

Automatic Focus Stacking

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Figure 1 This is a 17-image focus stack of the John Oliver cabin in Cade's Cove of Smoky Mountains National Park. Exposure is $\frac{1}{4}$ second, f/8, and ISO 125 using the manual exposure mode. F/8 was used because that is a sharp aperture. Stopping the lens down more is not necessary because the depth in this image is captured in the focus stack that is processed with Helicon Focus. The lens used is a Canon RF 24-105mm.

Focus stacking is the process of shooting two or more images where everything remains the same except focus distance. It works on any completely still subject like a flower on a calm day and most landscapes. The technique is especially useful to closeup and landscape photographers because it enables photographers to capture incredible depths of field in the final image while simultaneously using the one of the sharpest apertures on the lens.

The procedure for shooting a focus stack set of images is quick and simple once you do it a few times. The sharpest aperture found in a lens is typically 2-3 stops down from the wide-open aperture setting. For example, if the maximum aperture of a lens is $f/4$, then $f/8$ to $f/11$ tend to be the sweet spot for sharpness. Since most lenses are sharpest around $f/8$, that is an excellent aperture to use when shooting the stack. There is no reason to stop down more because the depth of field is captured in the image stack you shoot and later process with focus stacking software like Helicon Focus, Zerene Stacker, Canon's DPP4, and even Photoshop. Some cameras even assemble the shot stack of images in the camera, but I have never owned a camera that did that.



Figure 2 A 22-image focus stack of Mingus Mill near Cherokee, NC in the Smoky Mountains. Exposure 1/5 second, $f/5.6$, and ISO 400 with a Canon RF 24-105mm lens set to 77mm.

First, let me describe the old way I shot my focus stacks. First I determine the exposure by using the camera's highlight alert and I manually adjust the exposure to produce the first blinkies in a bright area of the subject. Since I always shoot RAW, and the highlight alert is based on a JPEG embedded in the RAW file, the exposure is not yet too bright, and all highlight detail can be rendered when the raw image is processed. Then I manually focus on the closest spot I want in sharp focus, photograph my hand in front of the lens to mark the beginning of the stack, and then shoot the first image of the stack. Since I shoot Canon, I know my Canon lenses focus a little further away by turning the focus ring counterclockwise as viewed from behind the camera. (Nikon is exactly opposite to Canon. If you shoot another brand, find out which way to manually turn the focus ring to focus on a spot further away.) So, I turn the focus ring manually to focus a little further away, shoot another image, and keep doing this until my focus is beyond any portion of the image that I want in sharp focus. The final shot is my hand again. All the images between the two images of my hand comprise the focus stack of images. I have shot thousands of macro and landscape focus stacks this way for more than a decade without much trouble, but it does burn some time to manually change the focus and you must be gentle about manually making the focus changes to avoid disturbing the composition.

In October of 2020 I bought my first mirrorless camera, the Canon R5. Under the red camera icon and set #5 in the menu, focus bracketing is a new feature offered that allows you to automatically shoot the stack. Of course, you still must process it, but at least I no longer have to manually turn the focus ring as I shoot the stack. The default is Disable, so I set this feature to Enable. Easy enough! But then there are three other options to set that include Number of shots, Focus Increment, and Exposure Smoothing. These are not so intuitive, so let me explain each of them.

Exposure Smoothing

If the exposure varies a little as the camera automatically shoots the stack of images, the camera makes the exposure similar among all of the images in the stack. Normally, the exposure does not change much when I automatically shoot the image stack since often the ambient light is steady and the process only takes seconds. Therefore, I leave Exposure Smoothing set on Disable when focus bracketing landscapes. However, things change for macro images. When using a macro, the exposure changes as the lens is focused to different distances. Changes are small, but Exposure Smoothing produces similar exposures in the stack of images that combine with focus stacking software better. Therefore, for macro images, I turn on Exposure Smoothing.

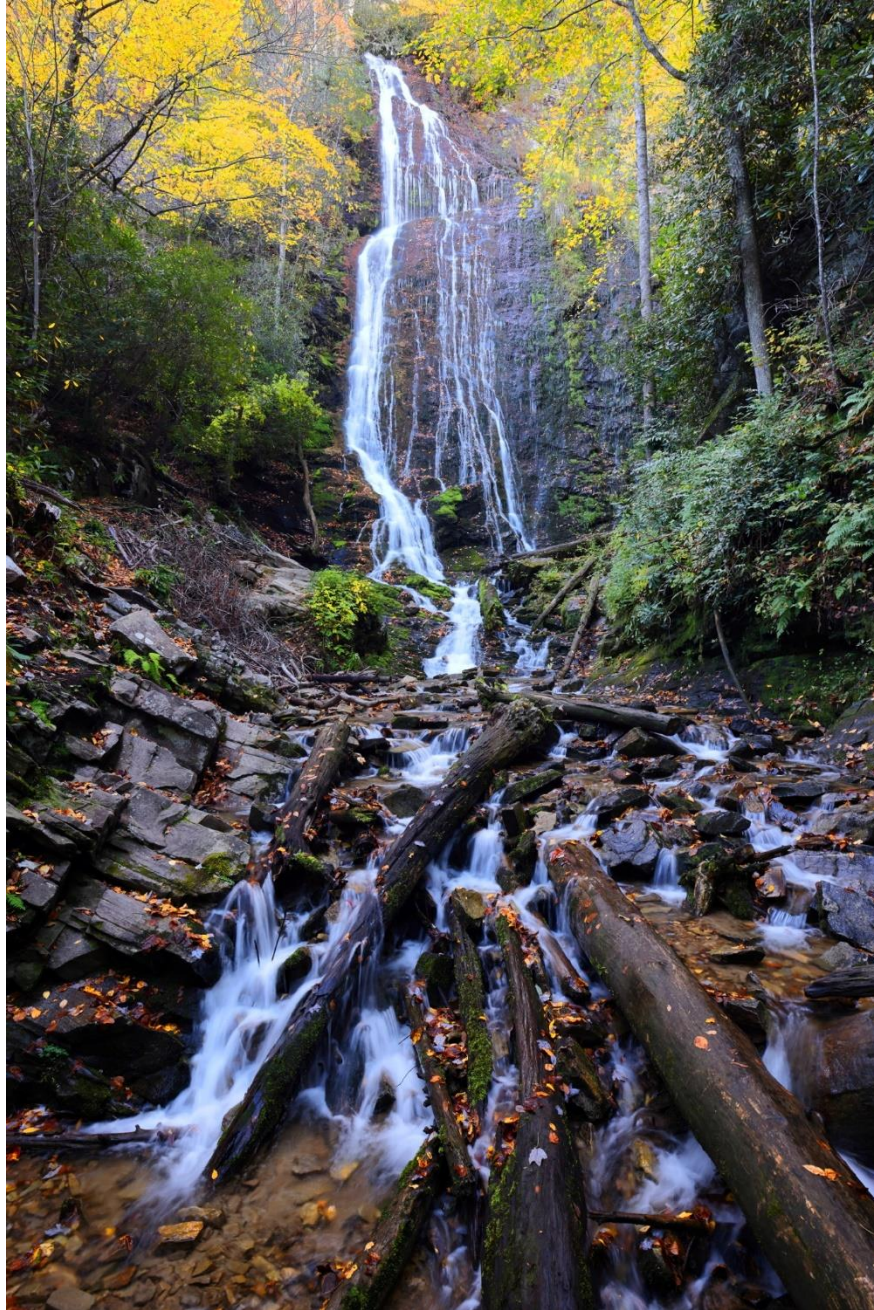


Figure 3 Seven images capture the depth at Mingo Falls in Cherokee, NC. Exposure is 1/4 second, f/8, at ISO 400 with a 15-35mm lens. Vertical images tend to benefit from stacking images more often than horizontal because the foreground is often closer to you.

Focus Increment

This offers ten settings from one to ten. One is the smallest increment and ten is the largest. There is no way to know exactly what the increment is, but you learn to set it with a little trial and error. For example, early on I evaluated a flower that was about 1/4x magnification and ran ten stacks using each of the 1-10 increment values. I found at 1/4x magnification, an increment of 3 worked fine. I gained nothing in sharpness by using the smaller increments of 1 and 2, and when using larger increments such

as six, I noticed the flower was less sharp because the camera changed the focus distance too much and a tiny portion of the subject was not adequately covered by the depth of field and that is primarily controlled by aperture and magnification. It makes sense to use a sharp aperture, so f/8 is my choice. At higher magnifications closer to life-size and greater, then more likely using an increment of 2 or even 1 is best. If magnification is less, perhaps only 1/5x or a landscape, then the depth of field at f/8 covers more distance allowing a larger focus increment. Keep in mind the smaller the focus increment, the more images that are automatically shot.

That said, I tend to go overboard on things such as sharpness. Therefore, I have been using the tiny focus increment of 2 with much success. I realize such a fine increment is likely unnecessary with landscapes, but I would rather shoot using an increment smaller than necessary to obtain superb sharpness, rather than use too large an increment and get some soft planes in the image because the depth of field at my chosen f/stop (probably f/8), does not cover the depth. You can shoot too few images when stacking, but never too many. There is little downside to shooting finer increments than you need outside of the fact it takes longer to stack more images. Some have suggested more storage space is a downside, but to me storage is cheap and that is not an issue to me.



Figure 4 The reflection at Jenny Lake in the Grand Tetons is captured with just a 2-image focus stack. The first shot was focused on the rocks in the lake's foreground and the second image was focused on the mountains. Exposure is 1/40, f/8, and ISO 100. Exposure set manually to produce a few blinkies in the white clouds. Canon RF 24-105mm lens with polarizer. I used the touch shutter on the Canon R5. I touched the rocks in the foreground with my finger on the LCD, and then touched the mountains and that was it. So simple with the touch shutter. Touch, the camera focuses on the spot touched, and the image is shot 2-seconds later since the camera is set to the 2-second self-timer.

Number of shots

This value can be set in the range of 2 – 999. I cannot imagine needing several hundred shots, but a subject at twice life size such as a jumping spider might need 60 shots or more with Increment level 1. However, for the flowers and butterflies I typically photograph, I normally use increment level 3, but my number of shots varies as it depends on magnification and how much depth must be covered in the stack and that depends on the angle of the subject to the sensor plane. Quite often I set the number of shots to 30. This means once you fire the first shot, the camera automatically focuses the lens that must be set to autofocus with the increment level selected and automatically shoots each image at a slightly greater focus distance. Hopefully, if you set 30 as the number of shots, the desired depth of field is covered in the stack of 30 images. If the depth of field is not fully covered, then you must increase the number of shots or select a larger focus increment and reshoot the stack. Keep in mind that however many images are selected for Number of shots, the camera will either stop automatically when the set number of images is reached, or infinity occurs – whatever comes first. I doubt you will ever reach infinity when stacking closeup subjects since you begin the stack so far away from infinity focus but reaching infinity focus is the norm when shooting landscapes.

Shooting and Stacking Macro Subjects

Let me walk you through how I shoot a focus bracketing set on a flower, process the images, and stack them together to create the final image with tremendous overall sharpness.

1. My equipment is the Canon R5, 180mm macro lens with the Canon mount EF-EOS R adapter. The adapter lets me use the older macro lens on the Canon mirrorless camera. I shoot all closeup stacks on a sturdy Gitzo tripod with Kirk BH-1 ballhead. More recently I have begun to shoot macro stacks with the Canon RF 100mm macro lens. This works fine with my studio macro setup where I use an artificial background and LED lamps for lighting. However, in the field, the 180mm macro is far superior as the narrow angle of view of the 180mm focal length covers less background, the greater working distance is enormously helpful, and the tripod color on the lens makes changing the shooting orientation easier – vertical to horizontal composition for example.
2. Focus bracketing is enabled, camera set to autofocus, Number of shots set to 30, Focus increment set to 3, and Exposure smoothing Enabled.
3. The subject must be still while the focus bracketed set of images is shot. For this example, I will do it in my garage where there is no wind and use three LED lamps for light and a photo background.
4. Set the aperture to f/8, ISO 100, and slow the shutter speed until the rightmost data of the histogram touches the right wall of the histogram. Then I shoot an image, play it back to check for blinkies, and if no blinkies, I slow the shutter speed down another 1/3 stop of light, shoot another image, and check again. If the first blinkies (highlight alert) appear, I go with that to expose my RAW image.
5. Now I manually focus the lens to the closest spot I want in sharp focus. Remember the camera and lens must be set to autofocus for this focus bracketing to work automatically, so make sure a single active AF point is on the closest spot that must be in focus. If the active AF point or points is on a more distance spot on the subject, you will have a problem when you press the shutter button to begin the focus bracketing as the camera immediately changes the focus to

the more distant spot and not to the closest spot where you want sharp focus to begin. This is annoying, but if you are careful, making sure the active focus point is on the closest spot works fairly well. I do not mean to complicate things, but I easily get around this problem by setting my camera to BBF (back button focus). Most cameras can be set to BBF in the menu, but the method varies with the camera model. Autofocus must be removed from the shutter button and AF is assigned (if not already active) to a button on the rear of the camera. Now manually focus on the closest spot and press the shutter button. The camera will not refocus for the first shot, but it will automatically change the focus for each shot in the stack according to the Focus increment parameter you set.



Figure 5 Automatic focus bracketing is super easy with close-ups. Unlike landscapes where I have never wanted the camera to continue the stack to infinity, I simply focus on the closest part of this bleeding-heart flower, photograph my hand to show the beginning of the stack, and start the stack usually using a focus increment of 3 (sometimes 2) and let it go. I watch the progression on the camera's LCD. When I see the focus bracketing is clearly past the subject, I press the shutter button again to stop the camera. When I go to process the stack of images, I look at all of them to make sure they are needed in the stack. If three images – for example – have nothing in focus at the end of the stack, no need to use them, so they are deleted from the stack.

6. Now let us shoot the stack. First, press the shutter button gently and hold your hand in front of the lens. When the camera begins shooting the stack, press the shutter button again to stop it. Now the beginning of the stack is marked with one or more images of your hand. Be sure to do this at the end of the stack too. Now manually refocus the subject and press the shutter button once again. With the camera set to two-second self-timer, any vibration you might create when you press the shutter button has time to dissipate before the camera begins shooting the stack.

7. As the camera shoots the stack, view the progress on the LCD at the rear of the camera. If your camera does not show you the progress where you can see the camera changing the focus distance from shot to shot, then shoot the stack, and let it finish.
8. To be certain the stack fully covers the subject, visually check. It is easy to do. Once the stack is shot, I know my Canon macro lens focuses further away by manually turning the focus ring counterclockwise. I look at the subject through the viewfinder, and slowly turn the focus ring. If I see any key portions of the image that should be in sharp focus come into sharp focus, then I know the stack did not sufficiently cover the depth. That tells me right away I must shoot another stack using a greater Number of images or increase the Increment level from three to four. Since I like using three for the increment level, I typically increase the number of images. If thirty images are not enough, then setting forty images might do it.
9. Of course, it is always possible to shoot more images than you need to cover the depth of field. That is not a problem. When you view the set of images with whatever software you use, delete any images from the stack you see are not necessary.
10. Let us say the last six images of the set of thirty images are not necessary, so I delete them. Now I have 24 images remaining. My workshop clients would tell you that I am really good with camera gear and shooting the images, but not so good with computers and processing and I agree. I am computer challenged, but even I think processing images with Canon's software and stacking images with Helicon Focus is super easy to do.



Figure 6 Another focus stack of Northern pitcher plants in the bogs of Michigan. Sixteen shots at f/8 covered this depth. The advantage of a longer working distance with the Canon 180mm macro is most helpful here as it helps me get this angle without being too close to the clump of plants.

11. I know nothing about Photoshop, Lightroom, and all other software programs, except Canon's own free Digital Photo Professional. So, I must process my Canon RAW files and they must be processed identically to stack them together. I process one image in the stack of 24 images. Typically, I adjust the bright and dark portions of the image and the mid-tones using sliders, crop the photo a little, adjust colors by adding a little more saturation, either overall or individual colors, and may remove a blemish or two. All of the changes I make in the Canon software are called the Recipe and it typically takes me less than 2 minutes to do it. Then, I copy the recipe,

highlight all the images in the stack (24 in this example), and now paste the recipe to all of them and then save them. Now all 24 images are processed the same.

12. Most stacking software can stack RAW images, but I prefer to convert the RAW images to 24 JPEGs and stack them. Therefore, I select all 24 processed RAW images and then run a Batch process (this takes some time) to create 24 JPEGs from the RAW images. I do not lose my RAW images. Canon's DPP4 software creates 24 new JPEG images and retains the RAW images. The 24 RAW images and the 24 JPEGs remain available to me.
13. I use Helicon Focus to stack the images together, but other software programs can stack images too such as Zerene Stacker and Photoshop. In Helicon Focus, I click on File and that allows me to select the images to be stacked wherever I have stored them – usually on a large external hard drive attached to my computer, but sometimes on my camera's memory card. I select all the images to be stacked and then press **Open Images**. The selected images are loaded into the Helicon Focus software and appear in the Source area in the upper right-hand corner. Select Method B (usually) and press Render and in seconds the set of images are stacked together. Now save the final result and give it a name to help you find it.

The entire process sounds like a lot to learn and do, but like so many things, after you do it several times, it rapidly becomes quite easy, and you will love the images stacking produces while enjoying your new stacking skills. From my own experience, stacking profoundly changed how I photograph both closeups and landscapes today. Finally, I have tremendous control over the depth of field in my images!

Shooting and Stacking Landscapes

Once I began focus stacking macro subjects 15 years ago, I quickly began to apply the technique to landscape photography. For 50 years, I have struggled with insufficient depth of field to cover many of the landscapes I composed and shot. I did all the hyperfocal stuff and used 4x5 view cameras and tilt-shift lenses from both Nikon and Canon with some success, but still depth of field remained a problem. This all went away with focus stacking.

I shot and sold numerous stacked landscape images over the years and did it all by manually refocusing the lens and shooting to produce the stack. Since Nov of 2020 when I got the Canon R5 that had the ability to automatically shoot the stack of images, things have changed for me. I no longer manually change the focus but rely on camera automation. Let me describe what I am doing now, but undoubtedly I will change my strategies as I gain even more experience with this new focus bracketing tool in my camera. Keep in mind, so far, my Canon mirrorless cameras only automatically shoot the stack of images, but they do not combine them in the camera. For that, I must use software such as Helicon Focus.

As of Oct. 28, 2021, I set my Increment level to 2, number of images to 30, and disable focus smoothing. The automatic stacking works so fast it is unlikely the ambient light will change much in the second or two it takes for the camera to shoot the stack. I also realize using increment level 2 is smaller than I need, and with further testing, I may increase it to 3 or 4. So far, 30 images or usually less has always covered the depth of field. The beauty of the Canon R5 is the camera stops shooting when the focus reaches infinity focus for the lens being used. That means many sets of images are ten or fewer. Naturally, it takes longer for the camera to reach infinity focus if you focus on a closer foreground and have small increments set. Often my foreground with a wide-angle lens like my Canon RF 15-35mm is

only a foot or two away. In that case, the camera might easily reach 20 images or a little more before infinity focus is reached. If the nearest object you desire sharp is ten feet away with a wide-angle lens, then infinity focus will be obtained quickly with fewer images being taken.

Again, I mark my shot stacks with my hand. With the Canon R5, activating focus bracketing makes the camera shoot quickly using the electronic shutter. So, I hold my hand in front of the lens, press the shutter button, wait 2 seconds for the 2-second self-timer to start the camera and once I see images of my hand appear, press the shutter button again to turn off series. Then I press the shutter button again and let it run until the camera reaches infinity. Once again I photograph my hand to mark the end of the stack, and that also doubles as the beginning of the next stack if I decide to shoot another one.

In processing, I look at all of the images using Canon's software and make sure I want to run all of them. You do not want the background in sharp focus? In that case, delete any images you do not wish to be included in the final image or load all of them in the stacking software and uncheck any you do not wish to run. Now stack the images in your usual way with your preferred software option. I started with Helicon Focus a long time ago, so still continue to use it. But now that Canon's DPP4 has the ability to stack images, I would certainly try that first if you shoot Canon. It is free.

Good luck with your adventures in focus stacking. It truly is a brilliant way to achieve incredible depths of field. And it is also the ultimate in selective focus too. Suppose you want a certain object in the photo super sharp, and the rest well out of focus. Use stacking to do it. Shoot wide-open – f/4 perhaps – stack only the object and not the other areas. Now you will have a sharp object and the rest of the image will appear as shot at f/4! There are even more uses for focus stacking, but I will leave that for a later article.

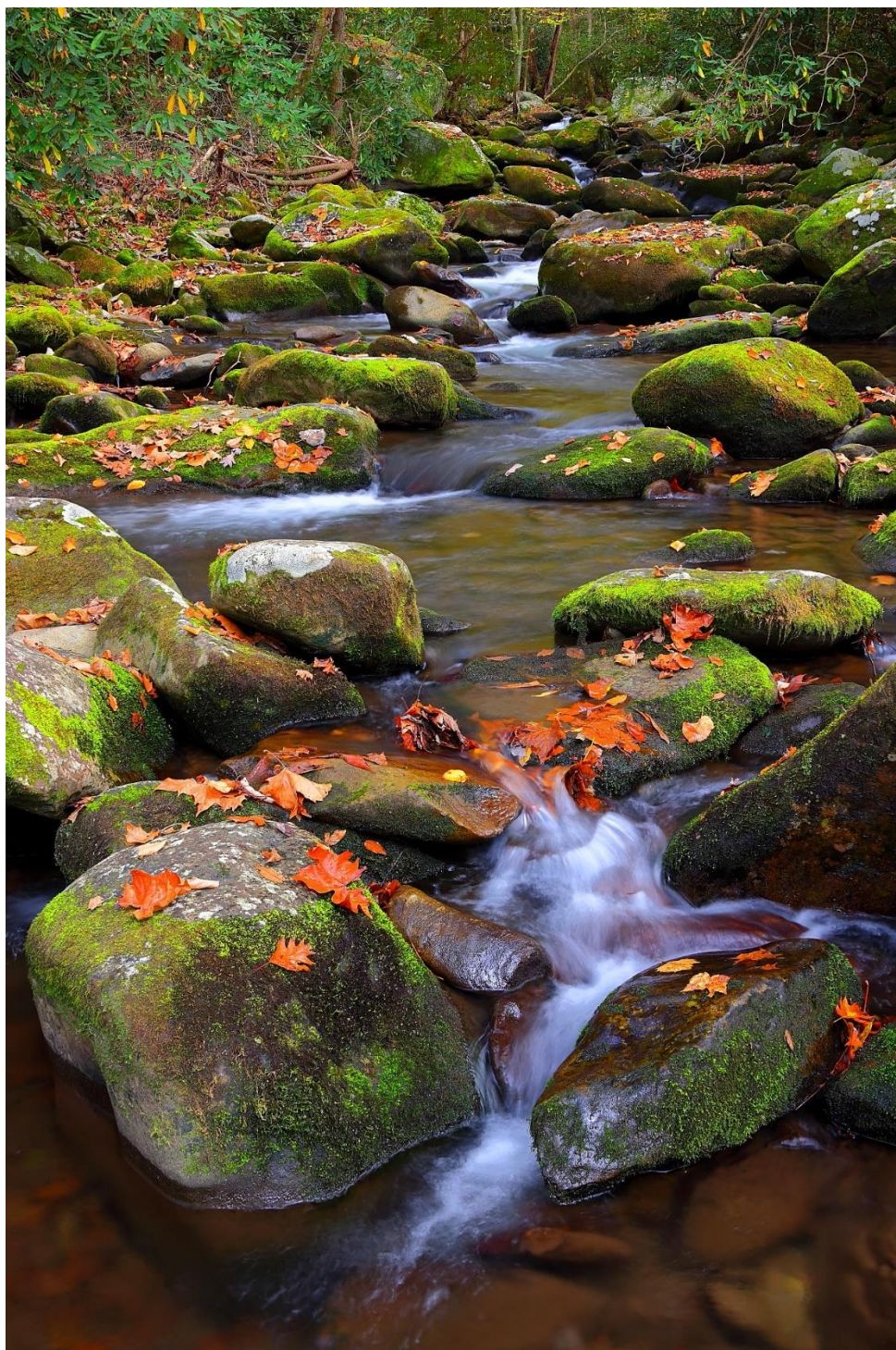


Figure 7 This river scene in the Smoky Mountains screams "stack me." Photographing right up the river means your sensor plane in the camera and the plane of the river are close to right angles with each other. No amount of stopping down can cover this much depth! In the past, I used tilt lenses to tilt the plane of focus to coincide with the plane of the creek more closely, but it was never a perfect answer. Now automated focus stacking using increment 2 makes this scene easy to sharply focus. I move a single active AF point over to the lower left corner to coincide with the rock and begin the stack. About 15 shots later my focus arrives at infinity and the auto focus bracketing stops in the camera. F/9, ISO 500, ½ second with a Canon RF 24-105mm lens makes this an easy shot to capture. The hard part was keeping my balance on the rock I was standing on in the middle of the creek. And naturally I am using a polarizing filter to remove glare on the wet rocks and the creek.

Shooting and Stacking Wildlife

To be clear, subjects that focus stack best are still. Any subjects that blow in the breeze or moves when the stack is shot typically does not stack well as the software cannot align the images properly. However, some wildlife subjects at certain times hold perfectly still or nearly so. Auto focus bracketing can accommodate relatively still wildlife because letting the camera change the focus and shoot the images is easy, efficient, and super-fast. The auto focus bracketing tool in my Canon R5 and many other cameras is amazingly quick because the camera switches over to electronic shutter! This means no shutter is being used as the camera merely turns the sensor on, shoot the image, turns the sensor off, focuses a little bit further out, turns the sensor on to record another image, turns sensor off and continues to repeat this cycle until the maximum number of images that is set by the user is reached or the lens focuses as far as possible. Often the entire image stack is shot automatically in one second or less. And the only images that really seem to matter for precise alignment are those images that are actually focused on the animal, and not in front of or behind the animal. Keep in mind stacking software selects the sharpest areas from each image, then combines those sharp areas into one image, and any areas that were not sharply in focus are then added to the final result as unsharp. That means if a moose or bighorn sheep holds still for those images that are being focused on it, and then suddenly turns its head when the stacking process is focusing on the background, your final result will still be pleasing. Why? If the animal is already out of focus when it makes a big movement, no part of the animal is in focus anyway and the software ignores the unfocused sheep as it continues to combine sharply focused areas in the background. That means if the animal turns its head when the auto bracketing sequence is not focusing on the animal, it will not affect the image.

The trick to getting a good stack is to wait for the animal to hold still, use a larger focus increment (4 in my case) and shoot the stack. I focus on the foreground, press the shutter to begin the stack, and hope the animal does not make any major movement when the subject is being focused on. Often I get a successful stack this way and I always try two or three stacks to make sure I do. When I first started doing this in Grand Tetons National Park with moose and bighorn sheep, I was surprised by how well shooting stacked sets of wildlife works. I enjoy excellent success thanks to the speed of auto focus bracketing. Currently I am using a focus increment of 4, but an even larger increment of 5 or 6 might work fine for wildlife. And keep in mind the larger the focus increment, the quicker the images focused on the animal are completed so there is less chance of it moving and preventing a successful focus stack.



Figure 8 This is a 30-image focus stack of a bighorn sheep near Jackson, WY. I began the stack of the sagebrush in the foreground and let it go when the ram looked like he was going to hold still for a moment. The camera shot all 30 images that I set in the auto focus bracketing tool and got to the distant background. However, I did not want the foreground and the background to be sharply focused, so I only ran about 15 images out of 30 with Helicon Focus to stack them together. Always keep in mind that you can always choose to not run all of the images in your focus stack, but of course, if you do not run enough images to cover the depth, then there is no way to sharply get portions of the image sharp that were never focused on in your stack.



Figure 9 Like the bighorn sheep before this one, I did not choose to use all of the images captured in my image stack as I wanted some of the foreground and most of the background softly out of focus.

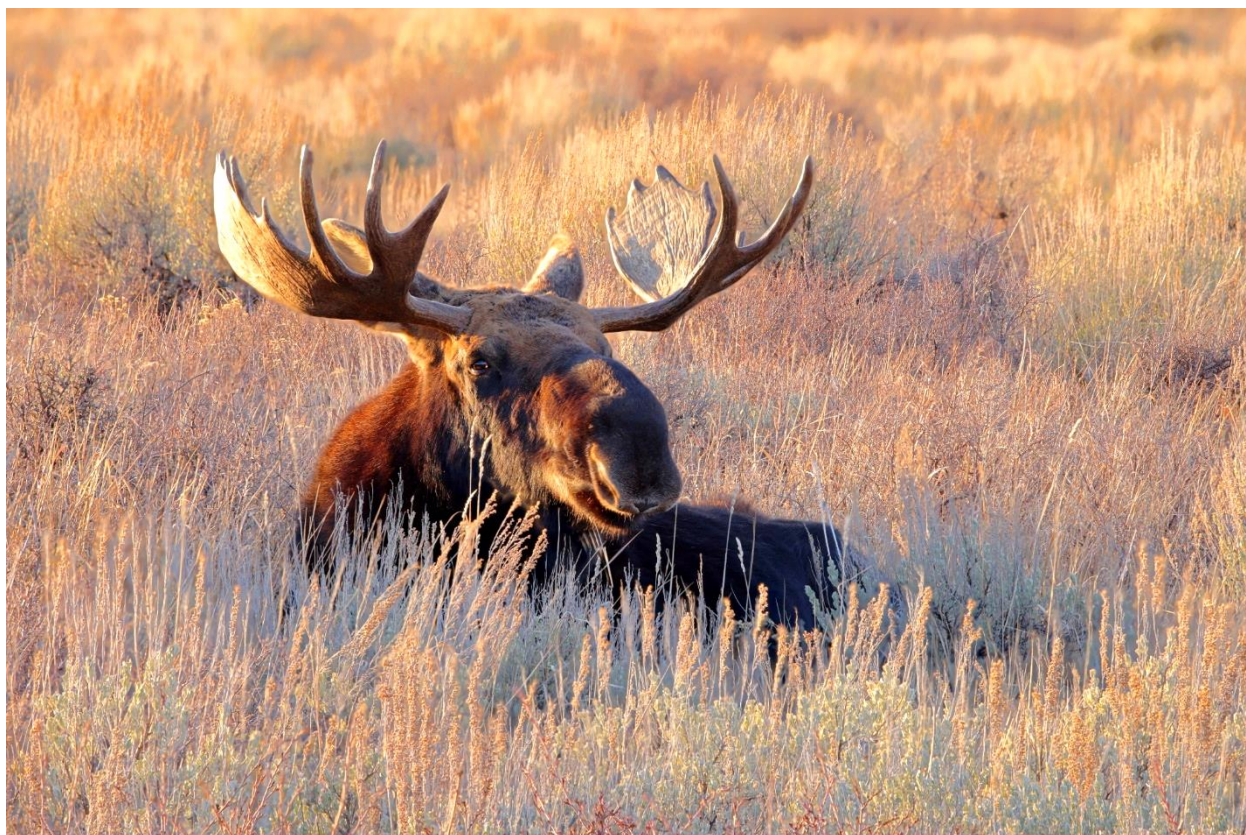


Figure 10 This was my first wildlife focus stack. I wanted to get both the moose and most of the sagebrush and other plants sharply focused and focus stacking let me do it. Never before have I been able to get so much foreground and background in sharp focus when making full-frame animal portraits like this. Normally, even at f/16 with a single image, only the moose is nicely in focus and the foreground and background are both soft due to limited depth of field at this magnification. In no way am I saying that foregrounds and backgrounds should always be sharp, but focus stacking now gives you the choice of making them sharp or not. Indeed, by selecting the images contained in your focus stack carefully if shot properly, you can have tremendous depth of field or superb selective focus too. If your stack fully covers the depth in your image, you have a choice of either great depth of field or shallow depth of field.

Focus Stack to Capture a Sharply Focused Image in a Snowstorm

I discovered an unexpected use for the automated focus bracketing feature in the Canon R5 when photographing in falling snow. Autofocus is so sensitive that nearly always I find the autofocus focuses on falling snowflakes right in front of the main subject. This means the subject, usually wildlife, is slightly out of focus. I notice this problem years ago and formerly got around it by setting my camera to manual focus, enlarging the face of the animal with the magnify button, and manually focusing on the eye or nose. This works and gets even easier when I no longer had to do that on the LCD of a DSLR but could look into the viewfinder and do it on the electronic image presented in there.

But manual focus takes time. Since the camera will focus on snowflakes immediately in front of the subject, why not use focus stacking or bracketing as Canon calls it. While I know the first image will be slightly out of focus, the images in the stack that are focused slight further away will eventually be on the intended subject. So, I tried this recently on Yellowstone bison in falling snow. I used a tiny focus increment of 2, set the camera for six shots, and tried it on the bison. As expected, the bison was a little soft on the first shot, but the second or third shot was focused precisely on the bison's face – exactly

what I wanted!!!! As I write this, I hope to test this more over the next two weeks in Yellowstone as I am leading two more photo workshops in the park this winter. We shall see how it goes and I will update this article once I get new info to share.



Figure 11 My first test using the auto focus bracketing in my Canon R5 to make a perfectly focused image of a bison. The 1st shot was out of focus, the second was on the nose, the third was around the eyes and the fourth was past the head. In this test I was using focus increment 3. I find that is too big of a jump, so I now set the focus increment to only two. Since the best focus tends to be image #2 or #3, I now set the total images to be shot to only 6. This means the camera automatically shoots the 6 images that are all focused at different distance quickly, so the animal only needs to be still for a moment.