

# BEST BINOCULAR FOR YOU

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If you ask a lens designer or optical engineer what are the best binoculars for birding you could be in for a lengthy discussion with as many ifs and buts as in a legal opinion. However, if you ask the same question of an optical designer or optical engineer who is also an experienced birder, then you might find the answer is more straight forward than you expect and is not difficult to work out for yourself.

The first thing that needs to be considered is the amount of light available for imaging. This can vary over several orders of magnitude depending upon whether you are in the bright light of the outback, gloomy southern forests in winter, or observing nocturnal birds in twilight. The unit of measure for the luminance of a surface is the candela per square metre ( $\text{cd/m}^2$ ) – a grey overcast sky has a luminance of about  $1000 \text{ cd/m}^2$  while typical twilight birding scenes have less than  $10 \text{ cd/m}^2$ . The response of the human eye to these different light levels is central to this discussion. In low light the ability of the eye to detect changes in contrast and resolve fine detail is diminished and the scene looks grainy. In an attempt to gather more light, the pupil of the eye opens up to its maximum extent. In bright conditions the pupil partly closes to reduce the amount of light imaged on the retina. The response of the pupil depends on the age of the subject – in young people the pupil is capable of opening to more than 7 mm diameter but in old people the maximum pupil size is about 5 mm. The measured light-adapted pupil size for normal people of various ages is shown in Table 1.<sup>1</sup>

TABLE 1

Age (years)	Pupil Size (mm) (Low light $9 \text{ cd/m}^2$ )	Pupil Size (mm) (Bright light $4400 \text{ cd/m}^2$ )
20	7.2	3.8
30	6.8	3.6
40	6.3	3.5
50	5.9	3.3
60	5.5	3.2
70	5.0	3.0
80	4.6	2.9

<sup>1</sup> Barry Winn et al., 'Factors Affecting Light-Adapted Pupil Size in Normal Human Subjects' in *Investigative Ophthalmology & Visual Science*, March 1994, vol. 35, no. 3, pp. 1132–7.

Optical systems like binoculars have an entrance pupil and an exit pupil. The entrance pupil is a circular aperture that forms part of the objective lens housing. The exit pupil is not a physical piece of the binocular hardware – it is the image of the entrance pupil projected by the eyepiece to a position just beyond its outer surface. The exit pupil is usually located 15–20 mm on the eye side of the eyepiece. You can see the exit pupil if you hold a binocular at arms length and look into the eyepieces – it appears as a small bright circle of light. It is more instructive to point the binocular towards a source of light and use a piece of paper to find the exit pupil. If you use thin paper as a semi-transparent screen you will see a circular patch of light about 5 mm in diameter that comes in and out of focus as you move the paper back and forth along the light path about 15 mm away from the eyepiece.

In an ideal optical system the exit pupil of one part (binocular) should match the entrance pupil of the following part (eye pupil). A good match will ensure the maximum transmission of light from one part to the next while at the same time keeping the components to the minimum size required to do the job. This will ensure the optical system has the minimum weight and cost. However, as the eye pupil is variable in size with age and light level, there is no one binocular specification that is optimal for all users and all applications. The solution is to personalize the decision making process to eliminate options and to make some basic assumptions regarding others. The first assumption is that the ideal binocular magnification for birding is in the range from about 7× to about 10×. The second assumption is that low light performance is critical and should therefore drive the selection process.

For optical systems like binoculars, the magnification is defined as the ratio of the size of the entrance pupil to exit pupil or, if we already know the size of the exit pupil, then the size of the entrance pupil (objective lens size) will be equal to (magnification × exit pupil size). This simple formula enables the construction of Table 2 which shows the ideal objective lens diameter (mm) for various magnifications and exit pupil sizes. In the table the exit pupil sizes correspond to the low light pupil sizes shown in Table 1.

TABLE 2

Age (years)	20	30	40	50	60	70	80
Pupil size (mm) (Low light level)	7.2	6.8	6.3	5.9	5.5	5.0	4.6
<b>7x</b>	<b>50</b> TF = 18.7	<b>48</b> TF = 18.3	<b>44</b> TF = 17.5	<b>41</b> TF = 16.9	<b>38</b> TF = 16.3	<b>35</b> TF = 15.6	<b>32</b> TF = 15.0
<b>8x</b>	<b>58</b> TF = 21.5	<b>54</b> TF = 20.8	<b>50</b> TF = 20.0	<b>47</b> TF = 19.4	<b>44</b> TF = 18.8	<b>40</b> TF = 17.9	<b>37</b> TF = 17.2
<b>8.5x</b>	<b>61</b> TF = 22.8	<b>58</b> TF = 22.2	<b>54</b> TF = 21.4	<b>50</b> TF = 20.6	<b>47</b> TF = 20.0	<b>42</b> TF = 18.9	<b>39</b> TF = 18.2
<b>10x</b>	<b>72</b> TF = 26.8	<b>68</b> TF = 26.1	<b>63</b> TF = 25.1	<b>59</b> TF = 24.3	<b>55</b> TF = 23.4	<b>50</b> TF = 22.4	<b>46</b> TF = 21.4
<b>10.5x</b>	<b>76</b> TF = 28.2	<b>71</b> TF = 27.3	<b>66</b> TF = 26.3	<b>62</b> TF = 25.5	<b>58</b> TF = 24.7	<b>52</b> TF = 23.4	<b>48</b> TF = 22.4

Included in the table is the twilight factor (TF), a figure of merit for low light level performance. The greater the twilight factor, the better the low light performance of the

binocular. The twilight factor is the square root of the (magnification  $\times$  objective lens diameter). It does not take account of the light lost in transmission through the binocular but for modern mid-range and top of the range systems this is of little consequence as the coatings are so good that more than 90 per cent of the light reaches the eye. In low light conditions the twilight factor needs to be greater than about 18.0 and is shown in the table by the shaded region.

To use the table you first select the column roughly corresponding to your age. If you are around 60 years old your dark-adapted eye pupil will be about 5.5 mm diameter and if low-light birding is important, then you will need an  $8 \times 44$  mm,  $8.5 \times 45$  mm or perhaps  $10 \times 56$  mm binocular. For someone 40 years of age the pupil will be about 6.3 mm and any specification from  $8 \times 50$  mm to  $10.5 \times 56$  mm will be fine. Note that binoculars with the objective lens greater than about 56 mm are just too heavy for field-work and for this reason they are not considered useful for birding. Young people are spoilt for choice and any system from  $7 \times 50$  mm to  $10.5 \times 56$  mm will perform well in low light. However, they need to be aware that popular birding binoculars like the  $8 \times 42$  mm will not permit the best low light viewing that their eyes are capable of providing. The exit pupil of  $8 \times 42$  mm binoculars is only 5.2 mm but the eye is capable of admitting much more light when the pupil is fully open (about 7 mm). To take advantage of this, young people should consider binoculars with at least 50 mm objective lenses.

Thus far the discussion has been generic, that is, without reference to any particular binocular design or manufacturer's product. To take the next step it will be necessary to start looking at particular products with the nearest combination of magnification and objective lens size that you have determined from Table 2. To be sure of choosing the best binocular for you, only consider mid-range and top of the range products. They cost more but with good reason including sophisticated optical and mechanical design, high performance coatings, the use of advanced materials, tight manufacturing tolerances and strict quality control. This is why some binoculars cost \$2000 while others cost only \$200. There are also a number of other important decisions you must make but as these are discussed at length in many other publications we will only treat them briefly.

The first is the need for long eye relief for spectacle wearers (15–20 mm). Most modern binoculars have this as a standard feature with pull-out eye-cups for the use of people who don't wear spectacles. Next is close focusing distance – for birding this should be less than 5 m and if you really enjoy close observation then one of the binoculars developed for butterfly watching would be ideal (for example the Nikon Monarch series). The field of view also needs to be considered – it should be at least  $6^\circ$  or 105 m at a range of 1000 m. Wider fields of view are possible but they come at some cost as the erector prisms and eyepieces need to be bigger and the lens design needs more elements for correcting field aberrations. If you want a wide field of view then it will be better to trade off low light performance and go for something like the Nikon Action  $7 \times 35$  mm with a  $9.3^\circ$  field of view. It is available with long eye relief for spectacle wearers and is superb for observing fast moving birds at close range.

This brings us to a few words on image quality assessment. The toughest test that a birder can do is available most nights – the star test. There is so much that can be learned about the shortcomings of binoculars by viewing stars and planets that it would take a lengthy article to tell all. Fortunately, there are a number of online sources for those who want to know more. The star test is great for comparing the performance of a number of binoculars you might be contemplating buying. One of the most useful tests is to bring a bright star or planet into focus in the middle of the field of view and then pan off until the object is near the edge of the field of view. Do this up and down and left to right and observe whether the object appears to go out of focus, changes shape from a

small circular object to a kidney shape or flare, and whether any colour fringes appear. This is testing how well the optical aberrations are corrected across the field of view of the binocular plus eye combination and if you wear prescription lenses they will be in the picture as well. The star test will reveal some shortcomings with all binoculars and is great for sorting the good from the bad and the best from the good. Beware of being too critical of one manufacturer's optics compared with another as there are variations in eye performance and certainly differences in prescription lenses that can make one manufacturer's binocular appear better than others. A binocular that is perfect for you will not necessarily be ideal for someone else and vice versa.

Then there is the question of balance and weight. Much has been written about both as personal preferences are involved providing plenty of scope for differences of opinion. As regards weight, my limit is about 1 kg and only then on a shoulder harness. My wife finds 1 kg just too much and has sensibly chosen a good low light performer weighing only 620 gms. The question of weight becomes a serious issue for binoculars with large objective lenses – most binoculars with lenses of 50 mm or more weigh at least 1 kg and this rules them out for many birders. It's not surprising then that the most popular birding binoculars are clustered around the 8 × 42 mm specification (8 × 44 mm and 8.5 × 45 mm should also be considered). They are not too heavy, provide good low light performance for middle-aged and older birders, and cost less than their big brothers. The question of cost is a sensitive one and for many birders will rule out top of the range products. Fortunately, there is very little difference in the optical performance of mid-range and top binoculars in most lighting conditions. However, if you are in the field every day working as a professional guide, wildlife officer, researcher or birder, then it is not hard to justify a top of the range binocular. Flagship binoculars manufactured by Carl Zeiss, Leica and Swarovski are superbly engineered, ensuring a long, trouble-free life of hard work in harsh conditions. However, it is questionable whether the casual recreational birder needs binoculars of this build standard let alone whether they are value for money.

If you follow the simple decision-making process outlined in this article you will be following in the steps of an optics professional who is also an experienced birder. The process will enable you to choose the best binocular for you.

Dr Wilson has a PhD in optical physics and thirty years experience in the design and manufacture of optical systems for imaging and spectroscopy. Before retiring he was the Chief Research Scientist in charge of optical systems engineering at CSIRO and Technical Director at Optical Engineering Associates Pty Ltd. He has been an active birder since childhood.