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Dose Reconstruction Project for NIOSH

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ACRONYMS AND ABBREVIATIONS

AMW	all monitored workers
cm	centimeter
cpm	counts per minute
CTW	construction trade worker
d	day
GM	geometric mean
GSD	geometric standard deviation
ID	identification
L	liter
MCPT	Monte Carlo permutation test
MDA	minimum detectable activity
MPM	maximum possible mean
nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Claims Tracking System
OPOS	one person – one sample
ORAU	Oak Ridge Associated Universities
ROI	region of interest
ROS	regression on order statistics
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TLD	thermoluminescent dosimeter
unk	unknown
WBC	whole-body count

1.0 INTRODUCTION

At the Savannah River Site (SRS), some workers might have been exposed to neptunium without being monitored for that potential exposure. The National Institute for Occupational Safety and Health (NIOSH) Dose Reconstruction Project uses coworker models to estimate doses to workers who were not monitored for exposure to radioactive materials but might have been exposed to such materials (ORAUT 2007, p. 13). Such a dose is referred to as an *unmonitored dose*. Coworker models are typically constructed using data from all monitored workers by fitting a lognormal probability distribution to the data (ORAUT 2005, 2006) to estimate the geometric mean (GM) and geometric standard deviation (GSD) of the doses. Coworker models for external dose are usually constructed from external doses assigned to individuals with film badges and thermoluminescent dosimeters (TLDs). Coworker models for internal dose are calculated using bioassay data that are later evaluated in terms of chronic intake rates and, ultimately, internal doses.

Rather than using all monitored workers to construct a coworker model, an analysis can stratify monitored workers into subgroups (i.e., strata) and construct separate coworker models for each stratum. Stratification offers potential advantages, such as more precise estimates of the dose to unmonitored workers in a stratum, but it has a number of potential drawbacks and limitations (ORAUT 2010). The purpose of this report is to evaluate two proposed strata in relation to bioassay data, potential intakes, and internal doses of neptunium. The two strata consist of (1) the construction trade worker (CTW) stratum, which includes workers classified as CTWs in accordance with ORAUT-OTIB-0052 (ORAUT 2011) and (2) the nonCTW stratum, which includes workers not classified as CTWs (non-construction trade workers). A statistically and practically significant difference between the CTW and nonCTW strata could warrant coworker models based on the individual strata rather than the entire population of monitored workers, designated as all monitored workers (AMW) in this report.

This evaluation includes a third stratum of workers whose job classifications are not available or unknown (abbreviated as unk). This is different from the application of ORAUT-OTIB-0052 (ORAUT 2011) during performance of dose reconstructions in which individuals are not considered to be CTWs unless there is a reason to classify them as such. In this analysis, unks are evaluated in two ways: (1) they are included with the nonCTWs, and (2) they are excluded entirely from the strata comparison. Exclusion of bioassay data from the strata comparison is the difference from the normal application of ORAUT-OTIB-0052. The distinction is made for this report because less information is available about all the workers with neptunium bioassay data than is available for energy employees whose dose is being reconstructed. For energy employees whose dose is being reconstructed, individual-specific information is available from U.S. Department of Energy records, the record of the telephone interview, and information provided by the U.S. Department of Labor.

2.0 BIOASSAY DATA VERSUS DOSE

Monitoring for workers who have the potential for exposure to external radiation typically consists of a dosimeter (e.g., TLD or film badge) worn on the upper torso of the body. The dosimeter indicates the cumulative dose to the whole body that is received between readings, which creates monitoring intervals that can be days to months in duration. A key property of the reported doses for each interval is that, for a given individual, the doses are statistically independent of each other. For example, the received dose in a given month, by itself, provides no information about the dose in the next month and, similarly, the received dose in a given year, by itself, provides no information about the dose in the next year.

Internal dose monitoring programs are in many ways similar to the above-described external dose programs, but internal dose programs tend to be based on bioassay rather than dosimeters. This is an important difference because, if an individual has an intake of radioactive material such that radioactive material is detected in a given sample, subsequent bioassay samples can also have detectable radioactivity even if there have been no additional intakes. This means bioassay results can correlate to each other and are no longer statistically independent. This correlation can exist for a brief period (after a small intake of tritium, for example), or for the length of a career (after a large intake of plutonium, for example).

Operational bioassay programs can generate multiple results for an individual in a given period (e.g., a year), which creates a related problem if an individual is involved in an incident and has more (potentially many more) bioassay results than other workers. If these are not accounted for, the problems of correlated data and unequal numbers of samples per person can skew evaluation of the data by unequally weighting data from that individual. The solution to this problem is to generate a single statistic that characterizes multiple bioassay results for each person in a given period. This is referred to as a *one person – one sample* (OPOS) statistic. The OPOS statistic is calculated using the maximum possible mean (MPM) methodology (ORAUT 2012).

3.0 METHODOLOGY

The CTW and nonCTW strata were compared using the methodology from ORAUT-RPRT-0053 (ORAUT 2012). The basic steps of this methodology, discussed in more detail below, are:

- Evaluate the complete set of neptunium bioassay data and determine the job classification (CTW, nonCTW, or unk) for each individual for each bioassay sample.

- For each individual and each period, determine the OPOS statistic for the AMW, CTW, and nonCTW strata, and for the combined nonCTW+unk stratum (see Section 4.1 for more detail).

- Determine the GM and GSD urinary excretion rates for the AMW, CTW, nonCTW, and combined nonCTW+unk strata for each period using the regression on order statistics (ROS), effective fit, and binomial methods (ORAUT 2012) as appropriate.

- Compare the CTW:nonCTW and CTW:nonCTW+unk strata using the Monte Carlo permutation test (MCPT) and Peto-Prentice test (ORAUT 2012) to determine if there is a statistically significant difference.

- If there is a statistically significant difference, compare the CTW:nonCTW and CTW:nonCTW+unk strata to determine if there is a practical difference.

At Savannah River, all personnel working in regulated areas ("Regulated Zones" and "Radiation Danger Zones"), including construction workers, were periodically checked for assimilation of radioactive material by urinalysis bioassay (DuPont 1961-1969). The only exception to this may have been when special exclusion zones were established, and when this occurred, the outer boundaries of the radiological areas were monitored (ORAUT 2008). Notification of sample request was given to employees through their supervision. Special bioassay samples were requested of workers, including construction workers, by Health Physics through the worker's supervision, when a potential assimilation of radioactive material was suspected (DuPont 1961-1969).

CTWs are potentially subject to different bioassay practices than other workers. CTWs, many of whom are contractors, commonly submit bioassay samples after suspected uptakes and at the completion of jobs. This is in contrast to other workers, especially those employed directly by the prime contractor, who are more likely to be on a routine bioassay program in addition to submitting bioassay samples after suspected uptakes. A post-job bioassay is more likely to be soon after an uptake, either suspected or unidentified, than is a routine bioassay sample and thus more likely to have a larger result. This potential difference in how the strata are monitored for intakes would result in higher results for CTWs compared to the other strata.

3.1 NEPTUNIUM BIOASSAY DATA

Neptunium urinalysis bioassay data were obtained from SRS laboratory notebooks (DuPont 1961-1969, 1969) and from NIOSH Claims Tracking System (NOCTS) records for years after 1969. The laboratory notebook data were transferred to a spreadsheet and subjected to a 100% verification review by a second person. Records with results or units of “LIP” (Lost In Process) or “IA” (Insufficient Amount) were excluded from the evaluation because those records represent instances in which samples were collected but not analyzed. Records with units of per-unit-volume were adjusted to “per-1.5L” based on an assumed 1.5 L/d of urinary excretion. Volumes greater than 1 L were assumed to represent a full day’s voiding and were not adjusted. Volumes less than or equal to 1 L were normalized to 1.5 L.

In the absence of site logbooks and databases after 1969, NOCTS whole-body count (WBC) data were selected as the best available compilation of data in a usable form. The NOCTS database was queried on May 7, 2008, to generate a list of all claimants who worked at SRS before 1991. This amounted to 1,421 individuals. Data for six additional individuals that became available during the data entry process were added for a total of 1,427 individuals. The NOCTS ID numbers of the specific individuals identified are listed in Arno (2011). Table 2 of this reference lists NOCTS ID numbers of the 923 individuals identified as having *in vivo* bioassay data during this time frame. The *in vivo* bioassay data for these individuals, 923 of which had WBC data, were entered into spreadsheets (some already existed in this form after the completion of dose reconstructions for individuals). The spreadsheets were subjected to a quality assurance (QA) verification in accordance with MIL-STD-105E, *Sampling Procedures and Tables for Inspection by Attributes* (DOD 1989), which it passed with less than a 1% error rate. For this QA verification, 315 records (out of the 33,088 total records) were checked with only 1 error found. Per MIL-STD-105E (DOD 1989), for a lot between 10,001 and 35,000 items, less than 8 errors results in lot acceptance based upon the statistical variability of sampling.

Most WBC reports in NOCTS do not quantify ^{237}Np body burdens or report a minimum detectable activity (MDA). However, some reporting methods provide sufficient information to determine or estimate the ^{237}Np body burden. Methods were developed to estimate ^{237}Np for three of the different reporting forms used. These methods use the fact that a region of interest (ROI) used to report activity for radionuclides other than ^{237}Np would also be reporting activity from ^{237}Np or its decay product, ^{233}Pa. Protactinium-233 has principal gammas of 312 keV (39% yield) and 300 keV (6.6% yield). By assuming that all the reported counts or count rate in the ROI is due to ^{237}Np rather than other radionuclides, the ^{237}Np may be estimated.

The first form, “Whole Body Counter Data,” was in use from approximately 1960 through the mid-1970s and was used with the 40-cm arc geometry (Taylor et al. 1995, p. 64). Results for nuclides other than ^{137}Cs and ^{40}K were reported in units of count rate (net counts per minute) rather than activity. This form reports count rates for ^{131}I based on the net counts in the ROI from 300 to 400 keV. Protactinium-233 has several gammas that fall totally or partially in that energy range – 300 keV (6.6%), 312 keV (38.6%), 340 keV (4.5%), 375 keV (0.6%), and 399 keV (1.27%) (Kocher 1981). The 300- and 399-keV peaks would fall half-out and half-in of the ROI, respectively, so in effect those abundances are only half of the stated values. Thus, the total gamma abundance in the 300-to-400-keV ROI for ^{233}Pa is 47.6%. It is possible to use the reported net cpm for ^{131}I to estimate the ^{237}Np body burden by assuming that all the net cpm in the ^{131}I ROI is due to ^{237}Np. The conversion factor from net counts in the ^{131}I ROI to nanocuries of ^{237}Np is 0.243 nCi/cpm. This conversion factor was determined by adjusting the ^{137}Cs calibration factor of 0.136 nCi/cpm (Watts1962-1967, p. 33) for the gamma abundances of ^{137}Cs and ^{233}Pa in their respective ROIs: $(0.136)(0.85) \div 0.476$. To refine the estimate, it is necessary to account for the Compton continuum contribution to the ^{131}I ROI from the ^{40}K body burden. The ^{40}K contribution to the ^{131}I ROI is 0.389 counts per ^{40}K ROI net count (Watts 1962-1967, p. 33). Thus, the ^{237}Np body burden can be calculated as:

$$\text{nCi }^{237}\text{Np} = 0.243 \times \left[\left(^{131}\text{I net cpm}\right) - 0.389 \times \left(^{40}\text{K net cpm}\right)\right] \quad (1)$$

The second reporting form is an untitled form used in the mid- and late 1970s. It is distinguishable by having the date, time, and name on successive lines on the left margin at the top of the form. This form also reports counts in the 300-to-400-keV ROI but does not associate this ROI with a particular radionuclide. For each ROI, gross, background, net, CALC, and DIFF values are reported. The CALC and DIFF values correct the net counts to account for Compton scatter, with the CALC value being the Compton scatter contribution and the DIFF value being the net counts minus CALC. Therefore, when using these data, there is no need to apply a ^{40}K Compton scatter as with the Whole Body Counter Data form. When the 40-cm arc geometry was being used, assumed to be the period before February 1974, the ^{237}Np body burden can be calculated as:

$$\text{nCi }^{237}\text{Np} = 0.243 \times (\text{DIFF counts for 300-to-400-keV ROI}) \quad (2)$$

After January 1974, when the stretcher geometry was in use, the conversion factor changes (Fleming 1973-1979, p. 162) and the ^{237}Np body burden can be calculated as:

$$\text{nCi }^{237}\text{Np} = 0.0125 \times (\text{DIFF counts for 300-to-400-keV ROI}) \quad (3)$$

The third reporting form is the “In-Vivo Count Results” form, which was in use from the late 1970s through the late 1980s. The ROI on this form applicable to determine ^{237}Np is the ^{51}Cr ROI covering the energy range from 290 to 349 keV. This form also reports DIFF values; in addition, it reports the MDA in units of nanocuries and counts. Having the MDA reported in both manners permits the determination of a count-specific conversion factor from counts to nanocuries. The remaining step is the ratio of the conversion factor for ^{51}Cr to that for ^{233}Pa, which is 0.211 (based on the ratio of gamma abundances in the ^{51}Cr ROI: 0.098 to 0.465). Therefore, the ^{237}Np body burden can be calculated as:

$$\text{nCi }^{237}\text{Np} = 0.211 \times (^{51}\text{Cr DIFF counts}) \times (^{51}\text{Cr MDA nCi}) \div (^{51}\text{Cr MDA counts}) \quad (4)$$

3.2 JOB CLASSIFICATION DETERMINATION

NIOSH directed the Oak Ridge Associated Universities (ORAU) Team to use *1954 Craft Payroll Codes* (Author unknown undated) as the source of crafts and occupations and the payroll ID field to determine workers that should be assigned to the CTW stratum. NIOSH and the ORAU Team reviewed the crafts in that document and determined that the following are CTW crafts at SRS that could have involved radiological exposure. The payroll ID prefix is listed with each of the crafts:

- 02 – Instruments (considered electricians)
- 05 – Laborer
- 06 – Carpenter
- 12 – Iron Worker
- 14 – Heavy Equipment Operator
- 15 – Steelworker
- 18 – Millwright
- 20 – Boilermaker
- 21 – Sheetmetal Worker
- 25 – Electrician
- 26 – Pipefitter
- 31 – Insulator
- 33 – Painter

In addition, NIOSH and the ORAU Team considered any worker in Payroll Roll #2 (which is different from payroll prefix 02 in the list above) with one of the craft (occupational title) listings above to be a CTW. An additional craft code, 17, was not in *1954 Craft Payroll Codes* but was determined to be associated with "Painter" from examination of SRS work history data. Worker history cards were reviewed to determine the payroll ID number or occupational title for each individual for each bioassay result. The last entry on the worker history card before the date of the bioassay was used to determine the payroll ID number or occupational title.

The following steps were used to create a spreadsheet and identify CTW, nonCTW, and unk data. For each bioassay record, the ORAU Team used the sample date, name, and payroll ID (PR ID) to retrieve the assigned job/ occupational title from the SRS work history card matched to the sampled worker and for the sampled date because a worker could have multiple occupational titles over time. In some instances, the value of the PR ID field was different on the card than in the bioassay file and was changed in the spreadsheet used for this evaluation. Occupational titles were recorded as stated on the card. If the personal information could not be found in the SRS worker history cards or if an occupational title was not recorded on the matched card, "Unknown" was recorded in the Occupational Title field. Once occupational titles had been queried for all bioassay records, instances of the same high-level occupational title were made consistent and recorded in the Changed Occupational Title field. For example, Research Chemist and Junior Chemist were considered to be Chemist. The values of two fields, "Changed Payroll ID#" and "Changed Occupational Title," were used to denote the value of the CTW field in that particular row. The name of these fields includes "changed" to distinguish them from the original payroll ID number and occupation title fields. The "changed Payroll ID #" field reformats the originally recorded payroll ID numbers into a consistent format (hyphens, leading zeros, etc.) while retaining the originally recorded number. No distinction was made between DuPont and non-DuPont workers.

1. If the Changed Payroll ID number was of the form "XX-ppppp" where "XX" is 02, 05, 06, 12, 14, 15, 17, 18, 20, 21, 25, 26, 31, or 33 and "ppppp" is a 5- or more digit number, the record was treated as that of a CTW.

2. If the Changed Payroll ID number was of the form "T-nnnn" where "nnnn" is a number, the record was treated as that of a nonCTW. [Payroll IDs starting with "T-" indicate payroll 1, which did not apply to CTWs.]

3. If the Changed Payroll ID number was of the form "mmmmm" where "mmmmm" is a 2-, 3-, 4-, or 5-digit number only, the value of Changed Occupational Title was checked.

    a. If the Changed Occupational Title was Boilermaker, Carpenter, CTW, Electrician, Glass Blower, Heavy Equipment Operator, Helper, Laborer, Maintenance, Mechanic, Millwright, Painter, or Rigger, the record was treated as that of a CTW.

    b. If the Changed Occupational Title was Roll 2, unknown, or null, the value of CTW was set to unk.

    c. For all remaining rows, the record was treated as that of a nonCTW.

4. All remaining records were treated as unk.

Only bioassay data from the laboratory notebooks contain unknowns. Sufficient data were available for all NOCTS-sourced bioassay data to classify the worker.

3.3 ONE PERSON – ONE SAMPLE STATISTIC

An average bioassay result using the MPM method was determined for each individual for each evaluated period and each job category. This resulted in a table of OPOS results for AMW that used all available bioassay data and three other tables for the CTW, nonCTW, and nonCTW+unk strata that used only bioassay data identified as belonging to each of those strata. Because it was possible for a worker to change jobs during the course of a single evaluated period, it is possible that a worker would have some samples identified as nonCTW and others as CTW in the same period. Therefore, one person might have as many as four different OPOS results, one each for the AMW, CTW, nonCTW, and nonCTW+unk strata.

Tables 3-1 and 3-2 detail the percentage of occurrences of multiple bioassay results averaged using the MPM method for each stratum for logbook and NOCTS data respectively.

Table 3-1. Number of bioassay results per period – logbook data.

No. of bioassay results	AMW (%)	CTW (%)	nonCTW (%)	nonCTW+unk (%)
1	64.2	60.6	64.5	65.1
2	22.2	26.7	21.5	21.2
3	6.8	5.2	7.4	7.3
>3	6.8	7.5	6.6	6.5

Table 3-2. Number of bioassay results per period – NOCTS data.

No. of bioassay results	AMW (%)	CTW (%)	nonCTW (%)
1	72.7	80.7	71.6
2	20.9	16.1	22.3
3	2.8	0.7	3.1
>3	3.6	2.6	2.9

Table 3-3 lists the ratio of CTWs and nonCTWs that received whole body counts from which potential neptunium body burdens were reconstructed for each year in the 1973 through 1981 time period. The number of manufacturing and technical workers (assumed to represent the nonCTWs) and the number of construction workers is based on the SRS monthly report abstracts prepared by Taulbee (2011) using the number of manufacturing, technical, and construction workers summarized for July of each year. There is no significant difference between the population and bioassay monitoring ratios for the two groups, which is consistent with the implementation of the same radiological monitoring procedures for the two groups.

Table 3-3. Population and neptunium monitoring ratios.

Year	# nonCTW+unks	# CTWs	Population Ratio	Bioassay Ratio
1973	5255	500	0.10	0.09
1974	5205	600	0.12	0.17
1975	5140	973	0.19	0.33
1976[a]	5407	995	0.18	0.86
1977	5598	1344	0.24	0.26
1978	5944	1973	0.33	0.26
1979	5709	1958	0.34	0.22
1980	6050	1991	0.33	0.22
1981	6593	2159	0.33	0.23

a. Very little bioassay data are available for 1976 resulting in anomalous ratios for this year.

3.4 STATISTICAL ANALYSIS

Statistical analysis of each dataset was performed in accordance with ORAUT-RPRT-0053 (ORAUT 2012). First, each period was evaluated using the ROS method. If this method failed or yielded an unacceptable fit, the effective fit (maximum likelihood) method would be used. If there was little or no uncensored data, the binomial fit method would be used. For this report, the ROS method was ultimately used for all evaluated years. For the CTW strata based on logbook data, some years (1964, 1965, 1967, 1968, and 1969) had insufficient data even to use the binomial fit and were not evaluated.

3.5 STRATA COMPARISON

For each period, the CTW stratum was compared to both the nonCTW and nonCTW+unk strata to determine if there were statistical differences at the 0.05 level of significance. Presence of a statistically significant difference was determined using the MCPT and the Peto-Prentice test. If the amount of data was so small that no evaluation was possible, no strata comparison was made because insufficient information was available.

4.0 RESULTS

4.1 BIOASSAY FITTING

Two sets of comparisons were made. The first set compared the CTW and nonCTW strata. The second set compared the CTW and combined nonCTW+unk strata. The unk stratum was included with the nonCTW stratum because this was the default assumption. Workers were assumed to belong to the nonCTW stratum unless there was justification to include them in the CTW stratum.

For the AMW and each of the three strata, the ROS fit was calculated for all periods for which there were sufficient data (i.e., more than one uncensored result). No fit was done for 1964, 1965, 1967, 1968, and 1969 because there were insufficient CTW data for those years. Attachment A contains the plots of the ROS fits for each stratum (including AMW).

4.2 STRATA COMPARISONS

For 1964 to 1973, 1976, and 1982, there were insufficient data to perform a comparison between the strata in either comparison set. The MCPT would not run for most of the years because of highly censored data. Almost all of the MCPT plots produced asymmetric clouds of points that were clearly not bivariate normal and nonparametric bagplots were not adequate, so MCPT analysis is not included. Sufficient data were available for all NOCTS-sourced bioassay data (1970 through 1989) to classify the worker as CTW or nonCTW and thus there are no unknowns in this time period. The Peto-Prentice test is used to determine whether the distribution of the OPOS bioassay data is the same in the CTW stratum and the nonCTW stratum (or the nonCTW stratum with unknowns). For the Peto-Prentice test, the result is a two-sided p-value. If the p-value is less than 0.05, the strata are considered different at a statistically significant level. Table 4-1 contains the results of these tests for the two comparison sets. Attachment B contains the plotted results of the Peto-Prentice tests. No multiple comparisons adjustments were needed, because no statistically significant differences were identified. Therefore, no evaluation of practical difference was performed.

Table 4-1. Strata comparison.

Period	CTW:nonCTW	CTW:nonCTW+unk[a]
1961	0.243	0.213
1962	0.899	0.789
1963	0.075	0.057
1974	0.876	N/A
1975	0.075	N/A
1977	0.975	N/A
1978	0.516	N/A
1979	0.666	N/A
1980	0.821	N/A
1981	0.310	N/A
1983	0.235	N/A
1984	0.850	N/A
1985	0.441	N/A
1986	0.685	N/A
1987	0.445	N/A
1988	0.142	N/A
1989	0.288	N/A

a. There are no unknowns in 1970 through 1989 and thus no difference between the nonCTW and nonCTW+unk strata. Comparison with the CTW strata would be identical and therefore was not repeated.

5.0 CONCLUSIONS

Statistical analysis revealed that the CTW stratum did not differ from the nonCTW or nonCTW+unk strata in a statistically significant manner for any periods with sufficient data. Therefore, there would be no benefit in evaluating the CTW stratum separately from other site worker strata and the SRS internal dose coworker study should evaluate neptunium intakes based on the AMW data.

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ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

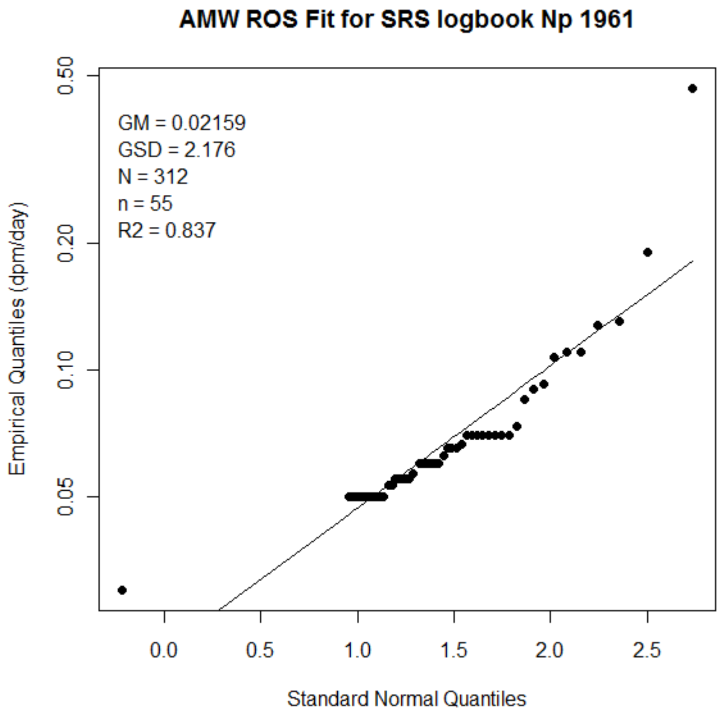

Figure A-1. ROS fit for AMW, 1961.

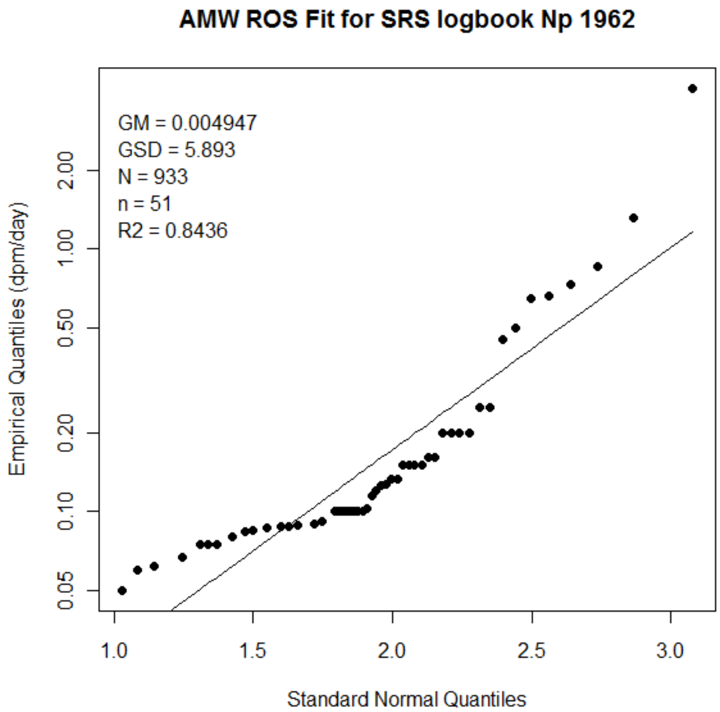

Figure A-2. ROS fit for AMW, 1962.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS
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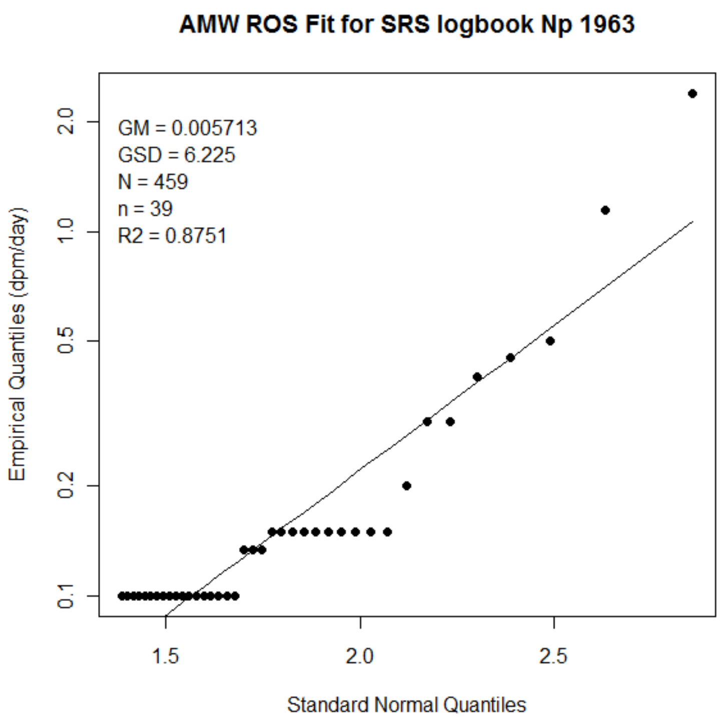

Figure A-3. ROS fit for AMW, 1963.

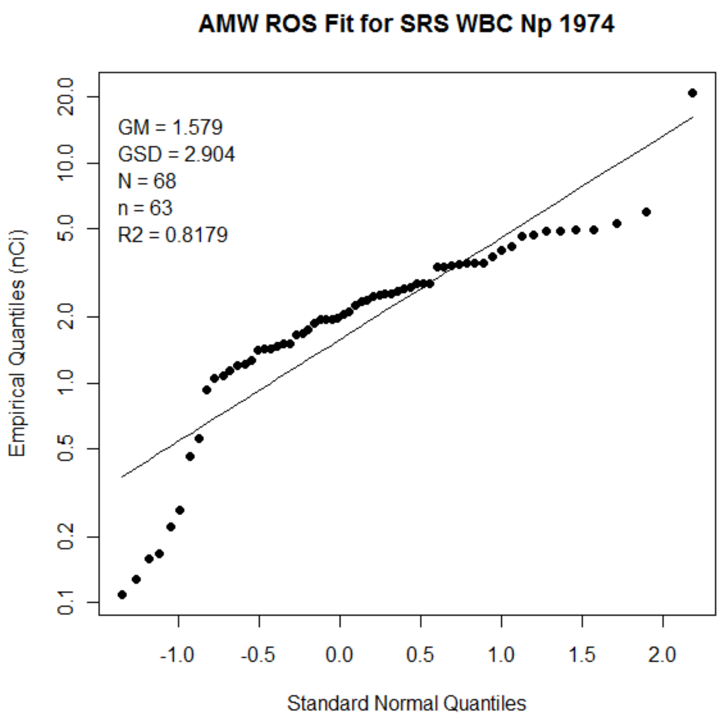

Figure A-4. ROS fit for AMW, 1974.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

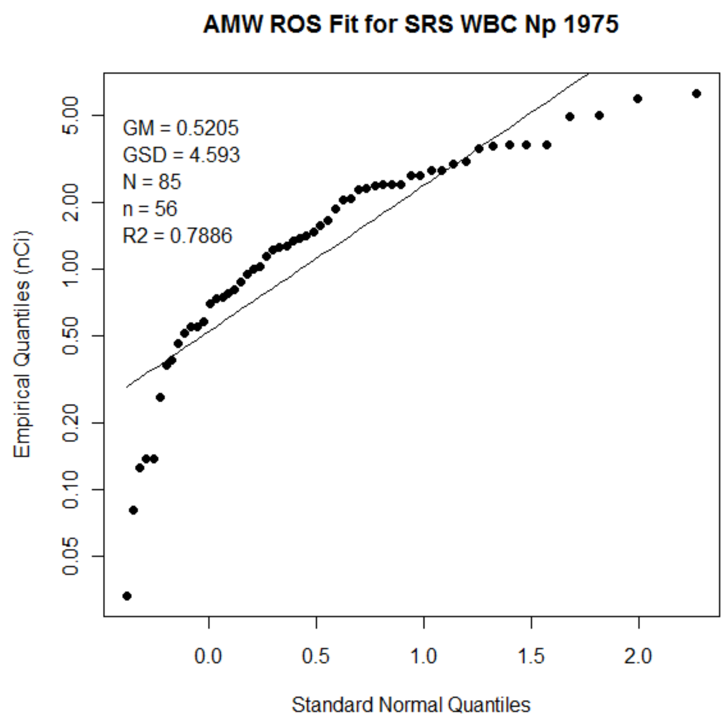

Figure A-5. ROS fit for AMW, 1975.

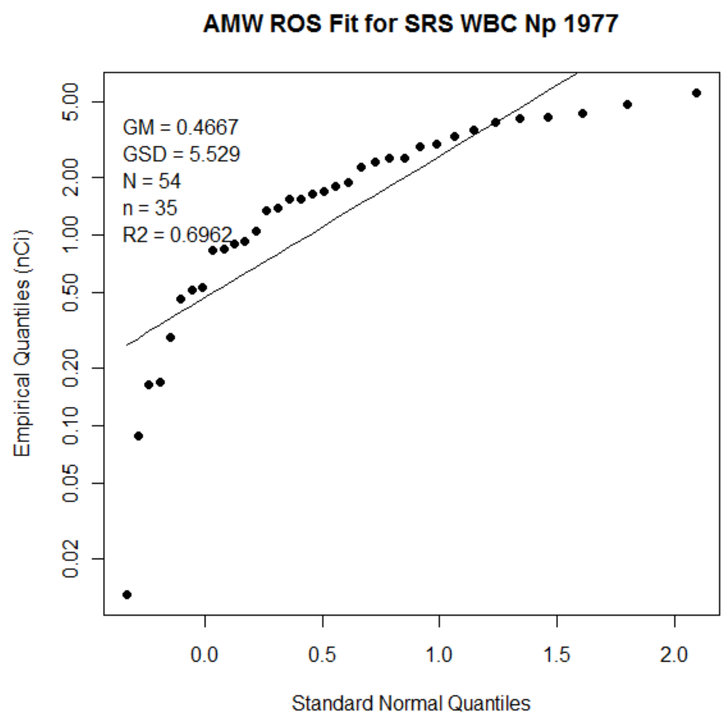

Figure A-6. ROS fit for AMW, 1977.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

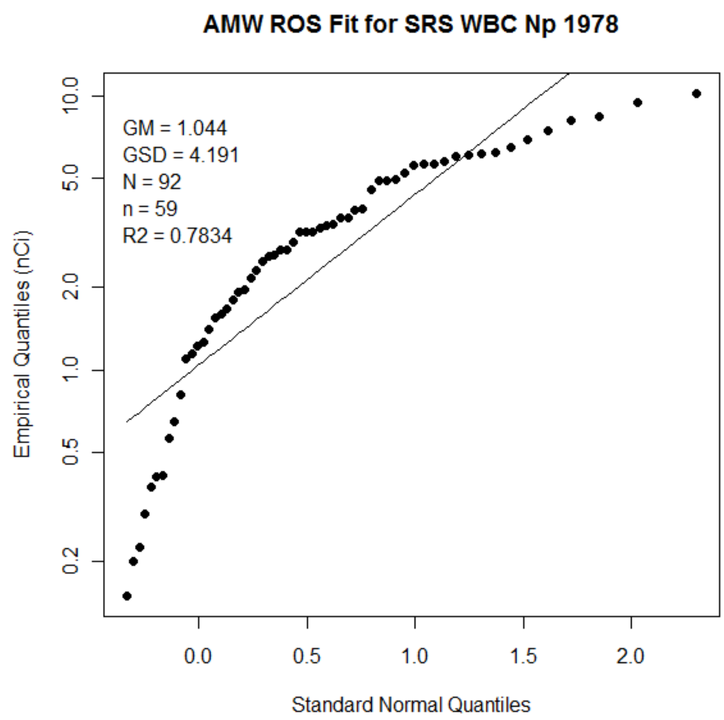

Figure A-7. ROS fit for AMW, 1978.

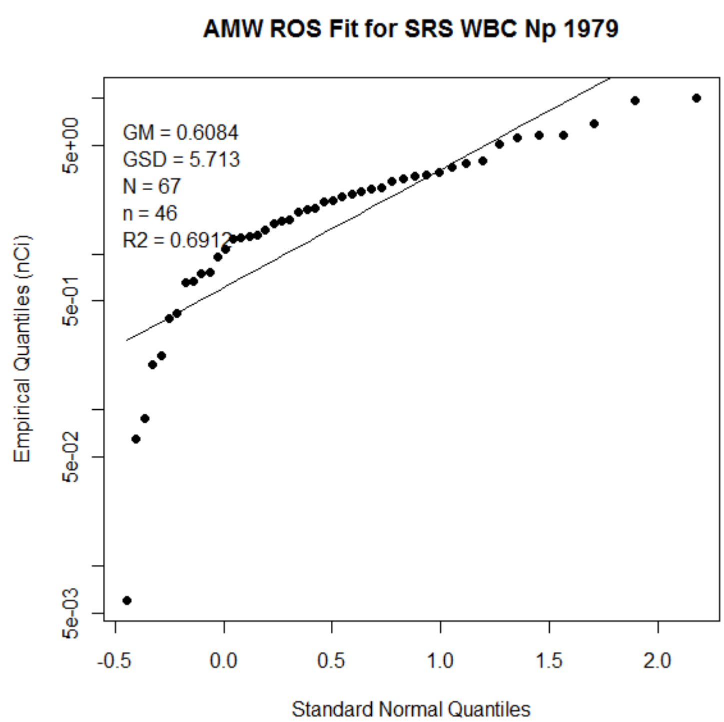

Figure A-8. ROS fit for AMW, 1979.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

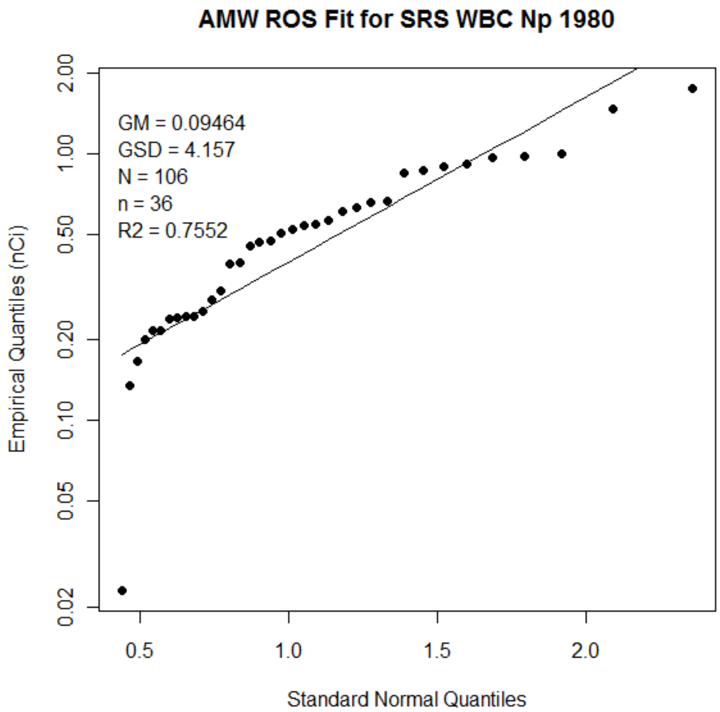

Figure A-9. ROS fit for AMW, 1980.

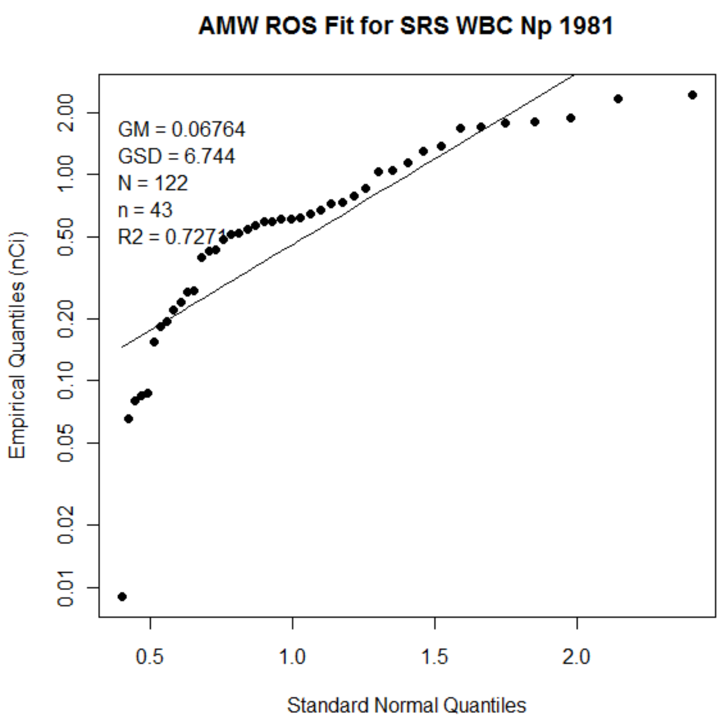

Figure A-10. ROS fit for AMW, 1981.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

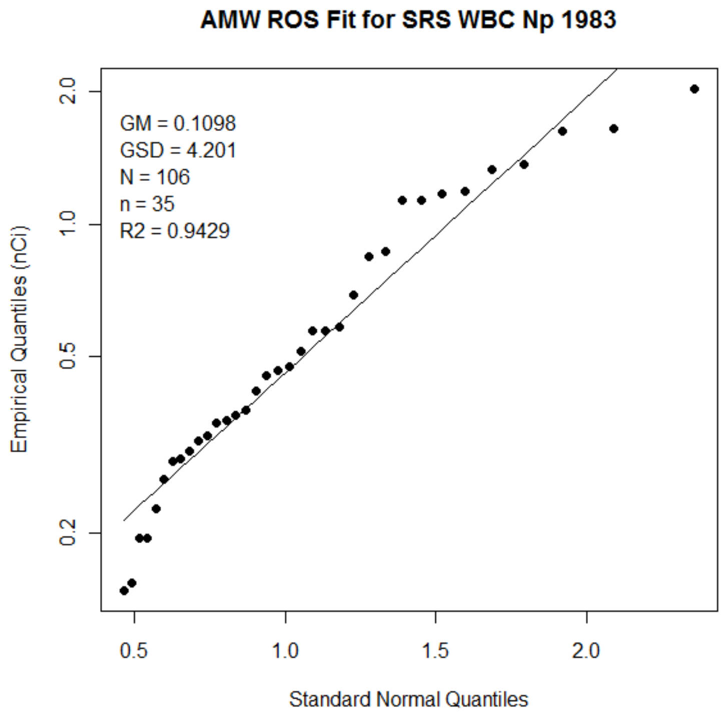

Figure A-11. ROS fit for AMW, 1983.

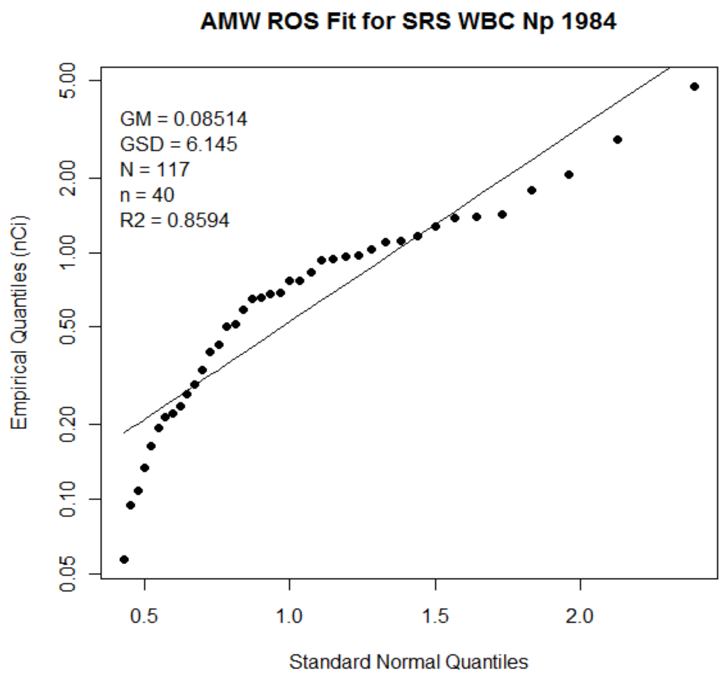

Figure A-12. ROS fit for AMW, 1984.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

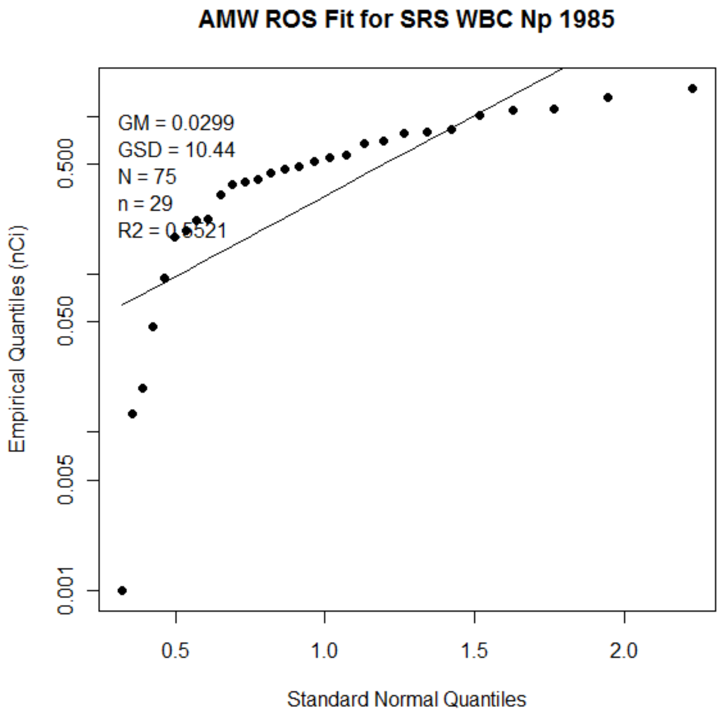

Figure A-13. ROS fit for AMW, 1985.

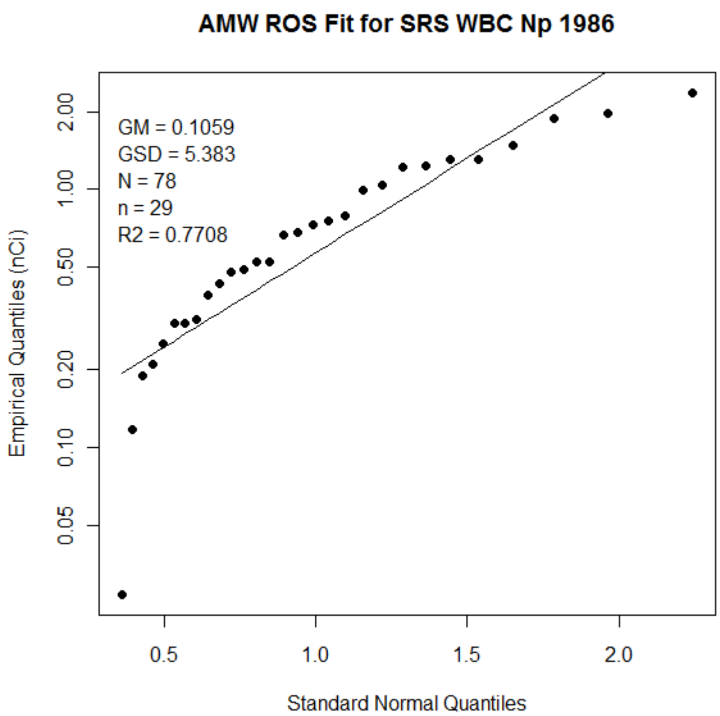

Figure A-14. ROS fit for AMW, 1986.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

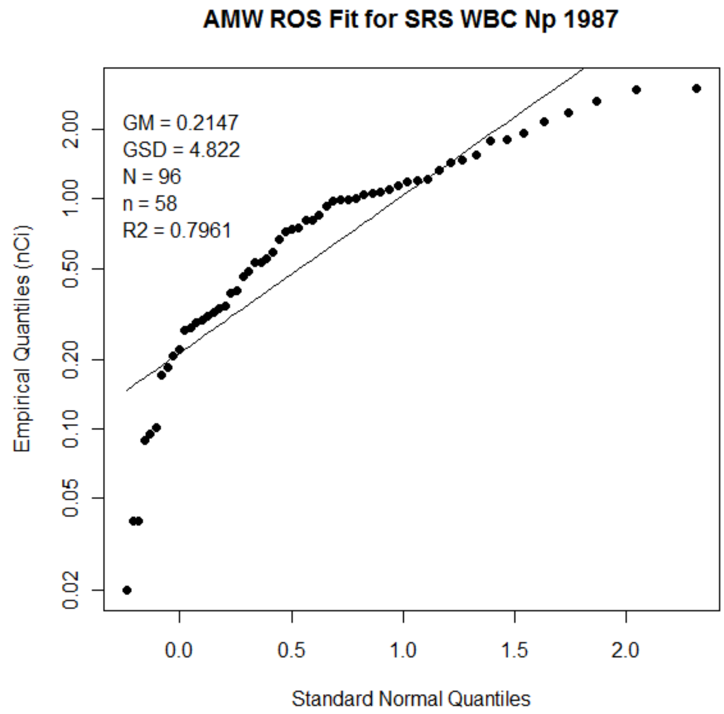

Figure A-15. ROS fit for AMW, 1987.

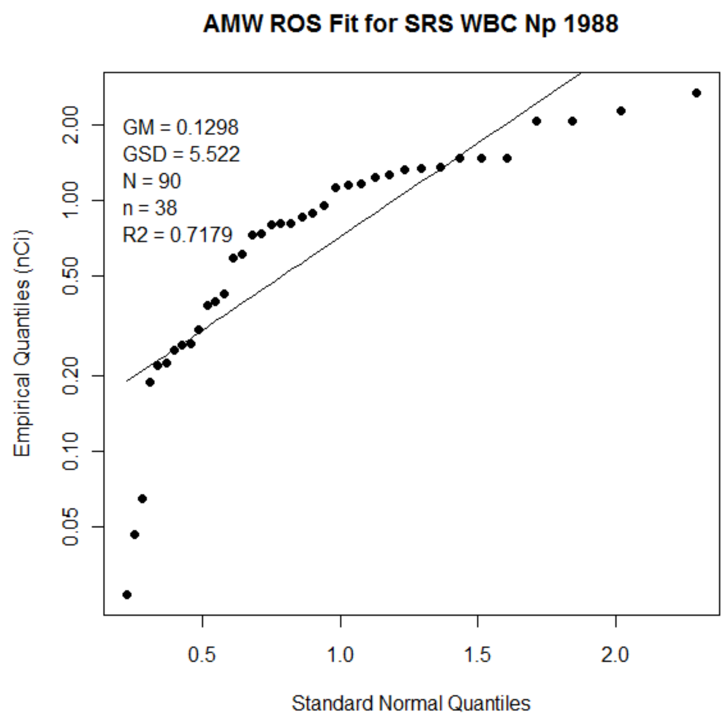

Figure A-16. ROS fit for AMW, 1988.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

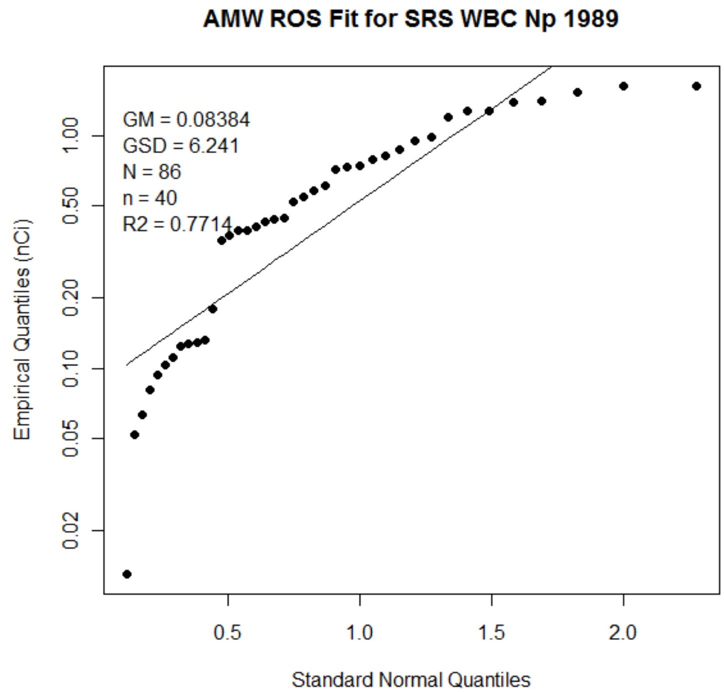

Figure A-17. ROS fit for AMW, 1989.

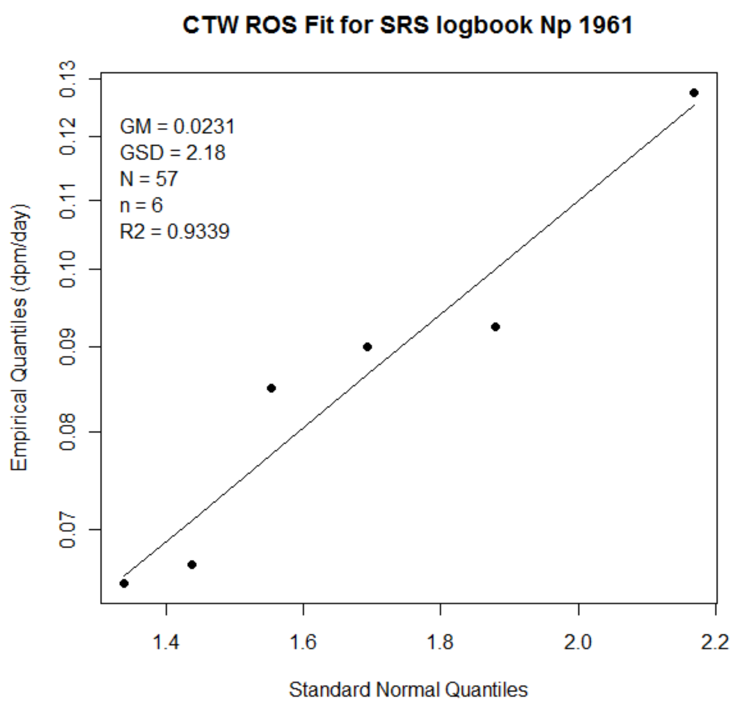

Figure A-18. ROS fit for CTWs, 1961.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

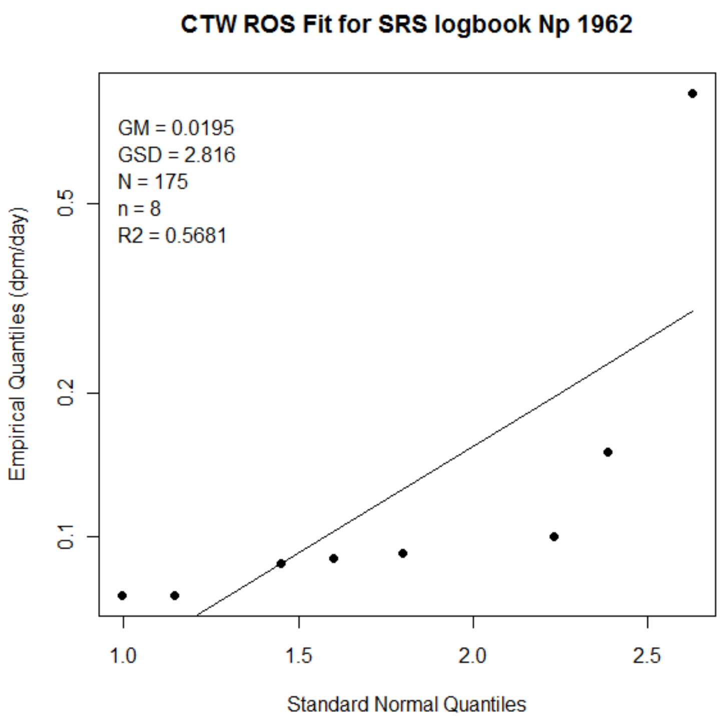

Figure A-19. ROS fit for CTWs, 1962.

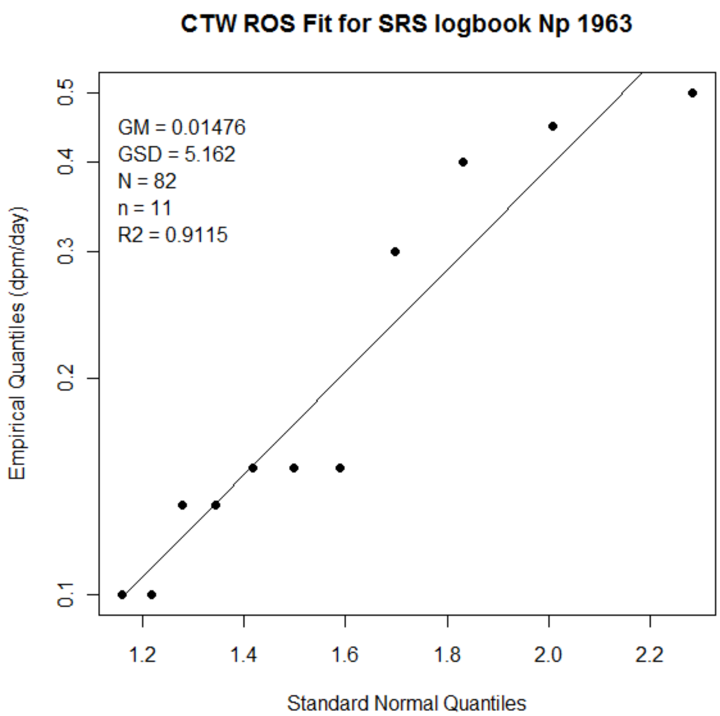

Figure A-20. ROS fit for CTWs, 1963.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

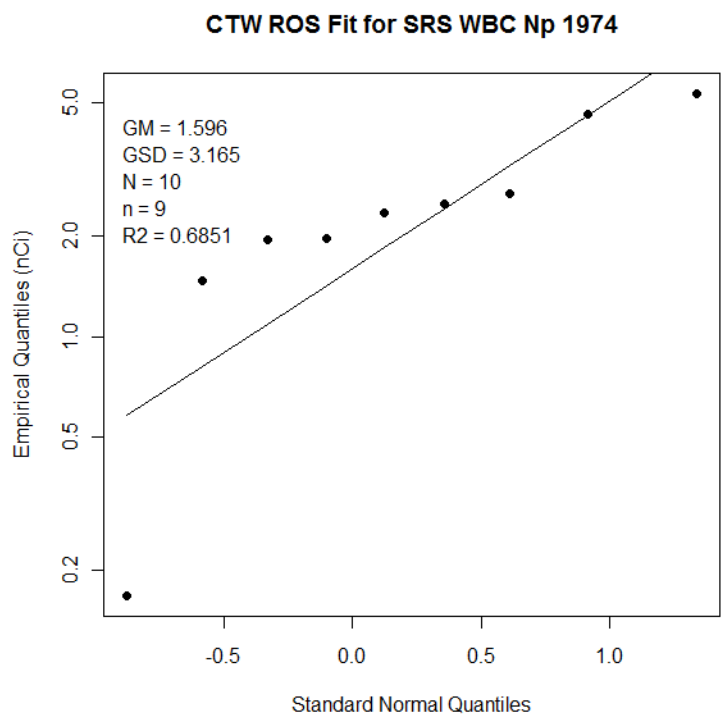

Figure A-21. ROS fit for CTWs, 1974.

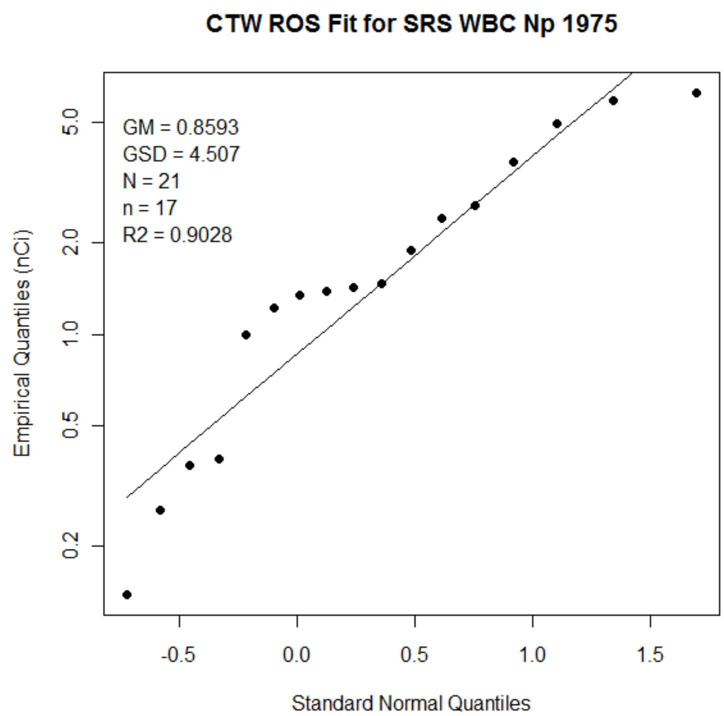

Figure A-22. ROS fit for CTWs, 1975.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

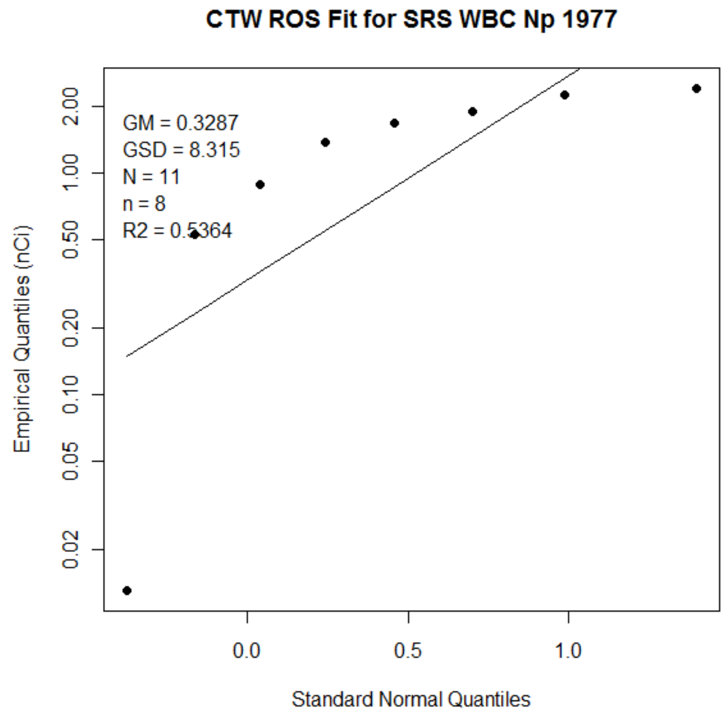

Figure A-23. ROS fit for CTWs, 1977.

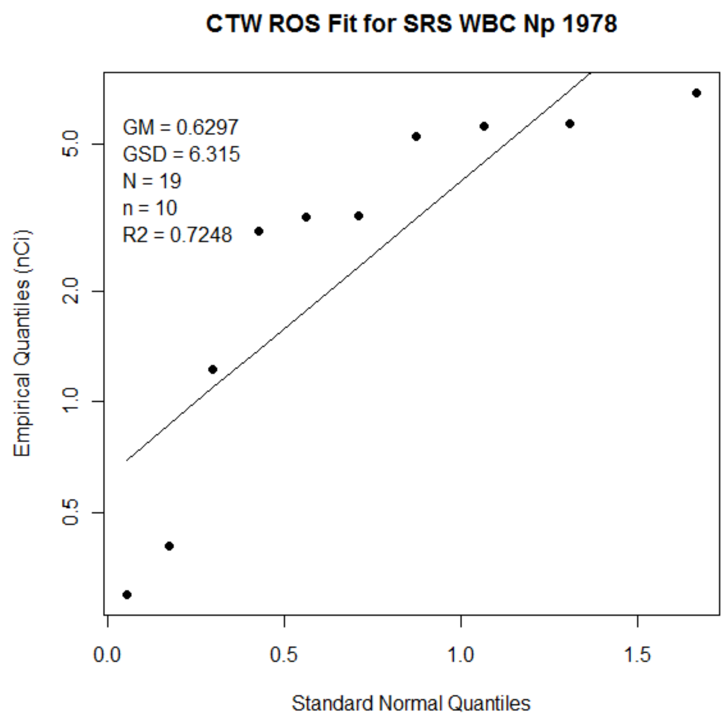

Figure A-24. ROS fit for CTWs, 1978.

ATTACHMENT A
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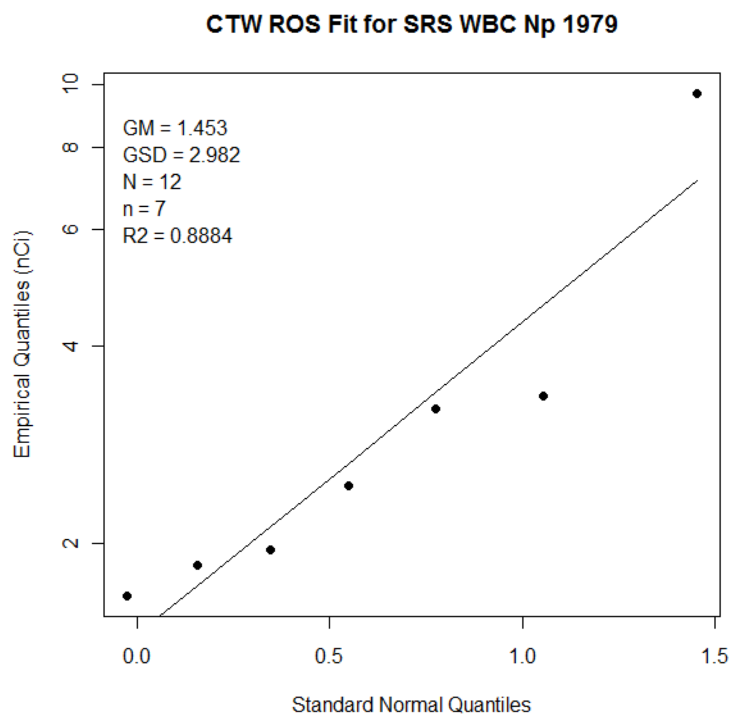

Figure A-25. ROS fit for CTWs, 1979.

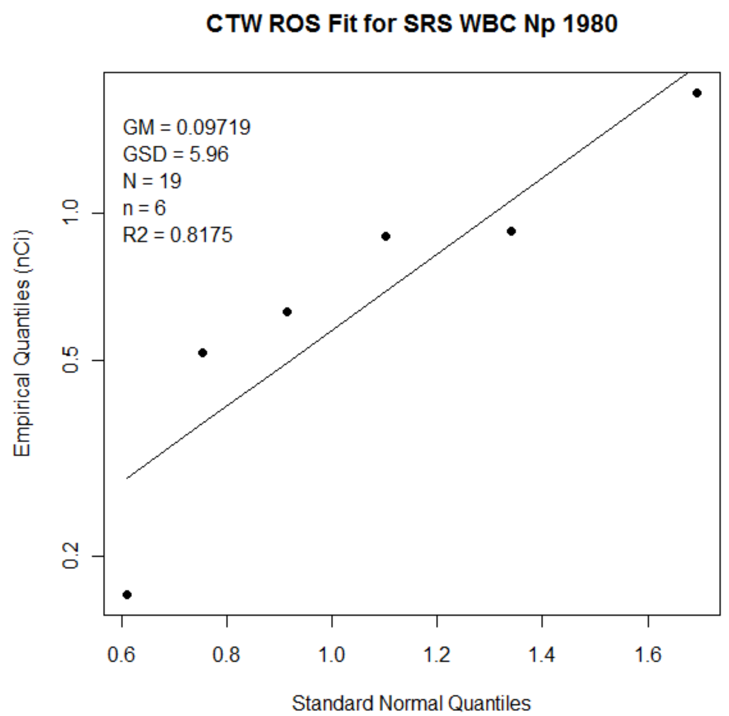

Figure A-26. ROS fit for CTWs, 1980.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

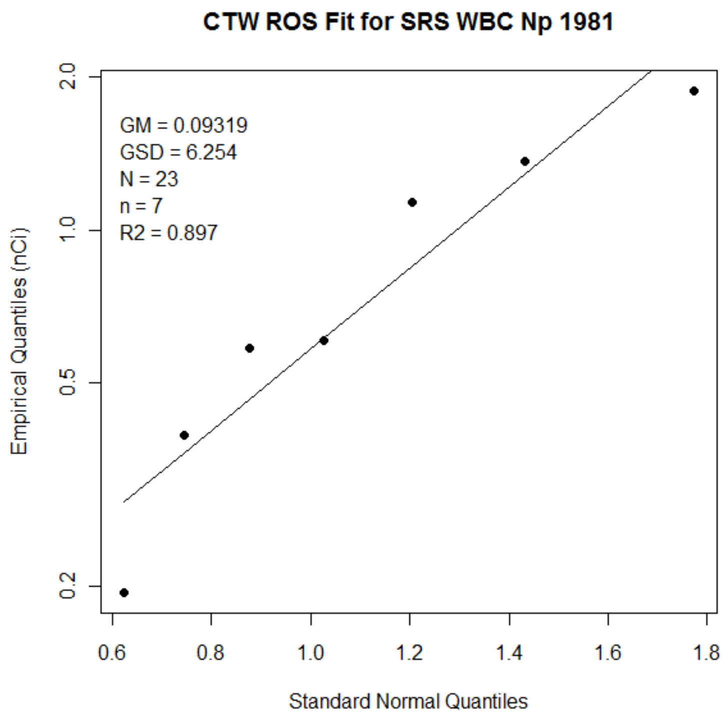

Figure A-27. ROS fit for CTWs, 1981.

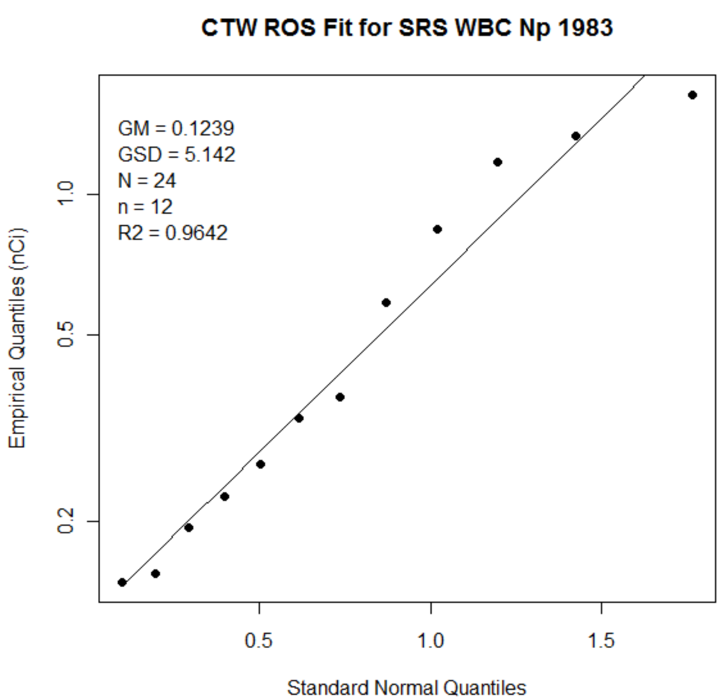

Figure A-28. ROS fit for CTWs, 1983.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

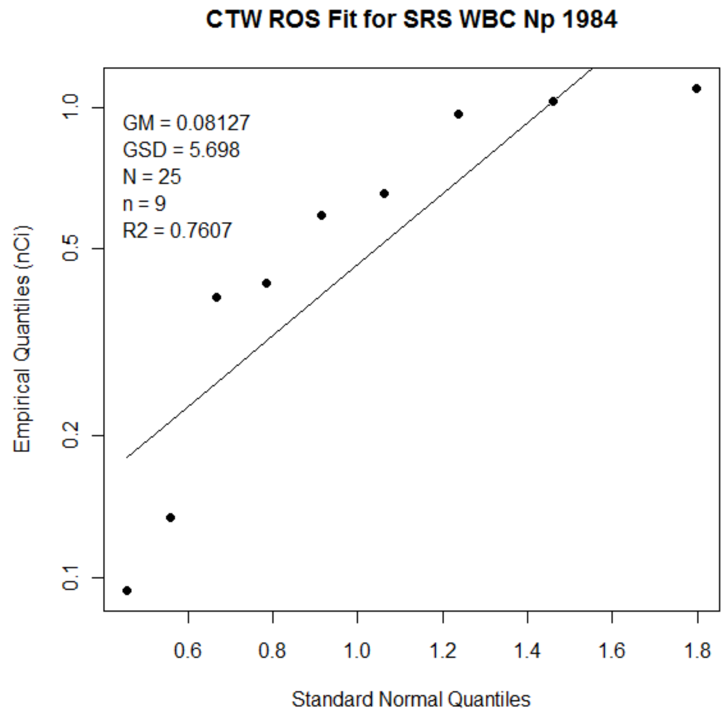

Figure A-29. ROS fit for CTWs, 1984.

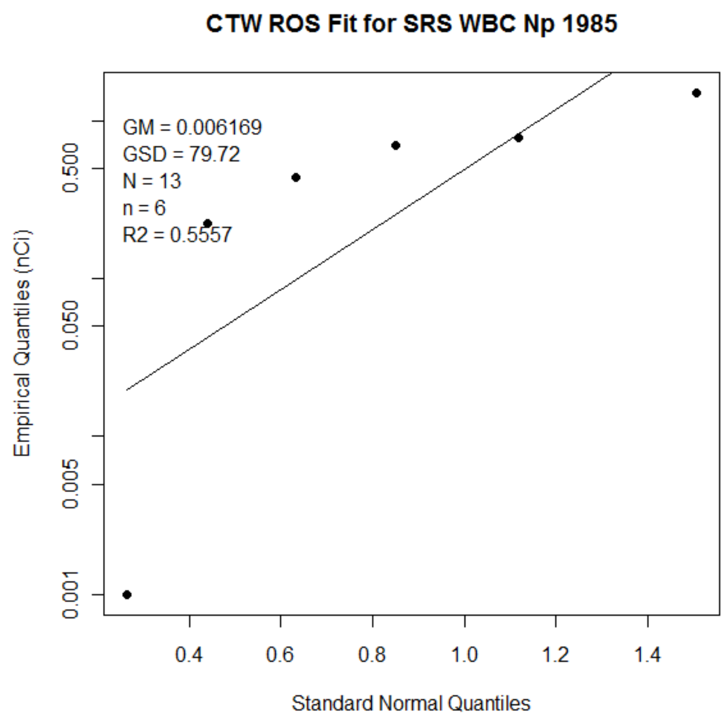

Figure A-30. ROS fit for CTWs, 1985.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

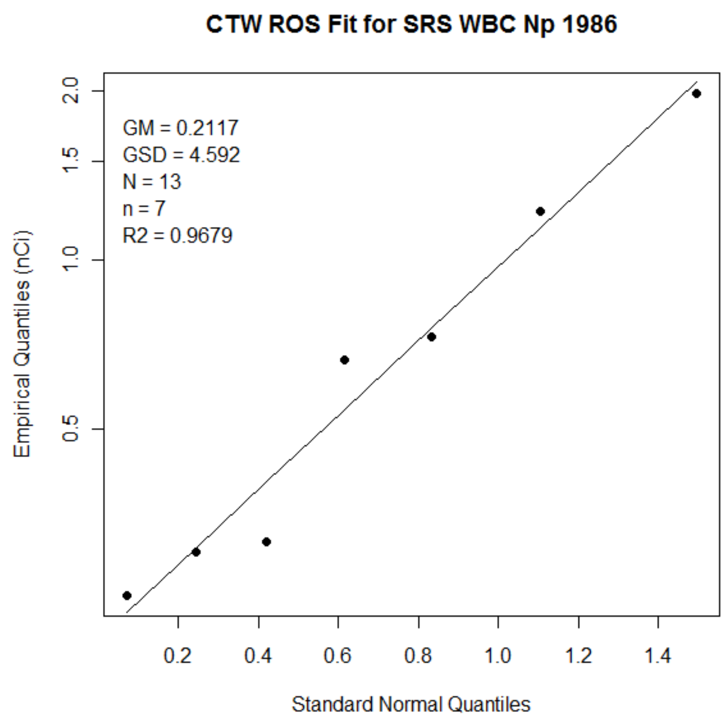

Figure A-31. ROS fit for CTWs, 1986.

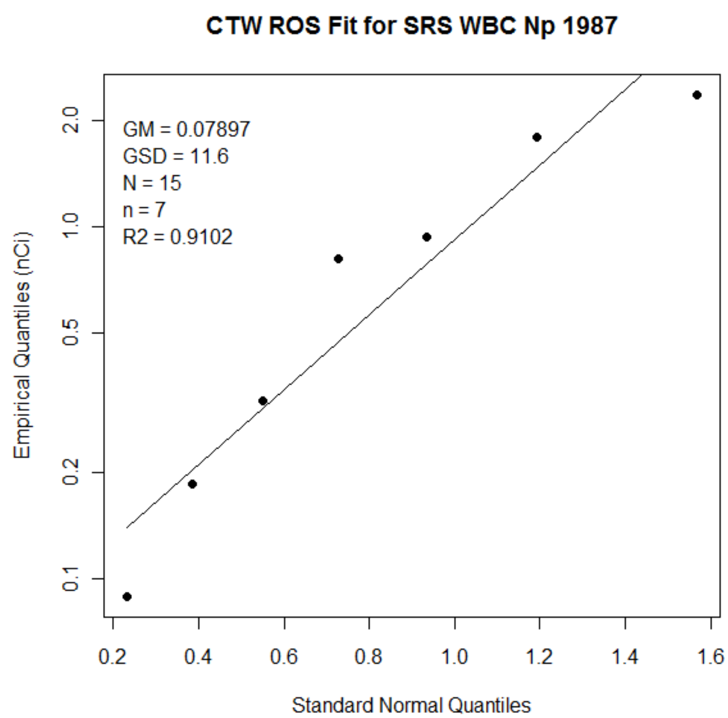

Figure A-32. ROS fit for CTWs, 1987.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

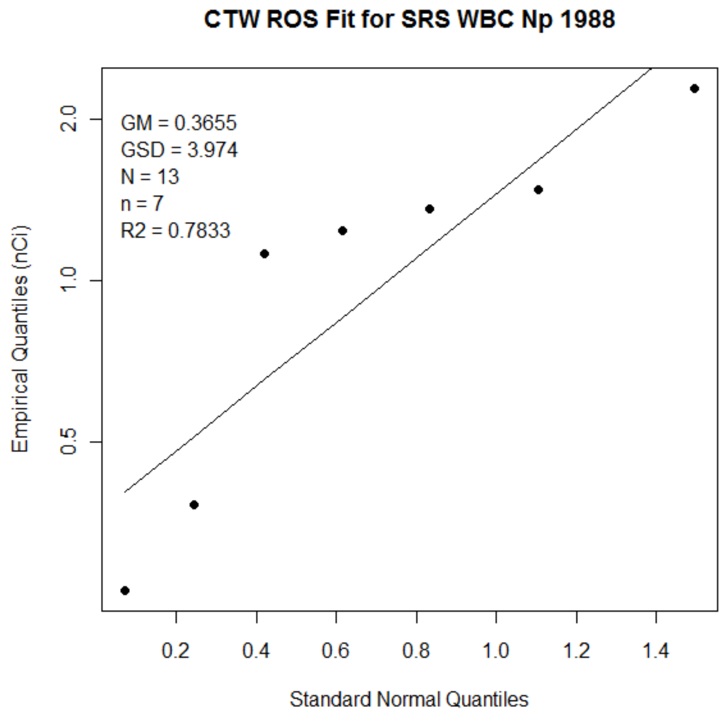

Figure A-33. ROS fit for CTWs, 1988.

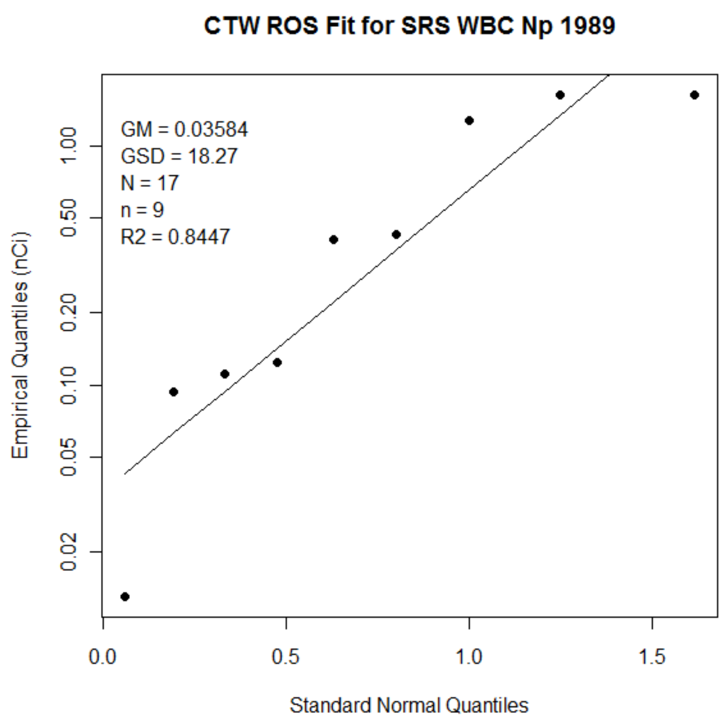

Figure A-34. ROS fit for CTWs, 1989.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

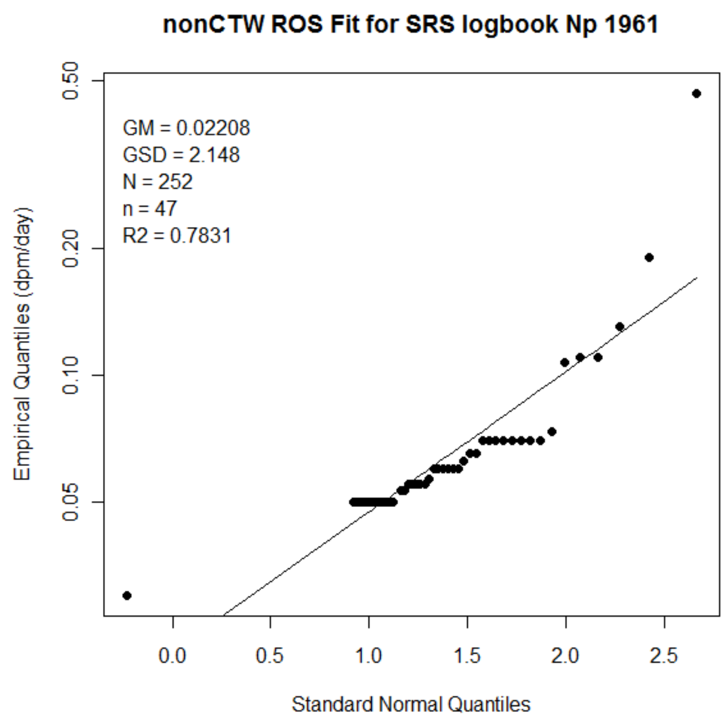

Figure A-35. ROS fit for nonCTWs, 1961.

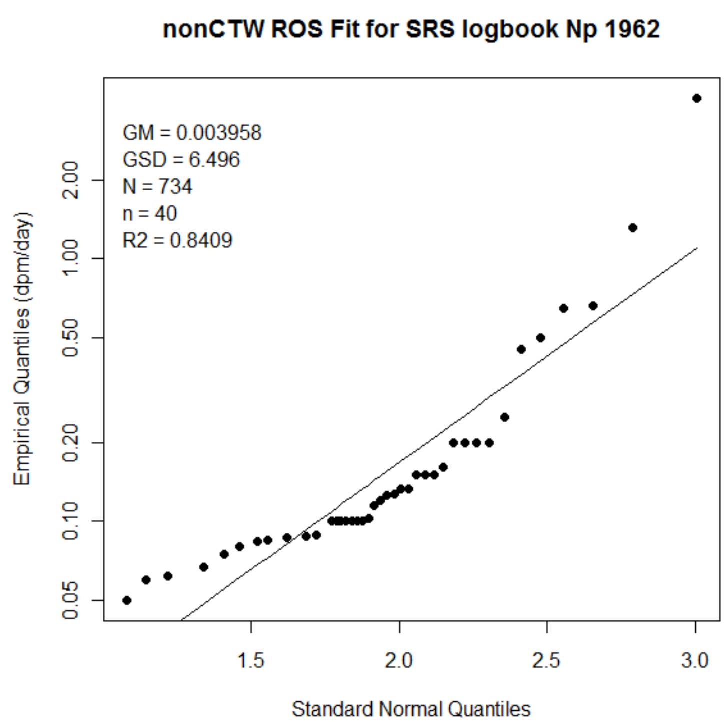

Figure A-36. ROS fit for nonCTWs, 1962.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

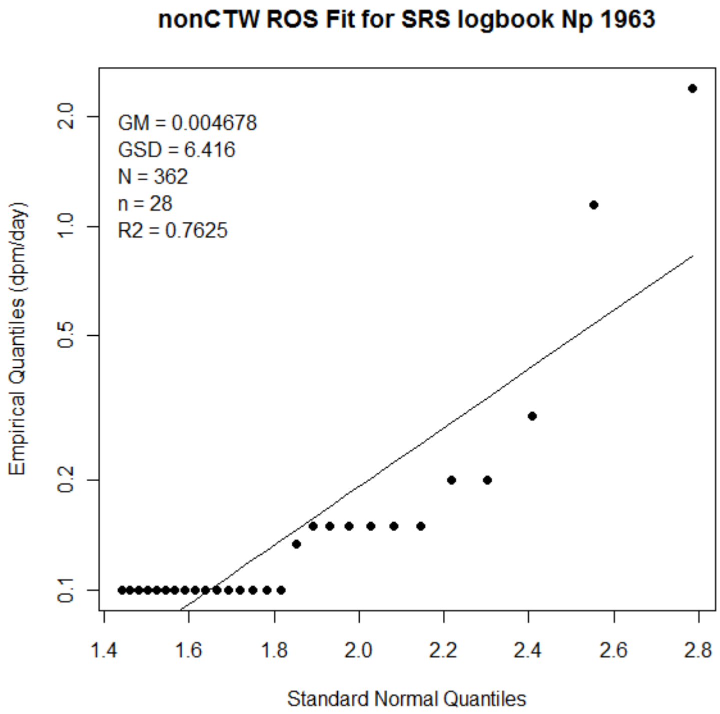

Figure A-37. ROS fit for nonCTWs, 1963.

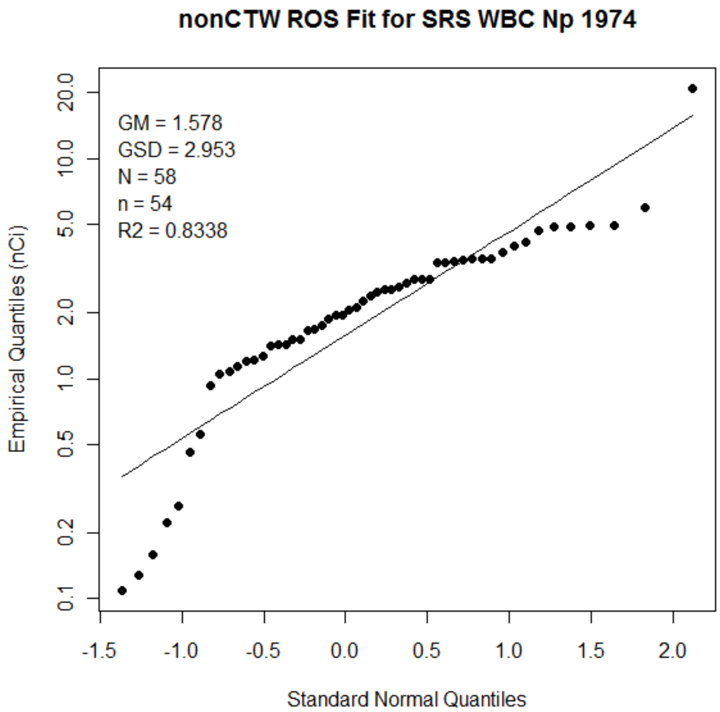

Figure A-38. ROS fit for nonCTWs, 1974.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS
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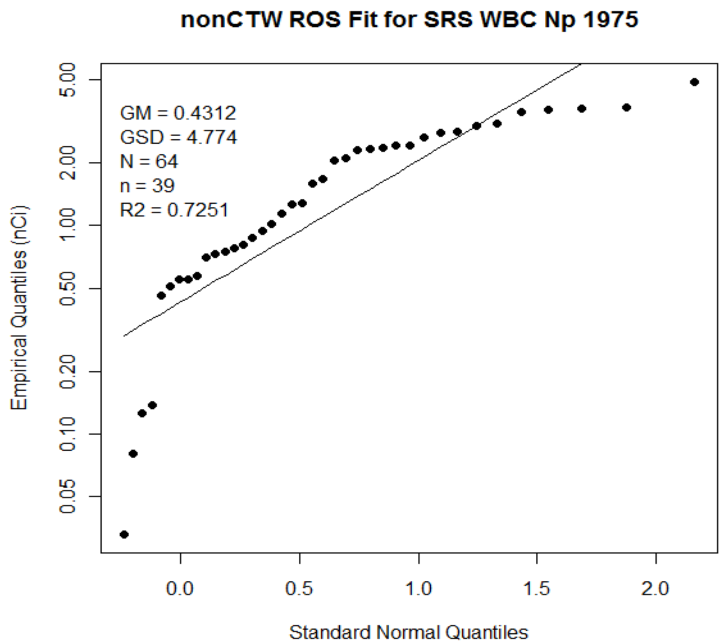

Figure A-39. ROS fit for nonCTWs, 1975.

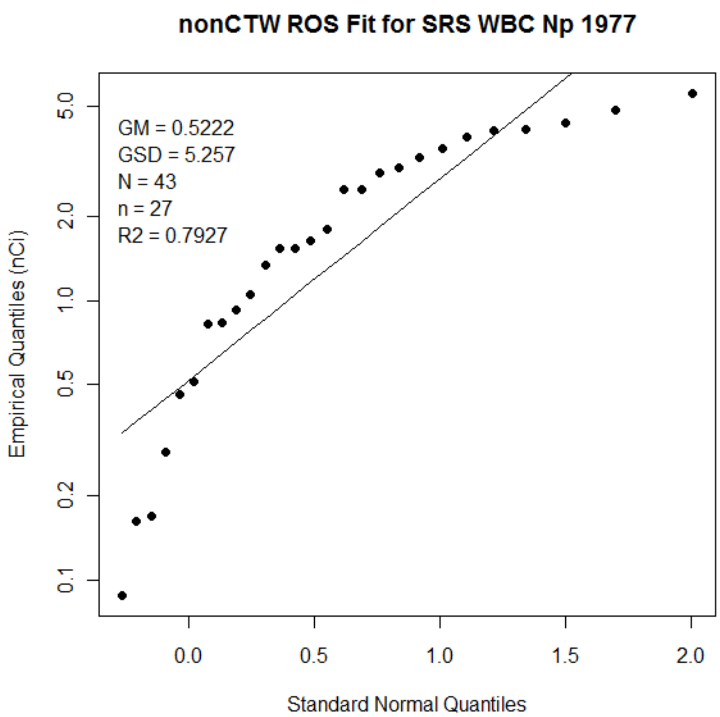

Figure A-40. ROS fit for nonCTWs, 1977.

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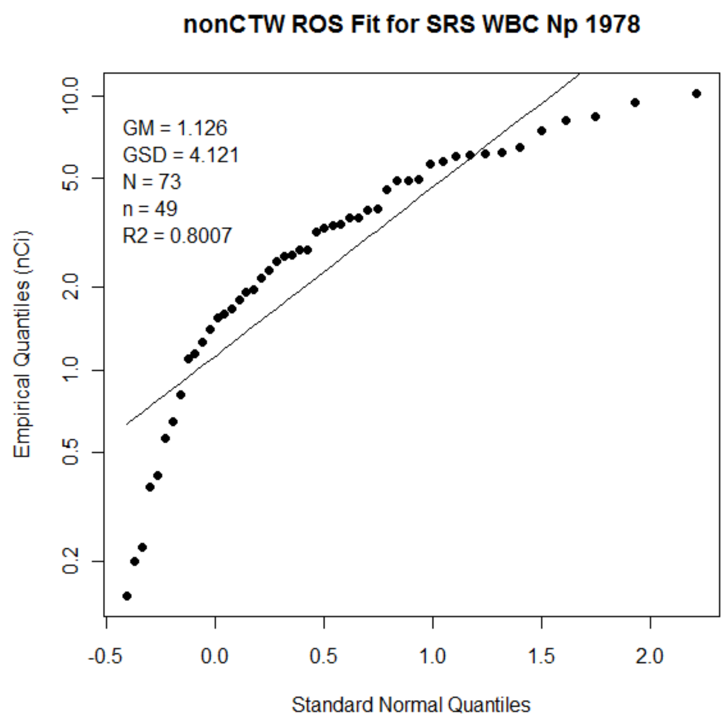

Figure A-41. ROS fit for nonCTWs, 1978.

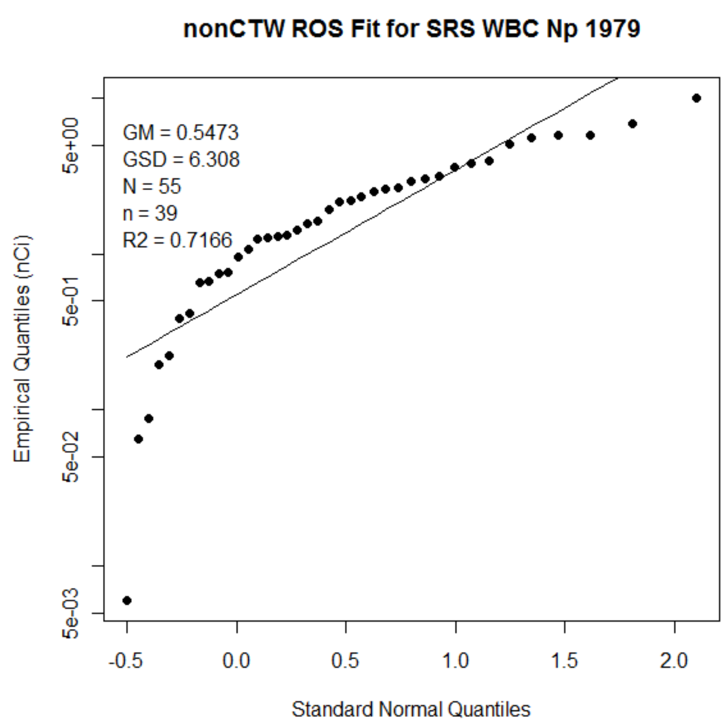

Figure A-42. ROS fit for nonCTWs, 1979.

ATTACHMENT A
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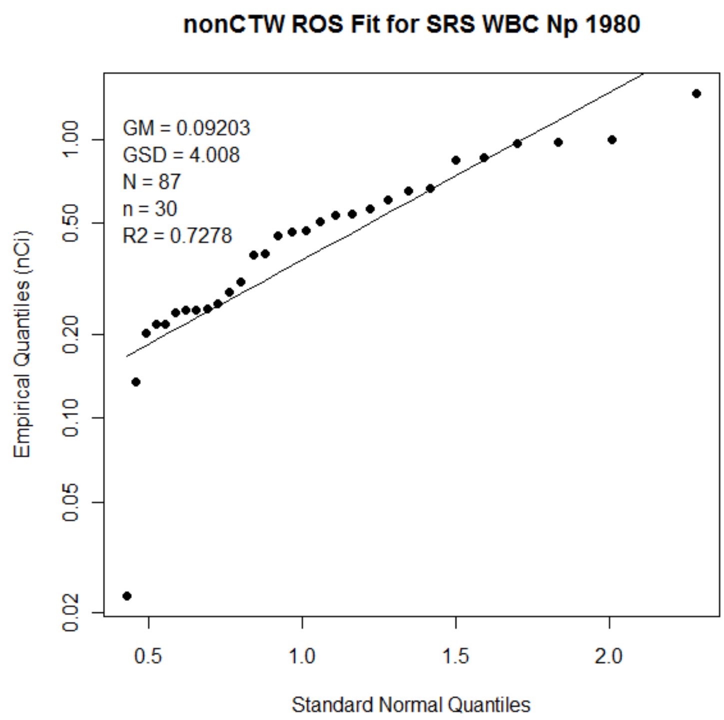

Figure A-43. ROS fit for nonCTWs, 1980.

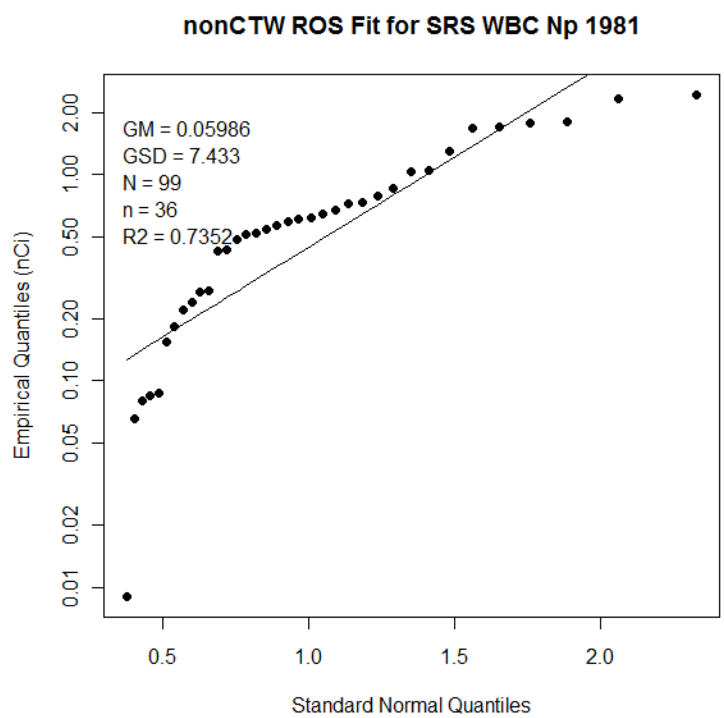

Figure A-44. ROS fit for nonCTWs, 1981.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

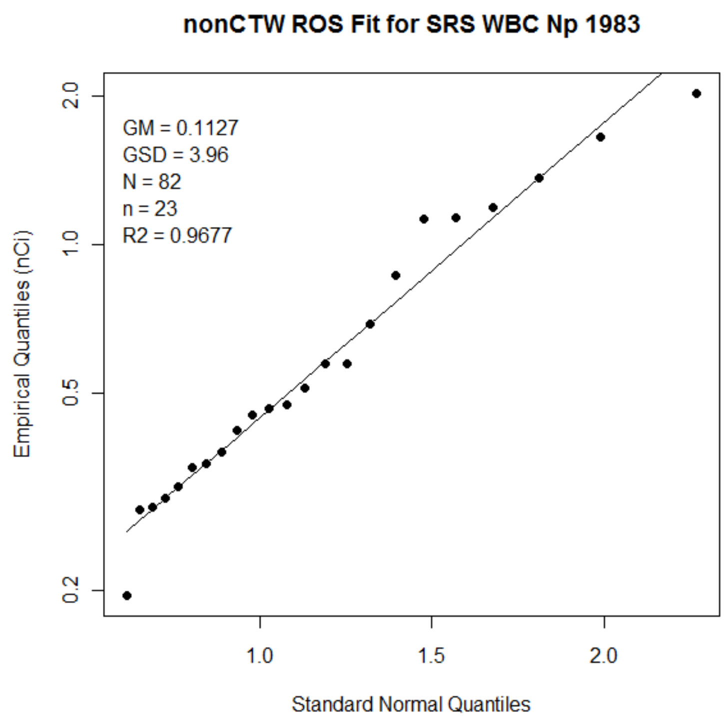

Figure A-45. ROS fit for nonCTWs, 1983.

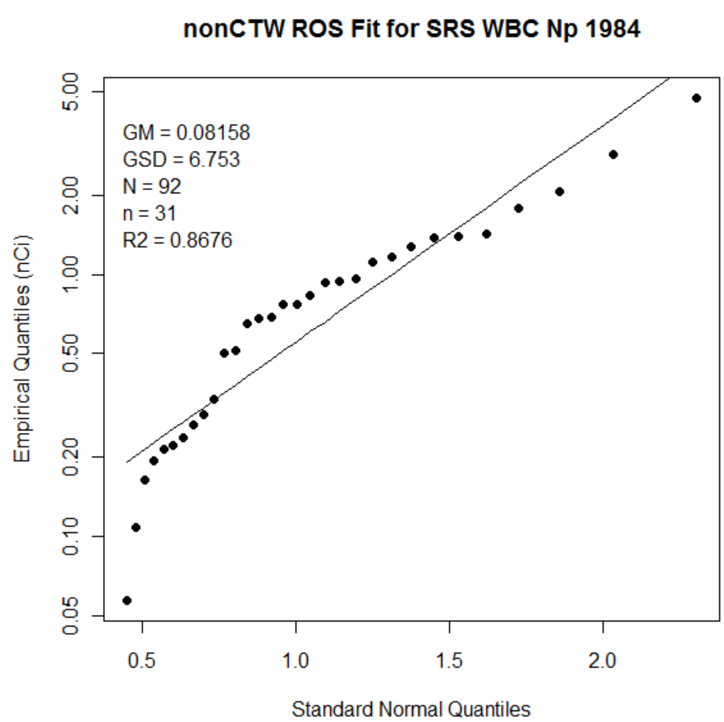

Figure A-46. ROS fit for nonCTWs, 1984.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS
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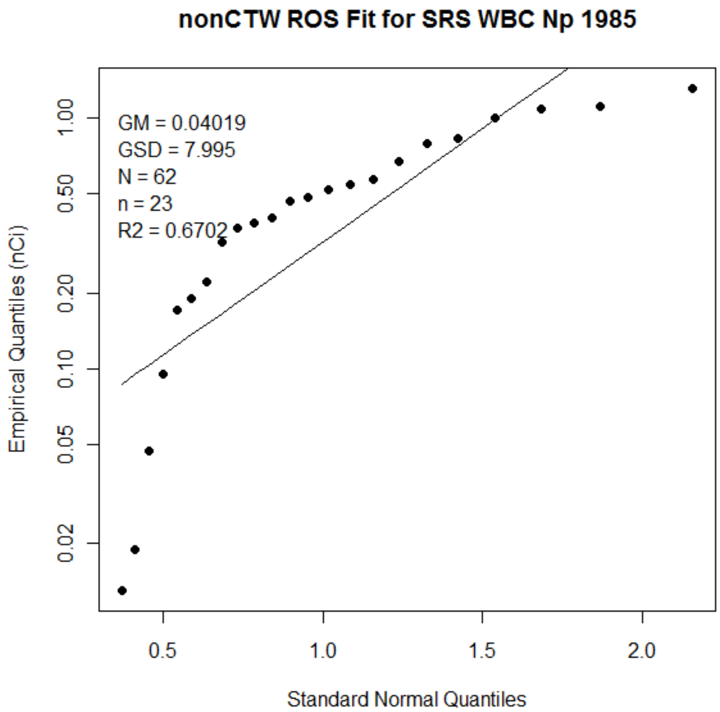

Figure A-47. ROS fit for nonCTWs, 1985.

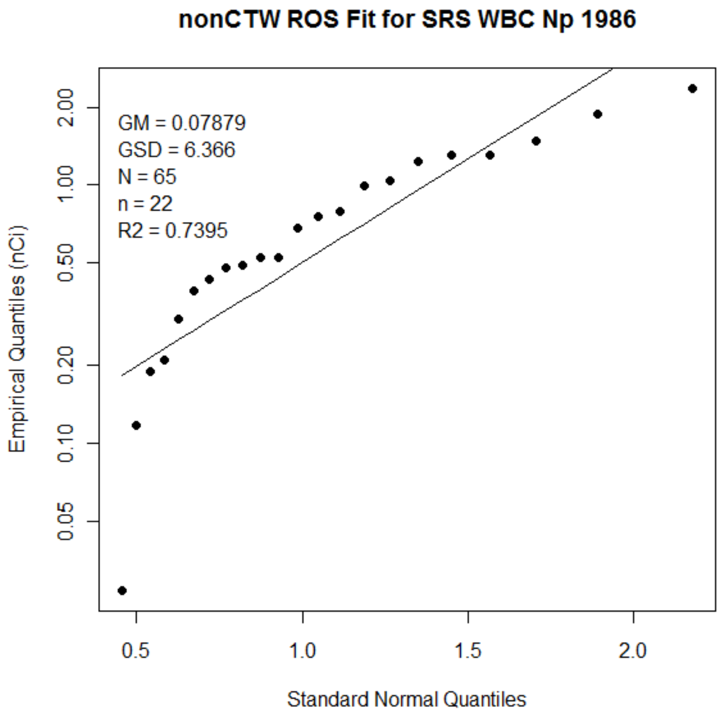

Figure A-48. ROS fit for nonCTWs, 1986.

ATTACHMENT A
ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS

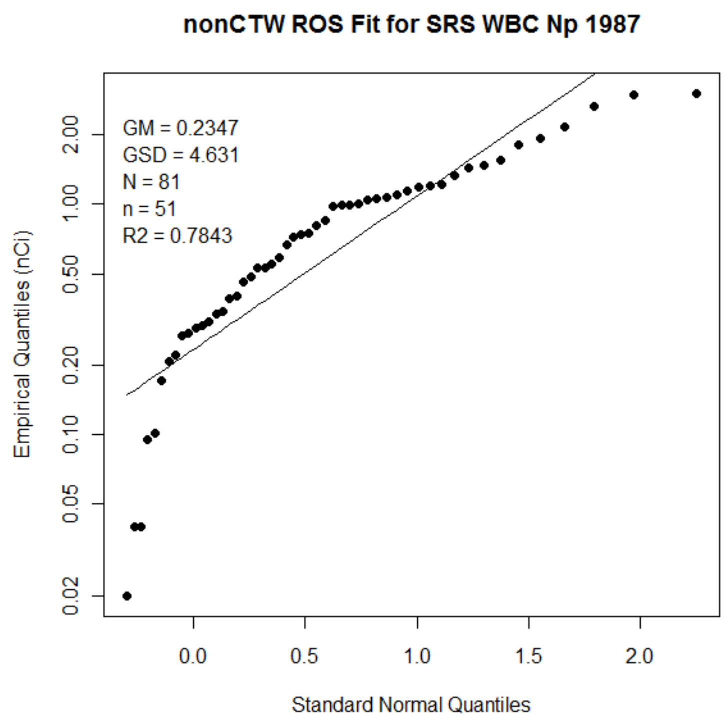

Figure A-49. ROS fit for nonCTWs, 1987.

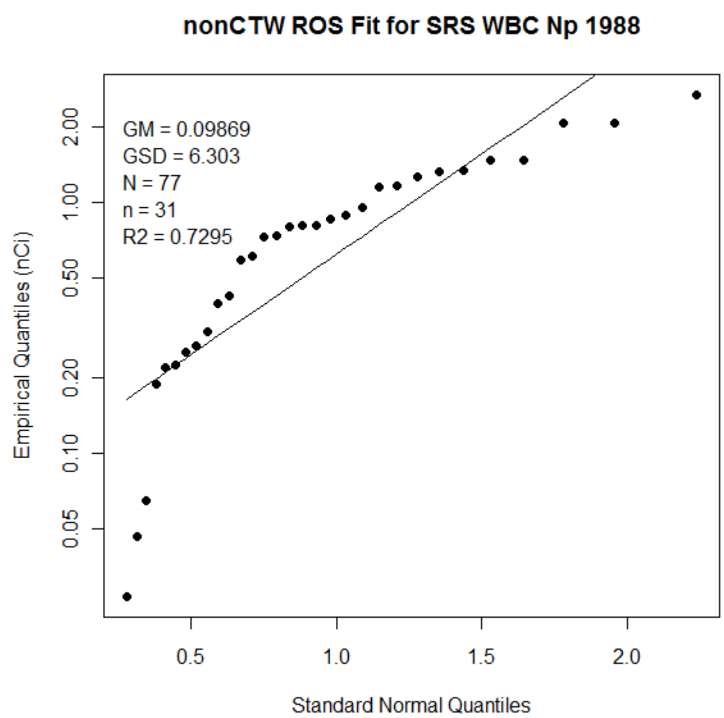

Figure A-50. ROS fit for nonCTWs, 1988.

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ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS
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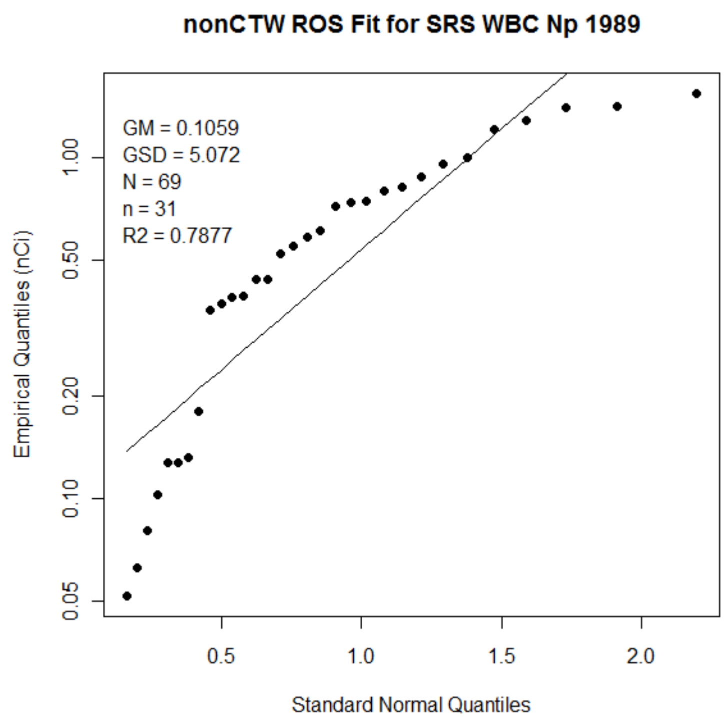

Figure A-51. ROS fit for nonCTWs, 1989.

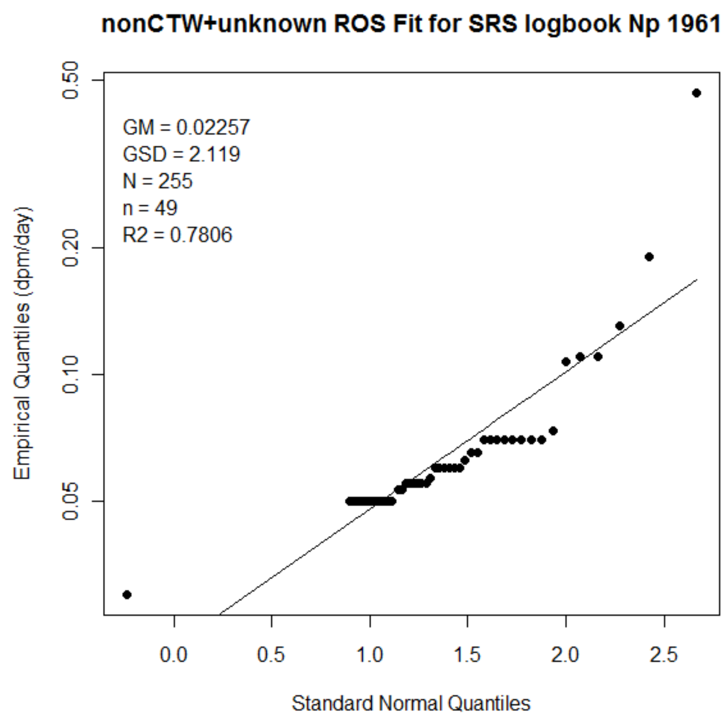

Figure A-52. ROS fit for nonCTWs+unk, 1961.

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ROS PLOTS FOR AMWS, CTW, NONCTWS, AND NONCTW+UNKS
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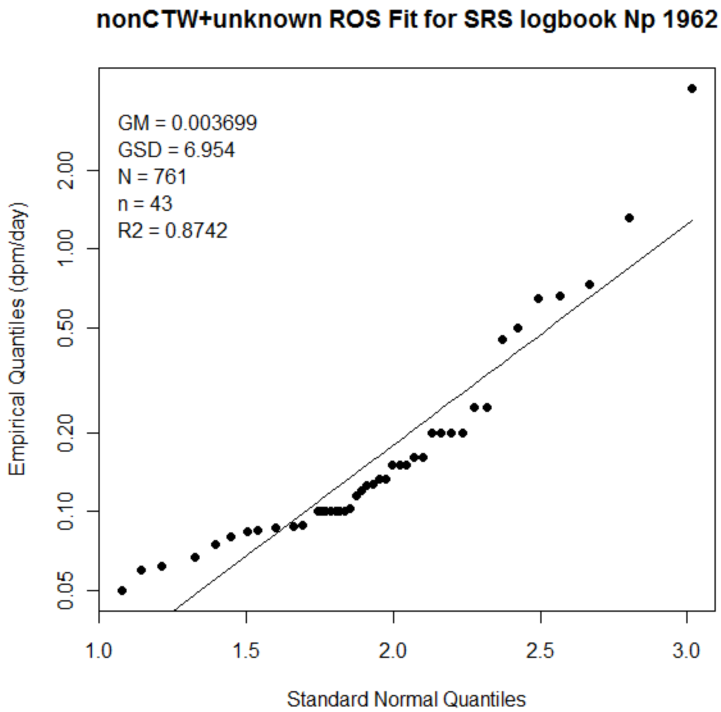

Figure A-53. ROS fit for nonCTWs+unk, 1962.

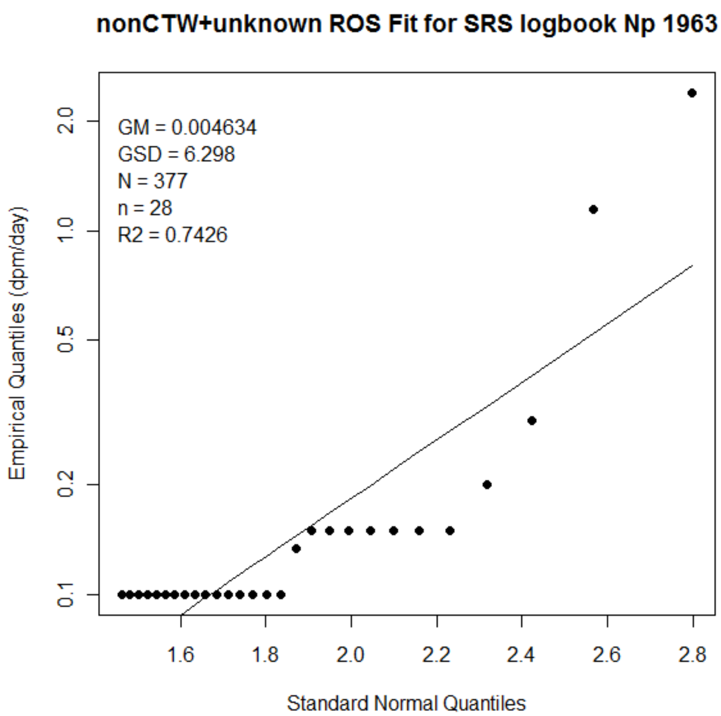

Figure A-54. ROS fit for nonCTWs+unk, 1963.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS

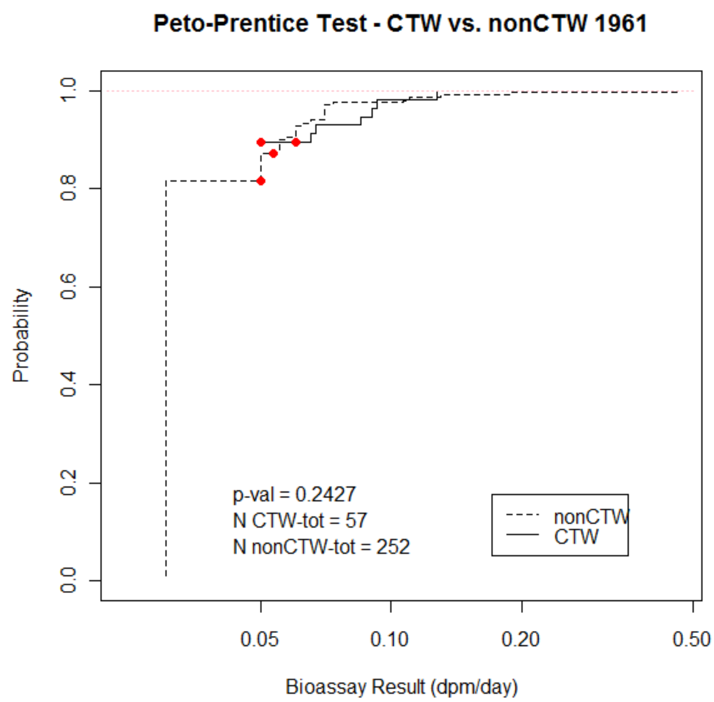

Figure B-1. Peto-Prentice test for CTW:nonCTW, 1961.

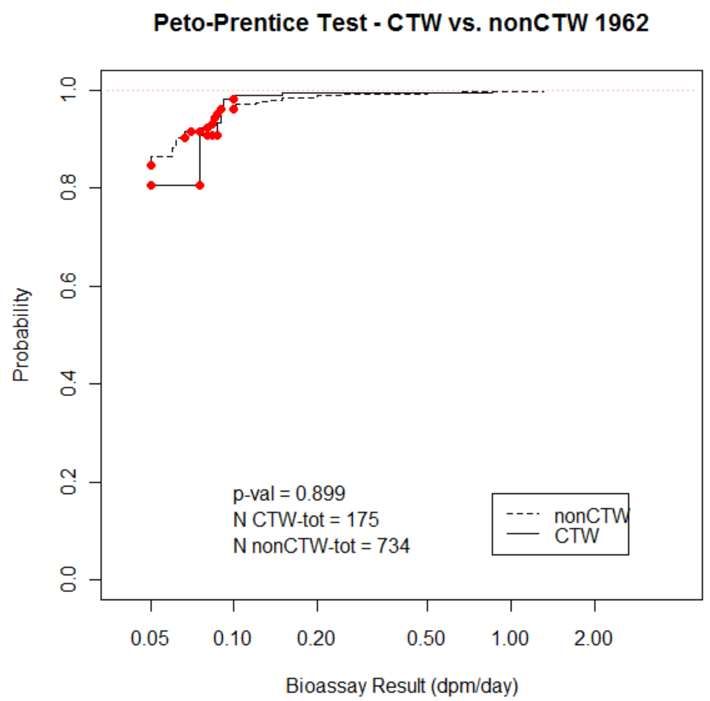

Figure B-2. Peto-Prentice test for CTW:nonCTW, 1962.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS
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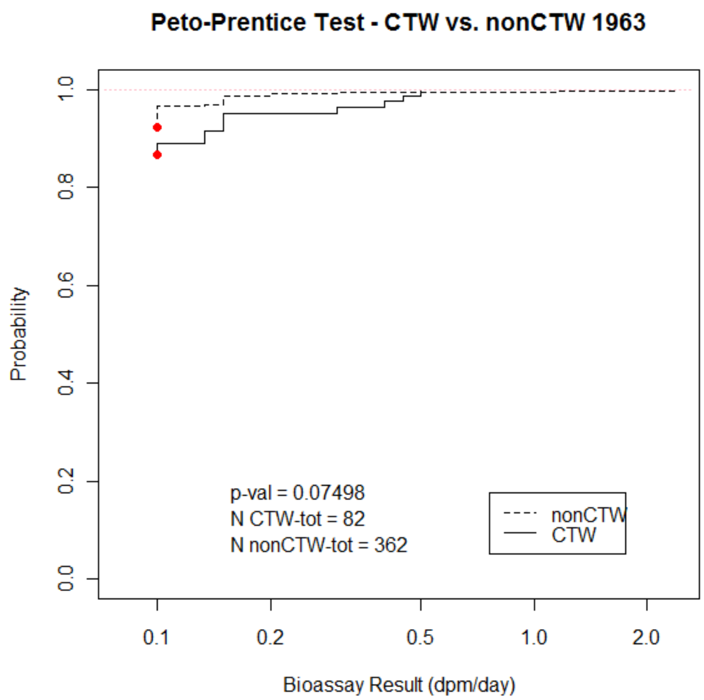

Figure B-3. Peto-Prentice test for CTW:nonCTW, 1963.

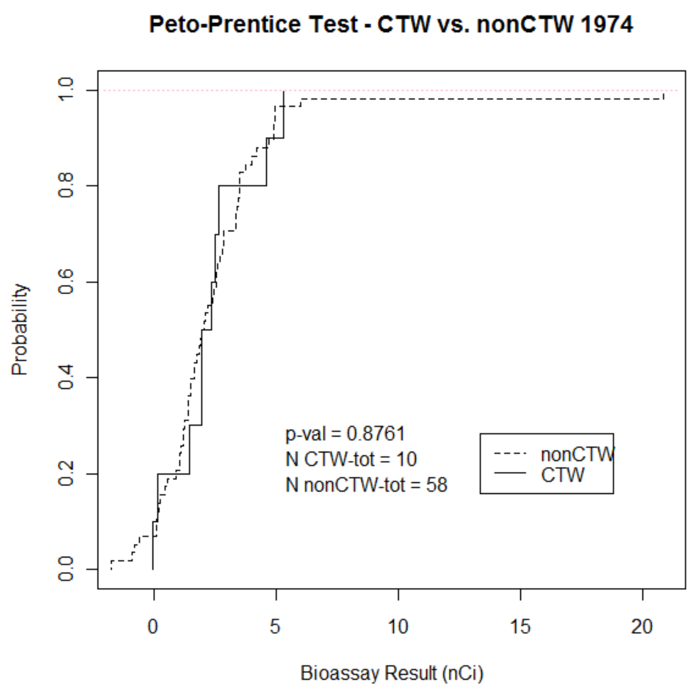

Figure B-4. Peto-Prentice test for CTW:nonCTW, 1974.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS

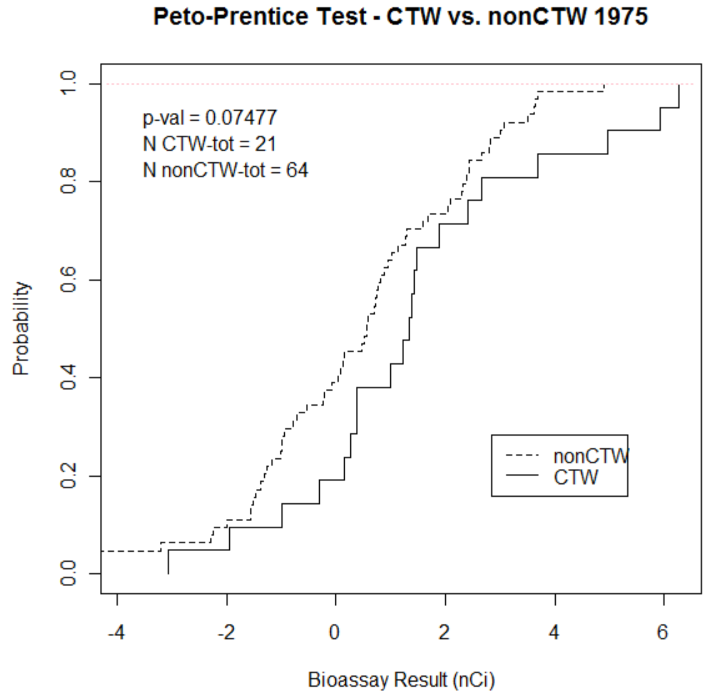

Figure B-5. Peto-Prentice test for CTW:nonCTW, 1975.

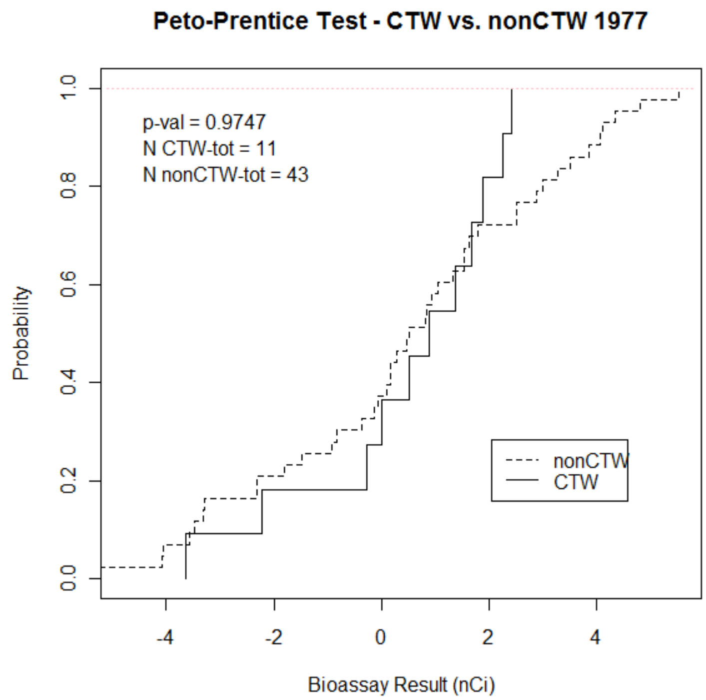

Figure B-6. Peto-Prentice test for CTW:nonCTW, 1977.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS

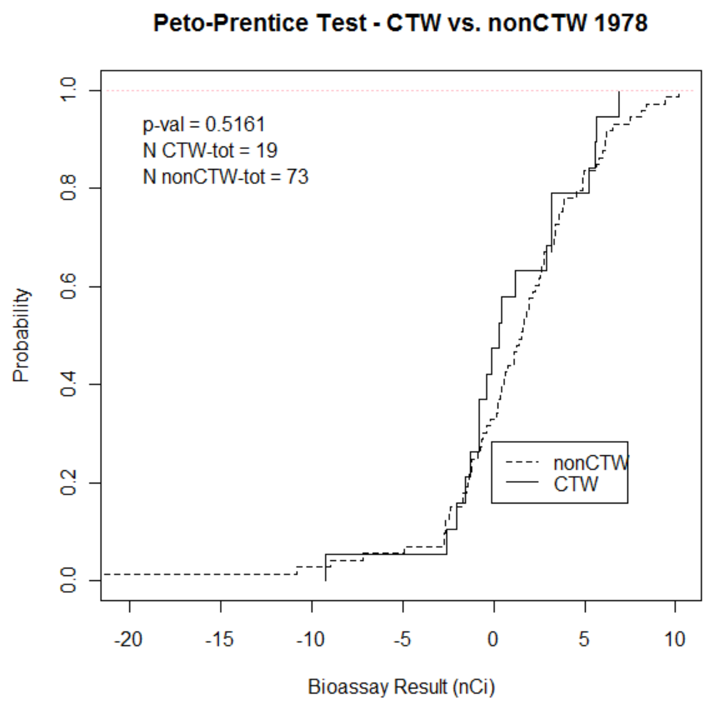

Figure B-7. Peto-Prentice test for CTW:nonCTW, 1978.

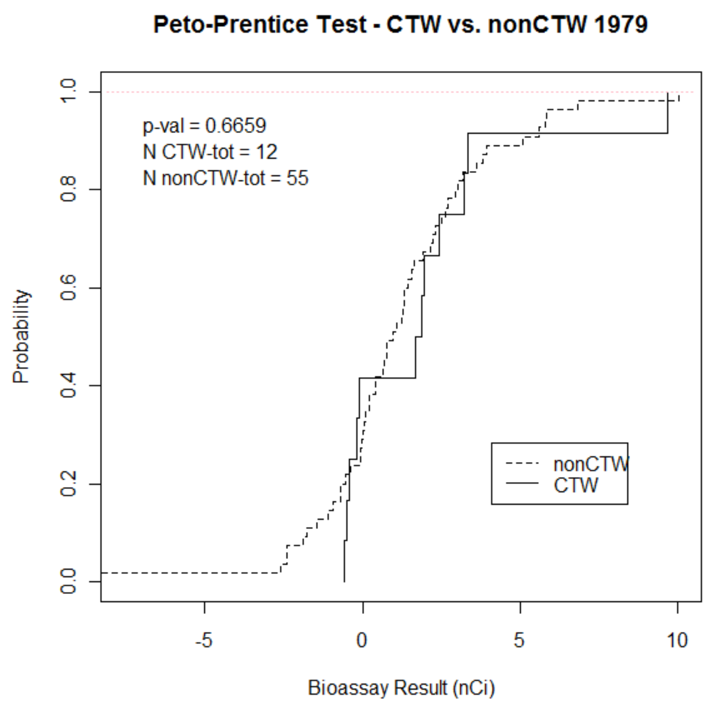

Figure B-8. Peto-Prentice test for CTW:nonCTW, 1979.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS

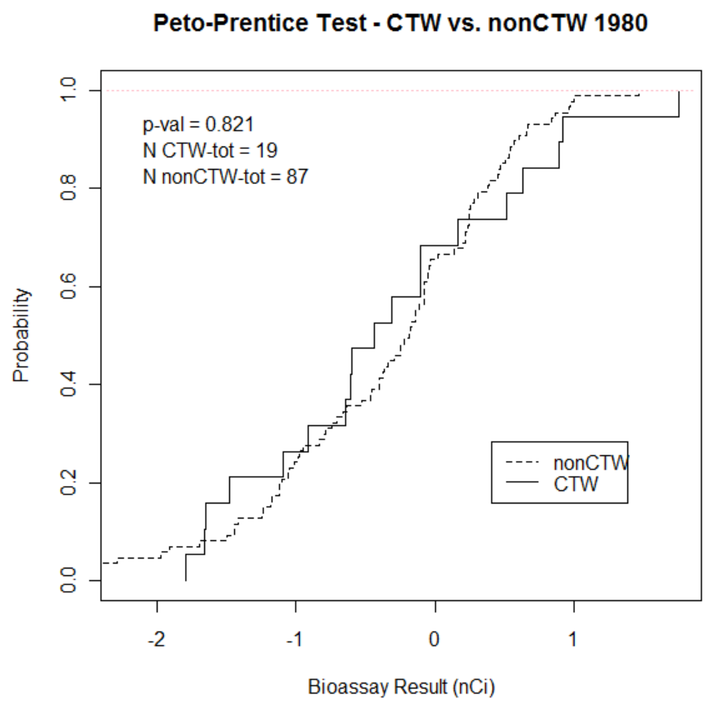

Figure B-9. Peto-Prentice test for CTW:nonCTW, 1980.

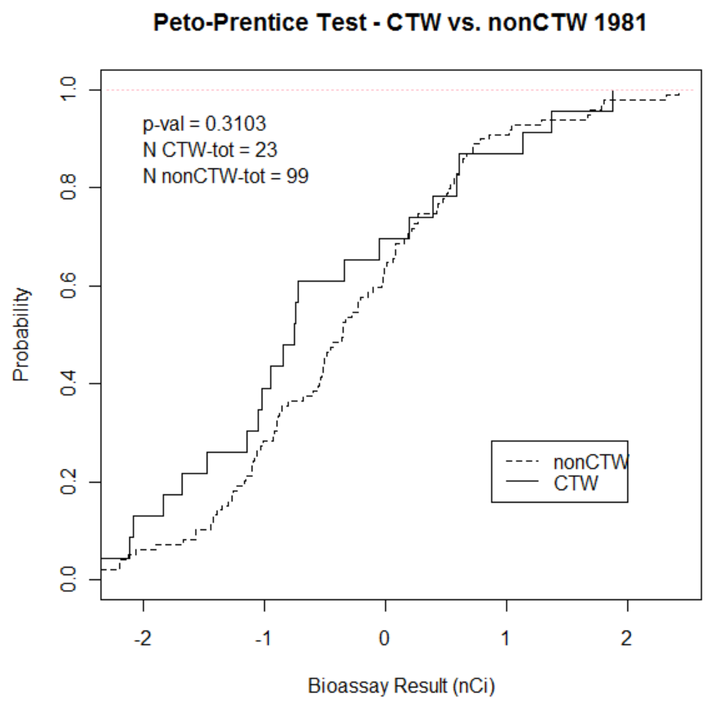

Figure B-10. Peto-Prentice test for CTW:nonCTW, 1981.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS

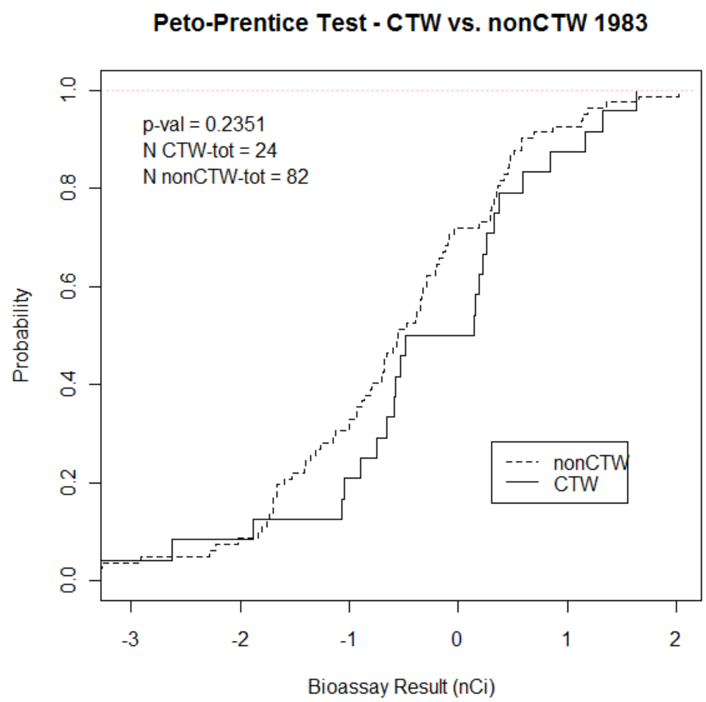

Figure B-11. Peto-Prentice test for CTW:nonCTW, 1983.

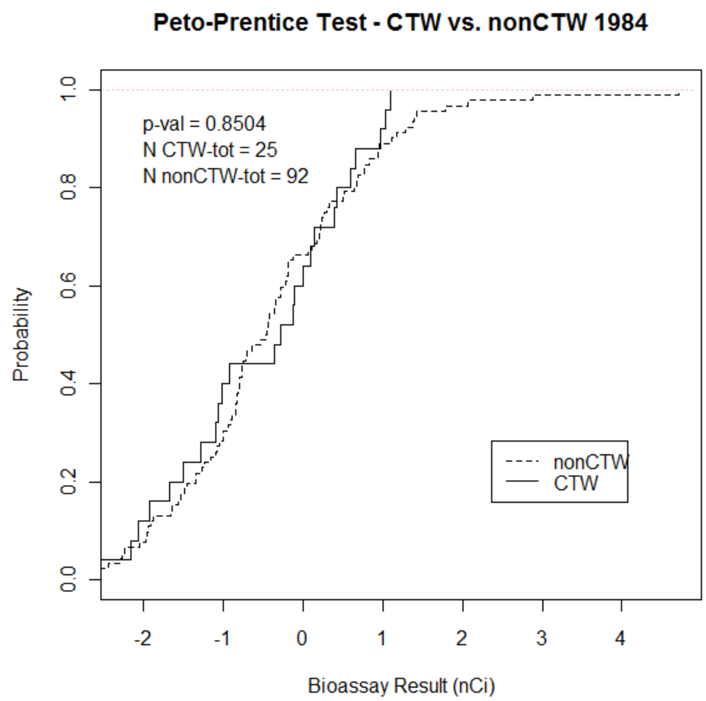

Figure B-12. Peto-Prentice test for CTW:nonCTW, 1984.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS
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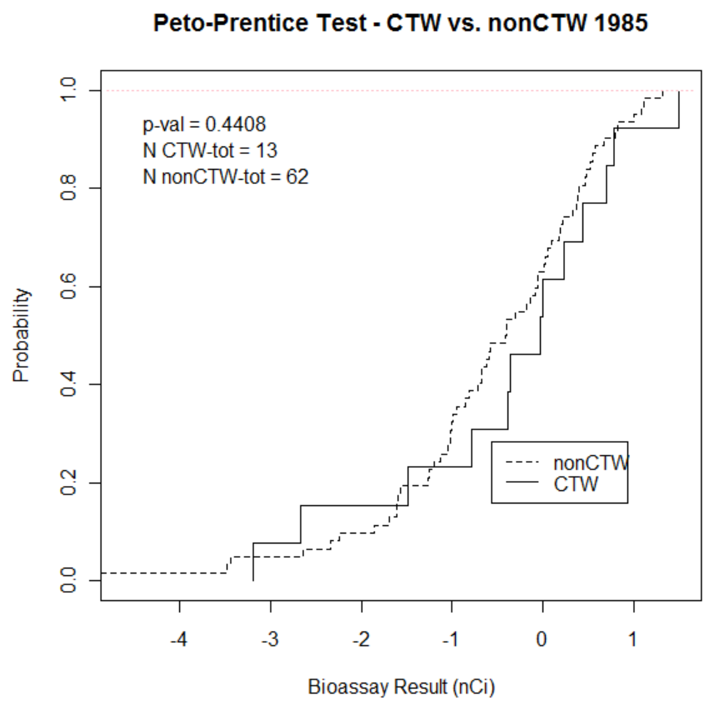

Figure B-13. Peto-Prentice test for CTW:nonCTW, 1985.

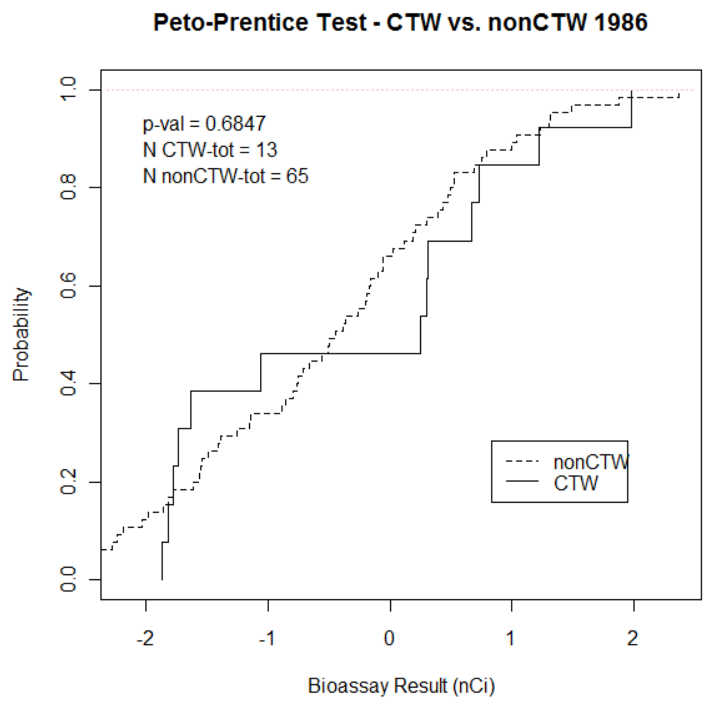

Figure B-14. Peto-Prentice test for CTW:nonCTW, 1986.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS
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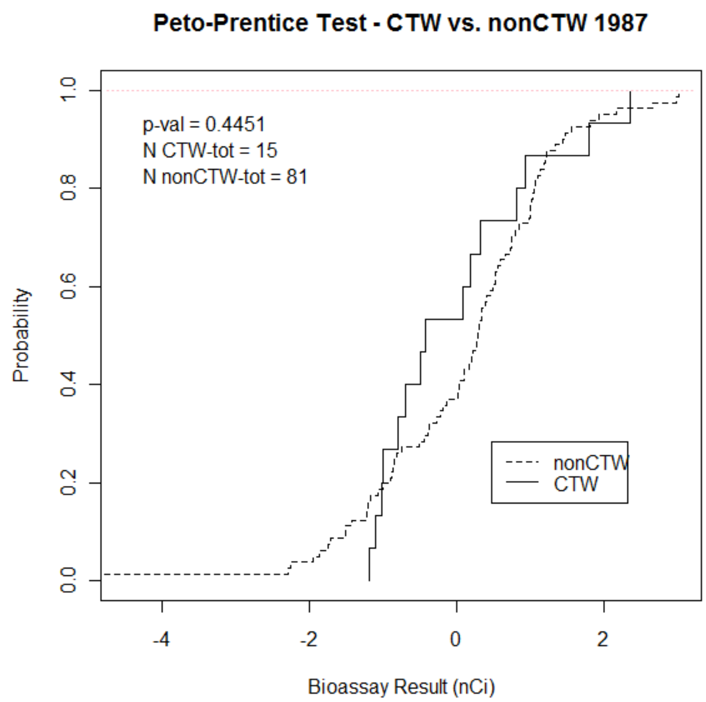

Figure B-15. Peto-Prentice test for CTW:nonCTW, 1987.

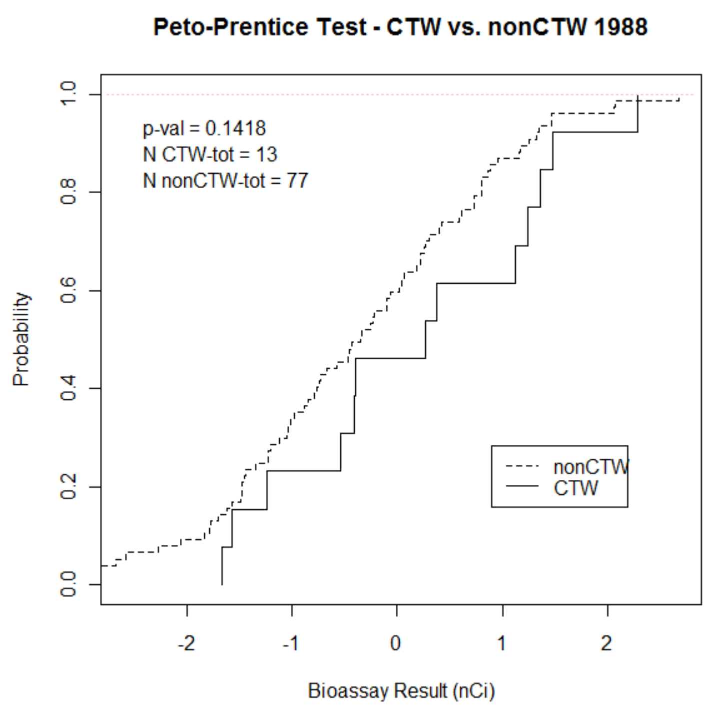

Figure B-16. Peto-Prentice test for CTW:nonCTW, 1988.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS
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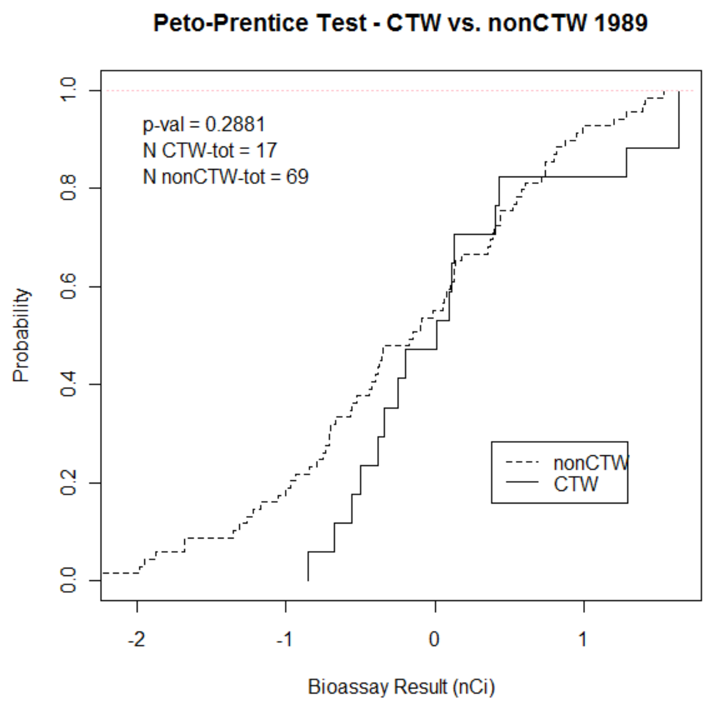

Figure B-17. Peto-Prentice test for CTW:nonCTW, 1989.

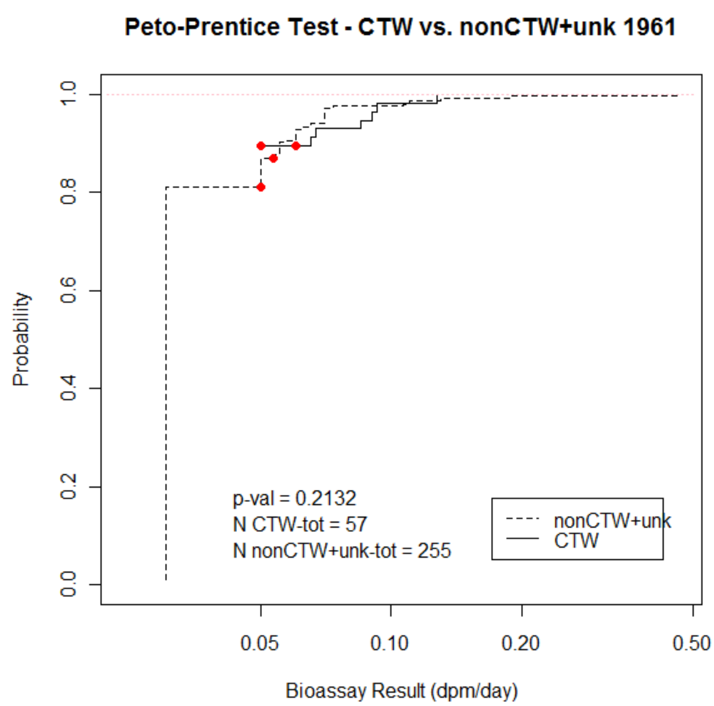

Figure B-18. Peto-Prentice test for CTW:nonCTW+unk, 1961.

ATTACHMENT B
PETO-PRENTICE PLOTS FOR CTW:NONCTW AND CTW:NONCTW+UNK COMPARISONS

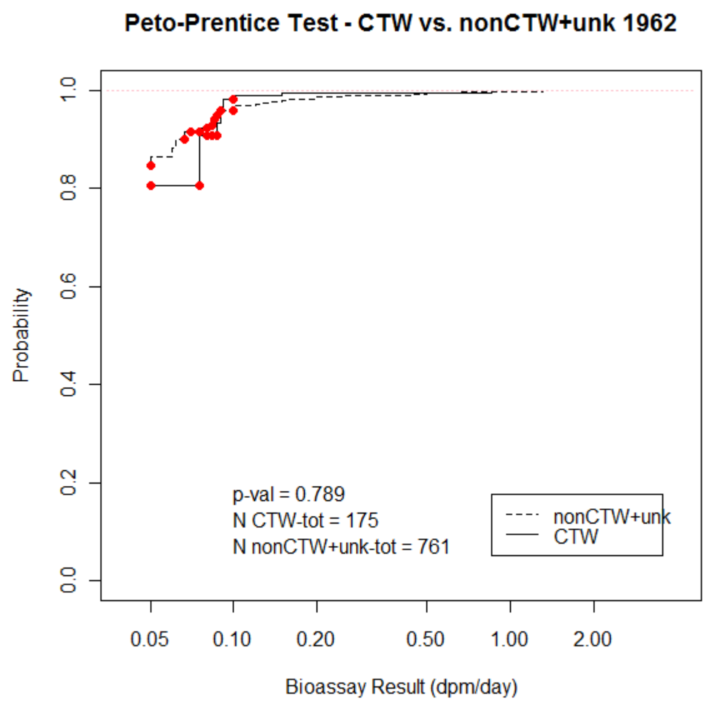

Figure B-19. Peto-Prentice test for CTW:nonCTW+unk, 1962.

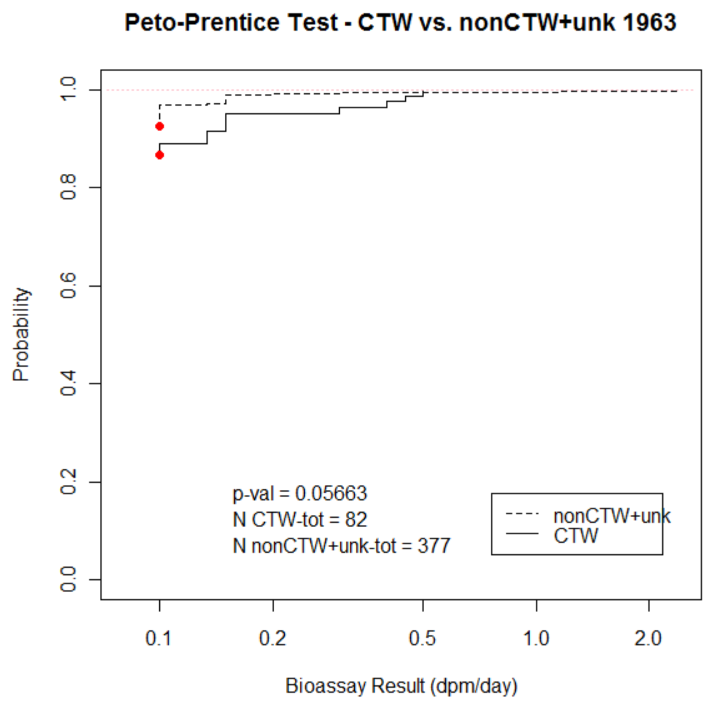

Figure B-20. Peto-Prentice test for CTW:nonCTW+unk, 1963.