Exposure and ISO: What is the best combination? – Glenn Pure

One of the 'seven deadly sins' referred to by BLP member Ian Wilson in his article in the June newsletter was incorrect exposure. In his commentary, he noted the value of over-exposing during the original image capture. When the RAW image is post-processed to fix the overexposure and bring it back to a normal tonal range, it has the bonus of reducing noise.

Following that logic suggests that increasing the ISO to enable an image to be over-exposed could be used as a means of reducing noise in the final image. So, higher ISO = lower noise! That seems totally counter-intuitive so I investigated further. At this point, I wish to gratefully acknowledge the excellent help and guidance Ian Wilson gave me as I prepared this article.

I'm no expert on this subject. I've researched and written it as a way of teaching myself more about how to get the most out of my relatively recent foray into DSLRs and bird photography. In the process, I've discovered some things I didn't know – and that perhaps others don't know either.

Why worry about noise at all? While it usually isn't apparent in the parts of an image that contain a lot of detail (typically the bird itself), it is much more obvious and distracting in smooth, even areas of tone – such as out-of-focus backgrounds and foregrounds.

As part of my investigation, I did some tests with my Canon 700D to see what would happen to noise levels if I overexposed an image simply by increasing the ISO without changing anything else. To enable easier comparison and quantification, I photographed a blank area of even tone (small, evenly lit patch of white ceiling with my camera lens de-focused to ensure no texture in final image). I set the camera to manual exposure and used the same shutter speed and aperture for each image but varied the ISO from 400 to 3200. This resulted in an image at ISO 400 that was underexposed by about 1.5 EV and one at ISO 3200 that was overexposed a similar amount. All images were adjusted back to mid grey and neutral colour balance in post-processing. All camera and post-processing noise reduction was turned off so it did not interfere with the results. Figure 1 shows the outcome. Note: you may have to zoom in on the image to see it properly.

Figure 1. Images captured on my 700D at different ISO settings. The shutter speed and aperture were exactly the same for each image: 1/50 sec at f8. The camera's high ISO NR was turned off. The images were post-processed to correct for the under- or overexposure. Each panel is a 1:1 crop from the original (ie. each pixel in the panel represents a pixel in the original image).

The noise at each ISO setting is very similar, although the ISO 400 shot looks slightly less noisy to me. Quantifying the results from the luminance histogram in my copy of Photoshop Elements showed the noise did, in fact, increase slowly and gradually from ISO 400 to ISO 3200. For those interested, the signal-to-noise ratio was 31.4 db at ISO 400 and deteriorated to 29.5 db for the ISO 3200 image.

So, overexposing an image solely by increasing ISO does more damage than good. My results show it makes noise slightly worse. The reason is that increasing the camera's ISO setting is achieved by turning up an amplifier that boosts the signal from the camera's sensor. As good as these amplifiers are in modern cameras, they are not perfect and become noisier as they are turned up. This injects more noise into the signal from the sensor and results in a noticeable but small increase in the image's relative noise level at higher ISO settings. This is much the same as the audio amplifier in a sound system. If it's turned up a lot, hum, hiss and other noise will become more apparent, especially during the quiet portions of a recording or moments of silence.

So what other sources of noise are there and how can over-exposing reduce it? Ian pointed me to the following recent article on camera noise:
http://www.dpreview.com/articles/8189925268/what-s-that-noise-shedding-some-light-on-the-sources-of-noise

I always thought that most noise in a digital image was the result of sensor noise and the downstream electronics that process the sensor's signal. That turns out not to be true for most situations that photographers, including bird photographers, would face. The sensors and their associated electronics do contribute noise but it is a relatively small amount, even at high ISO settings – as shown in Figure 1. Most noise actually comes from the subject being photographed. ***Brightly lit subjects are less noisy (higher signal-to-noise ratio) than those in poorly lit situations (lower signal-to-noise ratio)***. Technically, this type of noise is referred to as photon shot noise.

To understand what's happening, you need to think of light as a random stream of little flashes or light packets (photons). The more photons there are hitting your camera's sensor, the brighter the object will look. However, the flow of photons is not smooth or even and can vary significantly from one moment to another. The contribution of this randomness is *relatively* smaller when there are a lot of photons flowing, as occurs in a brightly lit situation. However, in a poorly lit situation, the difference in flow of photons from one moment to the next will vary by a much greater percentage. The brief moment your camera shutter is open results in those variations being recorded even though we don't observe them with our eyes. The result is noise in your final image.

An analogy may be helpful. Imagine your camera's sensor was the size of a tennis court and recorded raindrops instead of light photons. If it was placed outside during a rain shower and uncovered for just 2 seconds, some of the pixels would not detect any raindrops while others might be hit by one, two or even more raindrops during that time. So, even though we would

consider the rainfall even over the entire area, there will be a large percentage difference in the raindrop count at each pixel. On the other hand, imagine leaving the raindrop sensor uncovered for one minute. It would be very rare for a pixel not to record any raindrops during that time. Say the average number recorded at each pixel was 30 raindrops. The lowest count at any pixel might be 15 and the highest 45 (statisticians can actually tell us what the distribution around the average is for random events like this). So for the one minute 'exposure' even though the variation in number of raindrops hitting each pixel is numerically larger at +/- 15, it is a much smaller percentage of the average compared to the 2 second exposure. The signal to randomness (or noise) ratio is much higher for the one minute exposure so it appears less noisy.

Coming back to your camera sensor, if only a small number of photons are hitting each pixel (because the light is poor or very fast shutter speeds and small apertures are being used), the variation from pixel to pixel will be much greater and the noise much worse. Don't forget, the signal recorded by your camera in such situations needs to be amplified by turning up the ISO or the equivalent done in post-processing to obtain an image with normal range of highlights, mid-tones and shadow areas. That process also amplifies all the random variation, resulting in a noisy final image.

To prove the point, I ran a different test with my camera, using a similar setup to Figure 1. This time, I left the ISO unchanged and varied the shutter speed (aperture was left fixed) so that the image with the longest exposure was overexposed by about 1.5 EV and the shortest exposure underexposed by a similar amount. The under- or overexposure was corrected in post-processing to give a neutral grey image in each case. Figure 2 shows the results. Again, you may have to zoom in to adequately see the differences.

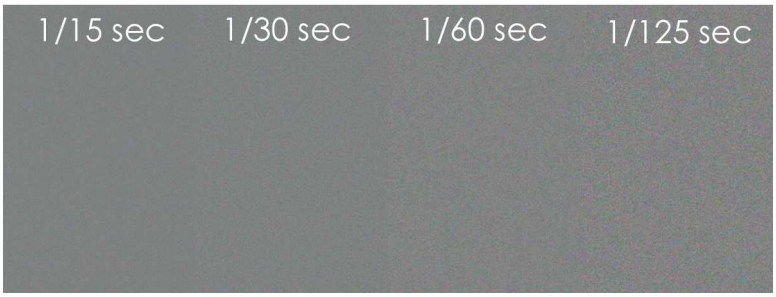

Figure 2. Images captured on my 700D at different shutter speeds but with ISO unchanged and aperture fixed at f8. The camera's high ISO noise reduction was turned off and no noise reduction was applied in post-processing. The images were post-processed to correct for the under- or overexposure and produce a mid grey final image. Each panel is a 1:1 crop from the original (ie. each pixel in the panel represents a pixel in the original image).

It is clear that the noise gradually gets worse as the exposure gets shorter, consistent with the source being photon shot noise. I measured the signal-to-noise ratio as for Figure 1. It was 34.6 db for the 1/15 sec overexposure and fell to 27.7 db for the 1/125 sec underexposure.

How does this translate to photographic practice? ***The more light you can get to your camera's sensor, the lower the noise you can expect***. The simple ways to do that are to

increase the exposure time (slower shutter speed) or use a larger aperture (smaller f number). That will also mean a lower ISO to obtain the correct exposure. However, when photographing birds, we don't have the luxury of choosing very slow shutter speeds otherwise motion blur will be a problem. Similarly, there are usually limits on how far open the aperture can be set. Long 'bird' lenses typically have relatively small maximum apertures. Also, if aperture is set too wide, depth of field may become a problem. So compromises often have to be made.

So far, so good. The testing I have shown is unrealistic though. We all photograph real-life subjects and are all going to post-process our RAW files to try and reduce noise. Most obviously, applying noise reduction in post-processing is going to affect noise, but sharpening and scaling will also have an influence (sharpening increases noise and scaling reduces it). So I did some real-world tests using my 100-400mm lens at 400mm and sharply focused on the subject. However, I could not find a bird that would sit still for long enough, so you will have to make do with a native orchid as the subject. I did the same thing as for Figure 2: ISO was fixed, aperture was fixed, and shutter speed was changed to alter the final exposure. After capture, I processed each RAW file by adjusting exposure to give a normal tonal range for each image. I also applied mild luminance noise reduction (3 out of 20 in Canon Digital Photo Professional (DPP)) and chroma noise reduction (8 out of 20 in DPP). I then sharpened in DPP ('Sharpness' adjustment set to 7) and scaled the original image (from 5184 x 3456 to 1800 x 1200). The degree of scaling would enable a 1400 x 1050 image (the maximum size allowed on the BLP website) to be cropped from the image. Finally, I sharpened the image in Photoshop Elements ('Adjust Sharpness' function: 'Remove Gaussian Blur' set to 50% and 1.0 pixel). Figure 3 shows the results.

Figure 3. Real-world images captured and post-processed as described in the text. The exposure adjustment necessary to bring each image to a normal tonal range ranged from -1 EV for the 1/60 sec exposure to +2 EV for the 1/500 sec image. A crop was taken from the centre of each image and is shown 1:1 (each pixel in the figure is a pixel in the post-processed final jpg image).

Clearly, even with post-processing, noise is noticeable and considerably worse in the underexposed image (1/500 sec in Figure 3). Stronger noise reduction in post-processing would have helped, but bear in mind that doing so will impact on sharpness of the final result. The

more noise reduction (notably luminance noise reduction), the greater the loss of sharpness, although the amount I applied for Figure 3 was relatively mild and had little impact on sharpness.

Conclusions

There is no escaping the fact that the more compromises that are made to reduce the amount of light reaching your camera's sensor, the more problems there will be with noise in the final result. When photographing in open areas under strong light, it would be unusual to have any problem but it will be an issue in low light situations, such as under tree canopies, early or late in the day etc.

The ideal camera settings to reduce noise will be the slowest shutter speed and widest aperture (smallest f number) you can get away with. After setting those parameters, ISO will then need to be adjusted to give a suitable final exposure. Using a lower ISO has the bonus of reducing electronic noise in your final image although this effect is quite small. If you are not using manual exposure, a slightly different approach is needed. I often find myself in that situation and normally use aperture priority metering since I typically photograph birds under tree canopies and around bushes where the light can vary considerably, making manual exposure impractical. By metering in different parts the scene I am working in, it's possible to determine the minimum shutter speed the camera is likely to select. Knowing this, I can then go about setting ISO.

Another more radical way I could increase the light on my camera sensor is to buy a full frame DSLR. Compared to my 700D, a full-frame with the same pixel count will have pixels that are twice the surface area on the sensor and will therefore capture twice as much light. Having said that, I won't be rushing out to buy a new camera any time soon.

While post-processing will help deal with some of the noise you may encounter, as discussed earlier it will impact on sharpness of the final result. The solution to this is to selectively apply noise reduction only to the background and foreground of the image, not the bird. Recently, I've tried using layer masks in Photoshop to achieve this. The layer with the bird can also be selectively sharpened using this method. Ian Wilson told me about another way using the Photoshop Quick Selection tool combined with the lasso tool to select the bird, then invert that selection to treat noise in the rest of the image (select 'Filter' menu, then Noise - Median). I hope to prepare something more detailed for a future newsletter. While these work-arounds are quite effective, it's always best to start with the least noisy image possible.

Another thing I took away from this piece of investigation was to turn off the high ISO noise reduction in my camera. I'd noticed before that it did impact on the sharpness of my RAW images at ISO 3200. I will now do all of my noise reduction in post-processing - where I can see the impact and better consider any trade-off between sharpness and noise.