How do the effects of temperature and altitude on shotgun performance guide us to our "best trap gun"?
What influences the outcome of pattern tests besides the shells and choke?

The result of a patterning experiment with a particular gun and shells cannot be expected to remain stable in all conditions; it is instead tightly tied to the location (altitude) and weather (temperature, air pressure, and humidity) of the day and place the test was conducted. The underlying controlling variable is air density and that is determined by the four elements named above.

Listed in the order of their influence with the most influential at the top:

- As altitude increases, the density of air decreases.
- As temperature rises, the density of air decreases.
- As air pressure decreases, the density of air decreases.
- As humidity of air increases, the density of air decreases.

Decreased air density leads to higher pattern percentages and reduced spread of shot.

**TEST 1: How a change of temperature affects pattern percentage**

A Perazzi Mirage was tested at two temperatures, 32 and 61 degrees Fahrenheit.

![Figure 1. Colder temperatures reduce observed pattern percentages.](image)

Now let’s look at the effect of temperature change on air density.

![Figure 2. Colder temperatures increase air density.](image)

It would be tempting to say “OK, we have a 5 or so percent decrease in pattern percentage with about a 30 Fahrenheit degree drop in temperature. Can we just divide and get our answer?” No, it’s more complicated—and less certain—than that.

Earlier I listed four things that change air density and they all assert their effects independently. We have only looked at one of them. When the temperature dropped from 61° to 32°, the air pressure also rose from 29.3 inches of mercury to 29.9, accounting for a 2% increase in air density. So let’s credit the change in air density, and the resulting effects on pattern performance, to at least two influences: about six parts to the change in temperature, two parts to the change in air pressure.

And how about the effect of humidity? I didn’t even measure that since at temperatures like this, it’s small enough to ignore. But it’s time to step back and consider how much precision is realistic as we try to pin down all the things that may have affected any pattern test. We’ve considered three, but we’ve left one out, an important one, namely “chance.” It is chance that makes it impossible to consider the result of any one ten-shot test to be taken as the “true value” of a gun’s performance.
Every measurement is an estimate of the true value of the quantity it describes.

In the case of pattern percentages it’s probably a close estimate, but if you replicate a test under identical conditions, you will not get exactly the same result, just something similar. Here’s an example:

Based on the patterns I’ve shot and counted over the last 30 years, I think a reasonable way to address the judgement of true pattern-percentage differences between two guns is as follows:

• If the average pattern percentages are within one percent or so there is no difference in their performance.
• If the average pattern percentages differ by two percent or so there may be a difference in their performance.
• If the average pattern percentages differ by three percent or so one performs better than the other.

In the same vein, if two guns are tested at large temperature differences, say 20 degrees, I informally credit the one that was shot at a colder temperature with an environmentally-caused deficit of three or four percent.

This is an expedient substitute for doing comparative testing the right way, that is, testing at one club on days with similar weather. If that can’t be done, just make corrections as your experience dictates and accept that your answer now has decreased certainty.

Probably the most valuable contribution made by the tracking of temperature as we shoot patterns is the way it can later help clear up otherwise puzzling results. Here is an example using data which will be revisited in the “altitude” section of this report.

Based on the effect of temperature differences presented in Figure 1 we can reasonably attribute the decrease in performance of the MX2000 at 900 feet to differences in weather. We can conclude that these two guns really perform about the same, as they did at 5000 feet.
TEST 2: How a change of altitude affects patterning results

Altitude changes have a far greater potential to change air density, (and so patterns) than anything that is likely to happen with temperature. We saw that a 30 Fahrenheit degree change in temperature might lower air density by nearly six percent. Altitude, on the other hand, reduces air pressure by about an inch of mercury every thousand feet as we go higher. That means that the weather that leads to a pressure of 29 inches of mercury at 1000 feet will record only about 25 inches at 5000 feet, resulting in a drop in air density of about 17 percent. That kind of change really affects how guns shoot!

Four guns, two of which were tested at Metro Gun Club (900 feet) and Spanish Fork (altitude 5000 feet) and two at Metro and Laramie, Wyoming (7300 feet) produced these results with the same shells in similar weather, sunny and mid-seventies.

This difference, 12%, is huge in the world of pattern percentages, two or three times what you would expect to be the difference in performance between modified and full chokes at 40 yards at 900 feet elevation. And as we will see in the next section, it exerts strong a influence not only on other measures of pattern quality, but also on the scores that can be shot at long yardage.

![Figure 5. Pattern percentages increase at higher altitudes.](image)
How does the increase in pattern performance at high altitude affect the scores shot there?

The best long-yardage handicap competitors shoot a lot better at high altitude than they do at lower elevations. Most of them know that if they want to get the handicap component of their “Grand Slam” (100 from the 27-yard line) the places to go are Spanish Fork or Vernal, both in Utah, or other clubs high up in the western mountains.

All the Satellite Grand Americans draw top handicap talent from across the country and everyone likes both the Great Lakes Grand at Mason, Michigan (900 feet) and the Western Grand at Vernal (7400 feet), but in spite of their similar attendance, the number of high scores from long yardage at Vernal far outpaces those from the other club.

Vernal shooters on 25, 26, & 27 yards shot 55 scores of 96 or above in 2015. Mason shooters shot 9 and 16 such scores in 2015 and 2014 respectively.

<table>
<thead>
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<th>Venue &amp; Year</th>
<th>Event</th>
<th>100</th>
<th>99</th>
<th>98</th>
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<tr>
<td>Vernal 2015</td>
<td>Handi 1</td>
<td>2</td>
<td>5</td>
<td>2</td>
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</tr>
<tr>
<td></td>
<td>Handi 2</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handi 3</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>5</td>
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</tr>
<tr>
<td></td>
<td>Handi 4</td>
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<td>4</td>
<td>5</td>
<td>7</td>
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</tr>
<tr>
<td>Mason 2015</td>
<td>Handi 1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Handi 2</td>
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<td>1</td>
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<tr>
<td></td>
<td>Handi 3</td>
<td></td>
<td>4</td>
<td>2</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Handi 4</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>Mason 2014</td>
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<td>3</td>
<td>7</td>
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</tr>
</tbody>
</table>

Figure 6. High altitude venues promote high long-yardage scores.

What accounts for the improved scores shot at high altitudes?

The program Shotgun Insight calculates the probability of a single-pellet hit in the inner 10-inch circle of a pattern, the 10- to 20-inch ring, and the 20- to 30-inch ring. The increased probability of a hit in the center 10-inch circle explains the increased effectiveness of the guns at high altitude.

Figure 7. The probability of a hit increases with altitude.

The graph tells us that a shooter at 900 feet who takes his targets at 40 yards and uses the whole 10-inch circle in the center of his pattern is going to lose quite a few targets that he would break if he were to shoot the same way at high altitude. Additionally, the number of good scores posted at low altitude is evidence that the best ATA long-yardage stars not only break their birds closer than 40 yards but also rely on a small central part of their patterns to break their birds, smaller even than a 10-inch circle.

The right side of the graph, particularly at high altitude, is distorted by a “ceiling effect” resulting from the fact that probabilities are capped at a value of 1.00. The magnitude of the increase in central-pattern lethality found at high altitudes is not apparent and must be addressed in another way.
What accounts for the improved scores shot at high altitudes (2)?

To sidestep the ceiling effect that obscures what’s happening in the 10-inch centers of these patterns, we go back to the data which underpin the probability calculations, the pellets themselves.

<table>
<thead>
<tr>
<th></th>
<th>Perazzi MX8 #1</th>
<th>Perazzi MX2000</th>
<th>Perazzi MX8 #2</th>
<th>Bowen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average number of</td>
<td>Average number of</td>
<td>Average number of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pellets in 10-inch</td>
<td>pellets in 10- to</td>
<td>pellets in 20- to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>circle</td>
<td>20-inch ring</td>
<td>30-inch ring</td>
<td></td>
</tr>
<tr>
<td>Perazzi MX8 #1</td>
<td>900 ft. = 75</td>
<td>900 ft. = 152</td>
<td>900 ft. = 107</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5000 ft. = 108</td>
<td>5000 ft. = 158</td>
<td>5000 ft. = 110</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Change: +44%</strong></td>
<td><strong>Change: +4%</strong></td>
<td><strong>Change: +3%</strong></td>
<td></td>
</tr>
<tr>
<td>Perazzi MX2000</td>
<td>900 ft. = 71</td>
<td>900 ft. = 135</td>
<td>900 ft. = 112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5000 ft. = 98</td>
<td>5000 ft. = 158</td>
<td>5000 ft. = 106</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Change: +38%</strong></td>
<td><strong>Change: +15%</strong></td>
<td><strong>Change: -5%</strong></td>
<td></td>
</tr>
<tr>
<td>Perazzi MX8 #2</td>
<td>900 ft. = 71</td>
<td>900 ft. = 134</td>
<td>900 ft. = 115</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7000 ft. = 106</td>
<td>7000 ft. = 159</td>
<td>7000 ft. = 104</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Change: +49%</strong></td>
<td><strong>Change: +18%</strong></td>
<td><strong>Change: -10%</strong></td>
<td></td>
</tr>
<tr>
<td>Bowen</td>
<td>900 ft. = 82</td>
<td>900 ft. = 148</td>
<td>900 ft. = 113</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7000 ft. = 102</td>
<td>7000 ft. = 159</td>
<td>7000 ft. = 102</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Change: +24%</strong></td>
<td><strong>Change: +7</strong></td>
<td><strong>Change: -10</strong></td>
<td></td>
</tr>
</tbody>
</table>

The most striking change resulting from the move from low to high altitude was the number of pellets in the inner 10-inch circle, an average increase in pellet count of 38% (an average of 29 pellets per pattern). The next area, the ring from 10 to 20 inches, experienced an increase of 14% (an average of 16 pellets per pattern) while the outer 20- to 30-inch ring lost an average of 5% (an average of 5 pellets per pattern).

The added pellets in the center 10-inch circle increased the pellets-per-square-inch by almost 1 per-square-inch to about 1.3. The added pellets in the 10- to 20-inch ring occurred over a three-times larger area and so the pellets-per-square-inch increased far less, from 0.44 to 0.50. The pellet density in the 20- to 30-inch ring stayed at about 0.26 pellets-per-square-inch. The decreasing effect of these added pellets on the probability of a single-pellet hit is documented to the right.

As mentioned before, the probability of a single-pellet hit in the inner 10-inch circle is confounded by the limit in probability calculations of a maximum of 1.0. As the altitude changed from low to high, the probability of a hit rose by only 0.2% in the 10- to 20-inch ring and in the 20- to 30-inch ring it changes by even less.

These two tables disclose the mechanisms by which the tighter patterns at high altitude promote the higher long-yardage scores we see.

1. The increased number of pellets in the center of the patterns make it more likely that at least one will hit a target, and
2. Since pellet density decreases (relatively) uniformly from the center to the periphery, at every area in the part of the patterns that high-average shooters must use (the center and near the center), there are more pellets with tighter patterns.

The result is a surprise. While one might think that a tighter pattern would require more accurate shooting, in fact high-scoring requires a little less accuracy with a very tight-shooting trap gun than with a more open one, since the “killing pattern” is a little larger.
What constitutes a good trapshooting pattern?
Comparison 1: Pattern Evenness

Choke tube makers tout the way their products combat the curse of hot pattern centers by means of engineering, geometry, and materials. Magazine columnists fall all over themselves in praise of a new model’s remarkably even patterns which are the result of this or that mechanical alchemy. We hear the same at gun clubs; we read the same online: even patterns are a necessity, the only certain path to higher scores.

The metric for “pattern evenness” is “central thickening.” It compares pattern percentages in the inner 20” circle of patterns with the 20” to 30” outer “ring” or “torus.” You can find a more complete explanation of central thickening in TERMS EXPLAINED on claytargettesting.com.

The inevitable consequence of the higher pattern percentages pictured in Figure 5 is increased central thickening.

![Figure 9. Central thickening increases at high altitudes.](chart)

The patterns which produce the great scores at Spanish Fork and Vernal are not the even ones we are told to admire and seek out; they are instead what guns produce at high altitude: uneven, hot-centered, and effective.

What have we gained by giving up the ideal of even patterns?
We have increased the probability that an accurate shot will result in a broken bird. Fewer perfectly-pointed targets will be scored “LOST.” Thus we will suffer less from the negative vagaries of chance and our scores will more faithfully reflect our skill rather than our luck.

What have we lost by giving up the ideal of even patterns?
If we aspire to winning scores, we have given up nothing. We can’t make any use of our patterns beyond the inner 20-inch circle (really, the 10-inch center) anyway. Shots which miss by more than 10 inches will be lost about 20% of the time and we can’t win shooting like that!
Learning to shoot trap well is a challenging and often frustrating task, and along the way many tyro shooters turn to books, magazines, and online or gun club pundits for advice on how to nudge their progress along. Early scores are often disappointing and frustrated journeymen want to be given a few simple and explicit reasons why they miss so many.

“Your choke is too tight” is near the top of the list of explanations.

“Gun makers have never understood that today’s ammunition shoots vastly tighter than it did even a generation ago; as a result you are likely saddled with a shotgun that shoots more like a rifle than the appropriately open-choked scattergun you need. Screw in a modified or improved cylinder choke tube and start to hit all the targets you deserve!”

“If your firearm is so out-of-date it’s only got a fixed choke, get ‘er opened up and pick up all those targets the wider pattern will give you.”

The metric for “pattern spread” is “75% diameter.” That is, the diameter of a circle which would contain, on the average, 75% of the shot. (See TERMS EXPLAINED on claytargettesting.com for more information.) How tight are the patterns shot at high altitude, the ones that figure 6 showed us worked so well?

Pattern diameter (and central thickening) march in lockstep with pattern percentage. As percentage increases, central thickening increases with it, and the diameter of the pattern decreases. They are interlocked, and you can’t change one and leave the others alone. If you want a larger handicap pattern diameter or a more even pattern you can open the choke, but you will sacrifice the concentration of pellets in the center of your patterns that produces winning scores.
How can we use the information from these experiments to find a trapgun appropriate to our goals?

If your interests in trapshooting do not go beyond the fun of breaking most of the birds now and then, one gun will serve about as well as another. Something reliable that looks nice, has been proven (by testing of this particular gun) to shoot straight horizontally and reasonably vertically, and doesn't kick you too badly will do just fine.

If you are, or aspire to become, a top-scoring long-yardage ATA or PITA competitor, you should take what you have read in this paper seriously and chose your equipment with high pattern percentages as the paramount consideration.

That means full or extra-full chokes. If you are looking for the tightest choke tubes you can get (and you should), I suggest one of the long steel ones with ports or slots. They have consistently outperformed most of the others in many tests.

It means AA, Gold Medal, or STS (or Nitro 27) ammo. There is no substitute for pellet hardness in producing tight patterns.

It means a lot of practice and a lot of competitive shooting too. Go to the ATA average book and see how many handicap targets most of the big dogs have shot! You will need to do that too. But if you have made the right gun choice, it is at least within your grasp; you have the equipment that will carry you there.