The Ideal Birding Binocular

The ideal birding binocular would deliver the kind of detail and color you would see if you had the bird in your hand, but would do it at any distance, and under any light conditions. You would be able to use and carry it all day long, day after day, without undue mental or physical fatigue. It would be perfectly safe from showers, the unexpected bath in a stream or lake, sudden temperature changes, any amount of bashing against tree limbs, and the occasional sudden stop when driving and its resulting catapult off the car seat. The ideal birding binocular would also be affordable (whatever that word means to you in terms of your budget). The ideal binocular doesn't exist. But . . . you can come close to *your* ideal binocular if you understand why perfection isn't quite attainable and are willing to accept performance in the field that may be a little short of perfection here and there.

For the birder, there are three critical areas that affect the performance of binoculars in the field: image quality, ease of use/handling, and durability/weatherproofing. While affordability can be an important issue to the individual, we won't use it for judging performance in this essay. We'll examine the three critical areas one at a time. First, image quality.

Image quality

There are five factors that determine image quality. They are:

1.- workmanship and materials,
2.- objective size,
3.- optical coatings,
4.- residual aberrations and distortions, and
5.- physical (and optical) alignment.

Let's discuss each of these factors separately.

Workmanship and materials: Unfortunately, when it comes to image quality, you usually get what you pay for. It takes high quality materials and precision manufacturing techniques (including close tolerances and rigorous quality control) to produce a consistently satisfying image. This is particularly true with roof prism binoculars, which require much higher optical tolerances than porro prisms to perform properly. No other single factor contributes more to the overall image quality of binoculars than the workmanship and materials that go into them!

Achieving the highest quality images requires sophisticated optical designs that include multi-element lenses (both objectives and eyepieces). That means that the best binoculars simply contain more glass, more expensive types of glass, and more glass surfaces, each of which must be carefully shaped and polished with an accuracy often measuring in a few millionths of an inch. All that glass must then be very precisely mounted and supported well enough so that normal use in the field won't knock it out of alignment. Moving parts must operate smoothly and predictably, both when the binoculars are new and over the full course of their usable lifetime, in all temperature extremes. All that adds up to higher cost.

Currently, it seems that *real* quality (or what passes for real quality these days) can be achieved at about the $200-250 level in porro prism glasses. Because of more demanding manufacturing techniques, the same level of quality will often cost $700-$1000 in roof prism glasses. For the sake of this argument, we are ignoring durability and consistency issues. Roof prism glasses are generally more durable than porro prisms and there is undoubtedly more variation in image quality between individual samples of any given model in most $250 glasses than there is in most $1000 glasses.

Objective size: The objective size is the diameter of the objective (light-gathering) lens in millimeters. It is the 35 in 7x35, the 42 in 8x42, etc. The larger the objective lens, the more detail it is capable of delivering to your eye.

Physics dictate that when light passes through a lens, normally distinct points in the object are unavoidably blended together in the image. The process is called diffraction. It is caused by those light rays that pass the edge of an object being diffracted (or bent out of their true course) by that edge, while the path of the light rays passing through the center of the lens is unaffected. When the light rays from the entire lens are recombined in the image, the edge-diffracted rays form small faint halos (or diffraction rings) around the distinct points formed by the undiffracted center rays. This reduces the sharpness of those individual points. When you pass light through a round hole (and a lens is essentially a round hole for the purpose of this discussion), the combined diffraction effects of the continuous edge of the hole amplify each other until you begin to lose the finest details. The smaller the lens, the further apart the points in the object have to be to remain separate in the image. The points that are closer together blur together. You might say that larger lenses simply do less damage to the image than smaller ones, allowing more detail to get through.

Then too, the larger the objective, the more light it is capable of delivering to your eye. The eye is an electro-chemical system that responds to the particular form of energy we call light. The level of energy entering the eye affects our ability to distinguish detail, especially color detail, in complex ways. In general, the more energy the better. Larger objectives collect and deliver more energy to the eye.

More detail, more light . . . when it comes to objectives, bigger is undoubtedly better. Still, high quality objectives as small as 23mm can provide a surprisingly satisfying image of the bird in the field, especially in full daylight and at reasonably close distances. For general field use, objectives in the 30-35mm range will often show you all there is to see, except for the extreme distance and darkness conditions noted below. In fact, at a typical birding distance of 40-60 feet, almost any binoculars will look good and provide a surprisingly satisfying image (at least until you compare them directly to something optically better). However, for binoculars that perform well in any condition, that deliver all there is to see, all the time, you need 40-50mm objectives.

There are three conditions that will clearly show the superiority of larger objectives.

First. whenever the distance gets out over 150 feet, especially on birds of sparrow size, larger objectives will pull out detail that simply is not there in smaller glasses. It is not just a matter of resolving power, though raw resolution has some effect. You will also see more color at those distances. The larger objectives gather enough light to excite the color receptors in our eyes, while smaller objectives leave us seeing some indeterminate shade of gray. Obviously when you combine long distances with low light levels, it only compounds the color problem. To me the lack of color detail in smaller glasses is more limiting, and more obvious, than the lack of raw resolution. It should be said that the differences in resolution and color detail are there, even at close distances, if you compare binoculars directly in the field on the same birds. However, the limitations of the smaller objective don't become obvious, or seriously affect your birding experience, until the distances become more extreme.

Second, when looking into deep shadow, especially when portions of the view are brightly lighted, large objectives will penetrate where smaller objectives fail. Again, it is a matter of the amount of energy the larger objectives capture, but this time we are talking about the number of rays (or the width of the wave front) that the objectives intercept from any given point in the object and focus back into the corresponding point in the image. Think of it like this: shadowed points are still reflecting a certain amount of light. The energy radiates outward so that at any given distance the energy from that point could be thought of as being spread over the surface of a hemisphere with the reflecting point at its center. Larger objectives intersect a bigger area of that sphere than smaller objectives do. That greater amount of energy their larger area captures is then focused back into an image of the reflecting point. Since the larger objective captures more energy, the point appears brighter and we, in effect, see deeper into the shadow. This is why, by the way, larger objectives can appear brighter in all situations, including full daylight, than smaller ones, even though in bright light it should be the contracted diameter of the pupil of our eye that is the limiting factor, and not the binoculars at all. Given a high contrast image, we interpret the full daylight view as brighter through the larger glasses because we see more detail in the shadows, not because there is any more light in the highlights.

The last condition is, surprisingly, the least obvious in actual use. I say surprisingly because it is the only one commonly cited anywhere as a distinct advantage of larger objectives. I am talking, of course, about low light situations: dawn, dusk, twilight, heavy cloud cover, and deep forest. As long as the light is fairly uniform, at moderate distances, a good 23mm objective will perform just about as well as a 50mm objective in dawn, dusk, and overcast . . . right down to darker than you really want to be birding anyway. There is certainly some advantage to a larger objective, but it comes to a matter of minutes or yards. A 50mm glass is useful about 5 to 10 minutes earlier in dawn and later into twilight than a 23mm glass . . . or, to put it another way, will reach 10 to 20 yards further in those same situations. You have to have a certain amount of light to work with for any size objective to work at all. In deep forest, however, the problem is similar to the deep shadow situation above, and larger objectives will give you more evident detail in the shadowed, darker portions of the view. At the powers common in birding binoculars (7 to 10x) and given the fact that they are generally hand held, you do not gain significant detail or color by going larger than 50mm.

Theory, by the way, would suggest that perfect 8x30 binoculars should be able to deliver all the detail and color the eye can use. In fact, in actual field tests, only two 30mm class binoculars I know of even come close. You can always see a difference by going to a larger objective of similar quality. Is it possible that we need the extra objective size primarily, or perhaps only, to overcome the current limits of real-world manufacturing?

Coatings: Both apparent sharpness and apparent brightness are affected almost as much by the coatings used on the lenses as they are by the lenses themselves. All uncoated air-to-glass surfaces (both the front and back surfaces of a lens or prism) reflect back about 4% of the light that should pass through them. This scattered light bouncing around inside the binoculars washes out details and blurs colors. Coated lenses have a very thin antireflection coating of magnesium fluoride vacuum-deposited on the surface of the glass. This coating cuts down the amount of light reflected back from the interior glass surfaces to about 1.5% . . . increasing the contrast of the image by reducing the amount of scattered light within the optics.

You generally see coatings promoted as a means of increasing the amount of light that passes through the glass (the light transmission). For example, if you had a binocular with seven uncoated lens elements per side (a two-lens objective, two prisms, and a basic three-lens eyepiece) you would have 14 air-to-glass surfaces. A 4% light loss per surface would result in only 56.5% of the light gathered by the binocular actually reaching your eye. Put a single layer of magnesium fluoride on each surface and the light reaching your eye increases to 80.9%. That brightness gain is certainly important, especially in compact binoculars, but it is not nearly as significant to image quality as the increased contrast.

Multicoatings (many layers of thin coatings of different materials, each keyed to a specific color of light) cut reflections down to a mere 0.5% light loss per surface (or even less with some of the most recent advanced coating packages), thereby increasing contrast even more than single layer coatings. Using the term "coated" on binoculars or in promotional materials means only that at least some of the lens and prism surfaces have single layer magnesium coatings. "Fully coated" means that all lens and prism surfaces are coated with magnesium fluoride. Using the term "multicoated" or "MC" on binoculars or in promotional materials means that at least some of the lens and prism surfaces have multicoatings. Some surfaces may be uncoated or have only single layer magnesium fluoride coatings. "Fully multicoated" (FMC) means that all air-to-glass lens and prism surfaces are multicoated. Some makers, even of the most expensive binoculars, still use a single coating on the outer surfaces of the lenses, on the theory that it is harder and more scratch resistant, and that light reflected from the outer surface does not significantly affect image contrast as does light scattered within the binocular optics.

In the real world, not all coatings, multicoatings, or full multicoatings are equally effective in increasing image contrast. Some simply work better than others. The best FMC compact 8x23 binoculars can, and often do, appear both sharper and brighter than full-sized 7x35 binoculars with poor coatings. The best coatings also increase the binoculars ability to penetrate shadow. Some are remarkably successful, giving 30mm objectives the shadow reach of common 40-50mm objectives.

Porro prism binoculars using BaK-4 (barium crown glass) prisms have very high light transmission, as BaK-4 prisms are 100% internally reflective. Their only light loss comes at the entry and exit faces of the prisms, which are generally coated or multicoated for high transmission. Lower quality binoculars use less-expensive BK7 prisms, which can have light losses approaching 10-15%.

The design of most roof prism binoculars requires that one surface of the prism be an aluminized mirror to work properly. This means that roof prism binoculars typically will not be as bright as similar-aperture/similarly coated porro prism models, due to the 12% light loss typical of an ordinary aluminized mirror (or the 4-6% light loss of an enhanced aluminum mirror). During daylight observing, however, this light loss is rarely visible. Roof prism binoculars that use high-reflectivity silver (98% reflective) or dielectric-coated mirrors (greater than 99% reflective), on the other hand, can be virtually as bright as similar-aperture BaK-4 porro prism models.

Due to a roof prism's design, the light entering a binocular's image-erecting roof prism is split into two halves by the vertex of the roof prism. The halves travel through the prism independently and are recombined by your eye at the eyepiece. Because light waves vibrating parallel to the roof edge (one of the halves) are retarded in phase compared with the waves vibrating at right angles to the edge (the other half), when the two halves of the image are recombined by your eye, one half of the light is slightly out of phase with the other half. This reinforces some colors and dims others, reducing the fine detail and contrast.

Phase correcting coatings are special multi-layer optical coatings applied to the prism's roof surfaces. The coatings correct the phase shift inherent in the roof prism design, causing the two halves of the light beam to be in phase with each other when they are recombined by your eye. With phase-corrected prisms, no colors are reinforced or cancelled, giving more accurate color reproduction and up to 30% higher contrast. The effect is particularly visible when looking at a back-lit or silhouetted bird, where more color and detail can be seen in the shadowed areas of the bird. Phase-correcting coatings are not needed, nor are they used, on porro prism binoculars.

Residual aberrations and distortions: It is impossible to form a perfect image of an object using lenses. The physics of light and glass introduce distortions in the image, and aberrations degrade it in several distinct ways. The distortions are the most obvious, and the least damaging! Curved surfaces form curved images. We humans expect flat, rectilinear images. Making our expectations and reality correspond is a real challenge for the optical engineer. In many binoculars, even the best, you can see the limits of what can be done (or what can be done at a price your average user is willing to pay). In some binoculars, especially "wide angle" designs, there is no way to get the edges of the view in focus at the same time the center is. You can get the edges to focus, but if you do, the center goes out. This is called "curvature of field" and is perhaps the most common distortion.

Then too, the edges of the field may appear stretched or pulled out of shape, especially when you place a straight line near the field edge (i.e. a telephone pole). If straight lines seem to bow outwards in the center, it is called "barrel distortion." If they bow inwards at the center, a much less common problem, it is called "pincushion distortion." Think of it as the same problem map makers face. Putting a round world onto a flat surface stretches and distorts the edges. Trying to flatten a curved image also distorts shapes at the edges. There are a very few, very special, binoculars that achieve both a wide flat field and minimal distortion of edge objects . . . but they sell for about $2000, have individual eyepiece focusing, and weigh three to five pounds – not ideal birding binoculars. One specialized astronomical eyepiece designed for a wide field and minimal distortion is the size and weight of a full can of soup . . . and that is just one eyepiece, mind you. Can you imagine binoculars made with the things!

Distortions can be eliminated, but how many birders are willing to pay the price . . . and how important is it anyway? The best binoculars balance their distortions in a way which presents a fairly normal view of the world. Then too, if the center of the field is fairly free of distortion, I can live with some edge flutter. I habitually put the bird I want to see in the center of the field, where my vision is sharpest, and I suspect the same is true of most birders. Very few birders put the bird at the edge of the field and look at it out of the corner of their eye.

I am coming to believe, however, that the residual *aberrations* inherent in most optical systems are much more damaging to image quality, and need a lot more study and attention. Aberrations are optical faults that result because all the light from a given point in the object does not come to focus at the same point in the image. Optical designers spend a good deal of energy compensating for aberrations in their designs, but, using standard lenses, there is only so much they can do. Some always remain . . . hence "residual" aberrations. There are four that are of real concern.

The one you see mentioned most often, because it is the most obvious, is chromatic aberration. Lenses, like prisms, split light into its different colors, because each color reacts with the glass by bending at a slightly different angle. That means that it is impossible to focus all the different colors of light that reflect from an object at the same point. If you bring the dominant color (yellow) to one focus, then you get a purplish fringe of unfocused light (red and blue) all around the object. Take that down to every single point in the object, each with its own fringe, and try to imagine the optical mud produced by an uncorrected lens. The larger the objective lens, the more apparent chromatic aberration becomes.

Achromatic lenses, like those used in almost all binoculars, use two complementary elements, each made of a different kind of glass (low refractive crown glass for one element, and high refractive index flint glass for the other), to bring both the yellow and red light to the same focus. That's a distinct improvement, and it makes modern binoculars usable. It is possible, by using exotic, very dense, glasses or other transparent materials (Extra-low Dispersion ED glass, Special Dispersion SD glass, or calcium fluorite crystal), and sophisticated objective lens designs using up to 5 individual pieces of glass, to produce an image in which all the primary colors reach the same focus. Apochromatic lenses do just that.

There are a few ED glass binoculars on the market right now. (Pentax, Swift, and Zeiss are advertising the fact. Leica is also using some ED in their binoculars, though they don't advertise it.) None of these glasses are advertised, nor do they perform, as true apochromats. The ED glass is used to reduce the amount of chromatic aberration, but it does not eliminate it completely. From my experience with the glasses in question, there is an observable improvement, but it is very subtle. What strikes you first is an impression of increased contrast. That is not surprising, considering that at least some of the unfocused light from the fringe that washed over into adjacent points has been eliminated. On closer study, you also begin to appreciate the purity of all the colors in the image . . . or rather you begin to realize that the colors in the images you are used to from regular achromatic binoculars were always just a little muddied compared to this. The ED glasses show subtler shades and hues, and finer differences between shades and hues, than any achromat is capable of. As pointed out above, the larger the objective lens, the more apparent the chromatic aberration becomes. That is why ED and similar exotic glasses are most often used in spotting scopes, which generally have larger objective lenses than binoculars. The color-correcting benefits of the special glass types are more apparent in a large aperture spotting scope than in smaller aperture binoculars.

The second aberration is astigmatism, where the rays from a given point object, especially those at the edge of the field, are elongated into an oval that points towards the center of the field on one side of focus and is at right angles to the center on the other side of focus. Since the curvature of field discussed above often puts the edges of the image out of focus while the center is sharply focused, astigmatism can contribute to the fuzziness of the image at the extreme edges of the field in some binoculars.

The third aberration, which is beginning to get some serious attention in commercial binoculars, is spherical aberration. There is no way that a normal lens can bring rays that pass through the edge of the lens on their way from an object to the same focus as the rays coming from the same object that pass through the center of the lens. Again, this confuses the image, creates optical mud, and causes a loss of information and detail. The cure is to form at least one surface in the optical path (generally in the eyepieces) into a complex aspheric (non-spherical) shape, a shape computed so that it corrects the image, and brings edge rays to the same focus as center rays.

Visually, correcting for spherical aberration yields both increased contrast and brightness. That stands to reason, since more of the energy from any given point in the object is focused at the same point in the image, or to put it another way, less energy from any given point is scattered into adjacent points. More energy should translate into more brightness, and less scatter should translate into increased contrast. On the test bench, optics corrected for spherical aberration also display higher resolution and better overall image quality. Aspheric optics are becoming a regular feature of more and more binoculars, particularly in the smaller apertures and lower price ranges, where the improvement is the most apparent. The improvement is evident in field use, allowing many compact aspheric binoculars to yield useful detail well beyond the point where non-aspheric compacts, and many full sized glasses, give up.

The final aberration is coma, where the rays from a given point object, especially those at the edge of the field, are smeared out into a cone that resembles the traditional images of the tail of Halley's comet. Coma is generally well controlled in modern optical designs, but it contributes to the fuzziness that is often seen at the extreme edges of the field even in expensive binoculars. Don't confuse curvature of field with coma. You can't focus coma out. The fuzz remains.

It should be pointed out that every piece of glass in the binoculars contributes to both the distortion and aberrations of the system. Eyepieces may be, and often are, more at fault in introducing both distortions and aberrations than the objective. Imperfect prism angles and surfaces also introduce their own defects. When you consider the complexity of the design, it is really quite amazing that binoculars work as well as they do.

When you examine the image formed by binoculars very closely, with an examination scope, as you do in testing binoculars for resolution, you quickly realize that there is more to image quality than the ability to separate lines on a chart. Two binoculars that have the same measured resolution, that can separate the same bars on the resolution chart, may have vastly different image quality. In one, the lines on the chart are sharply defined. In the other, the lines are surrounded by a gray blur. I am becoming convinced that the difference in image quality is the result of residual aberrations, especially spherical aberration and coma. I am also becoming convinced that the differences are visible in the field.

Those binoculars that have well corrected aberrations do indeed impress you as being somehow subtly sharper than those with aberrations not so completely under control. The effect of treating spherical aberration in some aspheric compact binoculars continues to amaze me, and can be taken as a case in point. Some aspheric compacts deliver as much usable detail to the eye, and as apparently as bright an image, as binoculars twice their size. I believe that the next level of optical quality, the next revolution in optical quality, will be achieved by better controlling the residual aberrations in current designs. I expect to see binoculars improve significantly (but incrementally) over the next 10 years, as manufacturing techniques for complex aspheric curves become less expensive and more available. I expect the same level of improvement we experienced in going from coated to multicoated optics, or in going from non-coated to phase-coated roof prisms. I'm hoping for even more!

I should say, too, that we birders should be the driving force behind this next round of optical improvement. Binoculars are already good enough for hunting. They are good enough for watching sports or general nature observation. They are good enough for surveillance. They are not good enough for birding! Birding places demands on optics that no other use does. There is more detail in a bird's plumage, especially when you consider the range of colors involved, than you will find anywhere else in nature. Birders use binoculars in a wider range of conditions, and over a wider range of distances, than almost any other users. We need to be able to see! No one else is likely to demand such perfection of optics makers. We birders have to do it.

Physical (and optical) alignment: It doesn't matter how good the lenses and prisms of binoculars are if the individual elements are not all perfectly centered. A typical binocular uses a minimum of 6 or 7 pieces of glass in each optical barrel. The highest quality designs may have as many as 10, or even more. Shift any one of those elements just slightly off center from the rest and it will visibly degrade the image. Then too, there are two optical barrels in each binocular. If the barrels are out of alignment, they will deliver two slightly different images to the eyes. Our brains can compensate for slight misalignment (almost no one has two eyes that match perfectly anyway, and a compensation mechanism is built into our brains to deal with that fact of life). However, it is a strain, and will lead to premature mental and physical fatigue as both the brain and eye muscles work to align the images. The compensation is never perfect either. We can see through slightly misaligned binoculars but we always know something is wrong. Finally the two optical barrels must be perfectly matched optically. If the focal lengths of the individual lenses in the two barrels differ at all, the two barrels will deliver images of different sizes. Again the brain can compensate, but the image will suffer, and so will you!

You will perhaps have noted that I have not up to now mentioned magnification (or power) except in passing, nor have I cited any of the magic numbers you see in the binoculars literature: exit pupil, relative brightness, or twilight factor. That is because they are relatively less important than the factors mentioned above, and do not directly impact image quality. Magnification, of course, is a measure of how much bigger the image of a given object appears through the binoculars than it would appear to the naked eye. A magnification of 7 times (often written as 7x) means that the bird will appear 7 times as large as it would without the binoculars (or seven times closer, which amounts to the same thing.) Magnification is the 7 in 7x35 or the 8 in 8x42. Within the common limits of binoculars (7-10x), magnification has very little influence on image quality, except as it influences ease of use (which will be discussed below).

In extensive comparison in the field, under actual birding conditions, on real birds, given high quality binoculars, there is no significant difference in the amount of detail delivered when you go from 7 to 8 power, or from 8 to 10 power (or from 7 to 10, for that matter). The amount of detail you see is determined almost exclusively by the image quality factors already discussed, regardless of how big you blow the image up! Personally, I find that the image produced by most 7x binoculars is just a little on the small size to be completely satisfying, from an aesthetic point of view, and most 10x binoculars are simply too hard to use over any length of time. That leaves 8x binoculars. I like 8x binoculars, but that doesn’t mean that I think you can see more through them.

Exit pupil is the size (diameter) of the image of the objective, as produced by the eyepiece. You can figure it out for any binoculars by dividing the size of the objective by the magnification. You can see it by holding the binoculars out at arms length and looking at the eyepieces. The exit pupil is the little circle of light floating in the dark eyepiece (or, to be more exact, it is the diameter of that circle).

Relative brightness is the exit pupil squared, on the theory that the total brightness of binoculars should be proportional to the total area of that circle of light, which, since we are talking circles, is proportional to the square of the diameter (A = (d/2)2). Got that? Both exit pupil and relative brightness are reputed to be a way of comparing the brightness of binoculars. They are no such thing; and, what is more, if you use them for that purpose, you may be lead seriously astray. Going by exit pupil alone, you would assume that 7x35 and 10x50 binoculars are equally bright, because both have a 5mm exit pupil. They are not. Most 10x50s will appear brighter in any situation. The actual, or apparent, brightness of binoculars is the sum of all the factors discussed above: objective size, coatings, and residual aberrations. No simple mechanical measurement is going to give any useful indication of it.

The twilight factor is a more useful judge of a binocular’s low light performance than its exit pupil, etc., in that it takes into account both light gathering and magnification. Both factors affect how much detail you can see – and seeing detail is what binoculars are all about. Simply put, the larger an image, the easier it is for you to see details in that image. By the same token, with a smaller image, the brighter it gets, the easier it is for you to see details clearly. So, within reason, if magnification goes up, brightness can go down without overly affecting resolution, and vice versa.

It’s like reading a newspaper in the light of a 3-way lamp. If the lamp is at its lowest setting, you have to hold the paper closer (making the image larger) to read the fine print. If the lamp is turned up to its maximum brightness, you can hold the paper further away (making the image smaller) and still read the same fine print. In other words, small bright images can often show you as much detail as large dim images.

Like the exit pupil, the twilight factor is also a mechanical measurement, based on physical dimensions, though it is more complex. You find a binocular’s twilight factor by multiplying its objective lens diameter by its magnification, then finding the square root of that product. This is actually a simplified form of a more complex formula which was originally based on objective studies, and, as such things go, has more validity than exit pupil or relative brightness. The twilight factor allows you to compare different combinations of aperture and magnification to determine the one that best balances an increase in power against a decrease in brightness (or vice versa). The larger the twilight factor, the better a binocular is in low light. Twilight factors of 17 and higher are best for twilight or early morning use.

The twilight factor can tell you that, in general, 10x40 binoculars (with a twilight factor of 20) should deliver more detail than 7x35s (with a twilight factor of 15.65), especially as light levels fall . . . but, since the size of the objective is the primary determinant of both detail and brightness, you already knew that. The twilight factor does not tell you anything about how much detail any *particular* 10x40 or 7x35 will deliver. It does not tell you that some 7x35s (or even 8x30s with a twilight factor of only 15.49) will outperform some 10x40s hands down, no matter what the light level is. It does not take quality, coatings, residual aberrations, or handling factors into account. What good is it? Very little, on an absolute objective basis.

It should be obvious from all this that image quality is the sum of many factors, very few of which can be quantified, and some of which are even very difficult to measure. The current best advice is to buy the highest quality binoculars you can afford and the largest objectives you are willing to carry. That is the only way to insure getting the image quality every birder needs.

Ease of use/handling

Of course, image quality isn't everything. You still have to carry and use binoculars. You have to be able to see through the things when you get them up to your eyes, to find a bird in them, to focus on the bird, to hold them steady enough to see anything at all . . . and you have to be able to do that as well at the end of a long day in the field as you did at the beginning. Again there are certain recognizable factors that determine ease of use. The first is weight and balance.

Weight and balance: Heavier binoculars hanging around your neck and held up to your eyes produce more physical fatigue, and produce it more quickly, than lighter binoculars. The difference between 20 and 28 ounce binoculars is easily apparent by the end of even a few hours in the field. The disadvantage of heavier glasses can be mitigated somewhat by using special straps – wide neoprene rubber padded neck straps, or binocular harnesses that put the binocular weight on your shoulders, rather than just on your neck. Any strap that spreads the weight and cushions its impact, or that takes the weight off the sensitive neck muscles and distributes it to the shoulders, will be more comfortable with any binoculars, and will make carrying heavy binoculars *much* less painful. I, personally, would not attempt to carry any binoculars that weigh over 25 ounces for more than an hour without some sort of specialized support system.

There are also those who maintain that heavier binoculars are harder to hold steady. They do indeed take more arm strength to keep at your eyes, and extensive or protracted use may cause muscle fatigue and tremors that interfere with the view. But keep in mind that your arms weigh more than your binocular does. It is holding up your arms that tires you out, not just holding up your binocular. On the other hand, heavier binoculars take more energy to move once you do get them steady (it's called inertia), and so are not as likely to bounce around with every breath and vagrant breeze. Their weight tends to soak up minor hand tremors, giving you a steadier image. The more I use and test binoculars, the more convinced I become that, when it comes to holding them steady, what I call *balance* is more important than weight alone.

Balance describes the way in which the weight of binoculars is distributed and transferred to the supporting hands and arms, and is influenced, obviously, by the size and shape of the binoculars. Binoculars must be designed so that, with your fingers wrapped around them, supporting them firmly, with comfortable control of the focus mechanism, the strain is spread evenly over the fingers and hands, and the weight is transferred through the wrists to the bones of the arms, not the muscles. Neat trick! Achieving proper balance in any particular design is an art, not a science. When I pick up binoculars that have that well-balanced feel, that simply feel right in the hands, I always say a silent thanks to the employee on the design team who took the prototypes out and used them long enough, and fiddled long enough with the shape and size of the housing, to get it right! With proper balance it is quite possible for most birders to hold binoculars in the 30-32 ounce range satisfyingly steady, without undue fatigue. With poor balance, even 20 ounce binoculars can be a nightmare after as little as an hour in the field. There are some light-weight compacts on the market (especially roof prism compacts) that are so poorly balanced that you simply can not hold them still enough to get a satisfying image of the bird.

You can check the weight of binoculars in our reviews, and in the manufacturers' literature, but only handling binoculars will tell you anything about their balance. In my experience it is impossible to predict what is going to work. There are massive porro prism glasses out there that, if you can get your hands around them, are simply wonderful to hold. There are slim little roof prism glasses that are just as nice. There are also both porro and roof prism glasses that don't look all that much different than the well-balanced models, or weigh all that much more or less, that are absolute miseries. To some extent, you can trust the reviews you see here in *BVD Online* . . . we try to be very sensitive to balance issues . . . but even then, impressions of balance are somewhat dependent on hand size and arm strength . . . what feels right to me, may not to you.

Focus placement and ease: There is nothing that is more uncomfortable than a focus knob you just can't quite reach, or one that is so awkwardly placed that your fingers are bent out of shape getting to it. A stiff focus, or one that is too sloppy or jumps every time you touch it, is almost as bad. We birders spend a lot of time focusing. The focus should fall easily and comfortably under the first fingers of both hands, without compromising support of the binoculars as a whole. Focus should be absolutely smooth. Any irregularity in the motion will continually throw off your concentration. Ideally, a single turn of the control should take you from close in to far out, and yet, you should be able to make minute adjustments for fine focus. Where the focus is placed on the body of the binoculars seems to have less bearing than how well it is placed. Again, for every well-placed focus you can, and should, thank some persistent and sensitive individual on the design team. There are no rules to follow. It all has to be done by feel.

Body shape and covering: Body shape has a lot to do with balance. You can, however, also immediately recognize a binocular that has had some energy lavished on the feel of the body in the hands. In extreme cases, the body may be contoured to match the angles at which the fingers grasp it, with hollows and bumps and curves made to fit the hand. In other cases it may be a simple matter of the texture that falls under the support points of the fingers . . . ribbed or diamond-cut sections, smooth or pebbled, which mate the binoculars naturally to your grip.

Finally, the whole covering texture, whether the surface is rigid or gives under pressure, whether it is smooth or rough, can affect how the binoculars feel in your hands. Again, if there were only some hard and fast rules here . . . but there aren't. I know of binoculars with ultra-modern, semi-soft, lightly pebbled, contoured shells that are amazingly comfortable in the hands, and I know of binoculars with a traditional hard leather-like surface that are just as comfortable. It's all in the execution. In general, however, I do find the modern semi-soft, rubberized, coverings to be more comfortable over time. Those are the physical features that affect handling and ease of use. There are also several optical factors.

Field of view: With our naked eyes, most of us see, essentially, everything that is in front of us. Our vision covers a hemisphere described by an angle of 160 to 170 degrees and is bounded by the ground below us, the horizon ahead of us, and sky above us. What is more, our sensitivity to motion and color is such that we reflexively swing our attention to attractive objects anywhere within that hemisphere. We are even coordinated enough to track moving objects, to keep them roughly centered in the view. When we stick binoculars in front of our face, however, the situation radically alters. Suddenly our view is restricted to a cone described by an angle of anywhere between 5 and 8.5 degrees. That is, by a charitable estimate, a 95% to 97% reduction in our field of view. Objects outside that narrow cone simply cease to exist. Our eye and body coordination, trained to track with the naked eye, suddenly has only 5% of the information it needs to do that trick. It is a wonder we can see anything at all through binoculars.

Part of the wonder is explained by the fact that we are accustomed to focusing our attention within a much narrower cone. We may see objects everywhere in front of us, but we generally only *look at* what is straight in front of us. The cone of active attention varies, of course, but I suspect it hovers around 10 degrees. Any binoculars that have a field of view that approximates the cone of active attention are going to feel fairly comfortable during extended use in the field. Any binoculars that restrict the field of view to much less than the cone of active attention are going to cause strain and extra fatigue in extended use.

A binocular with a 5° field, half of the cone of active attention, seems to be the practical lower limit. A 6.5° field binocular is fairly comfortable, while an 8.5° field is very comfortable. With an 8.5° field you actually get little or no feeling of restricted view. Putting the glasses in front of your eyes is simply like focusing your attention on a particular object within the naked eye view. It feels quite natural.

Field of view is generally given in feet at 1000 yards, i.e. 346 feet at 1000 yards. That means that if you were 1000 yards from a fence running at right angles to your line of sight, you would see 346 feet of fence. To translate that to an angular field, divide the feet by 52.5. To translate a field in degrees into feet at 1000 yards, multiply the angle by 52.5. Thus an 8.5° field would be 446' wide at 1000 yards. A 5° field is 262.5' wide at 1000 yards. Keep in mind, however, that we do little birding at 1000 yards. To get the field at a more typical birding distance of 100 feet, divide those numbers above by 30. That 8.5° field is down to a little less than 15' across at a typical 100' observing distance (and a tad less than 1.5' across at a 10' woodland birding distance). That 5° field binocular (typical of many 10x binoculars) has a field less than 9' across at a 100' distance and only about 10.5" across at a 10' distance (which is why high power binoculars are rarely used for extremely close-in birding, no matter how good their close focus).

Field of view is determined by two factors. The first is simple magnification. Lower power binoculars have inherently wider fields of view than higher powers. The second is eyepiece design. Eyepieces can be designed to provide a wider apparent field of view, at the cost of more complexity, extra weight, and often a whole other set of optical compromises (see *Residual aberrations and distortions* above).

Eye relief: As optics actually operate in the real world, there is a maximum distance your eye can be from the back of the eyepiece and still see the complete field. We call that distance the eye relief, and it is most often given in millimeters. A "wide angle" eyepiece may provide a field of 8.5°, but it also may require your eye to be all but touching the glass of the eyepiece to see the whole field. In general, the closer your eye has to be to the eyepiece, the more fatigue the glasses will cause. Having your eye close to anything continually triggers the blink reflex. We can control the reflex to an extent, and we have to when using almost any binoculars, but it causes a certain amount of mental and physical fatigue.

To be comfortable, you need an eye relief of about 10mm if you don't wear glasses. Eyeglass wearers need, obviously, more, since they can get the binoculars no closer to their eyes than the outside surface of their eyeglass lenses. Almost all binoculars come with some kind of eyecup that folds down or pops in to allow eyeglass wearers to get as close as possible to the eyepiece. The actual eye relief needed by any given eyeglass wearer varies, but, in general, 12-15mm will allow you to see 70-80% of the field, and 20mm will allow you to see the whole field.

I am more comfortable with eye relief that is slightly on the short side than I am with eye relief that is too long; if, that is, there is no easy way to adjust the eyecups for different distances. I would rather sacrifice some of the field than fight to keep the too long cone centered over my pupil. When the eye relief is too long, with eyecups completely collapsed, the view "blacks out" unpredictably. The ideal solution, which is only now started to be adopted by some manufacturers, is to have a retractable eyecup with a number of discrete height stops that let it be set precisely for the individual birder's eyes and eyeglasses. If the binoculars you are considering don't have such a feature, err on the short side of the eye relief, not the long.

A point to consider about eye relief is that the manufacturers' published figures do not always quite agree with reality. Manufacturers measure the eye relief from the last surface of the eye lens to the point where the image forms behind the eyepiece. While this is technically the correct way to measure eye relief, most binocular eyepieces are recessed slightly below the rims of the collapsed rubber eyecup. This is to protect the eyepiece from being scratched by contact with your eyeglasses or sunglasses, etc. The amount that they are recessed reduces the true *usable* eye relief by the same amount. I mentioned that eyeglass wearers can get binoculars no closer to their eyes than the outside surface of their eyeglass lenses. If that distance is reduced by the recessing of the eyepieces, the true eye relief for them is likewise reduced.

A manufacturer can't very well start listing the true usable eye relief of his optics, even though those realistic numbers would be more meaningful to real world birders. Other manufacturers would continue to use the technically correct (but longer) eye relief figures they do now, putting the first manufacturer at a competitive disadvantage. Christophers, Ltd., the sponsor of *BVD Online,* measures the actual *usable* eye relief of the optics they carry. They list both the real-world values they measure and the manufacturers' technically-correct figures in their write-ups on most of the products they carry. This makes it easier for potential buyers to more accurately judge the optics they are considering.

Depth of field: The naked eye, as well as seeing everything in front of it, also produces, in good light, a fairly sharp image of everything from about 10 feet out to the horizon. We also have the unconscious ability to shift our focus to closer objects, right down to about 8 inches from our eyes. Again, when we look through binoculars we are faced with a different situation. The point at which everything is in focus and is equally sharp is pushed out by a factor equal to the magnification of the binoculars. Because much of our viewing falls inside that new limit, we have to manually shift the focus of the system every time we move our eyes.

Our eyes are somewhat forgiving when it comes to focus, and, in fact, can themselves alter the focus of the system within narrow limits. The zone within which the eye and brain can extract enough information to form a satisfying impression of the object is called the zone of acceptable focus, or the depth of field. As with field of view, lower power binoculars have an inherently wider, or deeper, zone of acceptable focus than higher power binoculars. Wide angle eyepiece designs can increase the apparent depth of field of even quite high power systems. Then too, as with field of view, the eye/brain is used to operating within a select range inside the actual depth of field of the eye. We expect that as we get closer to objects, as we focus our attention on individual objects to study them, the depth of field will diminish. You might say that there is depth of field associated with our cone of active attention.

Depth of field is much more important to overall viewing comfort than it is generally given credit for. The most comfortable binoculars to use are the ones that come closest to approximating the natural depth of focused attention of the human eye at any given distance. Some come close enough so that we experience no noticeable strain in using them. Given practice with the focus control, it becomes just as natural to focus through the binoculars as it is without. Some binoculars, on the other hand, have such a narrow zone of acceptable focus that we are always straining to see through them, we are always fiddling with the focus . . . and that is a recipe for fatigue and discomfort. Over an hours' use in the field, there is no other single factor that will be more obvious to the experienced user than the amount of focus fiddling necessary for a satisfying view . . . and yet, this is a factor that seldom, if ever, gets any attention.

Magnification: We have already noted, in the discussion above, two ways in which higher magnifications can adversely affect binocular handling performance. Higher magnifications generally limit both the field of view and the depth of field of binoculars. Worse, however, is magnification's affect on image steadiness. As you increase the magnification, you are also magnifying every motion of the binoculars. It is next to impossible to extract information from an image that is bouncing around. With practice, and given exceptionally well-balanced binoculars, the average birder can learn to extract detail from a 10 power image. Extracting detail from an 8 power image is even easier, and, in objective tests conducted by Zeiss, birders consistently extracted the most detail (at least on eye charts) from a 7 power image. As noted above, my experience has been that there is no practical difference in the amount of detail you can see in hand-held binoculars of equal quality between 7 and 10 power. There is, however, a real difference in the amount of fatigue generated over a day's use.

The extra effort and concentration needed to hold 10x binoculars steady and extract detail will tire many birders after a fairly short time in the field, especially if the depth of field is shallow enough to require constant refocusing. A tired birder will, in the long run, see less. There are exceptions, of course, but my general recommendation, after years of testing and using binoculars, is that 8x is just about the ideal power for birding . . . enough power to give a satisfyingly large image of the bird, but not enough to cause undue fatigue.

Durability/weatherproofing

Binoculars are precision instruments. No binoculars are going to take routine abuse without showing its effects. Optical elements can become decentered. Barrels can go out of alignment. Glass can chip and crack. Coatings can scrub off. Dust and dirt gets inside and fouls the system. Durability is, not surprisingly, almost directly proportional to cost. (What is more surprising is that it is the only factor that is!) Most $1000 binoculars can take a good deal of rough handling. Most $100 binoculars can take practically none at all.

It is sometimes assumed, on the basis of the current state of the market, that the roof prism design is inherently more durable than the porro prism design. That is not true. $200 roof prisms glasses are no more durable than $200 porro prisms (not to mention the fact that, at that price point, the image quality of the porro prism glasses will often blow the roof prism glasses right out of the water). Roof prisms may *seem* more durable, but that's because most porro prisms sold nowadays are coming from the bottom of the pricing ladder. There are a lot of them out there and they tend to break more easily than the mid-priced roof prisms many birders favor. $1000 porro prism glasses *could* be made every bit as durable as $1000 roof prisms, should the marketplace demand it, but that has yet to happen.

Weatherproofing is another matter altogether. Most roof prisms, those with true internal focusing, are inherently easier to seal than porro prisms that focus by moving the eyepieces in and out. In a closed system, it is even possible to purge the interior of the glass by pumping it full of some dry gas (nitrogen or argon) and sealing the gas inside. Such binoculars are safe from both external and internal moisture (they don't fog up on the inside when you take them from the cold into a warm room). Besides moisture problems, any porro prism that moves an external element actually works like a little vacuum pump to pull dust into the insides (where it settles on the prisms and lens surfaces to become a permanent and unwelcome addition to your view). An optics maker can mitigate the problem somewhat by using "O" ring seals on the moving elements, but seals wear out over time and, from day one, cause focusing friction problems. Again, the issue is not just roof verses porro. There is no inherent reason that someone couldn't produce an internally focusing porro prism glass that was every bit as weather tight as a roof prism. It would probably cost $1000 too.

The binoculars described in the first paragraph way back there . . . the easy to carry, easy to use, indestructible, weatherproof, ones with the bird in the hand view under any circumstances . . . do not yet exist except in the fevered minds of visionary birders (and maybe in the imaginations of a few optical designers with too much time on their hands). We should consider ourselves blessed, I guess, that among the hundreds of models of binoculars currently on the market, there are a handful that come as close as they do to meeting the needs of birders. There are almost certainly binoculars out there that you will find satisfying. Read the on-going reviews here in *BVD Online* and in the various birding magazines. Handle and take a look through any binoculars you see that are new to you. Above all, don't settle for anything less than the best view you can get (and are willing to pay for). We birders spend too much time behind binoculars to settle for anything less but the better view we all desire!

Written by Stephen Ingraham, 1995,
updated and with additional material by Fred Bieler, 2007

Contact: Christophers, Ltd
http://www.betterviewdesired.com