THE PSEUDOSCIENCE OF LAND SEARCH PROBABILITY THEORIES

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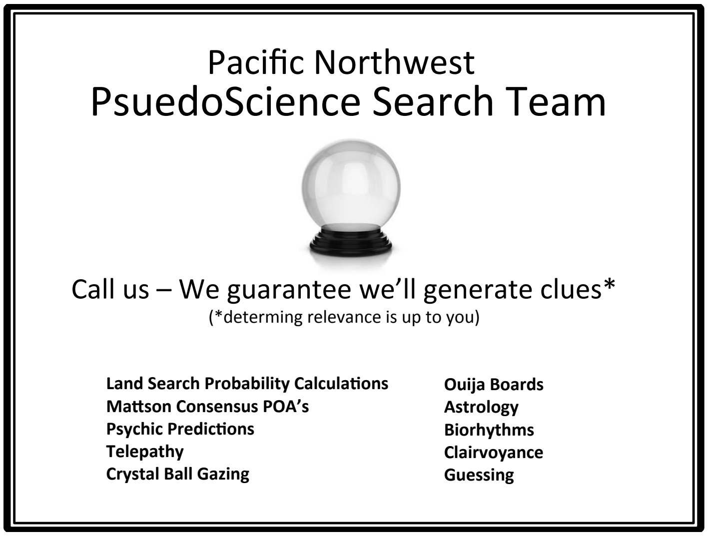

Introduction

Wikipedia defines pseudoscience as "*a claim, belief, or practice which is presented as scientific, but does not adhere to a valid scientific method, lacks supporting evidence or plausibility, cannot be reliably tested, or otherwise lacks scientific status. Pseudoscience is often characterized by the use of vague, exaggerated or unprovable claims, an over-reliance on confirmation rather than rigorous attempts at refutation, a lack of openness to evaluation by other experts, and a general absence of systematic processes to rationally develop theories*" (see http://en.wikipedia.org/wiki/Pseudoscience).

Over the past three decades proposals and debates regarding various land search probability theories and ideas have appeared in training curricula and papers to the degree there seems to be a belief that probability mathematics are essential and necessary tools for resolving missing person reports. This paper questions that assumption, contends that many of the land search probability theories and debates reflect pseudoscience, and asserts that strict adherence to the maritime search probability model isn't appropriate for land search.

Thumbnail History

The use of probability as a search planning aid was broadly introduced to the land search community in the 1970's through the Managing the Search Function curriculum. That course taught the formula POA x POD = POS: with POD being the acronym for "Probability of Detection", POA for "Probability of Area", and POS for "Probability of Success". The concept was adapted from methodology originated by the U.S. Navy and subsequently expanded by the U.S. Coast Guard for locating vessels and other objects at sea. Today the POA x POD = POS formula remains a foundation of land search probability theory.

This land search probability theory involves dividing a search area into subunits, assigning a POA to each, and individually searching each with resource(s) whose effort(s) supposedly can be quantified. This quantification is called POD. Theoretically, the product of a subunit's POA multiplied by the POD of a search effort generates a POS that can then be compared with other subunit POS's, allowing prioritization of subunits for future efforts, and/or providing a quantifiable rationale for ceasing search efforts.

Associated with the formula POA x POD = POS are concepts such as shifting POA (POAshift), cumulative POD (PODcum) and Probability of Density (PDEN).

POAshift attempts to quantify the logic that upon being searched with a POD effort, the original POA of that subunit decreases, and the decrease moves to the other subunits. The distribution of the decrease is proportional to the percentage of POA in each of the other subunits. There is disagreement on the proper manner to calculate POAshift (see www.sarinfo.bc.ca/Library/Planning/Adjustmentof**POA**.doc).

PODcum combines the POD's of multiple subunit search efforts (see www.sarinfo.bc.ca/sartechnology/POD_Calculator.htm).

PDEN standardizes the POA of a subunit for purposes of prioritization of resource allocation in comparison with other subunits, by dividing the subunit's POA by the subunit's size (acreage, square meters, square feet, etc.).

POA

There are two different uses of the term "Probability of Area" in land search. The first is POA developed from analyzing the behavior of subjects of past missing person incidents. The second is POA generated through a "Mattson Consensus" or "Consensus" exercise.

POA based on Subject Behavior Statistics

This is the probability that a specific missing person will behave in certain ways, based on analyzing previous incidents involving persons of similar age and/or activity. This is commonly called "lost subject behavior statistics" (but more properly should be called "missing subject behavior statistics"). These statistics provide estimates such as the probability of the subject being within "x" distance of his/her last known location. Lost subject behavior statistics have been compiled and published since the 1970's. While individually some have been subject to criticism related to sample size, veracity of data, or methodology, the concept appears to be broadly accepted.

This POA is misapplied when it is used - as has been traditionally taught - to establish the boundaries of a search area. This traditional method has four steps: determining theoretical search area, selecting a subject behavior statistical zone, conducting a terrain analysis ("deductive"), and finally subjectively selecting an area. The region where these four zones overlap becomes the established search area.

Step 1: Theoretical

The radius of a circle defining the theoretical search area is calculated by multiplying the estimated speed of the subject by the time missing. This step assumes the subject can indefinitely travel any direction in a straight line at a steady speed. Such assumption results in an unnecessarily large search area which the next three steps attempt to mitigate.

Step 2: Statistical
The statistical zone is selected from the lost subject behavior data. It may be the 10% zone, the 100% zone, or something in between.

Step 3: Terrain Analysis (Deductive)
Areas are eliminated that are unlikely to contain the subject due to topography, subject information, or other factors.

Step 4: Subjective
The person(s) establishing the search area eliminate areas they feel aren't important.

This traditional method has flaws, with the ones germane to this discussion being in Steps 2 & 4. Step 2 requires compromise if the probability zone selected is less than 100%, which normally is necessary as the 100% zone is usually very large. Step 4 results in subjective elimination of some portion of area, which further sacrifices POA.

Steps 2 & 4 thus contribute to the establishment of a search area with a degraded and unknown POA. (Reference the <u>Search Management Systems Workbook</u> if interested in an alternative method for determining the search area that strives to avoid the above flaws.)

<u>POA Based on Mattson Consensus</u>

The second use of the term POA in land search assigns a quantitative value to subunits of the established search area. This involves dividing the search area defined by the process described above into subunits commonly called segments: areas with homogeneous features, boundaries visible on the ground, and small enough to be area (grid) searched in one effort (shift) by any of the different resources deployed on the incident. Thus the segments must be relatively small. An established search area for a missing person in an outdoor setting may need to be divided into 30 or more such segments.

The next step is to convene a group and have each member individually assign a value to each segment, each such value reflecting that individual's belief as to the likelihood of the particular segment containing the target. The individual values for each segment are then combined, and converted to percentages. The land search community knows this procedure as the "Mattson Consensus".

Mattson Consensus isn't a consensus, nor does it produce a probability of the target's location. The only consensus is participant consent to accept the result. What it actually produces is an averaged opinion of subjective outputs. You might argue that the more informed a person is the more likely he/she will be to assign values based on objective criteria. But reference the instructions for use of the <u>Computer Aided Search Information Exchange III (C.A.S.I.E. III)</u> software application which is designed to calculate Mattson POA's and cumulative POD's. It states "*This should be done only once at the beginning of a search.*"

The subjective outputs described above are then assigned to each segment as POA's. Imagine 100% being distributed as subjective POA's among 30 or more segments. The numerical difference between most if not all the segments will be statistically insignificant.

These subjective POA's serve as the POA's for both the POA x POD = POS and the POAshift calculations.

POD

Probability of Detection as used in land search is the quantification of the thoroughness of a search effort, such as "50% chance of discovering the target, if the target was in the segment".

The resource conducting the search effort estimates POD, usually based on subjective opinion. An exception to relying on subjective opinion is a handful of studies that have calculated the POD for specific resources under very specific conditions (such as Mountain Searches: Effectiveness of Helicopters in which the authors report the POD's of the 37th ARRS, USAF in experimental searches over certain Arizona desert and mountain terrain).

Another exception (applicable to grid searchers but not aircraft, canines, or other resources) is a practical and easy to apply technique titled Critical Separation, originally described by Dave Perkins and Pete Roberts in 1989 and most recently refined by Perkins in 2011, which when properly applied generates a POD of 72-87%.

In 2002 Robe and Frost presented a report to the National Search and Rescue Committee (see www.uscg.mil/hq/cg5/cg534/nsarc/LandSweepWidthDemoReportFinal.pdf) in which they proposed a procedure for determining ground searcher POD for grid searching. The document was produced by the Potomac Management Group, a for-profit business under contract with the U.S. Coast Guard. The authors' biographies indicate experience in theoretical mathematics and maritime search, but not with land search. The authors claim their proposed procedure is simple, practical, and low cost. It essentially involves placing items in an area with features identical to the area to be searched, and having individuals search through the area to locate the items. The number of items located is then entered into calculations to produce POD's. This procedure hasn't had widespread implementation, probably because of the almost infinite number of variables (team member competency; weather; vegetation type; foliage condition; weather; light conditions; texture, size, color of clues; mobility and responsiveness of subject; etc.). Even if this proposal was widely implemented there is no assurance the results would meet scientific standards as the report was neither peer nor professionally reviewed.

In summary, other than narrow exceptions such as described above, POD's are subjective guesses rather than scientifically based.

ROW

One of the early issues regarding the adoption of the maritime methodology for land search of missing persons is that the maritime methodology didn't consider the possibility that the target of a land search might be outside the established search area. John Bownds, a professor of mathematics at the University of Arizona, suggested also considering the Rest Of the World (ROW) when conducting a Mattson Consensus (see Dougher, Hugh, et al. Applying Shifting POA: A New Concept in Search Mgmt. NASAR Conference Proceedings. 1983). Land search probability theorists commonly refer to the maritime model as a "closed" system, and the Bownds model with ROW as an "open" system. Debates between open system and closed system proponents are ongoing (see page 83 and Appendix B of http://www.uscg.mil/hq/cg5/cg534/nsarc/LandSearchMethodsReview.pdf).

GOA x GOD = GOS

Given that POA in land search is a subjective value generated first in search area establishment and then compounded by the Mattson Consensus, and most land search POD's are subjective searcher guesses, the product (POS) and derivatives (POAshift and PODcum) are therefore also subjective. For land search, the formula POA x POD = POS might be better expressed as GOA x GOD = GOS where GOA is the "Guess of Area", GOD is the "Guess of Detection", and GOS is the "Guess of Success".

Observations

1. Land Search Probability Theory is Flawed

   The 177-page Compatibility of Land SAR Procedures with Search Theory is a fairly comprehensive litany of criticisms targeted at land search probability theory documents which have been written over the past couple decades. The report (and related papers by those authors) has generated considerable discussion as to the validity and relevance of land search theory documents (for example, see http://www.newsar.org/controlandsar.pdf, and http://www.newsar.org/ContrTopicsFEB04bc.pdf).

   The same for-profit company as the earlier referenced Land Sweep Width document produced the report. Two of the three authors are the same as for that document. Author credentials are unstated. The report's abstract claims its intent is *"… identify which procedures* [being advocated in land search literature] *are compatible with the application of formal* [maritime] *search theory to land search, …"* (see http://www.uscg.mil/hq/cg5/cg534/nsarc/LandSearchMethodsReview.pdf).
   The report fails to directly address this intent, but rather focuses in detail on the authors' opinions as to the theoretical mathematical weaknesses, mistakes, and misperceptions they found in documents related to land search theory. They recommend:
   1. Developing a standard methodology for land search planning.
   2. Refining and validating the procedures for establishing land sweep width values.
   3. Performing sweep width experiments for the land SAR environment.
   3. Developing computer-based search planning decision support tools for land SAR.
   4. Developing improved resources allocation guidance for area land searches.
   5. Improving procedures for estimating POD on land.

   The report was not peer reviewed.

   While the reader of that document might not agree with every conclusion postulated by the authors; may sense a lack of understanding of incident/search management processes (such as confusing incident objectives with team assignments, not understanding the importance of clues and hasty searching, and ignoring the guiding principle of the land search crucial "Grid search as a last resort"), may question the presentation of unsubstantiated opinions as facts (accepting beliefs and speculation obtained through personal communications), and may suspect that the recommendations were crafted to set the stage for further contracts for the for-profit business, the sheer number of alleged weaknesses, mistakes, and misperceptions cataloged is a compelling argument that at least some documents related to land search theory have mathematical flaws, and therefore as a body of knowledge land search probability theories reflect at least some level of pseudoscience.

2. There is no scientifically valid evidence that the maritime model applies to the land search environment.
The assumption (www.uscg.mil/hq/cg5/cg534/nsarc/**LandSweepWidth**DemoReportFinal.pdf) and assertion (http://www.newsar.org/ContrTopicsFEB04bc.pdf) that the maritime model as adapted from the U.S. Coast Guard is applicable and/or important to land search for missing persons lacks scientific validity. There are obvious and significant differences between searching for an object floating on or in a homogenous body of water, and a person wandering in a heterogeneous land environment where vegetation, terrain, and other factors influence target movement and/or detectability much differently. Secondly, there are fewer variables influencing a waterborne target's direction and rate of travel (wind, current, tide for items adrift, and maximum speed for vessels under power), than for a human lost and wandering on land. Third, clue frequency, distribution, and variety is much different. Fourth, detectability of a waterborne target can arguably be predicted with greater accuracy as the resources (essentially military and Coast Guard aircraft and vessels) are less diverse, and their POD's have been determined through extensive study (see page 5 of above referenced report). Fifth, land search employs strategies not common in maritime search (investigation, containment, hasty search, attraction, sign cutting, subject behavior statistics, resource diversity, etc.). Sixth, maritime resources can be controlled more precisely (compare a plane flying along a predetermined route at a predetermined height and speed over a homogeneous ocean surface, with a search dog or ground team working through a rugged canyon). Finally, land search is fundamentally different from maritime search in that land search is a component of a law enforcement missing person investigation. Whether these differences are significant enough to impact the relevance of the maritime mathematical probability model for land search has not been scientifically explored.

3. Absence of Evidence (or Even Allegations) that Current Land Search Practices are Deficient
The authors of Compatibility of Land SAR Procedures with Search Theory did not investigate and make no claim as to whether or to what extent agencies, incident commanders, and searchers involved in land search are aware of, subscribe to, and/or practice any of the theories criticized. Nor whether the publication of such documents over a period of three decades has in any way negatively impacted land search efforts.

4. Failure of Formal Probability Theorists to Understand the Search Crucials
Authors of documents advocating strict adherence to formal probability theory in the land search environment have failed to consider that land search is based on a set of "search crucials". One of these crucials is "Search for clues, not the subject" (perhaps it would be better stated as "Search for clues, and the subject"). Another crucial is "Grid search as a last resort". (The application of formal probability theory requires grid searching – systematically searching a subunit of the search area to produce a POD that can be entered into calculations to determine cumulative POD, shifting POA, and POS. Hasty searching – a quick peek into a subunit to try to locate a clue or subject or investigate specific locations –

doesn't provide POD's that can entered into those calculations [unless of course the specific route of the hasty team is delineated as a very narrow and small subunit]).

Land search is driven by another search crucial "Search is an emergency" and prioritizes the saving of life over finding the subject. Efforts are often focused on resolving scenarios in which the subject may be at risk, rather than trying to locate someone who may be wandering but not a risk, not lost but overdue, or other low risk scenarios.

Grid searching is time and resource intensive, often impractical in a reasonable period of time due to the extent of the search area, and less effective in saving life than hasty search strategies.

5. Relevance of Formal Mathematical Probability Calculations

I was employed by the National Park Service for 34 years, and as such was involved in SAR as a ranger, park SAR coordinator, special agent, plans section chief and incident commander on Type I all-hazard incident management teams, search management course instructor, and regional chief ranger with SAR program oversight for 56 parks. I was deployed to assist other agencies with major search incidents on multiple occasions, and have a broad network of contacts among SAR practitioners. I have personal knowledge of only a small handful of searches where formal mathematical computations (Mattson Consensus; and grid searching to generate POD's for POA x POD = POS, shifting POA, and cumulative POD calculations) were employed. In each incident the decision to use these processes were due to unique circumstances, and reflected efforts to generate clues in the form of probabilities where direct clues (items, footprints, witnesses, etc.) were absent.

George Ratayczak, SAR Deputy for Whatcom County, WA from 2000 through 2012 has responded to about 150 search incidents. He's only employed formal mathematical computations once (personal communication). His competency is reflected by the amount of years the Sheriff's Department has assigned him to SAR.

While the above two observations are admittedly anecdotal, Unit 1 of the Search Management Systems Workbook references government statistical documents (Alberta, National Park Service, New Mexico, Oregon, United Kingdom) that cumulatively analyzed about 12,000 searches. The agencies reported that between 91% and 99% of their searches were resolved in 24 hours or less. Also, Oregon's 2011 annual SAR report indicate that 50% of its searches from 2007 to 2011 were resolved in less than four hours, 81% in the first operational period, and 93% within 24 hours (see http://www.oregon.gov/OMD/OEM/tech_resp/sar_docs/annual_sar_report_2011.pdf?ga=t). Although these reports don't reveal whether formal search probability computations were employed in these incidents, the amount of time needed to conduct the grid searching required to generate POD's for such computations suggests they weren't.

Conclusions

Many of the land search probability theories and ideas published over the past three decades – and the criticisms of those theories – have validity issues.

Applied land search management is a skill, not a science.

The maritime search probability model shouldn't be strictly applied to land search. It doesn't fit.

I'm not aware of any studies (or allegations) claiming flawed land search probability theories and concepts are being widely utilized.

Nor am I aware of any evidence (or allegations) alleging that failure of the land search community to strictly adhere to the maritime search probability model has compromised finding missing persons and saving lives.

The implementation of processes required to implement formal mathematical theory - establishing the search area, delineating segments within the search area, conducting Mattson Consensus, and then mobilizing, coordinating, assigning, and supporting the considerable resources needed to grid search the segments - require an unattainable commitment of resources and time in the critical first hours of a search. Searches are simply not resolved, and lives not saved, by mindless adherence to formal mathematical theory.

Strict adherence to the maritime search probability model conflicts with the time-proven and broadly accepted land search management crucials of "Search is an Emergency", "Search for Clues, not the Subject", and "Grid Search as a Last Resort".

That said, application of formal mathematical search computations does have a role in land search, albeit different than for maritime search. Although of limited use for generating scientifically accurate mathematical calculations, subjective POD's and subjective Mattson POA's can be useful for communicating, planning, and prioritizing. POD's, POA's, and other products of mathematical calculations are also useful when recognized as clues, especially when efforts to discover other clues have been unsuccessful, and the agency having jurisdiction has consciously decided to expend the considerable resources necessary to conduct extensive grid searching.

Incident commanders should anticipate every search might evolve to a complexity where formal mathematical search computations are useful, and thus understanding and appropriately implementing scientifically valid probability theory is desirable.

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