

# The Price/VanBlaricom study lacks statistical rigor

November 12-15, 2013

Gary A. Ritchie, Ph.D.

# Impact of geoduck harvesting on benthic communities

- Proponents claim that there are no significant effects of geoduck harvesting on benthic communities in Puget Sound.
- Claim is based largely on a Master of Science thesis written by Jennifer Price at the University of Washington.

# Jennifer Price MS Thesis

- “Quantifying the Ecological Impacts of Geoduck (*Panopea generosa*) Aquaculture Harvest Practices on Benthic Infauna”, Jennifer Price; August 18, 2011.
- Study Objectives...” (page 8) to quantify the [geoduck] harvest impact (if any) on benthic organism abundance, diversity, and community structure...”
- Conclusion (page 33): “...the effects of geoduck harvest on the benthic community in Puget Sound are at most minimal.”

# Result is widely reported in meetings, hearings and the media

- Examples:

- Longbranch SHB hearing. March 1, 2012. Dr. Glenn VanBlaricom Presented results and conclusions of Price Thesis.
- Sea Grant Symposium, Alderbrook WA, March 6, 2012. Dr. Van Blaricom, again presented results and conclusions of Price thesis.
- Kitsap Sun, March 10, 2012. “Glenn Van Blaricom, a researcher with the UW School of Aquatic and Fishery Sciences, said *benthic organisms, which live on or in the sediments, don't appear to be affected much by geoduck harvesting.*”
- Henderson Inlet Hearing November 26, 2012. ENVIRON (a consulting firm) presented a review of environmental effects of geoduck aquaculture. Cited the Jennifer Price thesis as indicating that geoduck harvesting has no significant effect on benthic organisms.

# I will argue that..

- the conclusion “...*the effects of geoduck harvest on the benthic community in Puget Sound are at most minimal.*” is not supportable.....
- ...because the statistics (experimental design and analysis) were not done correctly.

# What are statistics?

- **Descriptive statistics**
  - Baseball scores
  - Populations of cities
  - Average income of a specific group
- **Inferential statistics**
  - Highly developed field of applied math that helps people “get their heads around” large volumes of data.
  - Essential in design of experiments and analysis/interpretation of experimental results.
  - Enables you to draw inferences regarding the results of an experiment.

# Example

- Test of dog food supplement:

Treatment	Weight gain (lbs.)
Control (no supplement)	10.2
Level 1 (1x supplement)	10.8
Level 2 (2x supplement)	10.7

- Are differences “real” or result of random chance?
- Compute a statistic called an “F-ratio”.
- F-ratio estimates probability of a “real” result.

# Price study overview

Three sites

One Cultured/Reference plot on each site

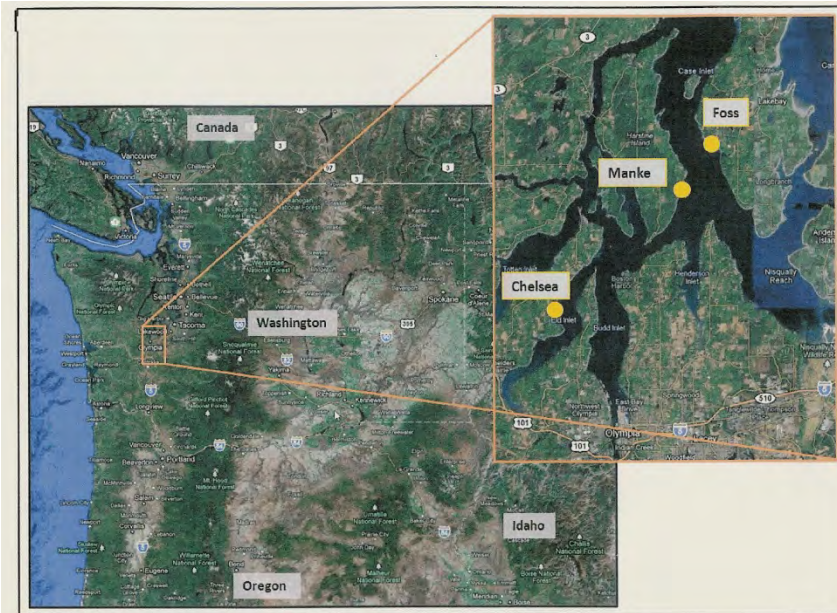


Figure 1.1. Location of study sites: Foss, Manke, and Chelsea.

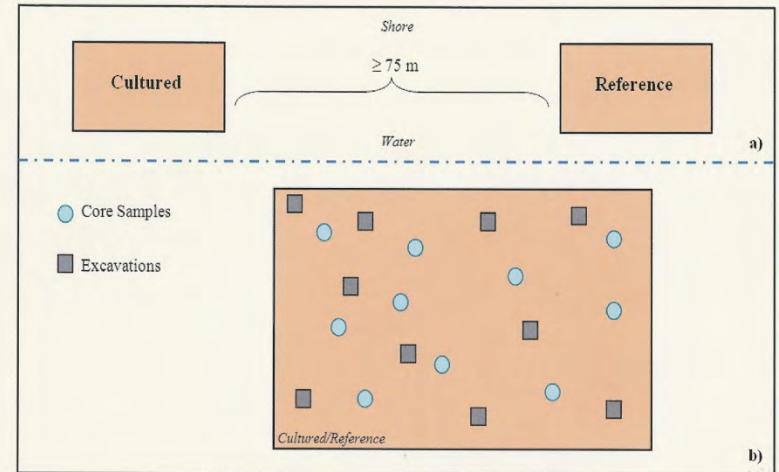


Figure 1.2. a) Relative layout of cultured and reference plots in the intertidal zone, b) sampling strategy within cultured and reference plots.



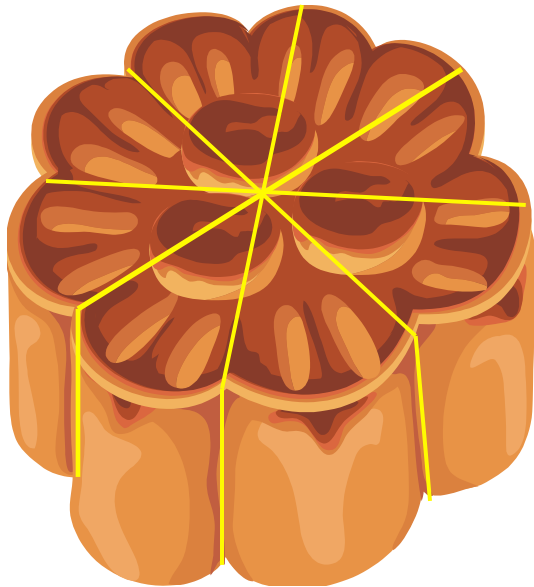
# So, what's the problem?

- The researchers failed to REPLICATE their treatments.
- Replication is the independent application of a treatment.

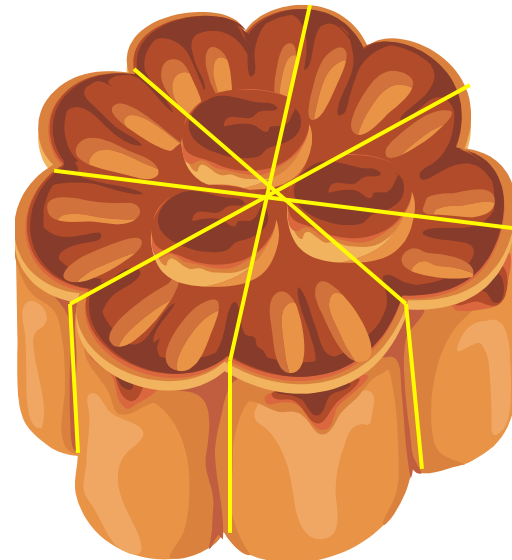
# How to identify replication in an experiment

# 1. Cake experiment

Betty Crocker



Brand X

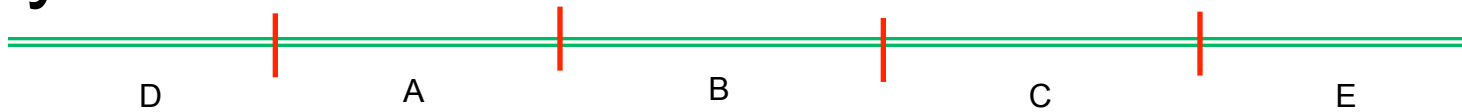


# 2. Row plot experiment

- Contr.



- Hybr. 1



- Hybr. 2

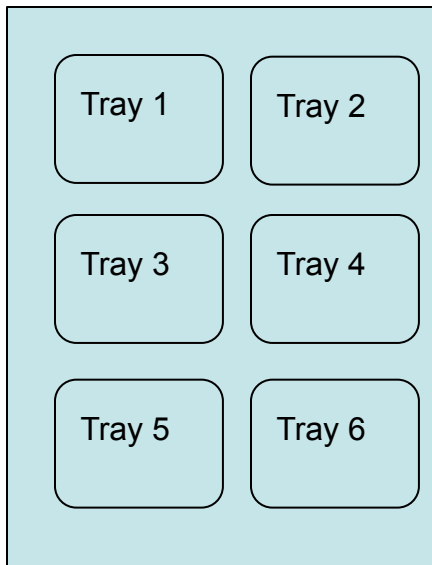


- Hybr. 3

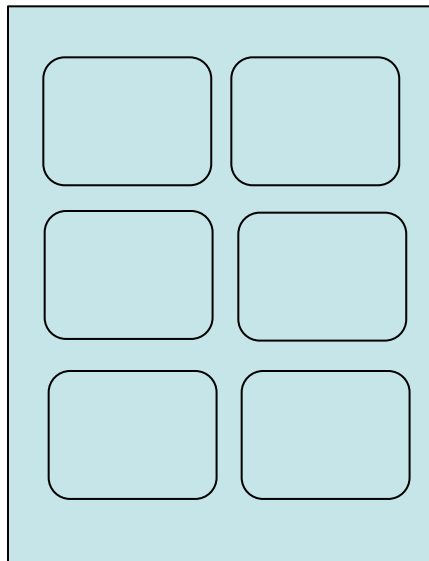


### 3. Controlled environment chamber experiment

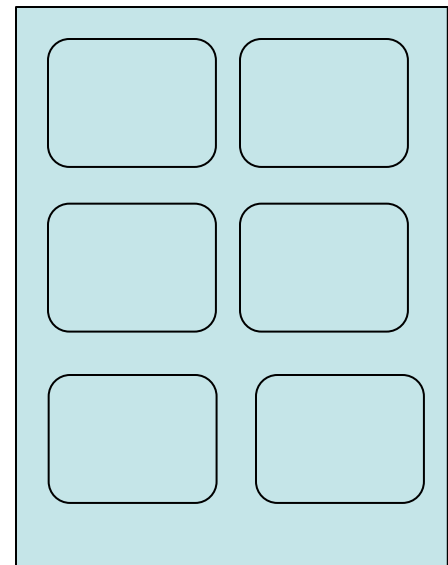
Control



Temp 1

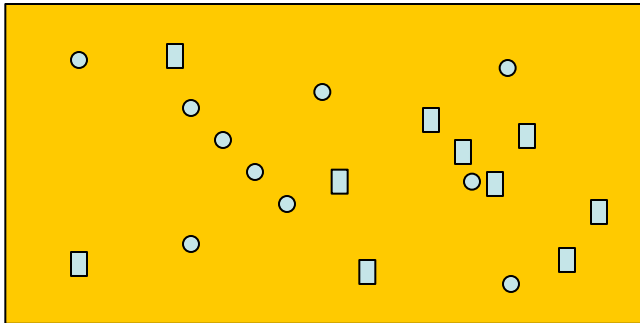


Temp 2



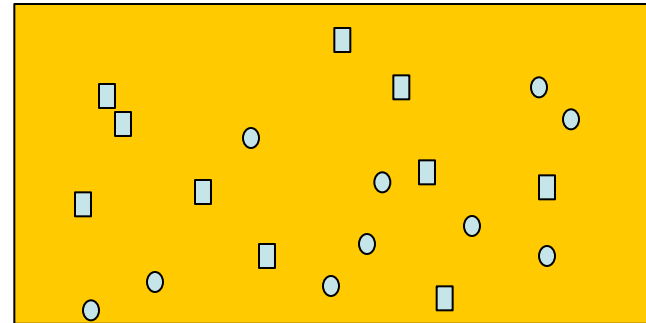
# Geoduck harvesting study

Cultured Plot



Buffer zone

Reference plot



# Why must a treatment be replicated?

- Without true replication you *cannot test for significance between treatments* because you cannot compute “error variance” necessary to test for statistical significance (Milliken and Johnson 1997\*).
- R.A. Fisher: “No one would...dream of testing the response to a treatment by comparing two plots, one treated and the other untreated.”
- George Milliken, Pers. Comm.: “it’ s is like going back to the same doctor for a second opinion.”

\*Milliken, G.A. and D.E. Johnson. 1997. Analysis of Messy Data: Vol. 1, Designed Experiments, Chapman and Hall, London, New York, 473 p.

# Lack of replication is a common statistical mistake

- I made this mistake early in my career with the Growth Chamber experiment I described earlier.
- I served for 25 years as a referee for nine scientific journals.
  - *Canadian Journal of Forest Research*
  - *Forest Science*
  - *New Forests*
  - *Journal of Tropical Forest Science*
  - *Scandinavian Journal of Forest Research*
  - *Annales des Sciences Forestieres*
  - *Western Journal of Applied Forestry*
  - *Tree Physiology*
  - *Annals of Botany*
- Lack of proper replication was the most common statistical problem I encountered.
- The ecological literature contains many examples of this mistake.



# Back to the Price study

- They had no replication on any of the three sites, hence they cannot make valid statistical comparisons between treatments at any site.
- But they had 3 sites:
  - Page 11: *“Because of site differences, each site was analyzed independently and the sites were not considered replicates.”*
  - So there is no replication either at the site or plot level.
- With no replication anywhere in the study, statistical significance cannot be computed and no conclusions can be drawn.

# Other concerns

Narrow scope of inference (moot)

- Three sites in SW Puget Sound would not seem to support the conclusion: “...the effects of geoduck harvest on the benthic community in Puget Sound are at most minimal.”

Lack of statistical power (moot)

- How big an effect were they looking for?
- How was size of the experiment determined?
- Not discussed in Price thesis.

Data quality control

- What measures were put into place to ensure that no data errors occurred?
- Not discussed in Price thesis.

# Summary and conclusions

- The Price thesis did not contain proper replication, so statistical tests conducted on the results are invalid.
- Even if the study had been properly replicated, the narrow scope of inference would not support Puget Sound-wide conclusions.
- In his verbal presentations and on the Sea Grant web site, Dr. VanBlaricom has emphasized that the results of the Price thesis have neither been peer reviewed nor published, hence they must not be cited.
- Unfortunately his admonitions have fallen on deaf ears.

# Rebuttal statement of Gary A. Ritchie, Ph.D.

## Shoreline Hearings Board Hearing, August 12, 2013

- In 1984 S.H. Hurlbert of San Diego State University published a classical and very influential paper in *Ecological Monographs* in which he coined the term “pseudoreplication”. He describes a simple type of pseudoreplication as follows: “The most common type of “controlled” experiment in field ecology involves a single “replicate” per treatment. This is neither surprising nor bad...What is objectionable is when the tentative conclusions derived from unreplicated treatments are given an unmerited veneer of rigor by the erroneous application of inferential statistics.” (pages 199-200). He then goes on to enumerate several types of experimental designs used in ecology that, according to his analysis, also fall under the label of pseudoreplication and therefore are not statistically valid.
- I read Hurlbert’s paper previous to my August 12, 2013 testimony and, while I used his term pseudoreplication in my PowerPoint, I did not cite his paper nor mention it in my testimony because it has become controversial.
- In his testimony, Dr. VanBlaricom cited three reports (Coss 2009, Oksanen 2001, and Schank and Koehnle 2009), all of which attack Hurlbert’s paper. Their shared complaint against Hurlbert has to do with his use of the word pseudoreplication to describe a broad range of situations in ecological research – situations that depart from a simple lack of replication. Schank and Koehnle argue that there are modern techniques for dealing with these issues statistically so these designs should not be rejected out of hand simply because they are lumped into a term Hurlbert calls “pseudoreplicates.”

# Rebuttal statement of Gary A. Ritchie, Ph.D. Shoreline Hearings Board Hearing, August 12, 2013 (continued)

- Their arguments for the most part seem clear and well-reasoned, so I would not quibble with them. An important point, however, is that they do not argue that it is appropriate to follow lack of replication with inferential statistics such as Analysis of Variance (ANOVA). In fact, they state: “If this is all Hurlbert (1984) intended then we can offer no substantial disagreement.” (page 421).
- My concern with the Price/ VanBlaricom study, regardless of whether or not they are guilty of some type of pseudoreplication, is that it is *totally devoid of any replication*. The ANOVA computations they made were, therefore, performed on sub-samples, not replicates, as Dr. VanBlaricom admitted in his testimony. This is an inappropriate analysis that results in an incorrect calculation of the error variance - a statistic necessary to compute the F ratio, which enables determination of the probability that the result of an experiment is “real” or could, alternatively, be a product of random chance. Lacking this information, they have no basis for drawing inferences regarding the results of the experiment - which they have done, and which is the central point of my criticism.
- This criticism is supported by the following assertion from Milliken and Johnson’s (1997) advanced statistics textbook, which I quoted at the hearing. “The most important aspect of a statistical analysis is to get a good estimate of the error variance... The error variance measures the accuracy of the experiment – the smaller the [error variance] the more accurate the experiment. One cannot make any statistically valid inferences in any experiment without some knowledge of the experimental error variance...But an estimate of the error variance cannot be obtained unless some or all of the treatments are replicated (my emphasis). A *replication* of a treatment is an independent observation of the treatment... Too often researchers use duplicate or split samples to generate two observations and call them replicates, when, in reality, they are actually subsamples or repeated measures. They certainly are not replicates.” (pages 3, 49). It’s the same as going back to the same Doctor for a second opinion.

Rebuttal statement of Gary A. Ritchie, Ph.D.  
Shoreline Hearings Board Hearing, August 12, 2013  
(continued)

- I suspect that the planners of the Price/VanBlaricom study were unaware of the problem with their experimental design, assuming that use of subsamples as replicates prior to ANOVA was appropriate. And that it was not until I had questioned their methodology that they became aware of this and scrambled to find support for their approach in the literature, leading to the discovery of the three papers listed above by Dr. VanBlaricom. In support of this contention I point out that none of the three papers was cited in the Price thesis nor did it contain any mention of the problem of lack of replication and how to reconcile it with their use of inferential statistics.

- References

- Coss, R.G. 2009. Pseudoreplication Conventions Are Testable Hypotheses. *Jour. Compar. Psychol.* 123(4): 444-446.
- Hurlbert. S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecol. Monogr.* 54(2): 187-211.
- Milliken, G.A. and D.E. Johnson. 1997. Analysis of Messy Data: Volume I Designed Experiments. Chapman and Hall, London, Weinheim, New York, Tokyo, Melbourne, Madras, 473 pages.
- Oksanen, L. 2001. Logic of experiments in ecology: is pseudoreplication a pseudoissue? *OIKOS, Copenhagen.* 94: 27-38.
- Shank, J.C. and T. J. Koehnle. 2009. Pseudoreplication is a Pseudoproblem. *Jour. Compar. Psychol.* 123(4): 421-433.

# CURRICULUM VITAE

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**Senior Scientist**  
**Weyerhaeuser Company**  
**Centralia, WA 98531**

(Rev. January 2004)

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## Education

- 1971: Doctor of Philosophy, Univ. of Washington
- 1966: Master of Forestry, Univ. of Washington
- 1964: Bachelor of Science (Wildlife Management.), Univ. of Georgia
- 1961: Associate in Arts, Valley Forge Military Academy, Wayne, PA
- 1959: Diploma, Upper Merion H.S., King of Prussia, Pennsylvania

## Thesis and Dissertation

Phenology and ontogeny of the reproductive and primary vegetative structures of *Abies amabilis* and *Abies procera*. Master of Forestry Thesis, University of Washington, 1966.

Transpiration, water potential and stomatal activity in relation to microclimate in *Abies amabilis* and *Abies procera* in a natural environment. Doctor of Philosophy Dissertation, University of Washington, 1971.

## Work Experience (Non-Weyerhaeuser)

**1976 - 1977**

**Congressional Science Fellow  
United States Senate**

Was one of four scientists from North America to be awarded a Congressional Science Fellowship by the American Association for the Advancement of Science (AAAS). As such, served as legislative assistant to U.S. Senator Pete V. Domenici, (R.- N.Mex.). In that capacity developed and oversaw legislative initiatives in areas of water resource and energy development, Veterans affairs, and American Indian affairs for Senator Domenici. Wrote speeches and floor testimony for Senator Domenici, handled constituent issues and correspondence and provided advice on scientific and technical matters (e.g. regulation of recombinant DNA research) for Senator Domenici. Organized and chaired a AAAS Symposium on New Agricultural Crops, edited and published proceedings as a book "New Agricultural Crops" (see page 10). Personally drafted two bills which, following introduction by Senator Domenici, ultimately became law: The "Native Latex Commercialization Act of 1978" and the "Water Resources Research and Development Act of 1977".

**1971 - 1973**

**1st Lt. U.S. Army**



### **Environmental Engineer**

Served two years with the Buffalo District, U.S.A. Corps of Engineers. Primary duty was to coordinate and write Environmental Impact Statements on a wide range of Corps projects including harbor maintenance, flood and erosion control, and upland dredge disposal facility construction. In two years wrote over 30 EISs and received Army Commendation Medal for meritorious service.

**1967 - 1971**

### **Pre-Doctoral Teaching Associate, Univ. of Washington**

Taught, or assisted teaching, courses in silviculture, forest ecology, and dendrology while working on Ph.D.

**1964 - 1966**

### **Research Associate, Univ. of Washington**

While working on Master's Degree assisted on various projects in College of Forest Resources. Some of the work, on phenology of two *Abies* species, led to fulfillment of Master of Forestry requirements.

# Weyerhaeuser Work Experience and Accomplishments

## 1986 - Present

### **Leader - Douglas-fir Rooted Cutting Team, Principal Investigator - Cone and Seed Biology, and Scientist - Taxol Team**

Provided leadership and coordination of team of biologists, engineers, operations researchers, region foresters and operational growers in developing and implementing use of Douglas-fir rooted cuttings as a new type of forest planting stock. Project began in 1986 and became operational in 1990. Currently approximately 5 million rooted cuttings are in various stages of production. This technology will enable Weyerhaeuser to produce as much planting stock as needed from our most elite genetic families.

To accomplish this, several significant technical hurdles had to be overcome by the Team. These included developing protocols for growing Douglas-fir seedlings (stock plants) to a height of 4 to 5 feet in one year by management of photoperiod, temperature, nutrition, and growing densities; developing optimum environments and procedures for rooting Douglas-fir cuttings - one of the more difficult conifers to root; developing an empirical understanding of the relationships between the timing of harvest and the duration of cold storage to maximize rooting and root system quality; engineering and implementing a system for handling and nursery transplanting of this new stock type; developing and implementing a process-based cost model used to estimate crop-production costs and to guide research to high-leverage opportunities. During this process, traveled extensively and became expert in rooted cutting technologies worldwide.

Became part of the Taxol Team in 1992. Assisted in adopting Douglas-fir rooting technology to *Taxus* crops. Conceived and installed several experiments aimed at improving propagation efficiency of *Taxus* rooted cuttings.

During 1993, undertook studies in support of Weyerhaeuser western seed orchards. Studies involve understanding maturation biology of Douglas-fir female cones at family level toward developing operational guidelines for harvesting and after-ripening cones and evaluating performance of wind machines in prevention of late spring frost damage.

## 1980 - 1985

### **Project Leader - Tissue Culture: Rooting and Evaluation**

Led and conducted research on development of aspects of tissue culture technology for Douglas-fir and loblolly pine. Developed techniques for rooting tissue culture-produced shoots in large quantities. Explored and perfected combination of hormone and environmental conditioning of shoots to maximize rooting potential. Developed procedures for nursery production of tissue culture plantlets to circumvent the problem of "plagiotropic" growth. This program met with a high degree of biological success as evidenced by 6 large field trials of Douglas-fir plantlets containing approximately 20

thousand plants - the largest test of its kind in the world. Gained international reputation through publication of aspects of this work.

**1977 - 1980**

**Project Leader - Seedling Physiology**

Developed seedling physiological knowledge base leading to successful implementation of freezer storage technology at Weyerhaeuser western forest nurseries and Weyerhaeuser Canada. This technology enables seedlings to be stored successfully for several months between winter lifting and spring planting and replaces the more costly and less successful containerized seedling production practices. The technology is based on an understanding of the dormancy physiology of Douglas-fir which was developed during the conduct of this research program. The worldwide acceptance of this work is evidenced by its publication in international refereed journals.

Developed a basic biological understanding of Root Growth Potential (RGP), what controls it and how it can be managed in the nursery. Disproved the popular theory that RGP depends upon the level of reserve carbohydrates stored in the root system. - Developed and published the hypothesis that RGP is controlled by the dormancy status of the plant and its interaction with carbon source-sink relationships between the root and shoot system within the plant. This work was published in refereed journals.

Pioneered and helped implement seedling physiological testing protocols currently used by Seedling Testing Business integrating Root Growth Potential, Cold Hardiness and Stress Resistance. Also conceived and published empirical seedling quality model based upon dormancy physiology and nursery chilling accumulation. This model is still in use by Weyerhaeuser and has been adopted by U.S. Forest Service Nurseries and certain nurseries in British Columbia. It enables lifting and storage decisions to be coordinated with the physiology of the seedling, providing a high degree of certainty regarding the outcome of regeneration activities. Received Weyerhaeuser Achievement Award for this work.

**1975 - 1976**

**Forestry and Raw Materials Strategic Planner**

Served as Strategic Planner for Forestry and Raw Materials R&D. Conducted financial analyses for 10 key research programs. Results of these analyses led to division funding decisions. Helped formulate technology plans and forecasts involving approximately \$7 million annual budget expenditures and more than 30 scientist-years (this, before spreadsheets were invented). Tracked R&E expenses against plan. Interfaced with planners from Fiber, Wood Products and Diversified Business to help coordinate overall Division activities. Also identified and evaluated potential research opportunity areas for Director (G. Staebler).

**1973 - 1974**

**Environmental Impact Analyst**

Developed environmental assessments and wrote Environmental Impact Statements (EIS) for Weyerhaeuser capital projects including Everett Sulfite Mill conversion, Valliant Mill Modifications, and Weyerhaeuser Technology Center. Work involved close coordination with engineering and business teams, consultants, environmental organizations, local municipalities and attorneys to identify all feasible project alternatives, evaluate environmental impacts of alternatives, and outline mitigation measures. Governmental approval of EIS was prerequisite to project implementation.

## **In-Company Training**

1996: Industrial First Aid and CPR re-certification

1995: Microsoft Access Level 2

1995: Microsoft Access Level 3

1995: Microsoft Access Level 4

1995: Mind mapping

1995: Information Mapping

1995: Microsoft PowerPoint

1995: Microsoft Excel

1994: Microsoft Access level 1

- 1993: SAS Programming; Introduction to EXCEL
- 1992: First Aid and CPR re-certification; Total Quality
- 1991: Introduction to Paradox; Total Quality
- 1990: Experimental Design and Analysis II
- 1989: Experimental Design and Analysis I
- 1988: Hard Disk Management
- 1987: Introduction to VAX

- 1984: First Aid and CPR and re-certification
- 1983: Management Skills Training
- 1983: SAS on the VAX computer
- 1982: PS<sup>2</sup>
- 1975: Strategy of Experimentation
- 1975: Business Mgt. Economics Financial Analysis
- 1973: Conference Leadership

## Refereed Publications

**Note: Since 1980 have received 460 requests for reprints of these -  
publications from 37 countries.**

1. **JERNSTAD, K.D., D.L. BASSONI, K.S. JECH, G.A. RITCHIE, N.C. WHEELER AND D.B. NEALE. 2003.** Mapping of quantitative trait loci controlling adaptive traits in coastal Douglas-fir: Quantitative trait loci-by-environment interactions. *Genetics* 165:1489-1506.  
(Awarded “Certificate of Merit”, U.S. Dept. of Agriculture, Pacific Southwest Research Station. October 2004).
2. **LI, M. AND G.A. RITCHIE. 1999.** Eight hundred years of clonal forestry in China I. Traditional afforestation with Chinese fir (*Cunninghamia lanceolata* (Lamb.) Hook.). *New Forests* 18:143-159.
3. **LI, M. AND G.A. RITCHIE. 1999.** Eight hundred years of clonal forestry in China: II; Mass production of rooted cuttings of Chinese fir (*Cunninghamia lanceolata* (Lamb.) Hook.). *New Forests* 18:160-175.
4. **RITCHIE, G.A. 1997.** Effects of shade and root confinement on the expression of plagiotropic growth in juvenile-origin Douglas-fir rooted cuttings. *Can. J. For. Res.* 27:1142-1145.
5. **RITCHIE, G.A. 1997.** Evidence for red:far red signaling and photomorphogenic growth response in Douglas-fir (*Pseudotsuga menziesii*) seedlings. *Tree Physiol.* 17:161-168.
6. **SIMPSON, D.G. AND G.A. RITCHIE. 1996.** Does RGP predict field performance? a debate. *New Forests* (13:253-277).

7. **RITCHIE, G.A. 1994.** Commercial application of adventitious rooting to forestry. pp 37-52 In: Biology of adventitious root formation, Ed. T.D. Davis and B.E.Haassig, Plenum Press, NY.
8. **RITCHIE, G.A., AND J. W. KEELEY. 1994.** Maturation in Douglas-fir: I. Changes in stem, branch and foliage characteristics associated with ontogenetic aging. *Tree Physiology* 14:1245-1259.
9. **RITCHIE, G.A., S.D. DUKE, AND R. TIMMIS. 1994.** Maturation in Douglas-fir, II. Maturation characteristics of genetically matched Douglas-fir seedlings, rooted cuttings and tissue culture plantlets during and after 5 years of field growth. *Tree Physiology* 14:1261-1275.
10. **RITCHIE, G.A., Y. TANAKA, R. MEADE, AND S.D. DUKE. 1993.** Field survival and early height growth of Douglas-fir rooted cuttings: relationship to stem diameter and root system quality. *Forest Ecology and Management* 60:237-256.
11. **TIMMIS, R., G.A. RITCHIE, AND G.S. PULLMAN. 1992.** Age- and position-of-origin and rootstock effects in Douglas-fir plantlet growth and plagiotropism. *Plant, Cell and Organ Culture* 29: 179-186.
12. **RITCHIE, G.A. 1991.** The commercial use of conifer rooted cuttings in forestry: A world overview. *New Forests* 5:247-275.
13. **RITCHIE, G.A., Y. TANAKA AND S. DUKE. 1991.** Physiology and morphology of Douglas-fir rooted cuttings compared to seedlings and transplants. *Tree Physiology* 10: 179-194.
14. **RITCHIE, G.A. 1990.** A rapid method for detecting cold injury in conifer seedling root systems. *Can. J. For. Res.* 20:26-30.
15. **RITCHIE, G.A. 1989.** Integrated growing schedules for achieving physiological uniformity in coniferous planting stock. *Forestry* 62:213-227.
16. **RITCHIE, G.A. 1986.** Relationships between bud dormancy status, cold hardiness, and stress resistance in 2+0 Douglas-fir. *New Forests* 1:29-42.
17. **RITCHIE, G.A. AND J.R. RODEN. 1985.** Comparison between two methods of generating pressure-volume curves. *Plant, Cell & Environment.* 8:49-53.
18. **RITCHIE, G.A., J.R. RODEN AND N. KLEYN. 1985.** Physiological quality of lodgepole pine and interior spruce seedlings: effect of lift date and duration of freezer storage. *Can. Jour. For. Res.* 15: 636-645.
19. **RITCHIE, G.A. 1984.** Effect of freezer storage on bud dormancy release in Douglas-fir seedlings. *Can. Jour. For. Res.* 14:186-190.

20. RITCHIE, G.A. AND R.G. SHULA. 1984. Seasonal changes in tissue-water relations in shoots and root systems of Douglas-fir. *Forest Science* 30:538-548.
21. RITCHIE, G.A. 1982. Carbohydrate reserves and root growth potential in Douglas-fir seedlings before and after cold storage. *Can. Jour. For. Res.* 12:905-912.
22. RITCHIE, G.A., AND J.R. DUNLAP. 1980. Root growth potential: its development and expression in forest tree seedlings. *New Zeal. Jour. For. Sci.* 10:218-248.
23. RITCHIE, G.A., AND T.M. HINCKLEY\*. 1975. The pressure chamber as an instrument for ecological research. *Adv. Ecol. Res.* 9:165-253.
  - a. \*(Awarded "Citation Classic"; Current Contents, Institute for Scientific Information, February 5, 1990. Article has been cited in over 400 publications).
24. RITCHIE, G.A. AND T.M. HINCKLEY. 1971. Evidence for error in pressure-bomb estimates of stem xylem potentials. *Ecology* 52:534-536.
25. FRANKLIN, J.F. AND G. A. RITCHIE. 1970. Phenology of cone and shoot development of noble fir and some associated true firs. *Forest Science* 16:356-364.
26. HINCKLEY, T.M. AND G.A. RITCHIE. 1970. Within-crown patterns of transpiration, water stress, and stomatal activity in *Abies amabilis*. *Forest Science* 16:490-492.
27. RITCHIE, G.A. 1969. Cuvette temperatures and transpiration rates. *Ecology* 50:667-670.

## Books

- RITCHIE, G.A. (Editor) **New Agricultural Crops**. Westview Press, Boulder, CO, 259 p, 1979.
- BALLARD, R., P. FARNUM, G.A. RITCHIE, AND J.K. WINJUM (Editors). **Forest Potentials: Productivity and Value**. Weyerhaeuser Science Symposium 4. 301 p, 1985.
- RITCHIE, G.A. 1991. Measuring cold hardiness. In: **Techniques and Approaches in Forest Tree Ecophysiology**, J.P. Lassoie and T.M. Hinckley (Eds.), CRC Press, Boca Raton, FL p 557-582.

**TALBERT, C.B., G.A. RITCHIE, AND P. GUPTA.** 1993. Conifer vegetative propagation: an overview from a commercialization perspective. In: **Clonal Forestry: Genetics, Biotechnology and Application**, R. Ahuja and W. Libby (Eds.), Springer-Verlag.



## Invited Papers

**Ritchie, G.A. 1995** Plant propagators to the rescue! Proc. Thirty-sixth annual meeting - Western Region, Int'l. Plant Propagators' Society, Portland, OR. Sept 13-16, 1995.

**LAMBETH, C.C., G. A. RITCHIE, AND B. STANTON. 1994.** Applied vegetative propagation programs in forestry. In: Proc. Southern Regional Information Exchange Group Biennial Symposium on Forest Genetics, G.S. Foster and A. M. Diner (eds.), 8-10 July, 1992, Huntsville, Ala., Southern Forest Experiment Sta., New Orleans, La., pp 123-136.

**RITCHIE, G.A. 1993.** The commercial application of adventitious rooting to forestry. In: Proc. First International Symposium on the Biology of Adventitious Root Formation. Dallas, TX, April, 1993.

**RITCHIE, G.A. AND Y. TANAKA. 1990.** Root growth potential and the target seedling. In: Target Seedling Symposium, R.Rose, S.J.Campbell and T.D. Landis, (Eds.), U.S.F.S. Gen. Tech. Rep.RM-200, 37-52.

**RITCHIE, G. A. 1989.** Integrated growing schedules for achieving physiological uniformity in coniferous planting stock. *Forestry* 62:213-227.

**RITCHIE, G.A. 1988.** Putting it all together: the challenge of Mt. Saint Helens. In: Taking Stock: The role of Nursery Practice in Forest Renewal. Ontario For. Res. Council Proc., O-P-16, p 86-90.

**RITCHIE, G.A. 1987.** Some effects of cold storage on seedling physiology. *Tree Planter's Notes* 38:11-15.

**RITCHIE, G.A. 1985.** Root growth potential: principles, procedures and predictive ability. In: Evaluating Seedling Quality: Principles, Procedures and Predictive Abilities of Major Tests, M.L. Duryea (Ed.), For. Res. Lab., Oregon State Univ., Corvallis, 93-105.

**RITCHIE, G.A. 1984.** Assessing seedling quality. In: Forest Nursery Manual: Production of Bareroot Seedlings, M.L. Duryea and T.D. Landis (Eds.), Martinus Nijhoff\Dr. Junk, The Hague, p243-259.

## **Weyerhaeuser Technical Reports**

One hundred fifty-one Weyerhaeuser internal Technical Reports. Not listed owing to their proprietary nature.

### **Professional Affiliations**

- Member, Society of American Foresters
- Member, International Plant Propagators' Society
- Full member, Sigma Xi (Scientific Research Honorary)
- Member, Xi Sigma Pi (Forestry Honorary)
- Member, Phi Kappa Phi (Scholastic Honorary)
- Member, Gamma Sigma Delta (Scholastic Honorary)

### **Honors and Awards**

- Awarded Army Commendation Medal (1973)
- Awarded Congressional Science Fellowship by AAAS (1976)
- Awarded "Citation Classic" by Institute for Scientific Information, Philadelphia, PA 1990, for an article published in 1975 (see page 10).
- Awarded Weyerhaeuser Fellowship (1966-1967)
- Awarded St. Regis Co. Scholarship (1963)

## Weyerhaeuser Commendations

- Achievement award for contributions to seedling quality, presented by Don Rush, 1984.
- [ Achievement award for contributions to Douglas-fir rooted cutting technology presented by Rex McCullough, 1989.
- [ Stage 1 and Stage 2 Innovator's Commendations (Making It Happen) Awards presented by Norm Johnson and Ed Soule in 1989.
- [ Weyerhaeuser Western Regeneration Special Recognition Award, 1993, for contributions to Seedling Testing Business.
- [ Weyerhaeuser Western Regeneration Special Recognition Award, 1994, For leadership in Douglas-fir Rooted Cutting Project (included stock options).

## Professional Service

- [ Served as Affiliate Full Professor of Forest Resources, University of Washington (awarded 1984)
- Served on editorial board of international journal *New Forests*
- Served on editorial board of international journal *Tree Physiology*
- Served as referee for following journals (refereed approximately 30 scientific papers during this time):
  - [ *Forest Science*
  - [ *Canadian Journal of Forest Research*
  - [ *New Forests*
  - [ *Journal of Tropical Forest Science*
  - [ *Scandinavian Journal of Forest Research*
  - [ *Annales des Sciences Forestieres*
  - [ *Western Journal of Applied Forestry*
  - [ *Tree Physiology*
  - [ *Annals of Botany*
- Served as evaluation officer for:
  - U.S.D.A. Competitive Grants
  - Natural Science and Engineering Council of Canada, Operating Grants
  - Science Council of British Columbia

- Served as instructor: "Silviculture Institute" University of Washington (since 1980)
- Served as instructor: "Silviculture Institute of British Columbia" (1986)

## **Professional Speaking Invitations**

- [ Invited speaker: Workshop, Northwest Tree Improvement Cooperative, Dept. of Forest Science, Oregon State Univ., November 14, 2001.
- [ Invited Speaker: Western Forest and Conservation Nursery Association meeting, Salem, Oregon, August 20-23, 1996.
- [ Keynote Speaker: International Plant Propagators' Society, Western Region Meeting, Portland Oregon, September 13-16, 1995.
- [ Keynote Speaker: I.U.F.R.O. Conference: "Making the Grade; An International Symposium on Planting Stock Performance and Quality Assessment", Sault Ste. Marie, Ontario, September, 1994.
- [ Keynote Speaker: "First International Symposium on the Biology of Adventitious Root Formation", Dallas, Texas, April, 1993.
- [ Invited speaker: "Target Seedling Symposium", Western Forest Nursery Association Conference, Roseburg, OR, August 1990.
- [ Keynote speaker: I.U.F.R.O. International Conference: "Producing Uniform Planting Stock", York, England, September, 1988.
- [ Invited speaker: 10th North American Forest Biology Workshop, Vancouver, B.C., July, 1988.
- [ Wrap-up speaker: "Taking Stock: Ontario Forest Research Council Symposium", Timmins Lake, Ontario, September, 1987.
- [ Invited speaker: Western Forest Nursery Council Meeting, Tumwater, WA, August, 1986.
- [ Conference Moderator: Cold Hardiness and Phenology, In: "Techniques and Approaches in Forest Tree Ecophysiology," Cornell University, August, 1986.
- [ Invited speaker: Symposium on Evaluating Seedling Quality, Oregon State University, October, 1985.
- [ Invited speaker: Forest Nursery Symposium, Oregon State University, October, 1983.

