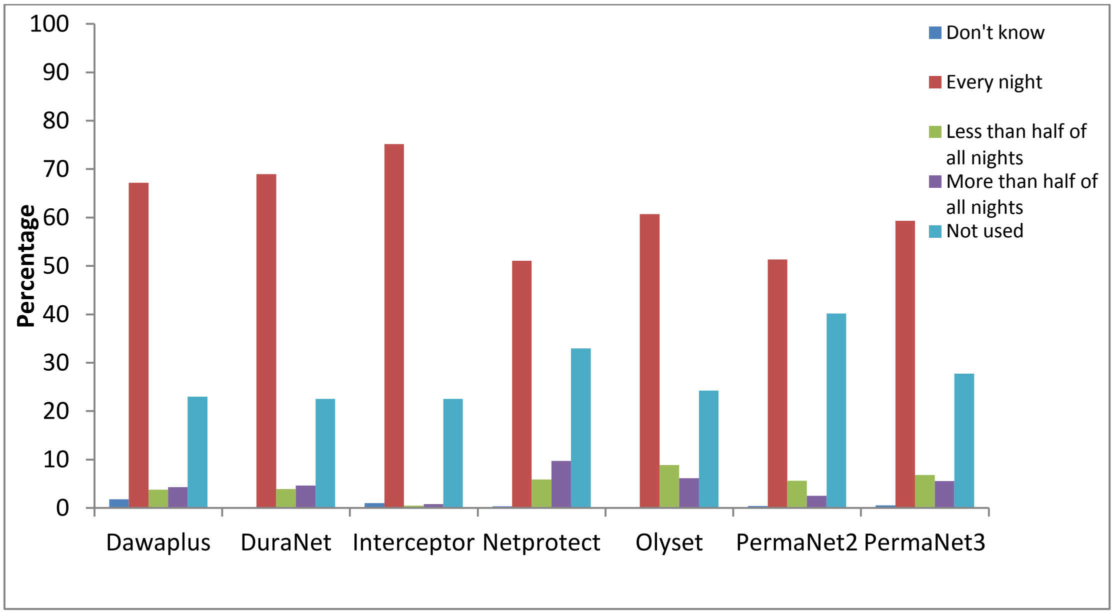


Figure 3b Net Use by Brand at Round 2

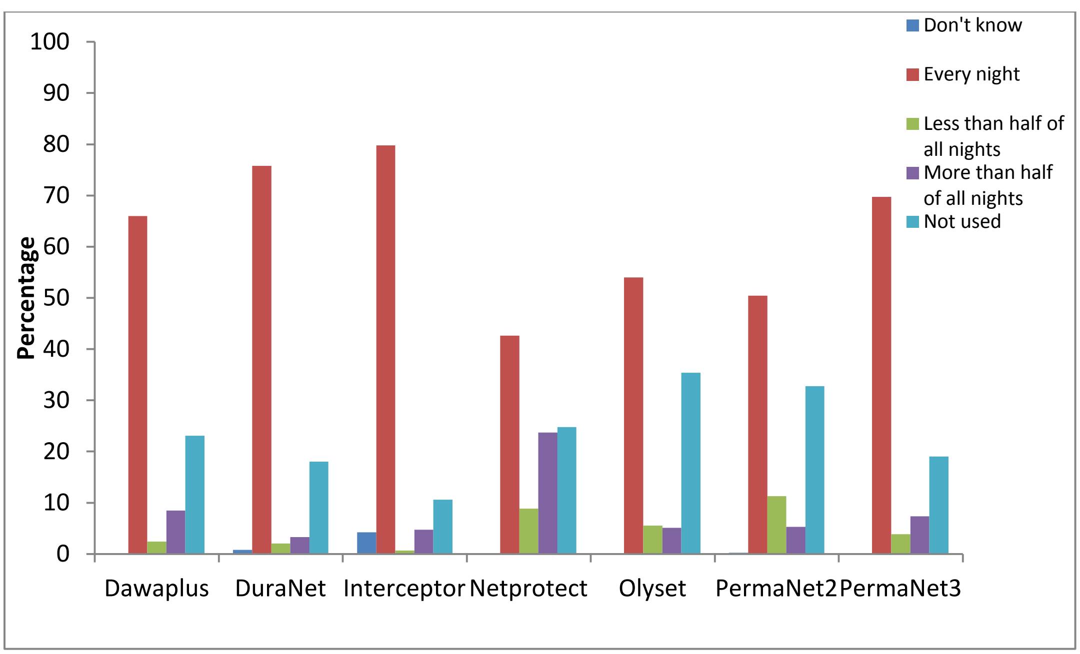


Figure 3c Net Use by Brand at Round 3

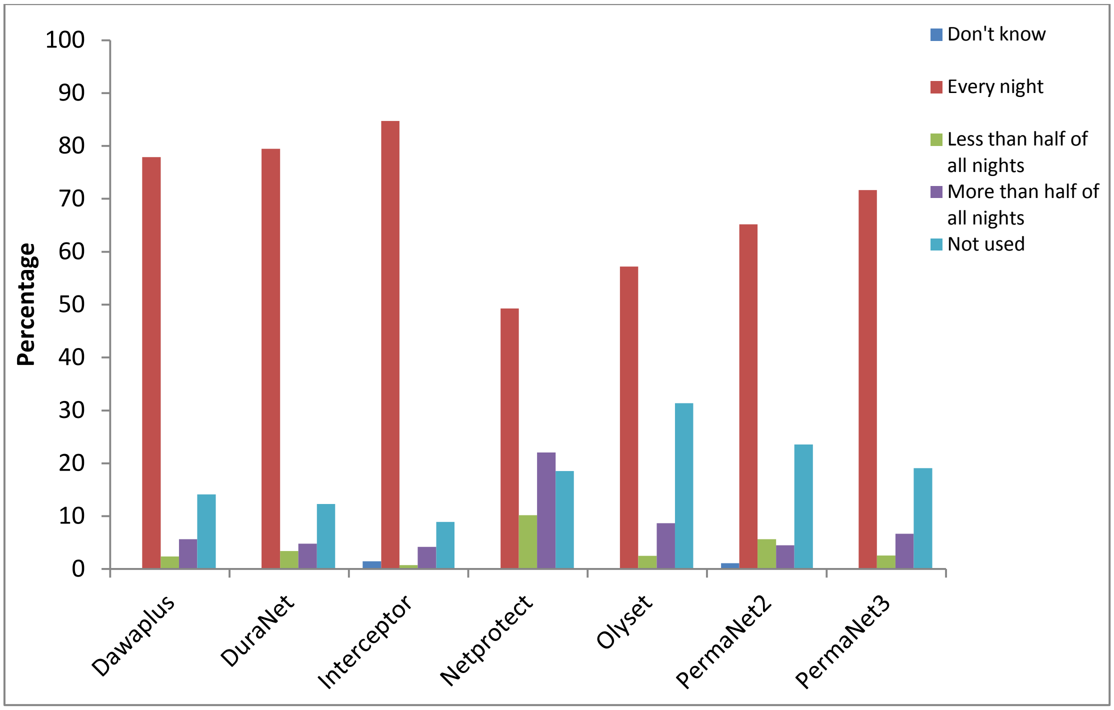


Figure 3d Net Use by Brand at Round 4

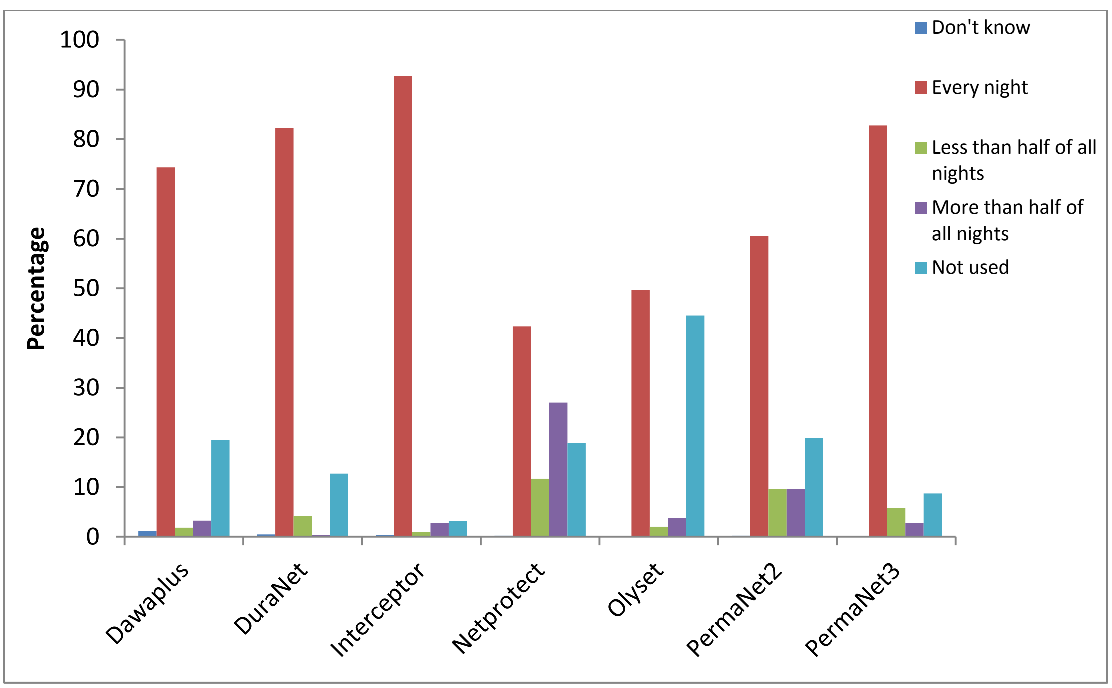
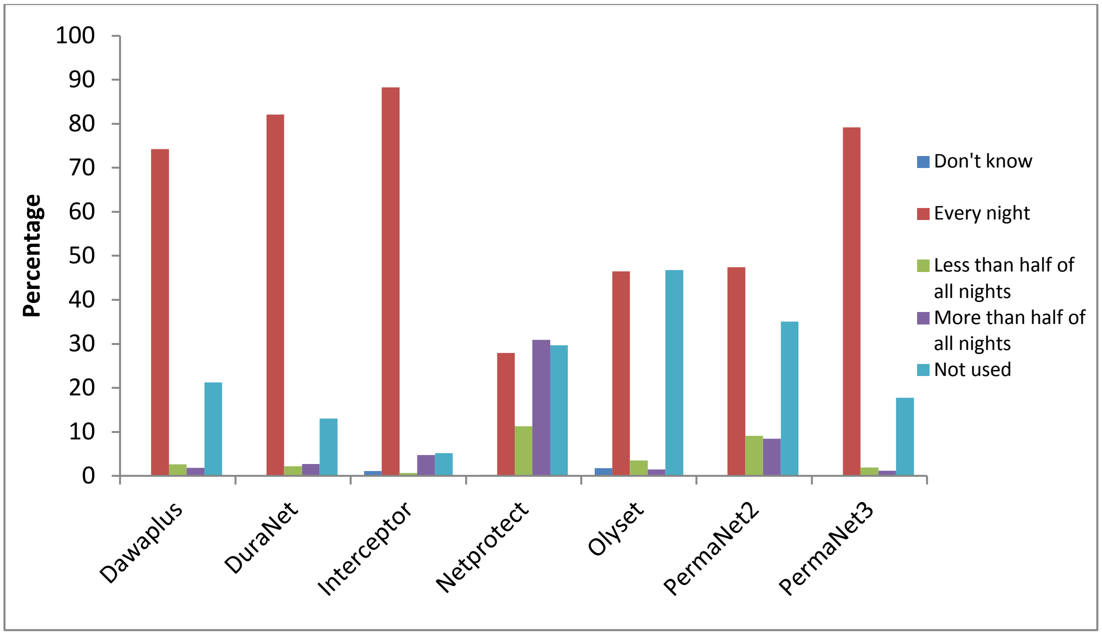


Figure 3e Net Use by Brand at Round 5



3.2 Net Use Last Night

Figure 4a Net Use Last Night by Brand at Round 1

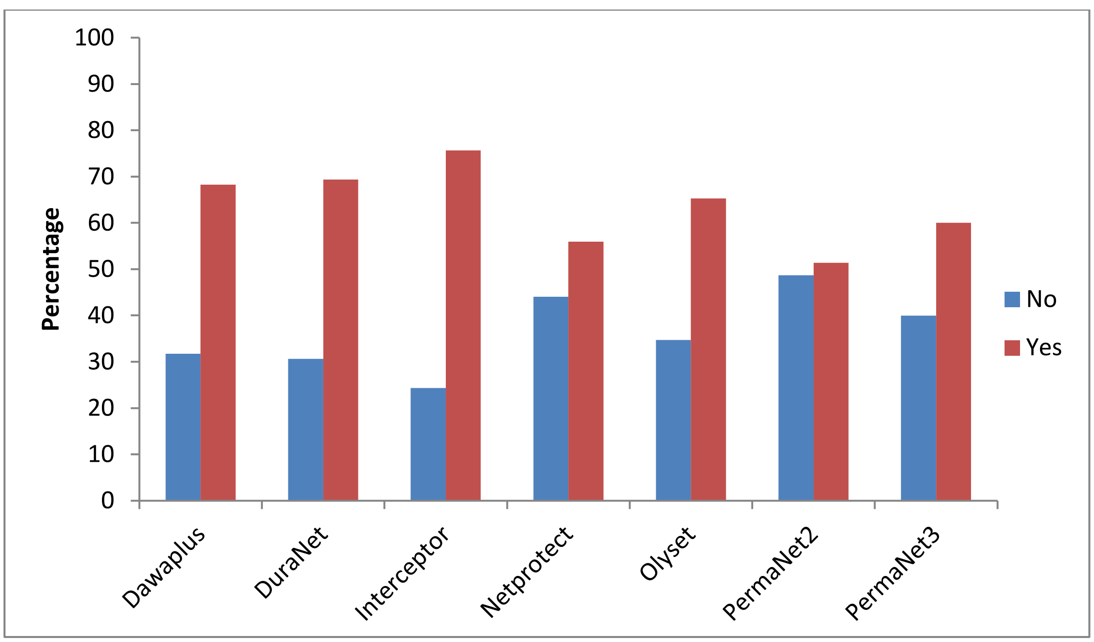


Figure 4b Net Use Last Night by Brand at Round 2

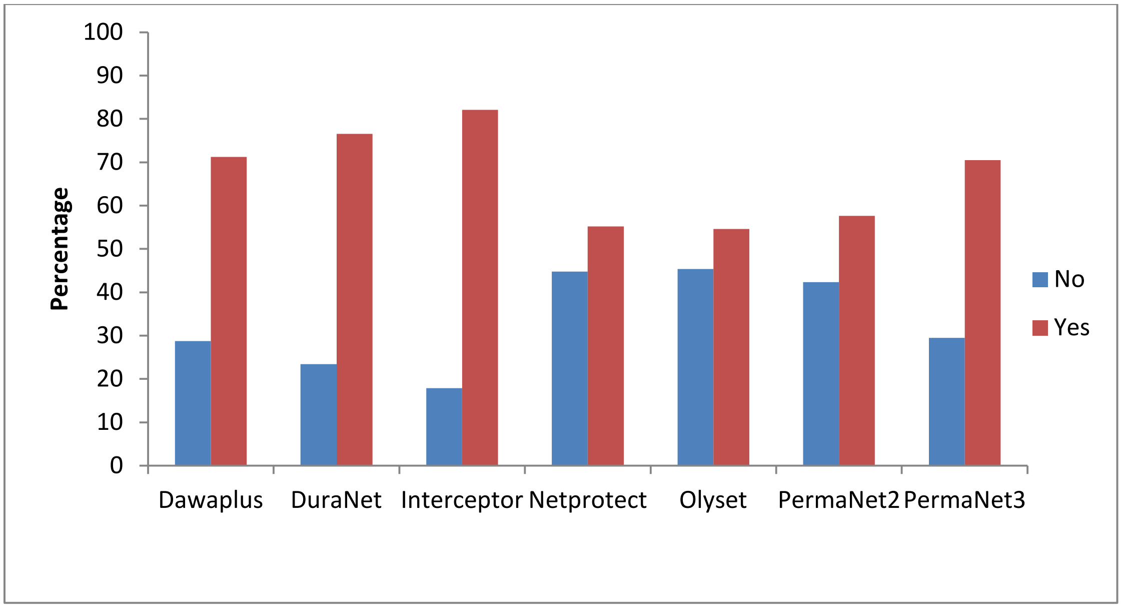


Figure 4c Net Use Last Night by Brand at Round 3

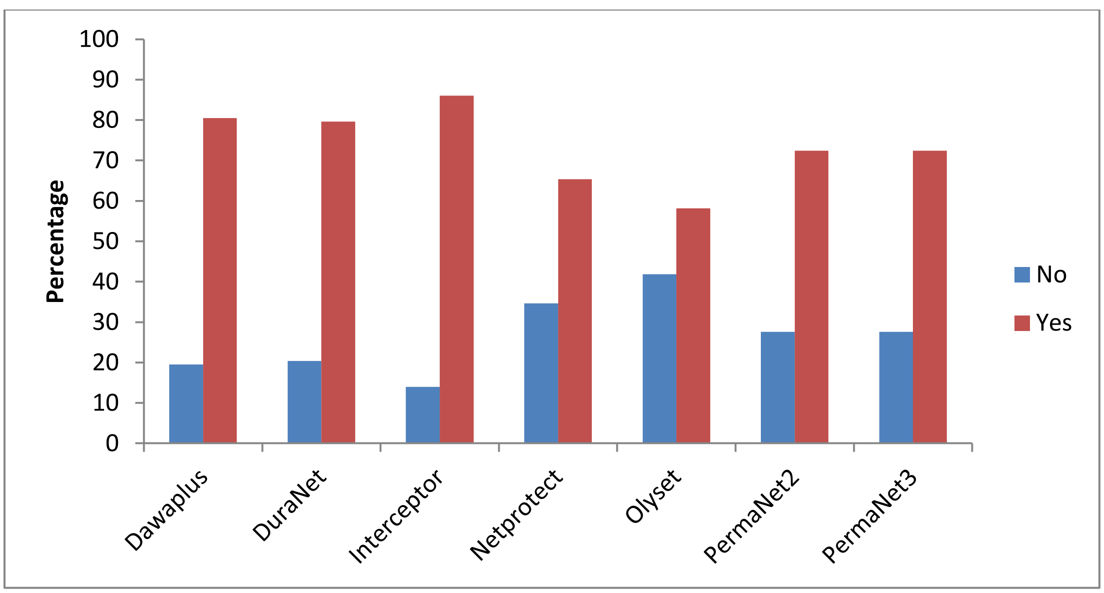


Figure 4d Net Use Last Night by Brand at Round 4

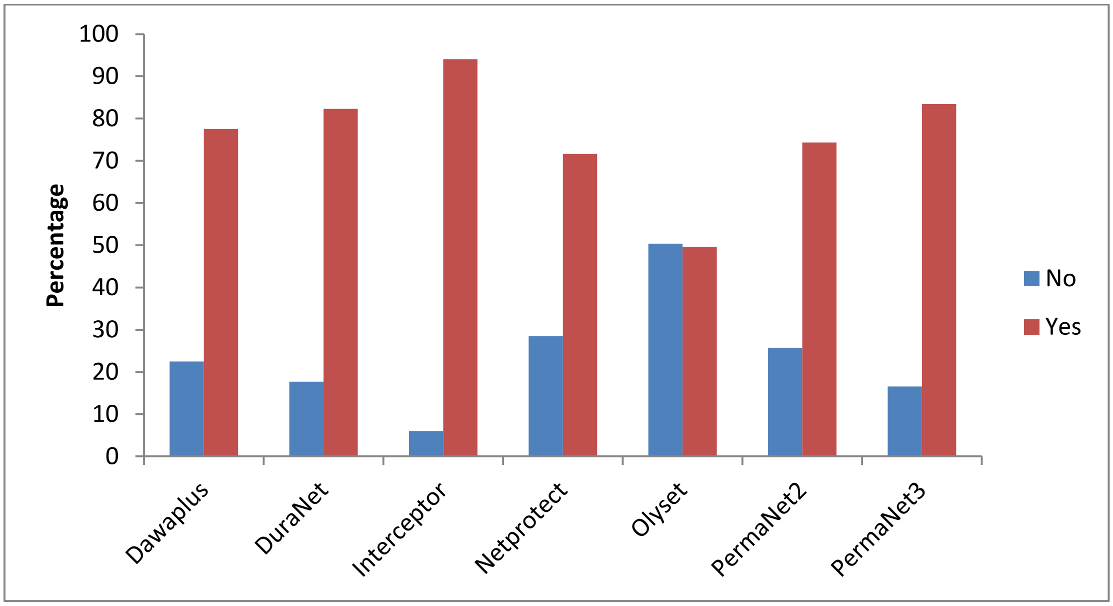
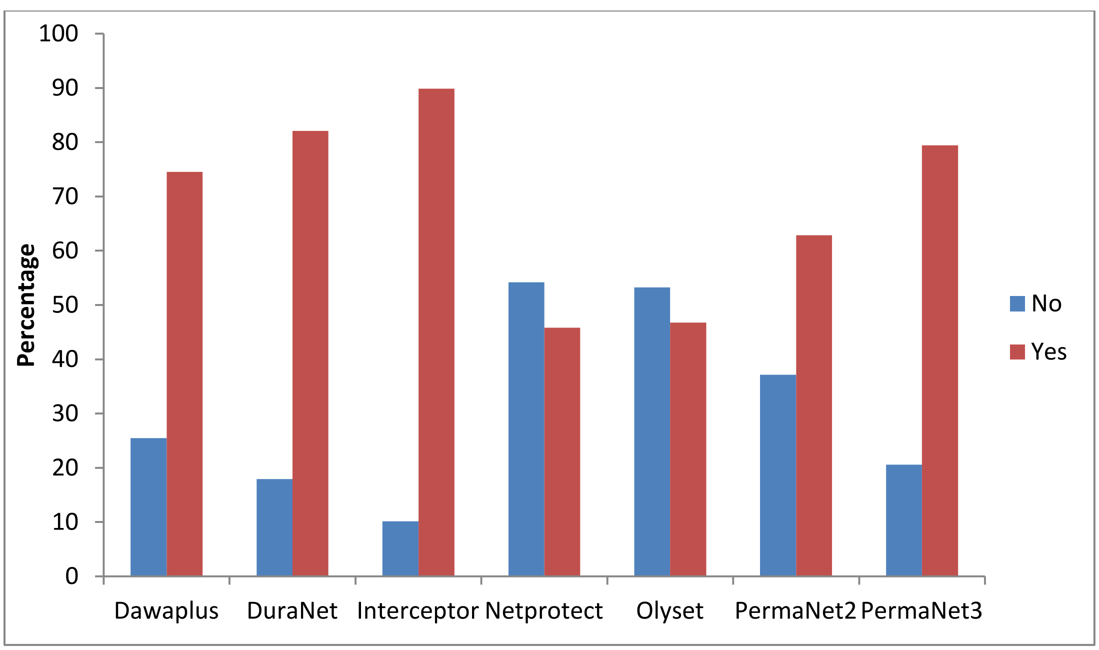


Figure 4e Net Use Last Night by Brand at Round 5



3.3 Net Wash

Figure 5a Net Wash by Brand at Round 1

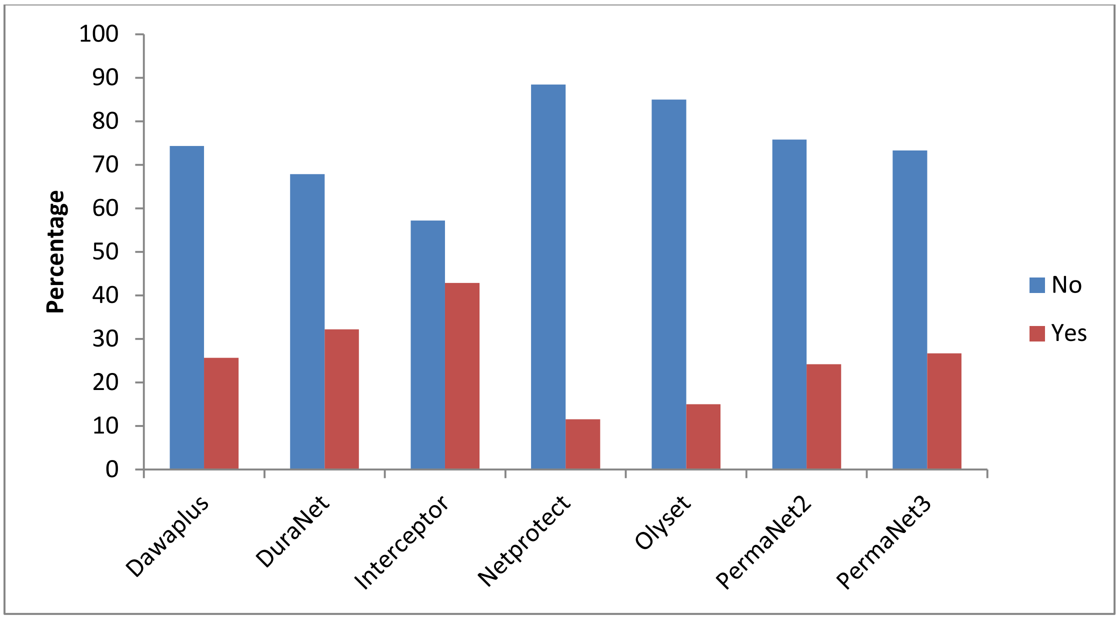


Figure 5b Net Wash by Brand at Round 2

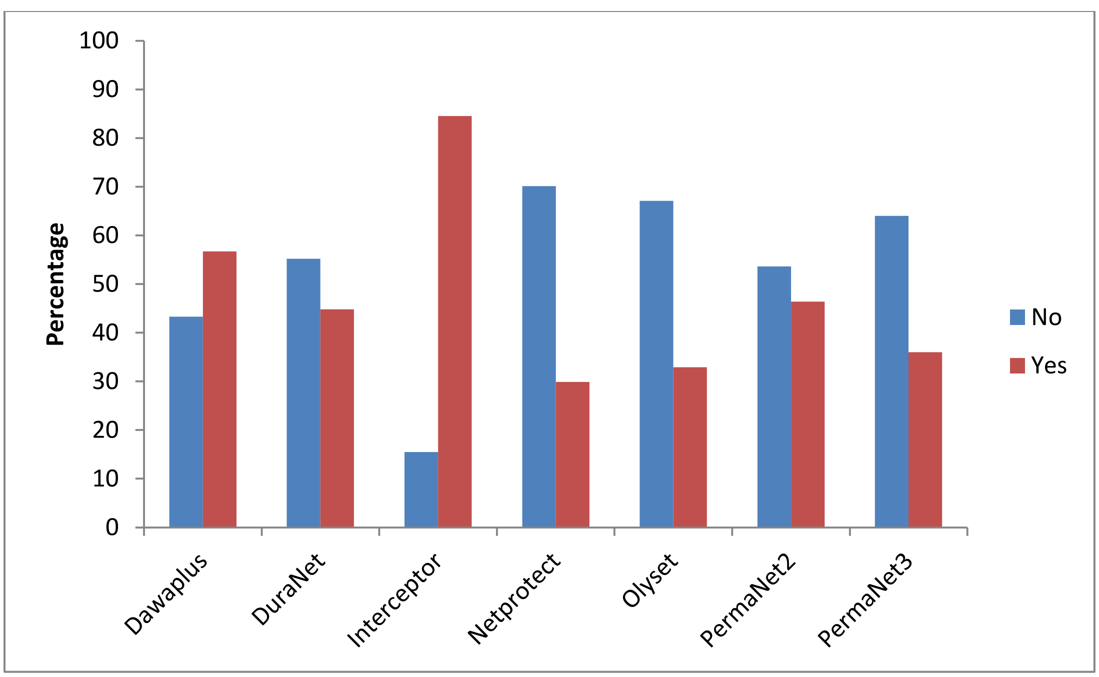


Figure 5c Net Wash by Brand at Round 3

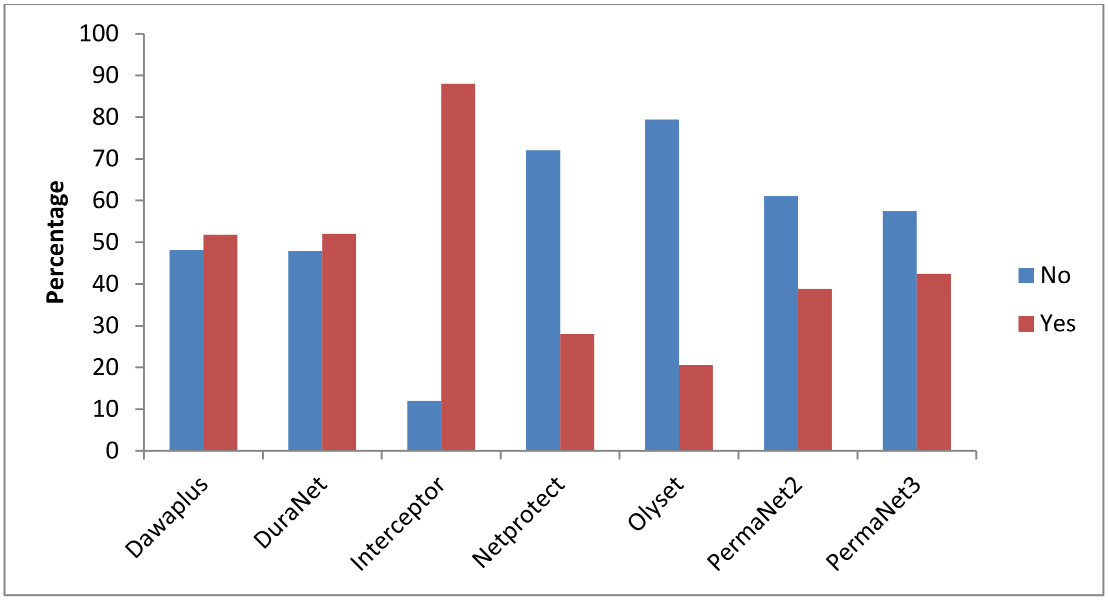


Figure 5d Net Wash by Brand at Round 4

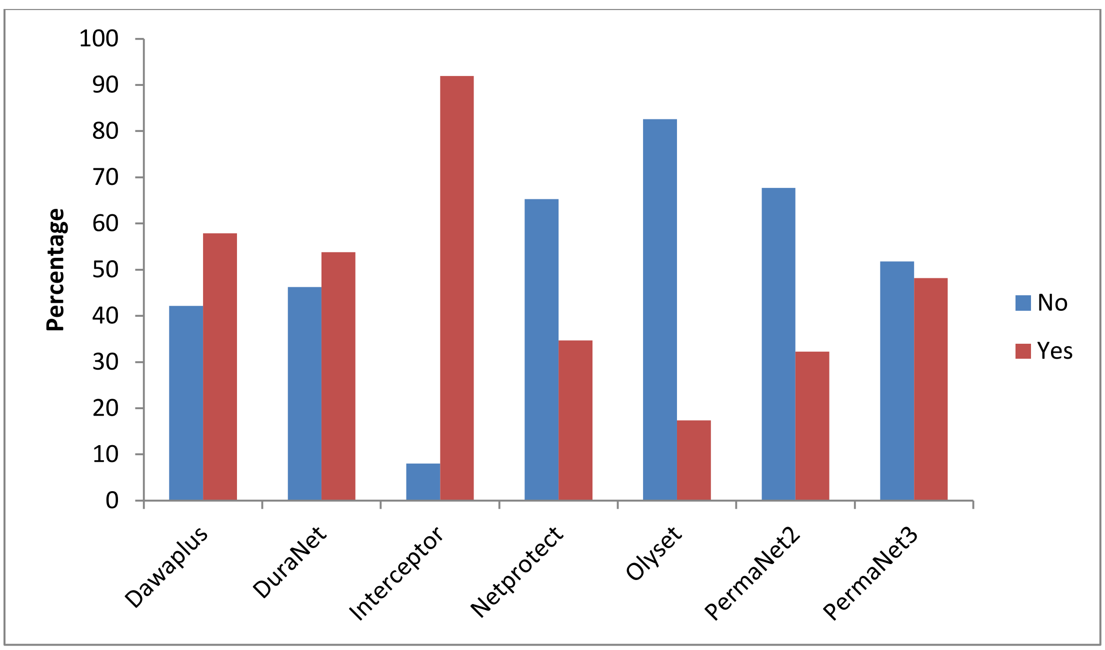
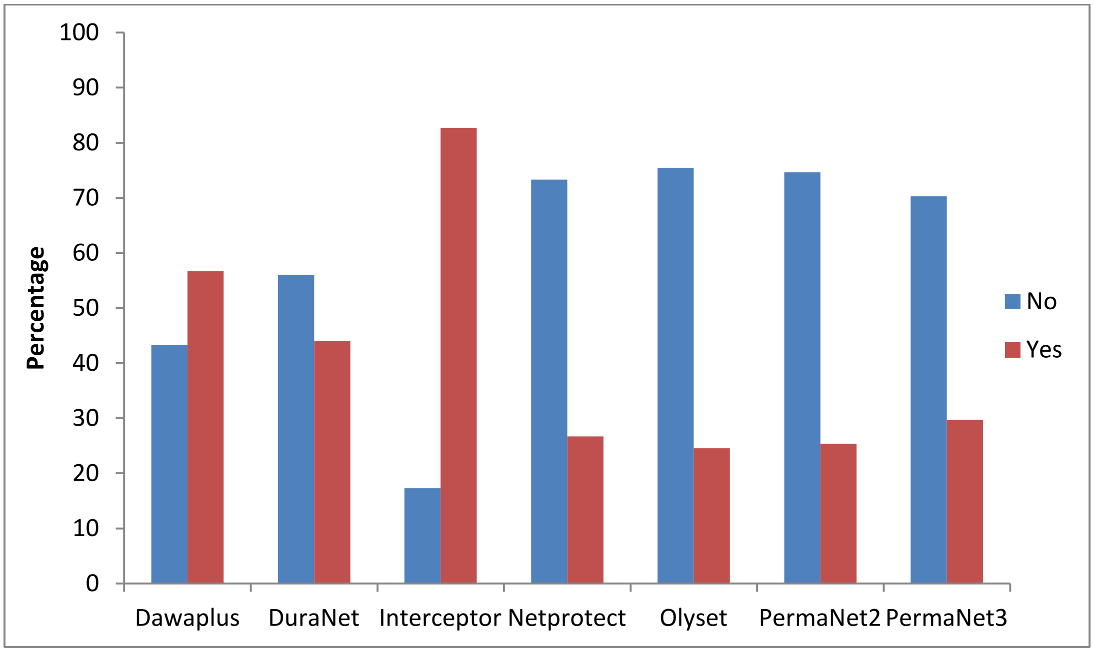


Figure 5e Net Wash by Brand at Round 5



3.5 Bed Net Types

Figure 6a Bed Net Types by Brand at Round 1

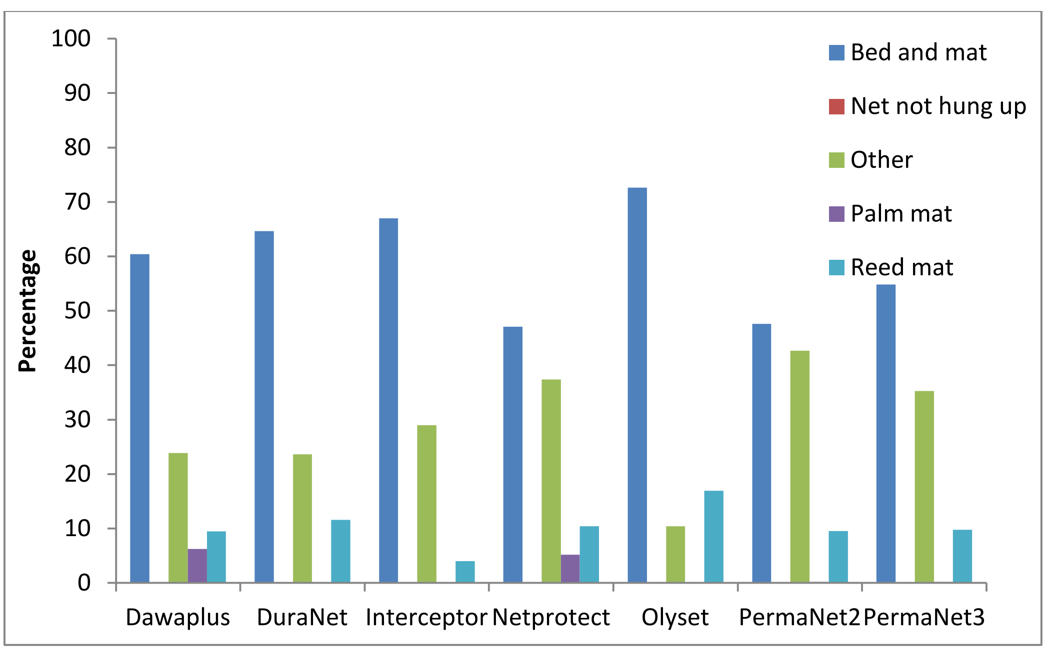


Figure 6b Bed Net Types by Brand at Round 2

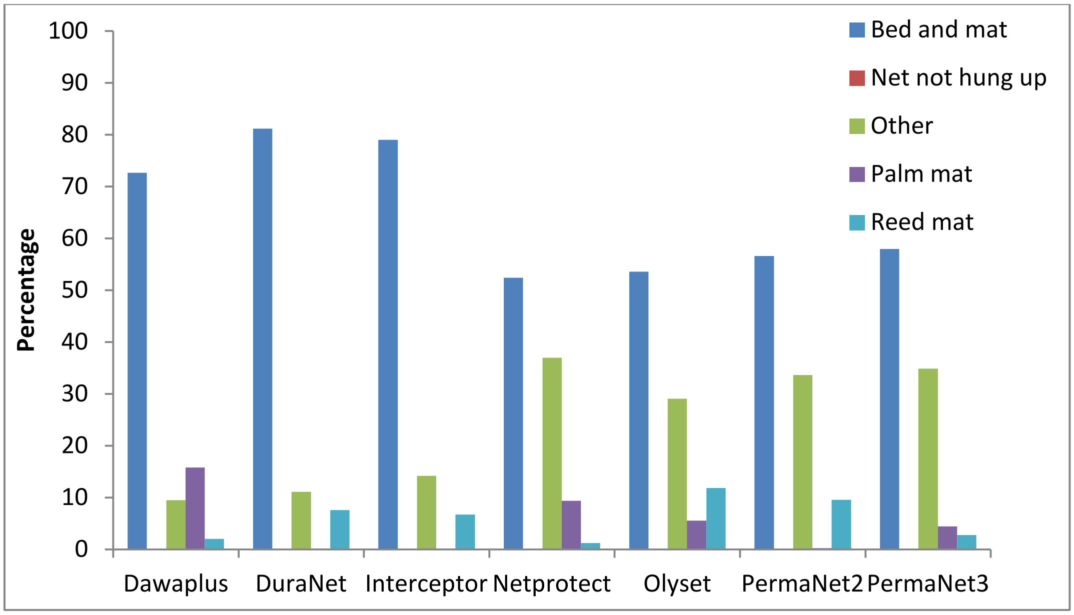


Figure 6c Bed Net Types by Brand at Round 3

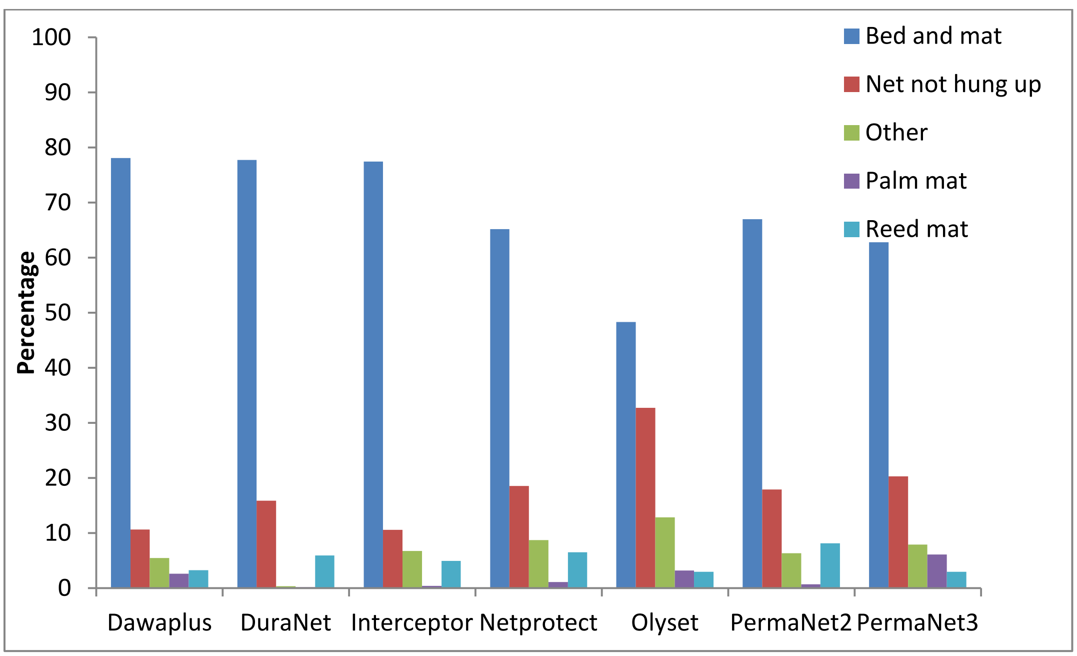


Figure 6d Bed Net Types by Brand at Round 4

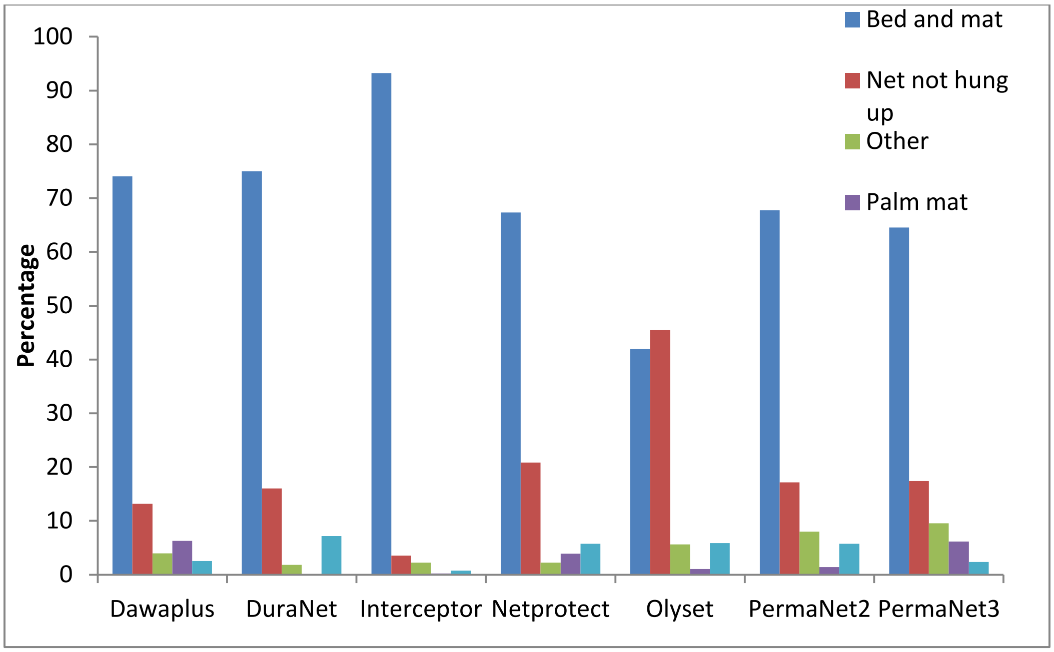
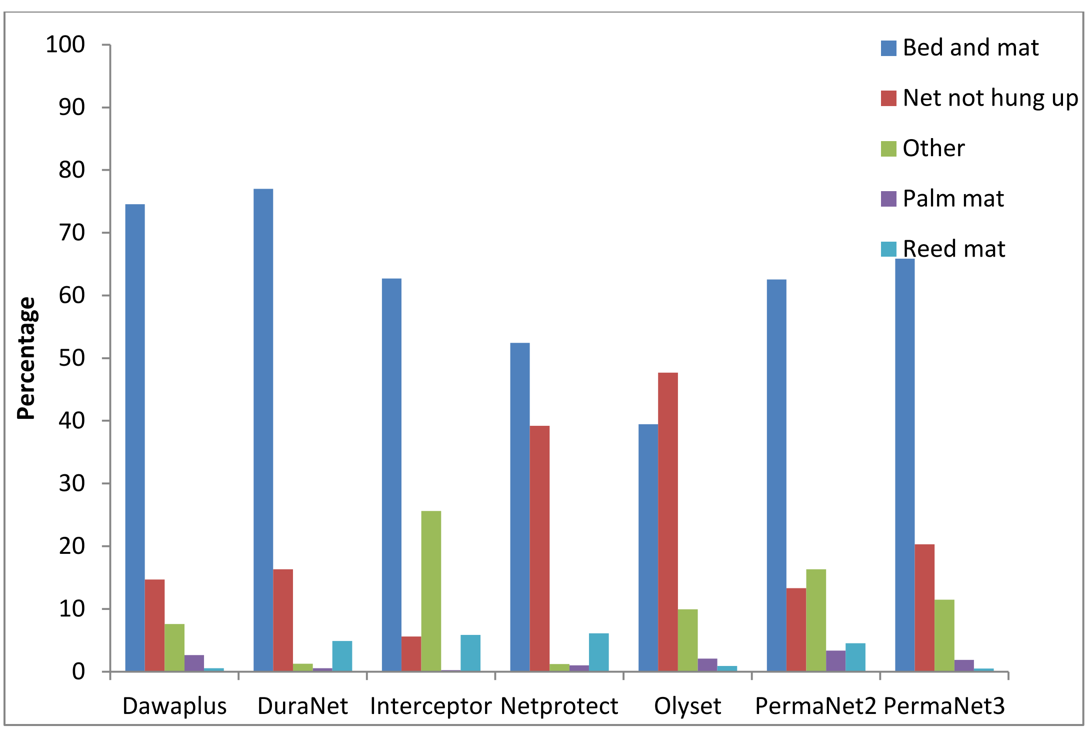


Figure 6e Bed Net Types by Brand at Round 5



3.6 Bed Net Location

Figure 7a Bed Net Location by Brand at Round 1

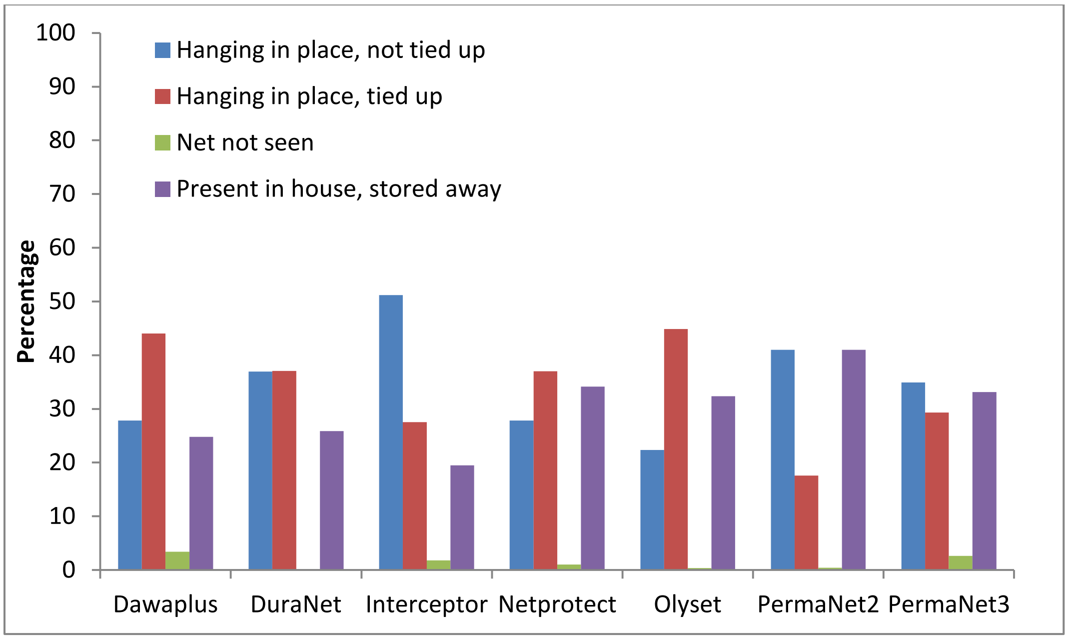


Figure 7b Bed Net Location by Brand at Round 2

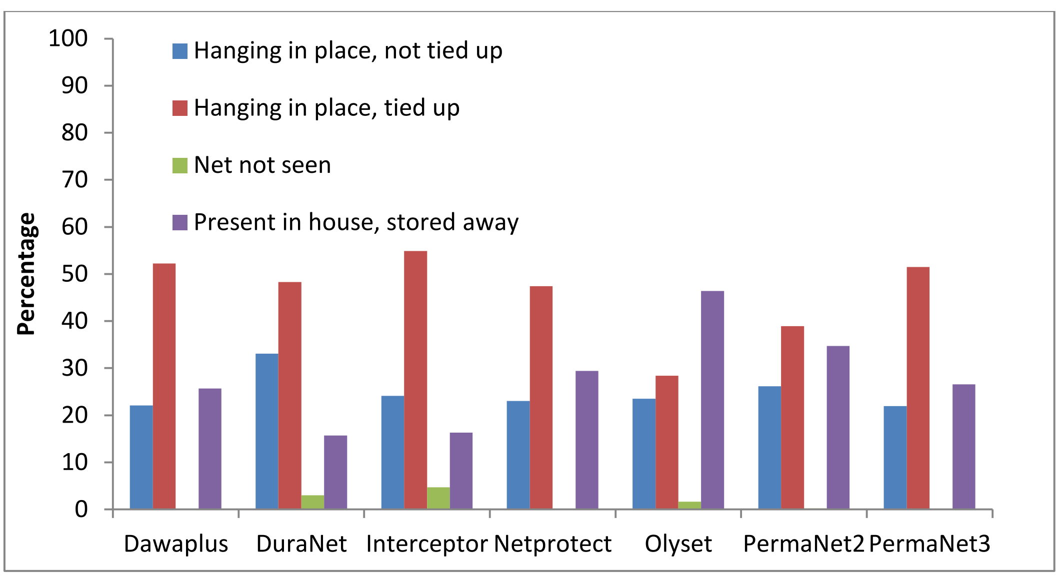


Figure 7c Bed Net Location by Brand at Round 3

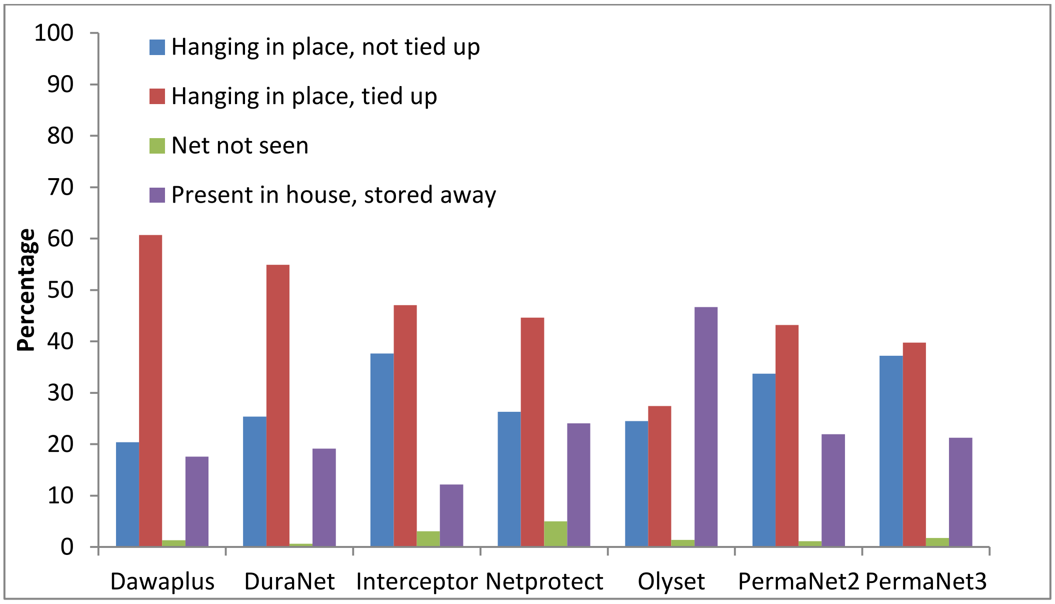


Figure 7d Bed Net Location by Brand at Round 4

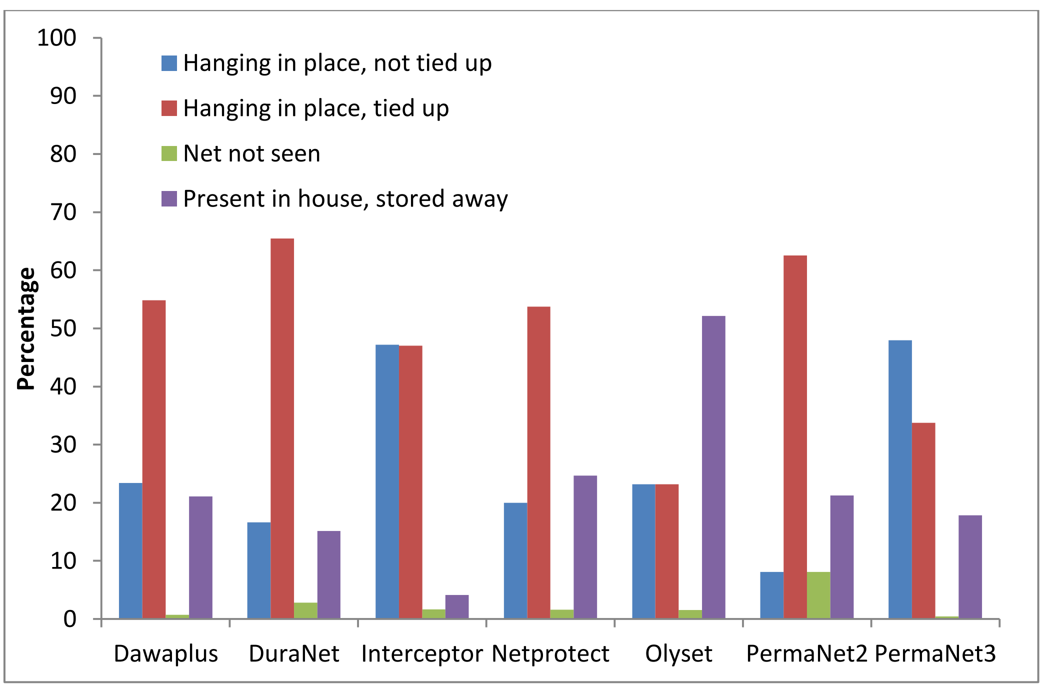
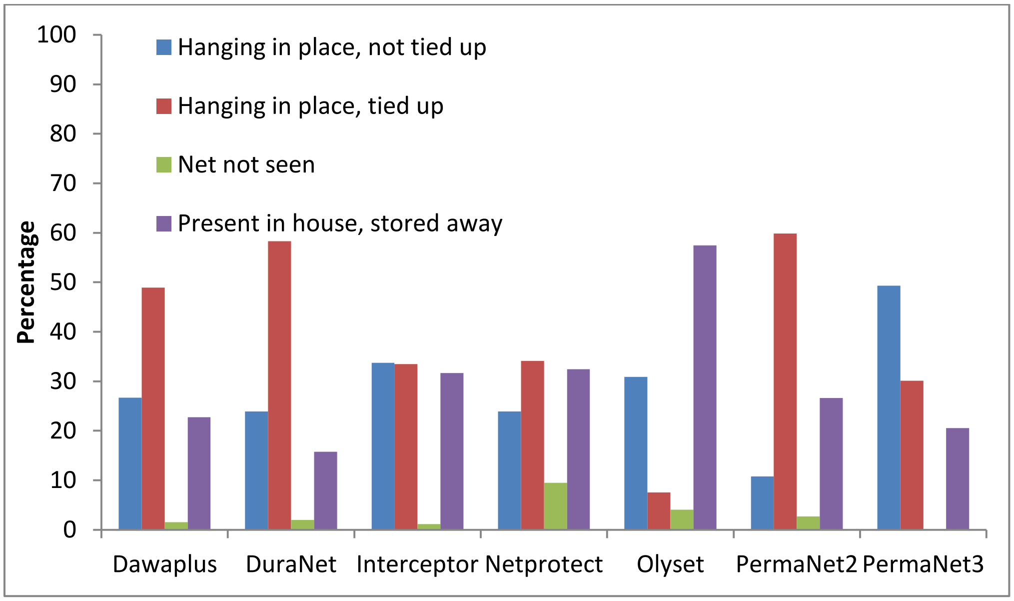


Figure 7e Bed Net Location by Brand at Round 5



4. Side Effects on Net Use

4.1 Presence of Side Effects

Figure 8a Side effects by Brand at Round 1

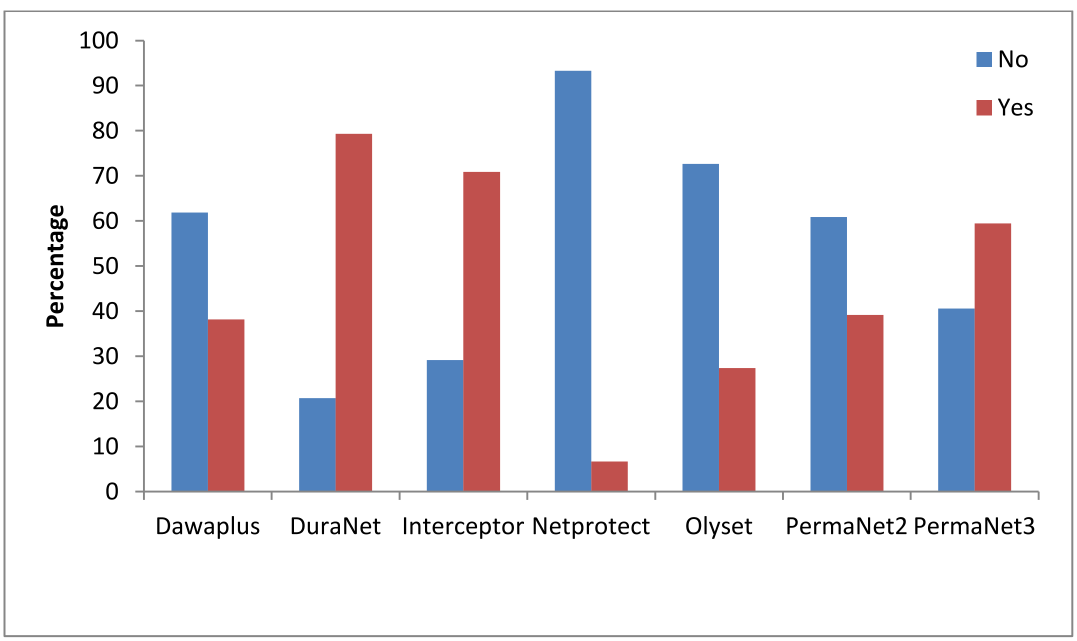


Figure 8b Side effects by Brand at Round 2

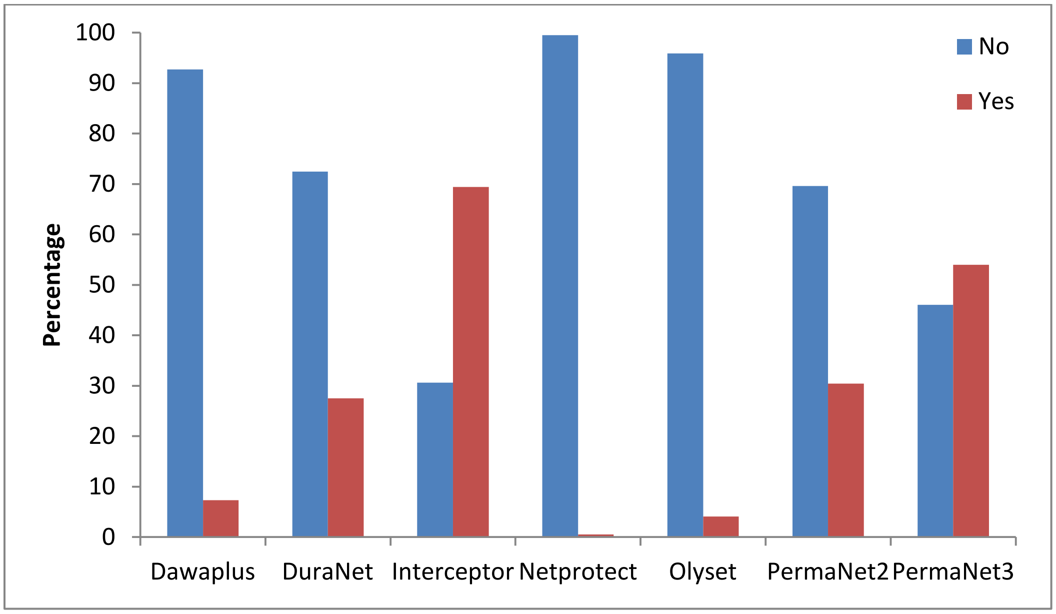


Figure 8c Side effects by Brand at Round 3

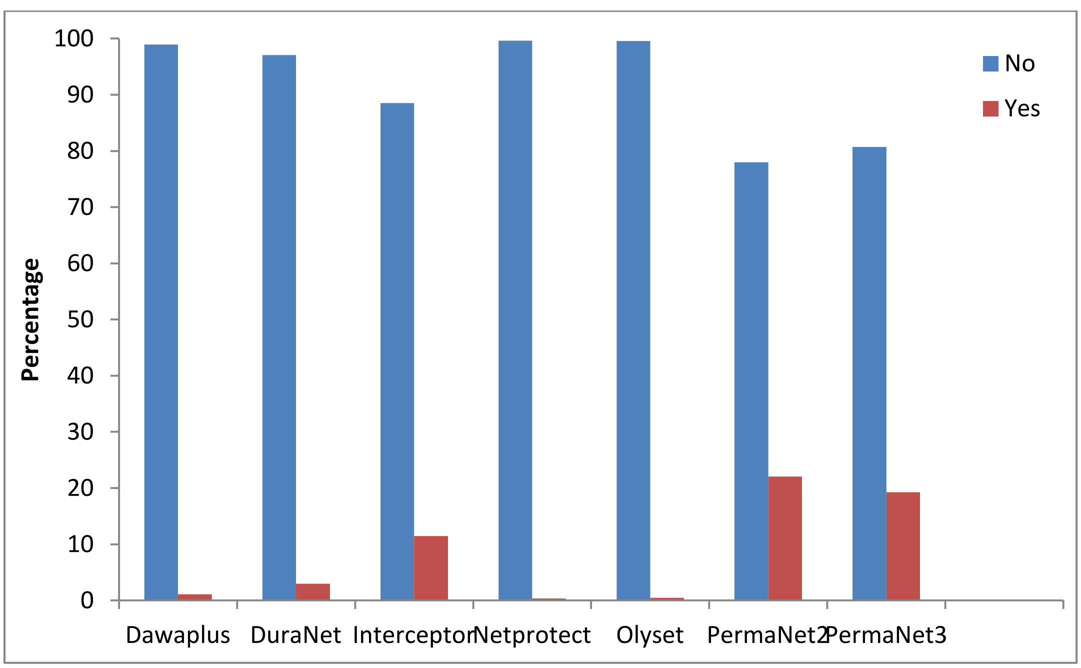


Figure 8d Side effects by Brand at Round 4

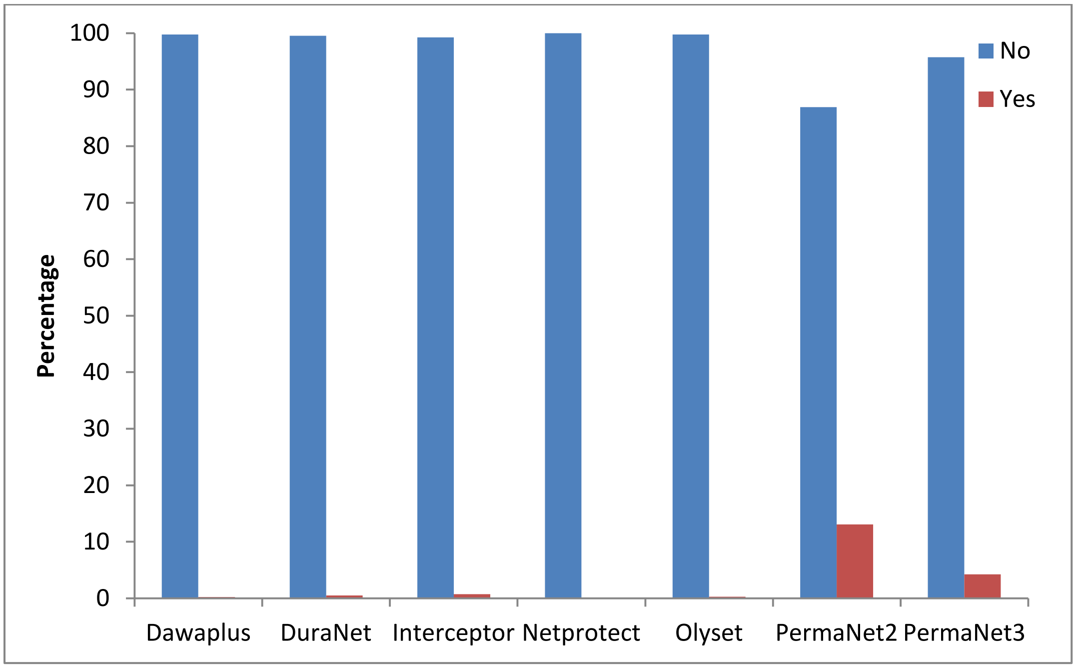
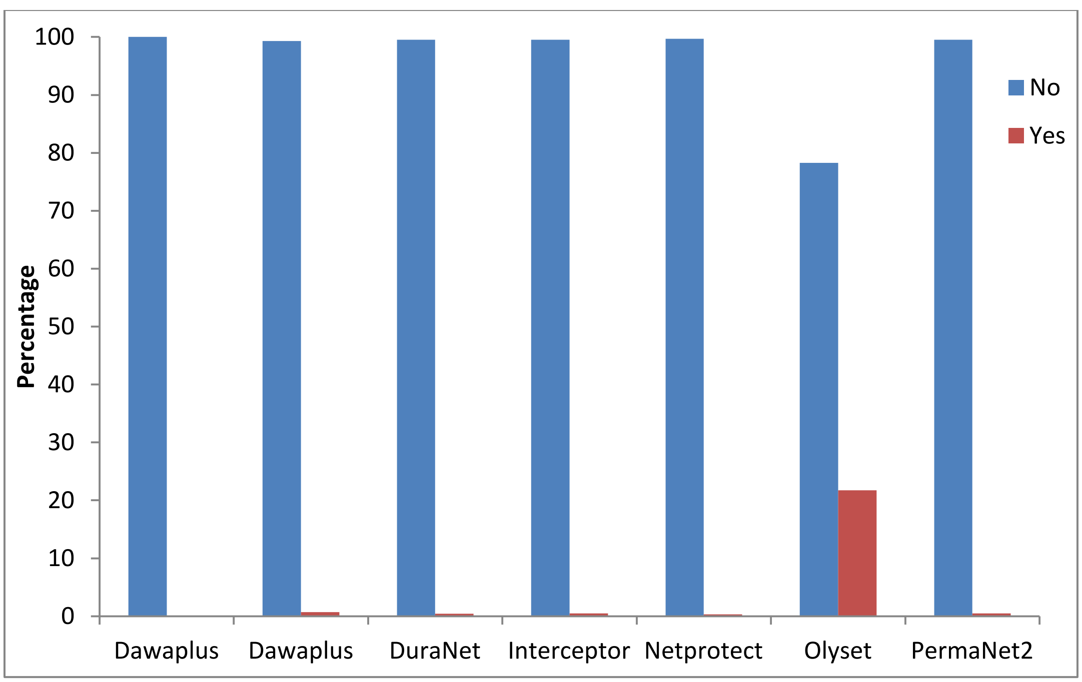
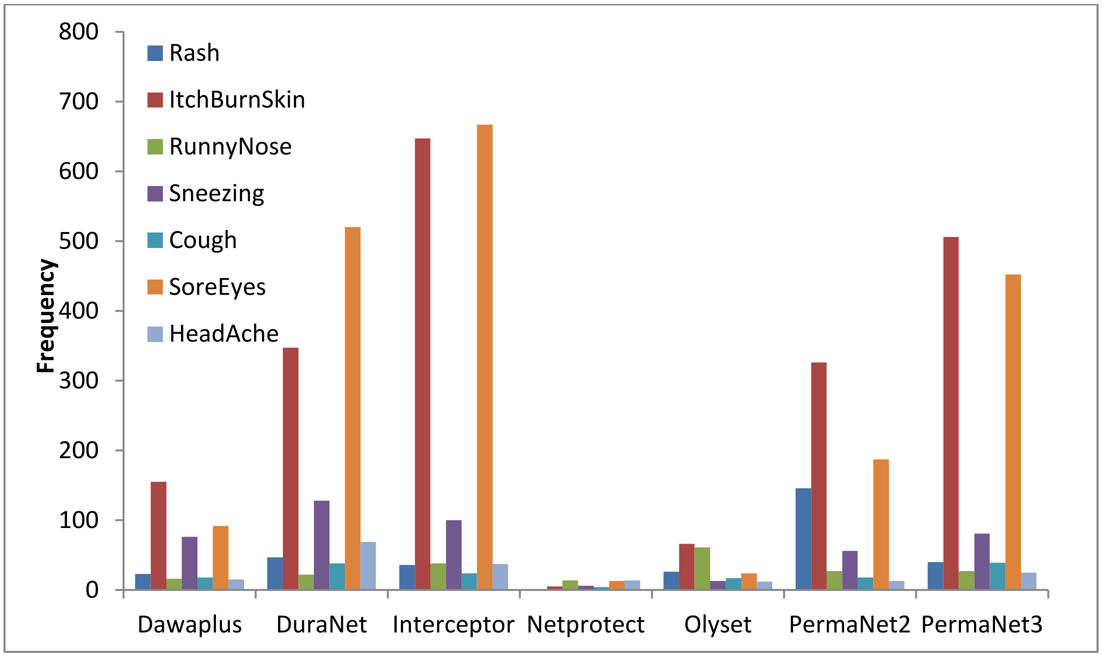


Figure 8e Side effects by Brand at Round 5



4.2 Symptoms of Side Effects

Figure 9 Frequencies of Side Effect Symptoms



<u>5. Effects of Brand, Round, Net Use and Net Care on Net Physical Integrity</u>

5.1 Linear Regression Analysis of Net Hole Areas

Table 4 Marginal Effects of Significant Covariates by GLM Regression

Source	*DF*	*Type III SS*	*Mean Square*	*F Value*	*Pr > F*
Brand	6	159.2445537	26.5407590	6.36	<.0001
round	3	84.3918518	28.1306173	6.74	0.0002
*Brand*round*	18	176.9914260	9.8328570	2.36	0.0016

Figure 10 Distribution of Log Net Hole Ares by Brand

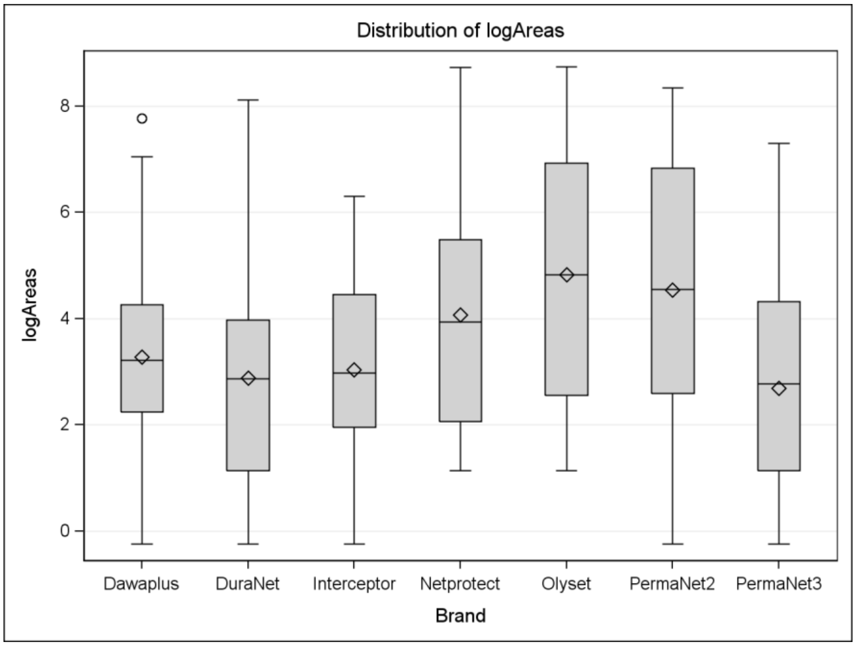


Table 5 Multiple Pairwise Comparison of Log Net Hole Areas by Brand

*Comparisons significant at the 0.05 level are indicated by ***.*

Brand Comparison	*Difference Between Means*	*Simultaneous 95% Confidence Limits*		
Olyset - PermaNet2	0.2866	-0.8073	1.3805	
Olyset - Netprotect	0.7575	-0.3681	1.8832	
Olyset - Dawaplus	1.5469	0.3753	2.7185	***
Olyset - Interceptor	1.7901	0.6757	2.9045	***
Olyset - DuraNet	1.9453	0.7737	3.1169	***
Olyset - PermaNet3	2.1364	0.9327	3.3400	***
PermaNet2 - Olyset	-0.2866	-1.3805	0.8073	
PermaNet2 - Netprotect	0.4710	-0.6761	1.6180	
PermaNet2 - Dawaplus	1.2603	0.0681	2.4525	***
PermaNet2 - Interceptor	1.5035	0.3675	2.6396	***
PermaNet2 - DuraNet	1.6587	0.4666	2.8509	***
PermaNet2 - PermaNet3	1.8498	0.6261	3.0734	***
Netprotect - Olyset	-0.7575	-1.8832	0.3681	

Comparisons significant at the 0.05 level are indicated by ***.				
Brand Comparison	*Difference Between Means*	*Simultaneous 95% Confidence Limits*		
Netprotect - PermaNet2	-0.4710	-1.6180	0.6761	
Netprotect - Dawaplus	0.7893	-0.4320	2.0107	
Netprotect - Interceptor	1.0326	-0.1341	2.1992	
Netprotect - DuraNet	1.1878	-0.0336	2.4092	
Netprotect - PermaNet3	1.3788	0.1267	2.6309	***
Dawaplus - Olyset	-1.5469	-2.7185	-0.3753	***
Dawaplus - PermaNet2	-1.2603	-2.4525	-0.0681	***
Dawaplus - Netprotect	-0.7893	-2.0107	0.4320	
Dawaplus - Interceptor	0.2432	-0.9678	1.4543	
Dawaplus - DuraNet	0.3984	-0.8654	1.6623	
Dawaplus - PermaNet3	0.5895	-0.7041	1.8830	
Interceptor - Olyset	-1.7901	-2.9045	-0.6757	***
Interceptor - PermaNet2	-1.5035	-2.6396	-0.3675	***
Interceptor - Netprotect	-1.0326	-2.1992	0.1341	
Interceptor - Dawaplus	-0.2432	-1.4543	0.9678	
Interceptor - DuraNet	0.1552	-1.0558	1.3662	
Interceptor - PermaNet3	0.3462	-0.8958	1.5883	
DuraNet - Olyset	-1.9453	-3.1169	-0.7737	***
DuraNet - PermaNet2	-1.6587	-2.8509	-0.4666	***
DuraNet - Netprotect	-1.1878	-2.4092	0.0336	
DuraNet - Dawaplus	-0.3984	-1.6623	0.8654	
DuraNet - Interceptor	-0.1552	-1.3662	1.0558	
DuraNet - PermaNet3	0.1910	-1.1025	1.4846	
PermaNet3 - Olyset	-2.1364	-3.3400	-0.9327	***
PermaNet3 - PermaNet2	-1.8498	-3.0734	-0.6261	***
PermaNet3 - Netprotect	-1.3788	-2.6309	-0.1267	***
PermaNet3 - Dawaplus	-0.5895	-1.8830	0.7041	
PermaNet3 - Interceptor	-0.3462	-1.5883	0.8958	
PermaNet3 - DuraNet	-0.1910	-1.4846	1.1025	

5.2 Logistic Regression Analysis of Net Use Condition

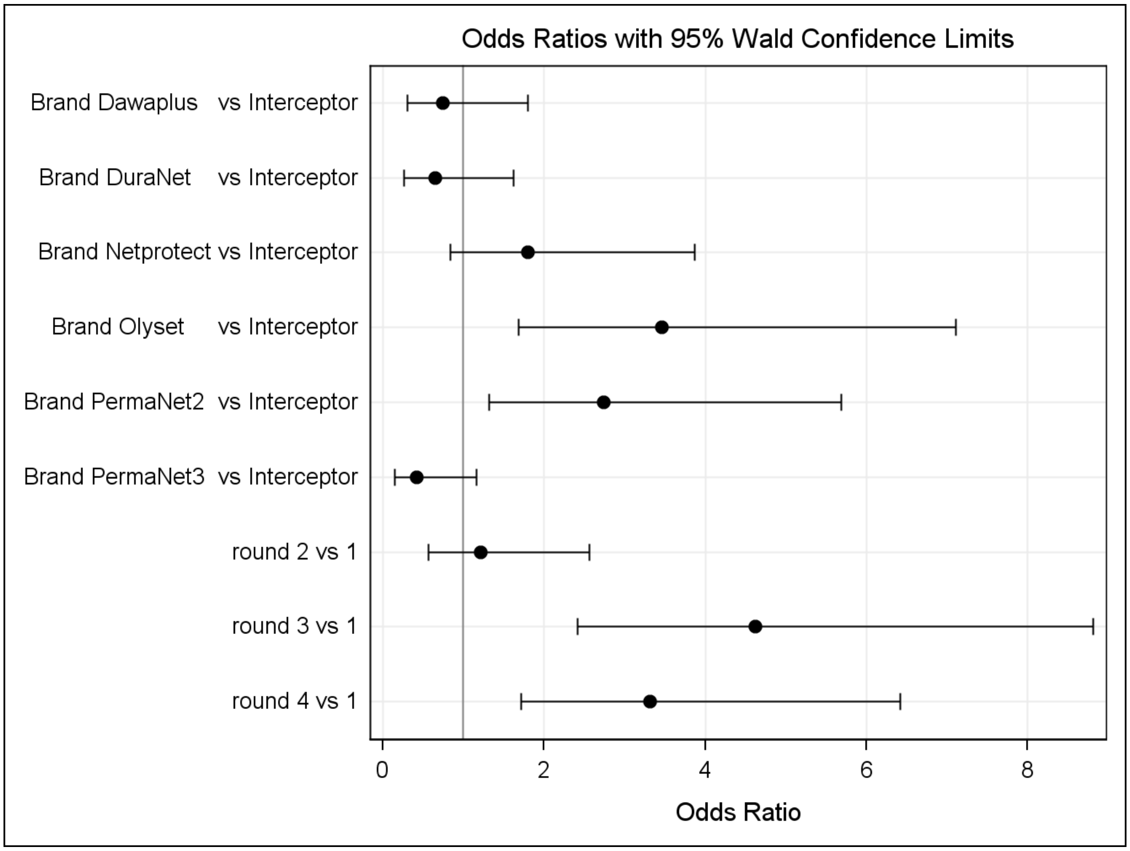
Table 6 Marginal Effects of Significant Covariates

Type 3 Analysis of Effects			
Effect	*DF*	*Wald Chi-Square*	*Pr > ChiSq*
Brand	6	42.9855	<.0001
round	3	33.1057	<.0001

Table 7 Odds Ratio of Significant Variables on Net Use Condition

Odds Ratio Estimates and Wald Confidence Intervals				
Effect	*Unit*	*Estimate*	*95% Confidence Limits*	
Brand Dawaplus vs Interceptor	1.0000	0.747	0.310	1.805
Brand DuraNet vs Interceptor	1.0000	0.655	0.265	1.620
Brand Netprotect vs Interceptor	1.0000	1.804	0.842	3.865
Brand Olyset vs Interceptor	1.0000	3.461	1.684	7.110
Brand PermaNet2 vs Interceptor	1.0000	2.735	1.317	5.682
Brand PermaNet3 vs Interceptor	1.0000	0.420	0.152	1.159
round 2 vs 1	1.0000	1.212	0.573	2.563
round 3 vs 1	1.0000	4.617	2.420	8.810
round 4 vs 1	1.0000	3.316	1.714	6.413

Figure 11 Odds Ratio Estimates on Net Condition by Logistic Regression



5.3 Poisson Regression of Net Hole Counts

Table 8 Marginal Effects of Significant Covariates by Poisson Regression

LR Statistics For Type 3 Analysis

Source	*Num DF*	*Den DF*	*F Value*	*Pr > F*	*Chi-Square*	*Pr > ChiSq*
Brand	6	1472	23.22	<.0001	139.34	<.0001
Round	3	1472	262.11	<.0001	786.32	<.0001
NetUse	4	1472	9.41	<.0001	37.65	<.0001
NetWash	1	1472	7.44	0.0064	7.44	0.0064

Table 9 Parameter Estimates of Coefficients by Poisson Regression

Analysis Of Maximum Likelihood Parameter Estimates									
Parameter		*DF*	*Estimate*	*Standard Error*	*Wald 95% Confidence Limits*		*Wald Chi-Square*	*Pr > ChiSq*
Intercept		1	-0.1009	0.1896	-0.4725	0.2708	0.28	0.5948
Brand	Dawaplus	1	-0.4422	0.1085	-0.6548	-0.2295	16.61	<.0001
Brand	DuraNet	1	-0.5111	0.1144	-0.7353	-0.2869	19.97	<.0001
Brand	Netprotect	1	-0.0673	0.0898	-0.2433	0.1087	0.56	0.4535
Brand	Olyset	1	0.3339	0.0819	0.1733	0.4946	16.61	<.0001
Brand	PermaNet2	1	0.0552	0.0890	-0.1192	0.2297	0.39	0.5347
Brand	PermaNet3	1	0.3091	0.0822	0.1480	0.4702	14.15	0.0002
Round	2	1	0.6952	0.2115	0.2806	1.1098	10.80	0.0010
Round	3	1	1.4126	0.1915	1.0372	1.7880	54.40	<.0001
Round	4	1	2.4317	0.1749	2.0889	2.7746	193.24	<.0001
NetUse	Don't know	1	-0.1998	0.9092	-1.9817	1.5821	0.05	0.8261
NetUse	Every night	1	0.0366	0.0644	-0.0897	0.1628	0.32	0.5705
NetUse	Less than half of all nights	1	-1.0764	0.2623	-1.5906	-0.5622	16.84	<.0001
NetUse	More than half of all nights	1	-0.4070	0.1396	-0.6805	-0.1334	8.50	0.0035
NetWash	Yes	1	-0.1505	0.0551	-0.2585	-0.0425	7.46	0.0063
Scale		0	2.2148	0.0000	2.2148	2.2148		

5.4 Negative Binomial Regression of Net Hole Counts

Table 10 Marginal Effects of Significant Covariates by Negative Binomial Regression

LR Statistics For Type 3 Analysis						
Source	*Num DF*	*Den DF*	*F Value*	*Pr > F*	*Chi-Square*	*Pr > ChiSq*
Brand	6	1472	12.28	<.0001	73.67	<.0001
rounda	3	1472	151.02	<.0001	453.06	<.0001
NetUse	4	1472	6.41	<.0001	25.63	<.0001
NetWash	1	1472	0.12	0.7271	0.12	0.7271

Table 11 Parameter Estimates of Coefficients by Negative Binomial Regression

Analysis Of Maximum Likelihood Parameter Estimates

Parameter		*DF*	*Estimate*	*Standard Error*	*Wald 95% Confidence Limits*		*Wald Chi-Square*	*Pr > ChiSq*
Intercept		1	-0.3593	0.1621	-0.6770	-0.0416	4.91	0.0267
Brand	Dawaplus	1	-0.3892	0.1300	-0.6440	-0.1344	8.96	0.0028
Brand	DuraNet	1	-0.5622	0.1317	-0.8204	-0.3040	18.21	<.0001
Brand	Netprotect	1	0.0184	0.1223	-0.2213	0.2581	0.02	0.8804
Brand	Olyset	1	0.4345	0.1228	0.1939	0.6752	12.53	0.0004
Brand	PermaNet2	1	0.1374	0.1223	-0.1023	0.3772	1.26	0.2613
Brand	PermaNet3	1	0.1798	0.1190	-0.0535	0.4131	2.28	0.1310
Round	2	1	0.7724	0.1512	0.4761	1.0687	26.11	<.0001
Round	3	1	1.4319	0.1434	1.1509	1.7129	99.75	<.0001
Round	4	1	2.4099	0.1220	2.1708	2.6490	390.26	<.0001
NetUse	Don't know	1	-0.0258	0.7186	-1.4341	1.3826	0.00	0.9714
NetUse	Every night	1	0.2574	0.0990	0.0634	0.4514	6.76	0.0093
NetUse	Less than half of all nights	1	-0.6896	0.2405	-1.1610	-0.2181	8.22	0.0041
NetUse	More than half of all nights	1	-0.2027	0.1689	-0.5338	0.1284	1.44	0.2301
NetWash	Yes	1	-0.0269	0.0770	-0.1778	0.1241	0.12	0.7271
Dispersion		1	0.9193	0.0555	0.8167	1.0349		