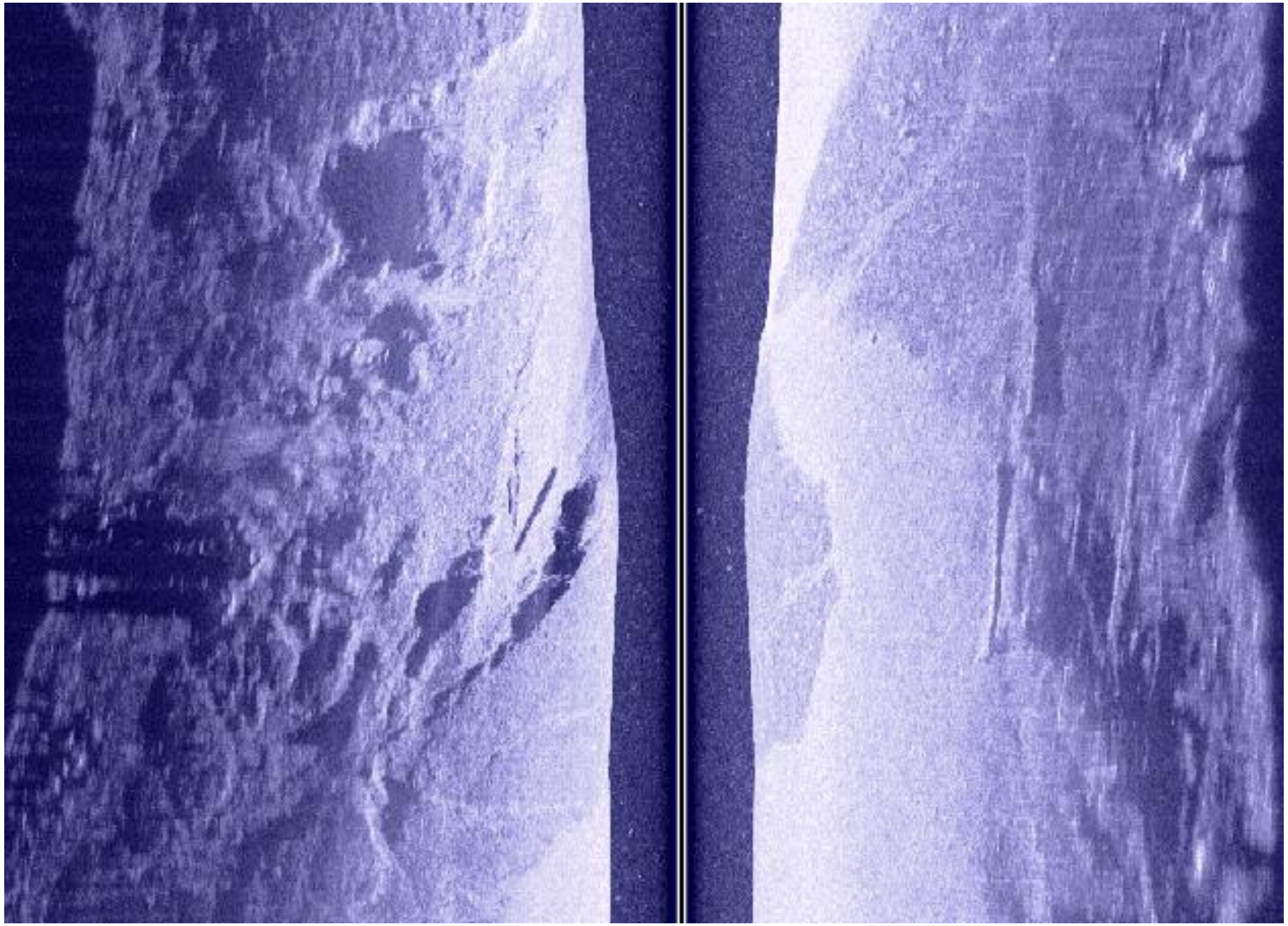
Session I- Part B

The approach we take to mapping habitat involves manual digitization and classification of features based on visual interpretation of sonar imagery. Photographic interpretation of imagery as a basis for map development is a long-standing, tried-and-true approach in the field of cartography.

A very relevant question, couched in terms of reducing potential subjectivity in the manual process, is whether classified habitat maps can be generated in an automated fashion? Automated, computer-based approaches to segmentation and classification of side scan sonar imagery are currently in various phases of development and evaluation. Few demonstrations of such approaches can be found in the literature, and most are limited to benthic marine settings with open, flat topography and reduced substrate complexity. User input is often required for computer "training" on the front end, and editing and correcting errors in draft maps generated from automated routines is typically needed on the back end. One could argue these inputs are user specific and potentially subjective as well. Automated, computer-based approaches are not widely available, and require additional image processing software packages and specific expertise.

Indeed, one of the hurdles for development of reliable, automated approaches to mapping with side scan sonar imagery is the inherent complexity of side scan data and sonar image products. Making sense of this complexity is the foremost topic of this chapter.

Image Interpretation



Visual interpretation

The process of creating habitat feature layers by visual interpretation of sonar imagery is much like tracing a scene from a photograph. High quality imagery, and the ability to critically examine, identify, and differentiate patterns (i.e., sonar signatures) common to the surveyed system are essential inputs to this process. Sonar interpretation and map making skills can be improved through training and experience, yet also draw upon a set of human aptitudes that includes keen observation, powers of discrimination, attention to detail, and consistency. These aptitudes serve both art and science!

The ability to accurately interpret sonar images is of such great importance that we devote the remainder of this session to the topic.

Creating a Habitat Map

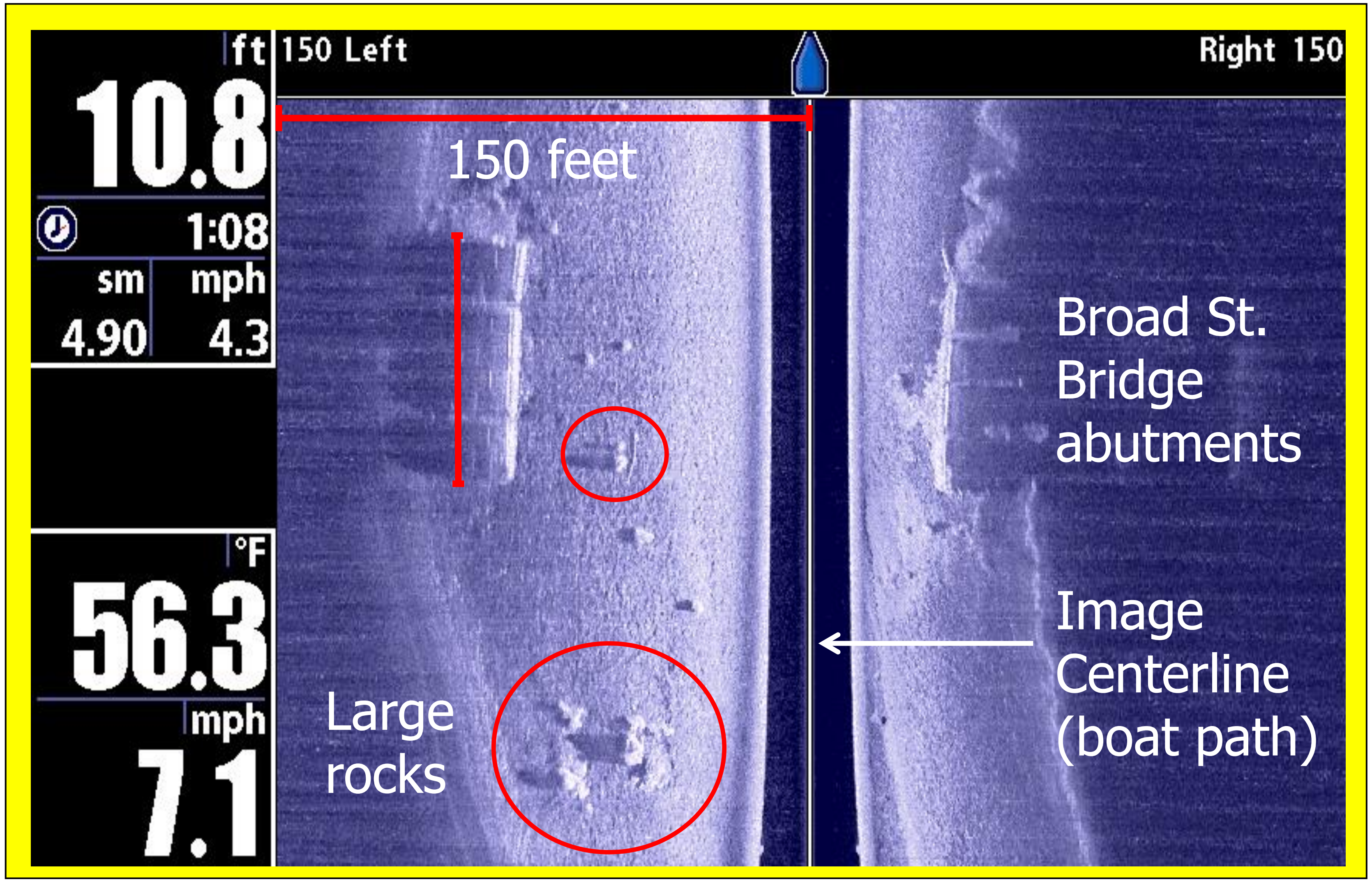
Truism #1- Image (Data) Quality and Interpretation are the foundation of low-cost, sonar habitat mapping

Large underwater features

Let's begin our discussion of image interpretation with this raw sonar image captured shortly after passing beneath a bridge spanning the lower Flint River in Albany, Georgia. Across the top of all HSI screen snapshots is a display of the range setting. A setting of 150 feet per side was used to create this image- this represents the distance from the centerline (i.e., the boat path) and the edge of the image. As we see here, the river bank was much closer than 150 feet on the right hand side of the image. The well defined dark margin along this edge represents the river bank. The rather large, blocky shapes in the middle of the image are submerged, concrete bridge abutments. These structures reflect the sonar signal, casting sonar shadows behind them. We have circled a few of the very large boulders that are resting on the riverbed in this reach. These boulders somewhat resemble cotton balls and also cast shadows- an indication that these objects are protruding up into the water column. A log can be seen resting next to the boulders in the middle of the image. If you look closely, you can find what appears to be part of a log sticking out from the edge of the upper right side bridge abutments.

The information panel along the left of the image can be manipulated to display a variety of information available at the exact time of capture, like GPS coordinates (not shown here). The depth, 10.8 ft, is the depth at the point of capture, which is the position located at the top center of the image (behind the blue boat icon).

Interpreting Sonar Imagery



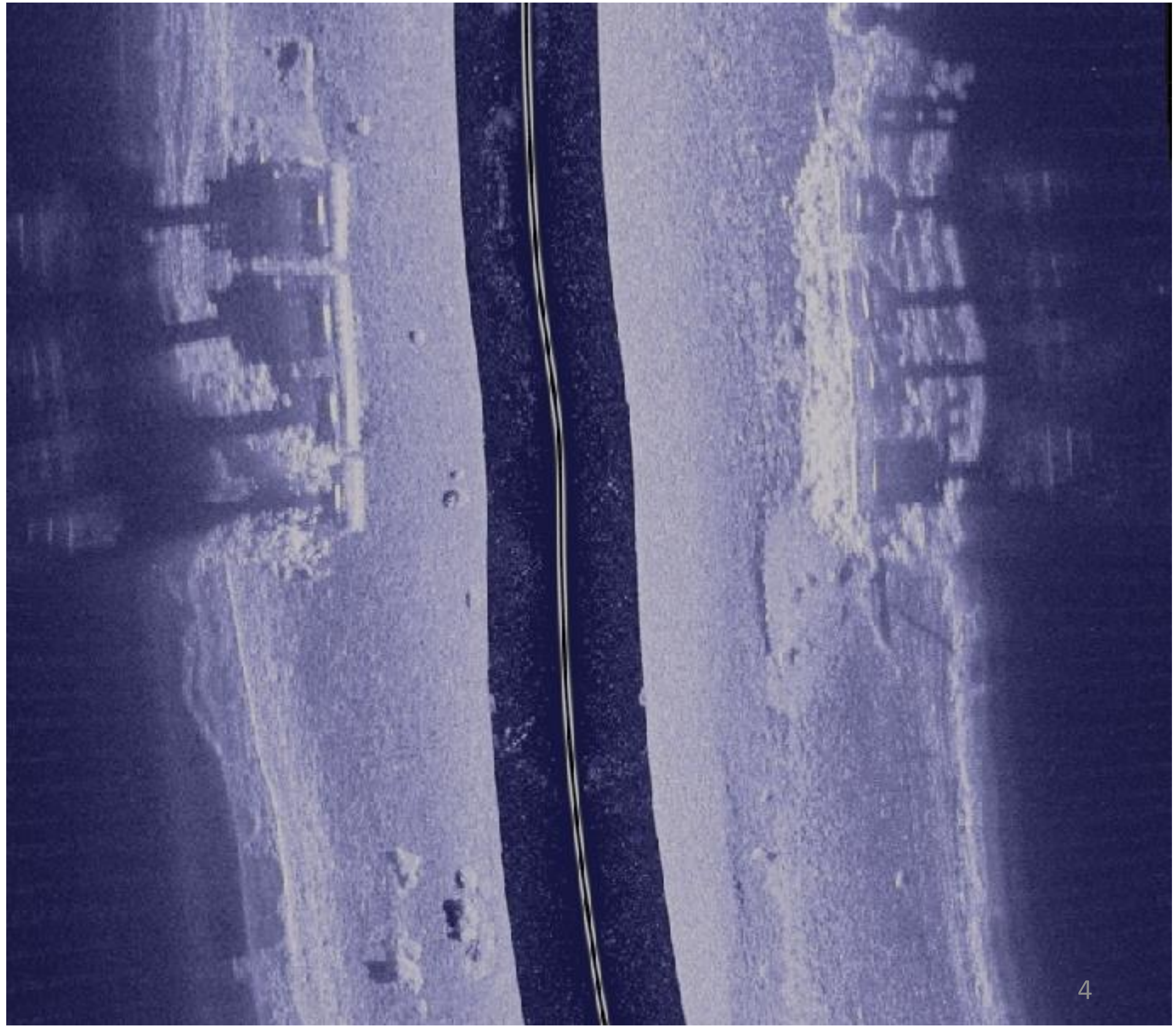
Same bridge abutments...

An interesting exercise in comparison can be made using the adjacent image. This image comes from the same reach of the Flint River approximately 1 year later- it has been rectified or transformed, unlike the previous raw image. Some rip rap was added around the bridge abutments on the west (right) side of the river, and around one abutment on the east side that did not exist when the earlier image was captured. The bridge abutments are more defined, and the shadows are well defined and narrower. The reason for this difference is that the river stage was higher when this image was made, and the water was completely covering the foundational elements. As we will see on the next page, the bridge uprights are narrower than their concrete bases. Another reason why this image is sharper and more well defined is that a front-mounted transducer was used to create this image rather than a rear-mounted transducer. The importance of this deployment will be discussed shortly.

A second truism of sonar imaging is that no two sonar images of the same area look exactly alike, even if captured on the same day just minutes apart. It is impossible to replicate the sonar imaging conditions experienced during the creation of an image.

Truism #2- No two sonar images of same area look exactly alike

Different Imaging Conditions



Low water conditions

Here is a digital photo of the west side bridge abutments of the bridge over the Flint River taken during low water conditions. The difference between abutment base and uprights is plain to see, as is the representative signature of these structures in the sonar image.

The Bridge Abutments

Texture difference

This photo was taken while looking at rip rap (i.e., boulders) added to the bridge abutment area. The sonar signature of this material is clearly different from the surrounding riverbed.

Rip Rap

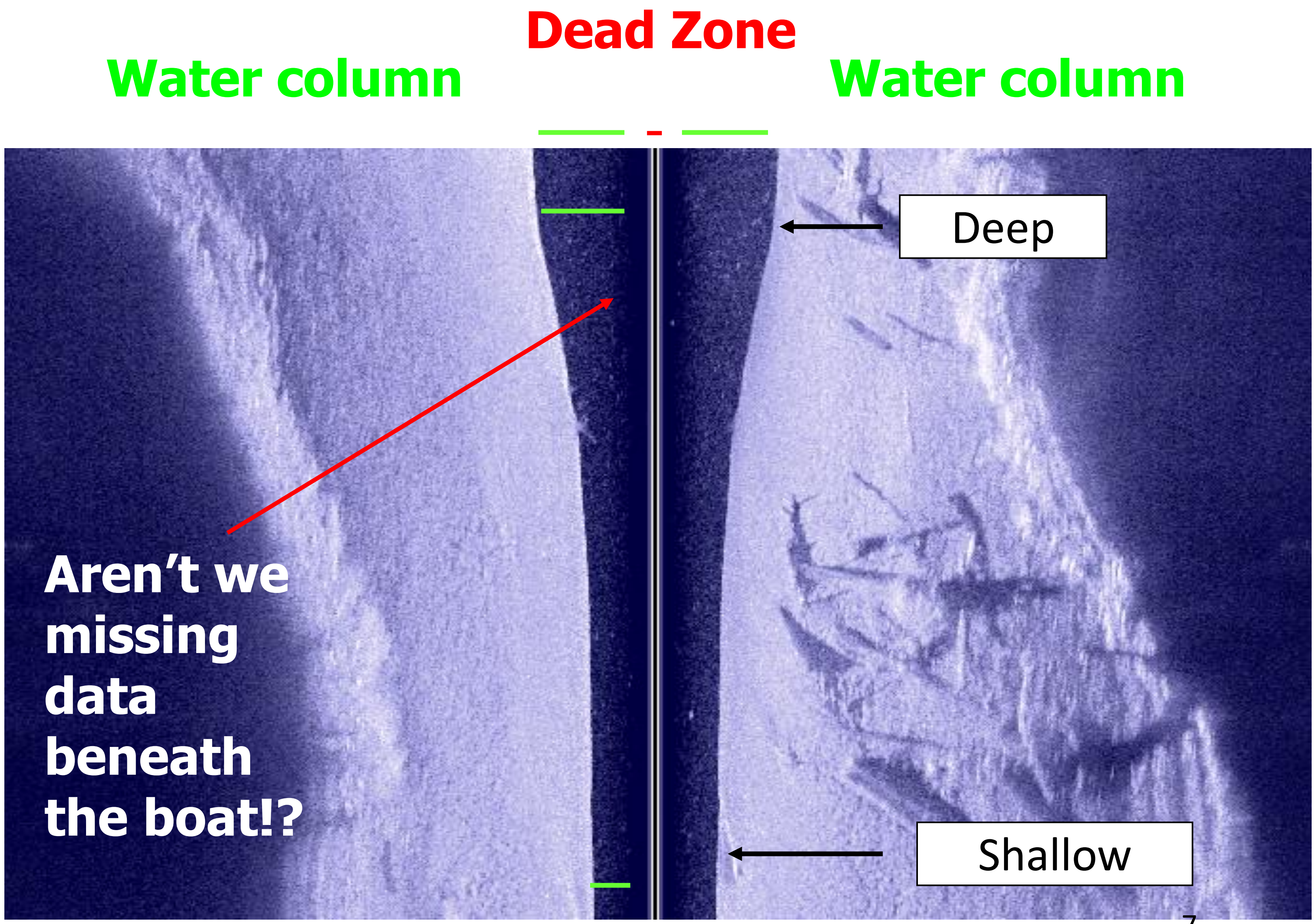
The water column

One of the unusual features of a sonar image that bothers a lot of people is the centrally located, dark area that represents the water column. The width of the water column is a direct representation of the depth of water beneath the transducer. A wide water column represents deep water, and a narrow column represents shallow water.

Many mistakenly assume that this dark area represents missing data. The truth of the matter is that there is very little missing data within this region of the sonar image. If missing data exists, it will occur in a very narrow band, here identified as the "dead zone".

If we are not actually missing data due to the water column, how then should a sonar image be properly interpreted?

Interpreting the Water Column

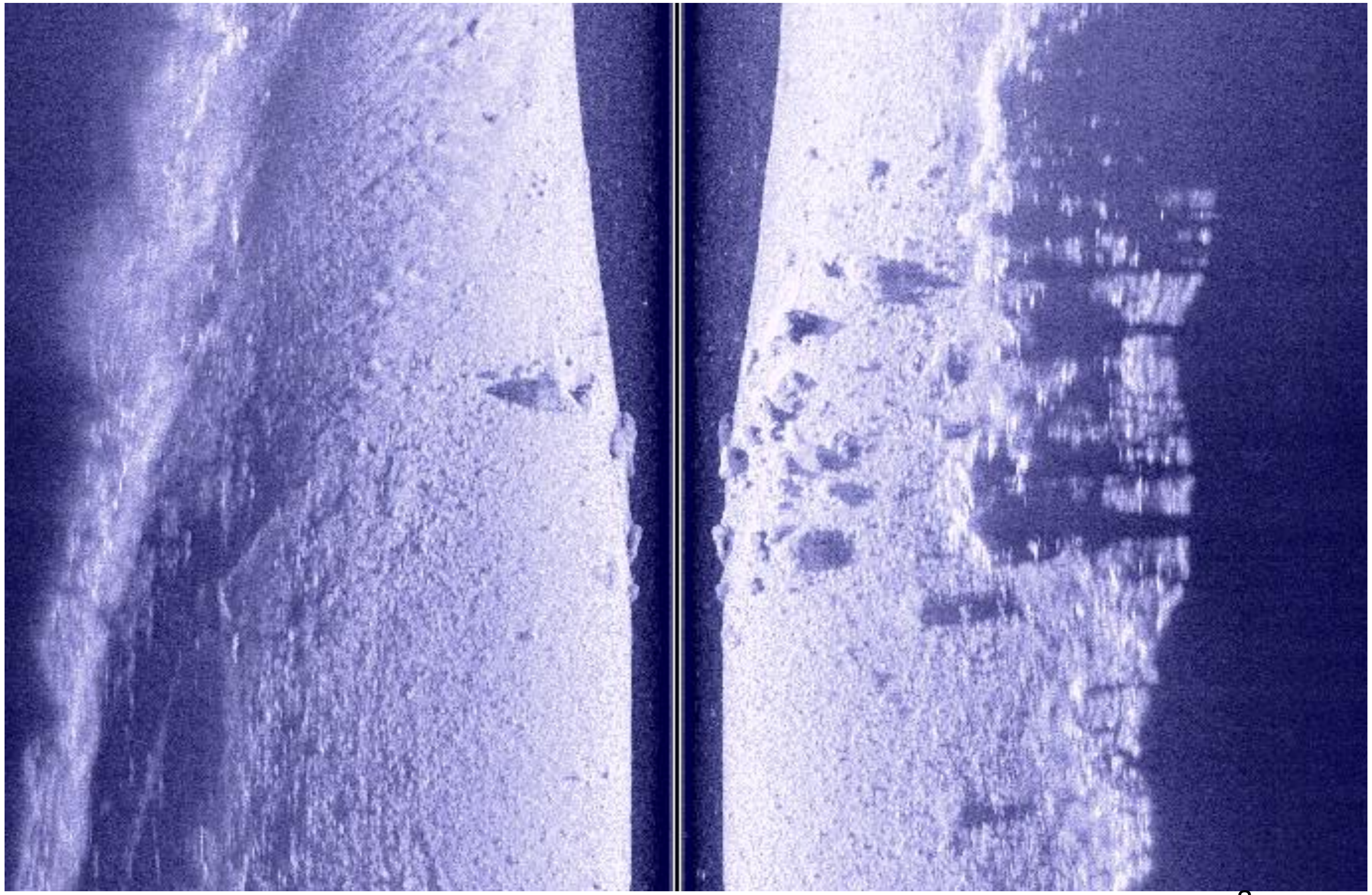


The water column

To properly interpret sonar imagery with the water column displayed we must imagine that both sides of the sonar image actually join together right down the middle of the image, as if the water column does not exist. Visual proof of this concept is occasionally obtained when the boat happens to pass directly over an object, or set of objects, like these boulders. The boulders appear as mirror objects on either side of the image. Imagine mentally removing the water column and stitching the two halves of the image together down the center- the modified image would have a series of three or so boulders that were located directly beneath the boat during the survey.

Objects directly beneath transducer

-Appear as mirror images on either side



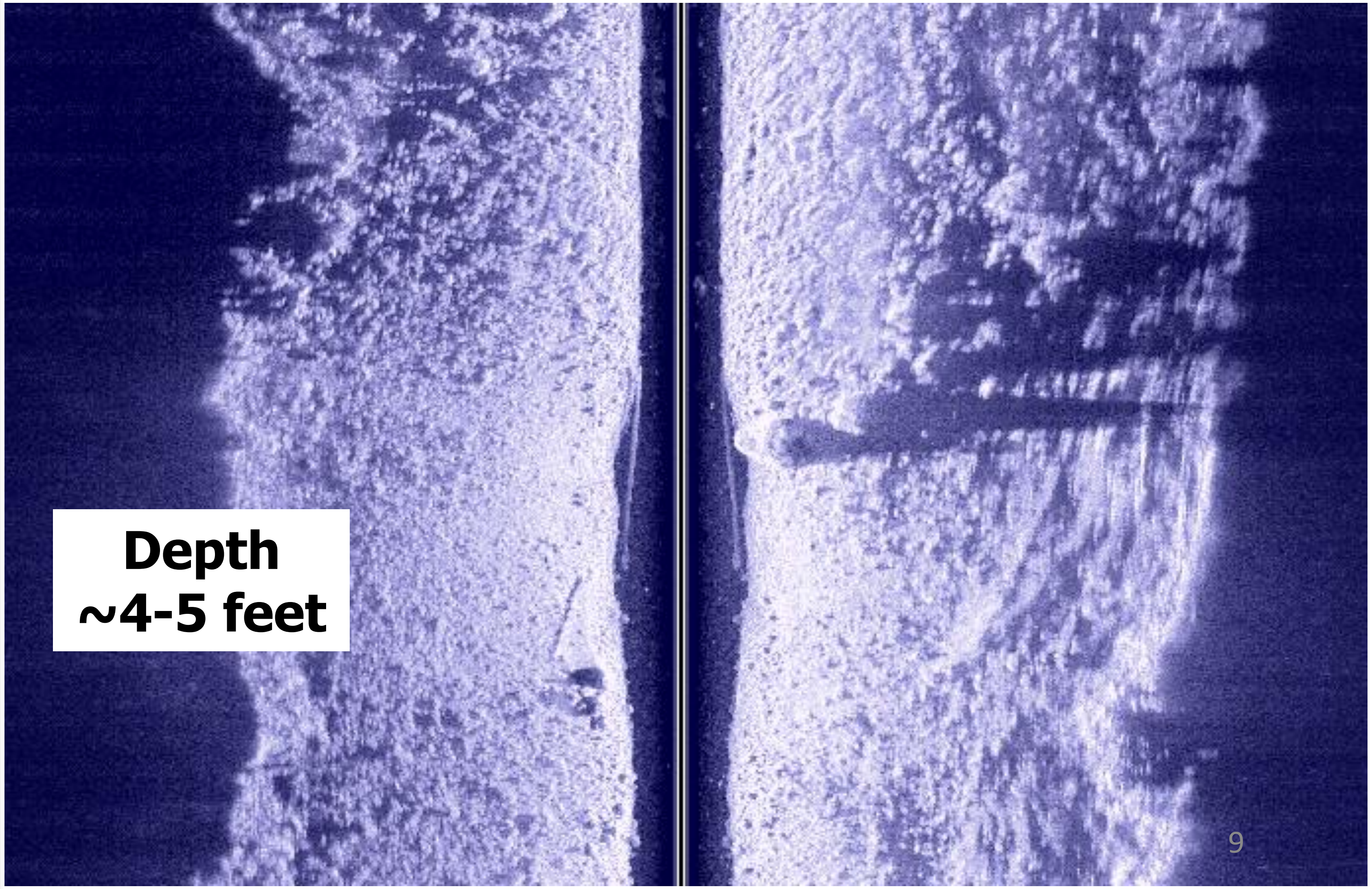
Mirror objects

Here is another example of an object that was directly beneath the transducer during the survey. In this case a log, oriented parallel to the river channel, appears on both sides of the water column in the center of the image. We are not, however, looking a two separate logs, but rather one log that was perfectly split down the middle during the survey (this is quite a rare occurrence!). If we imagine removing the water column, and stitching the two halves of the image together, we are left with one log directly beneath the boat.

A skeptic may think this phenomenon is limited to shallow waters- that objects located beneath the boat in deeper water would not appear as mirror objects as seen here.

Objects directly beneath transducer

-Appear as mirror images on either side (the log in this example)



Objects in deep water

Here is visual proof that objects located directly beneath the transducer, even in deeper water, will appear as mirror objects on either side of the image.

So, if the water column does not represent missing data, what effect does the inclusion of the water column have on the representation of objects and features in this image?

Objects directly beneath transducer

Appear as mirror images on either side another log, this time in deeper water

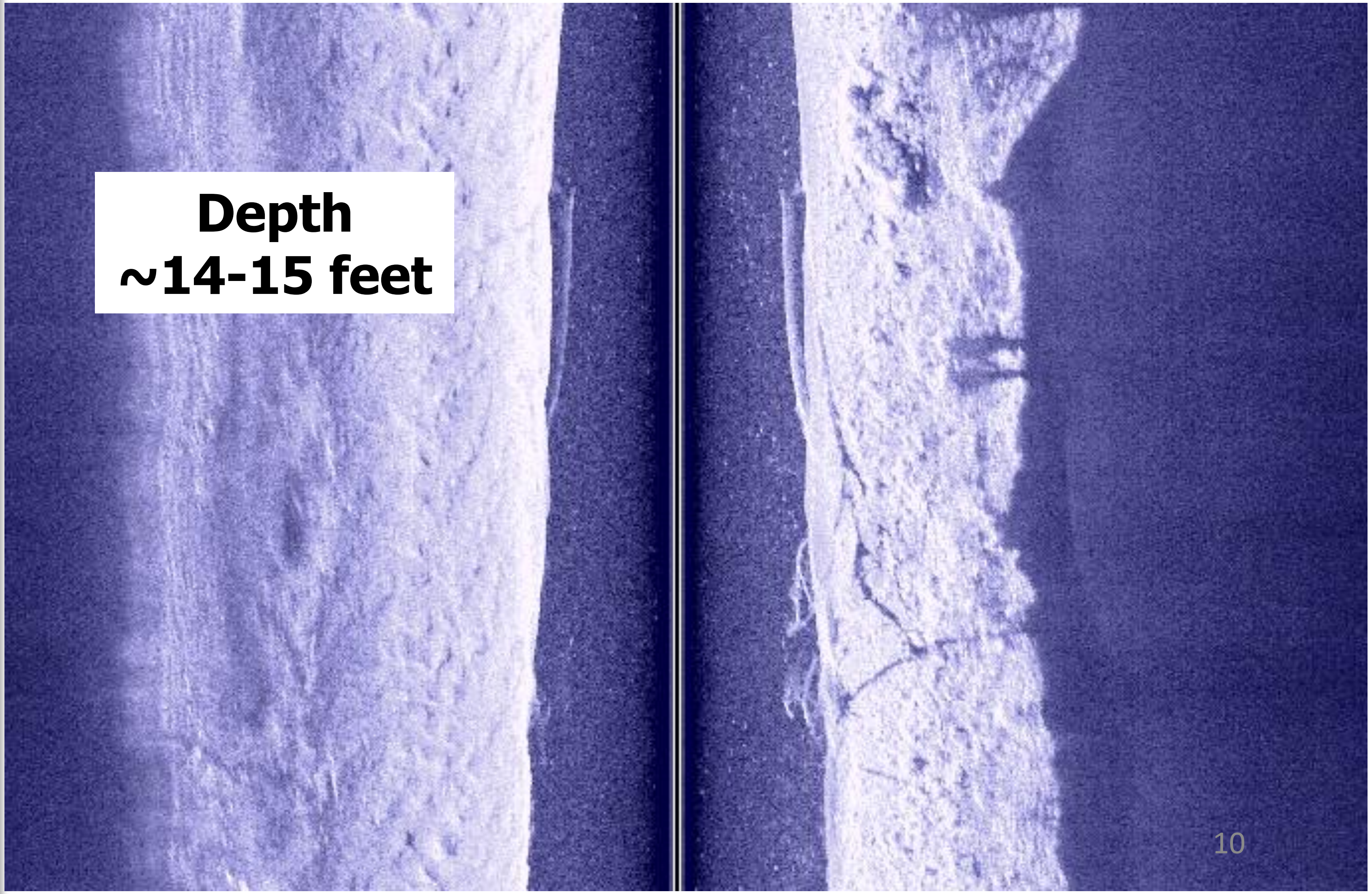


Image compression

The water column occupies some of the space available for image creation, and in doing so leads to some compression of objects and features appearing in the near-field (near water column) portion of the image (red boxed area). Compression of near-field features increases as the width (depth) of the water column increases relative to a fixed range setting; the compression effect dissipates with increasing distance from the water column. Likewise, the positional error of features attributable to compression increases with increasing depth (i.e., more water column showing).

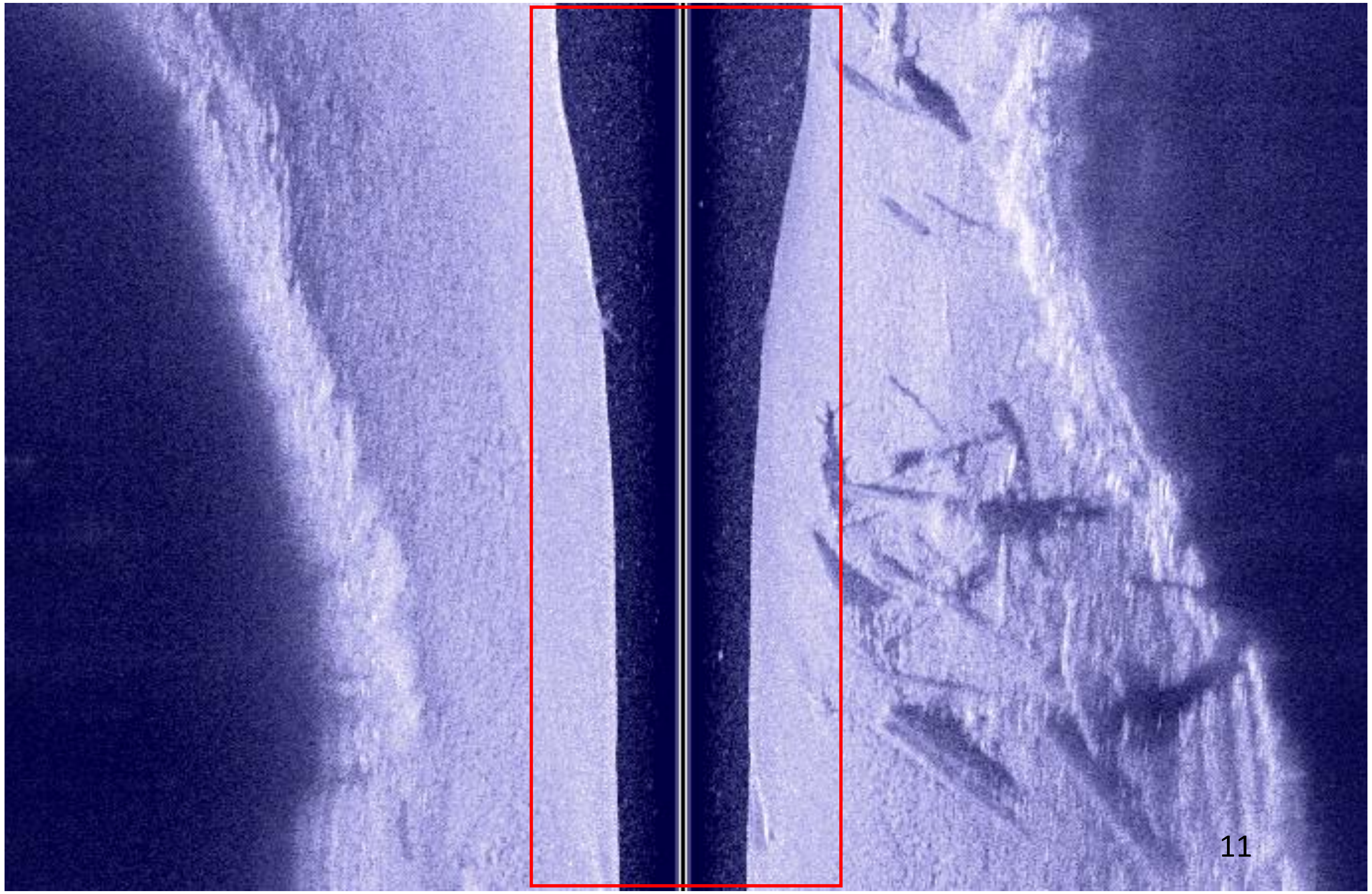
Due to compression, objects or features in the near-field portion of the image are smaller and closer to each other than in reality, and these features are not truly in their proper spatial location, as pointed out during our previous discussion of mirrored objects. The image distortion created by near-field compression is also called slant range distortion. The processing required to remove the water column from the image and undo the compression is called slant range correction.

When interpreting images that include the water column you (the reader) must mentally perform slant range correction by imagining the removal of the water column and the slight adjustment of size and position of features appearing in the near-field portion of the image. The process of digitizing features when the water column is showing will again be addressed in the chapter on habitat mapping.

How is the image affected?

Slant Range Distortion

Near-field Compression



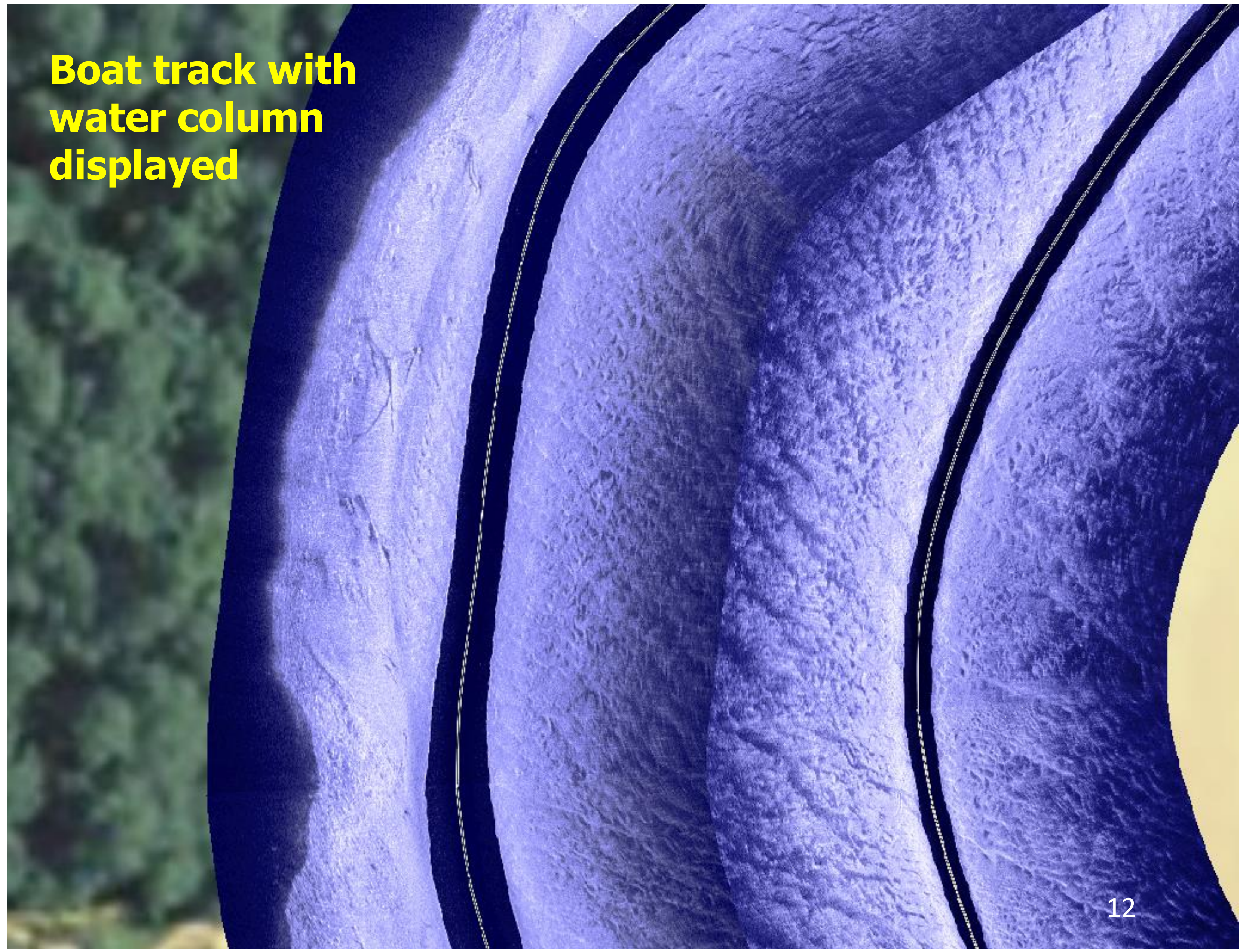
Water column present

For several years since the release of the Humminbird® SI series it was not possible to perform slant range correction on sonar screen snapshots. All screen snapshots, by default, displayed the water column. A recent firmware update (Jan 2011) has added a feature called "Contour Mode", an option under the SI Enhance tab of the control head settings menu. Contour mode enables the sonar operator to choose between screen imagery that either includes the water column, or performs on-the-fly slant range correction to remove the water column from the image display. We call this an "on-the-fly" process because the control head is incorporating slant range correction into the internal processing that occurs in real-time during field scanning.

In other, high-end sonar systems, slant range correction is applied after the raw sonar data has been recorded, during the data processing phase. This approach to slant-range correction is often partially automated, with user input required to edit and correct output wherever necessary (i.e., where the computer fails to properly identify the true bottom).

On the right are two rectified sonar image layers obtained using parallel transects to cover the entire channel across a river. The imagery obtained during this survey included the water column in the display.

Slant range correction now available!!



Water column removed

When slant range correction is applied via the contour mode setting, the near-field portion of the image is decompressed, bringing both halves together along the survey path (centerline). When performing optimally, slant range correction produces imagery that seamlessly covers the survey swath. In the pair of slant range corrected mosaics to the right the boat path is barely perceptible as a faint line down the middle of each layer.

The ability to remove the water column on-the-fly is pretty slick, and water column haters will rejoice at this development. Let's briefly discuss, however, some of the costs and benefits of enabling this feature.

Slant range corrected imagery

Boat track with water column removed

Pros and cons

Not unlike several other options and settings that can be manipulated during data capture, the choice to remove the water column by slant range correction has its pros and cons. One of the notable benefits of removing the water column is the improvement in spatial positioning and dimensionality of features located in the near-field portion of the image. In the slant range corrected image to the right we find a well-defined outcrop of hard bottom substrate (perhaps clay) that crosses the centerline in this image. Slant range correction has cleanly brought the two halves of the image together, making it easier to digitize the apparent boundaries of this substrate patch. Note that the water depth at the point of image capture was nearly 19 feet. At this depth, and with a range setting of 110 feet, a total of 34% of the upper portion of this image would have been occupied by water column if slant range correction had not been applied. This amount of water column would have compressed the near-field portion of the image and made the work of accurately digitizing the boundaries of this patch a bit more difficult.

By removing the water column, however, we have lost a very useful, and easily referenced source of information on depth, and depth changes, as we undertake the process of sonar image interpretation. It is true that we can reference depth data from other sources (e.g., trackpoint data- to be described later), yet the water column provides a continuous record of this information displayed front and center in the image. Changes in substrate composition often accompany changes in depth, making this information quite useful during mapping.

Slant range corrected imagery

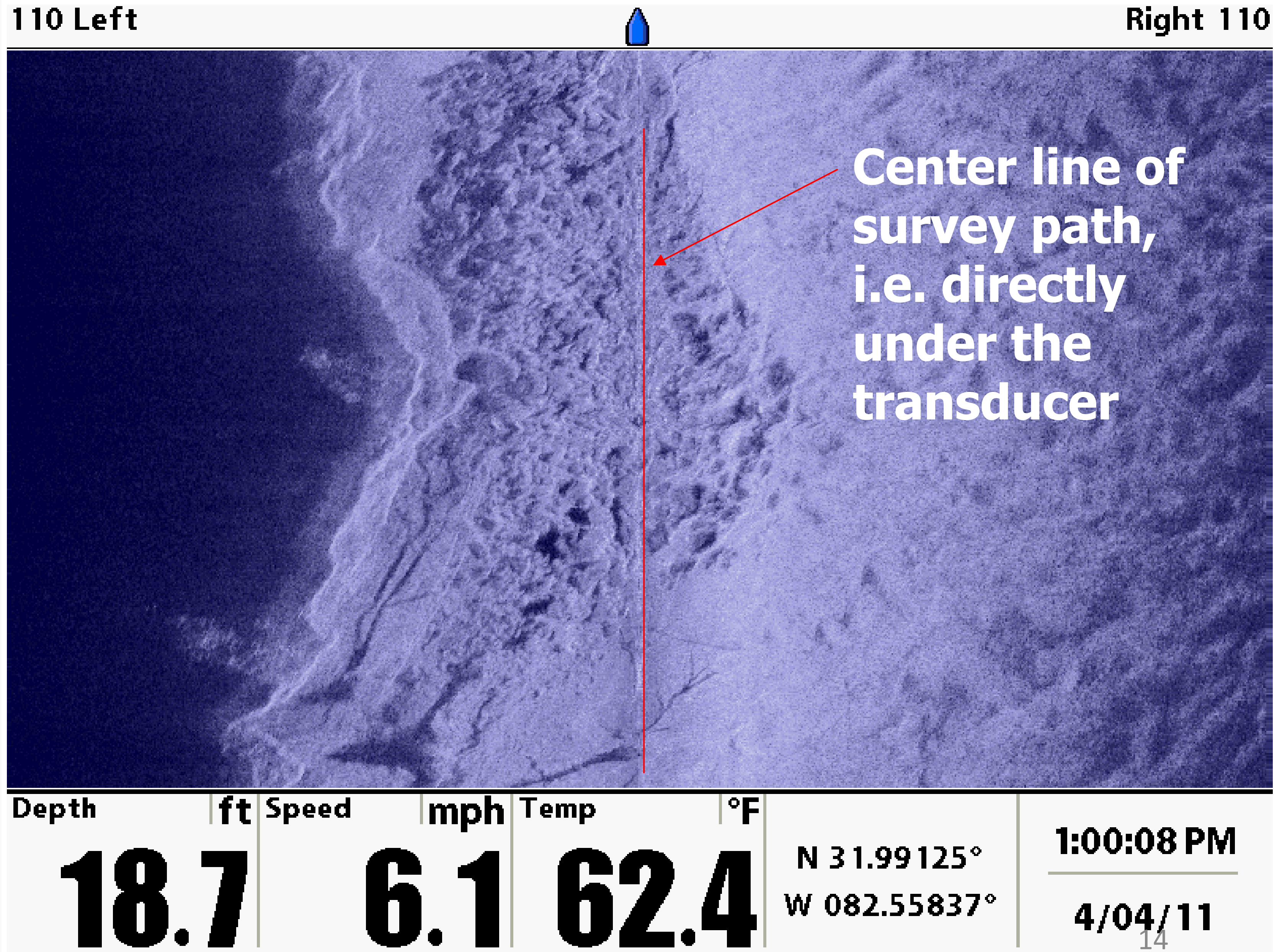


Image artifacts

Unfortunately, the use of on-the-fly slant range correction can lead to some very unusual image artifacts. In this example a strange, saucer-shaped disk has appeared in the middle of the image. These shapes sometimes appear when imaging undulating bedforms, such as ripple and dune sequences on sand bed rivers, although the bottom in this image appears relatively flat. It is not practical to attempt removal of these artifacts from raw imagery.

Strange distortion forms

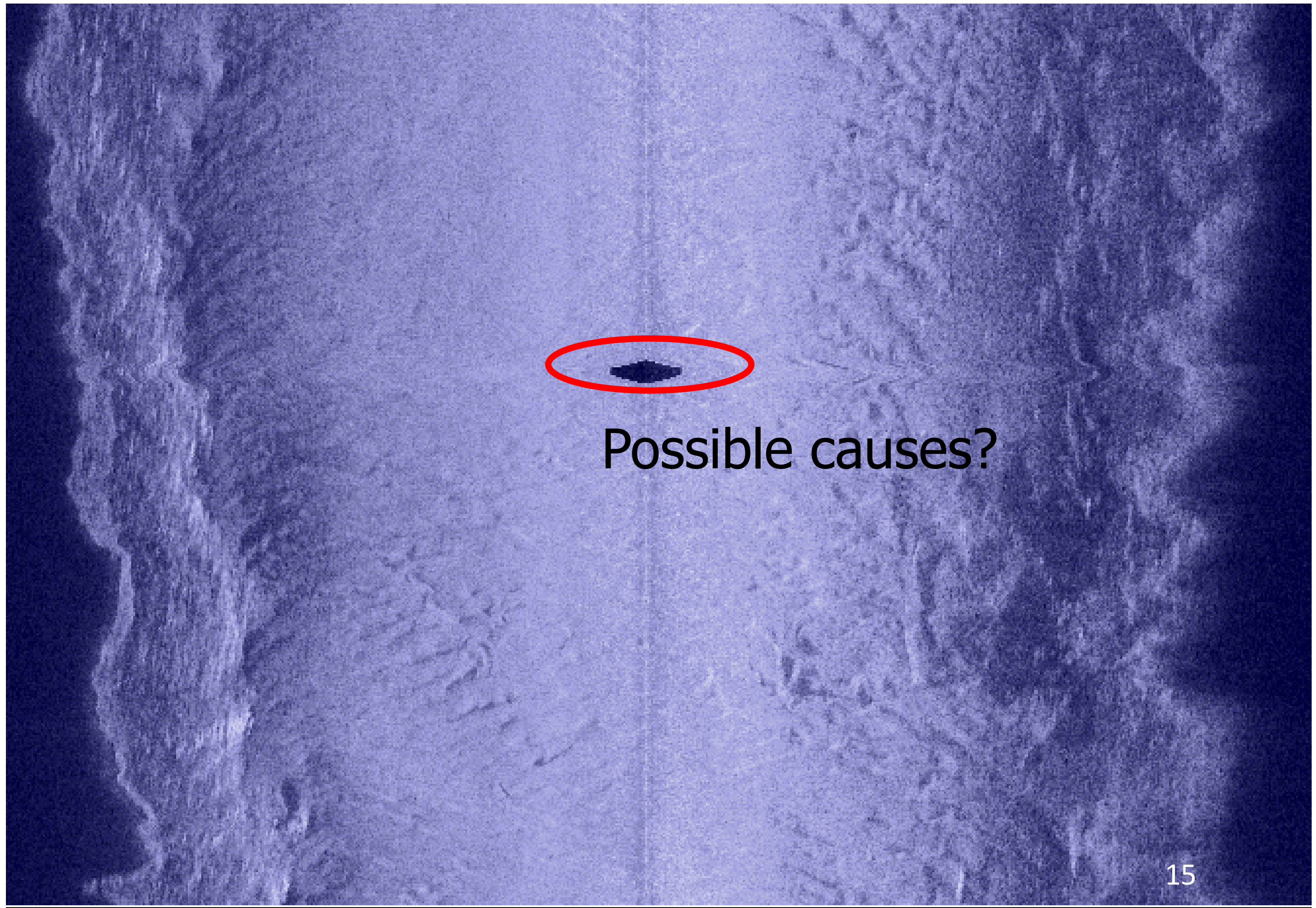


Image distortion

One of the features associated with a lot of image distortion when applying on-the-fly slant range correction is large woody debris. The distorted tree shapes and shadows in the image on the right are better suited to a Tim Burton movie than a sonar habitat map.

Strange distortion forms

Deep, outside bend of large Coastal Plain river with large submerged trees

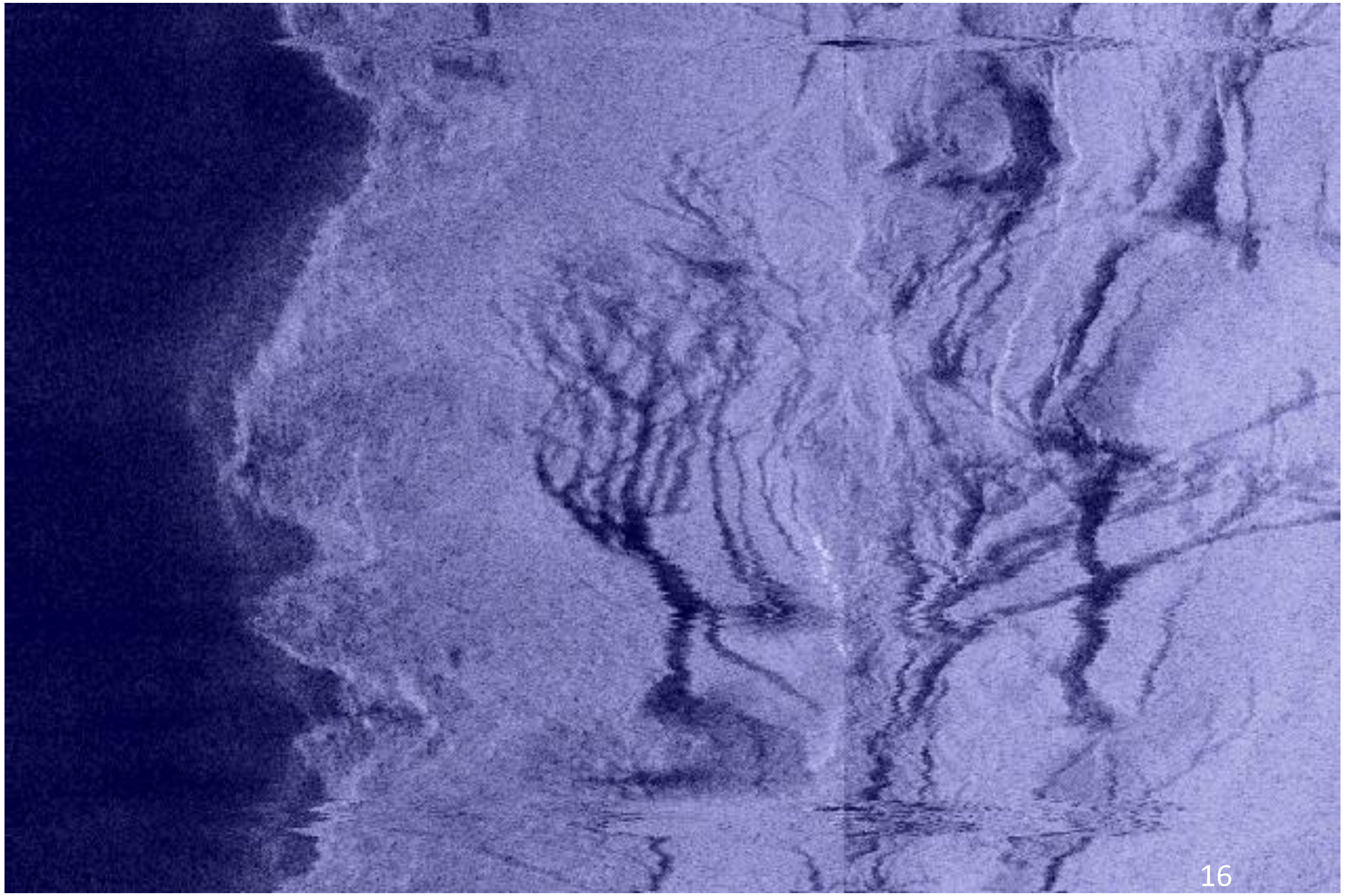


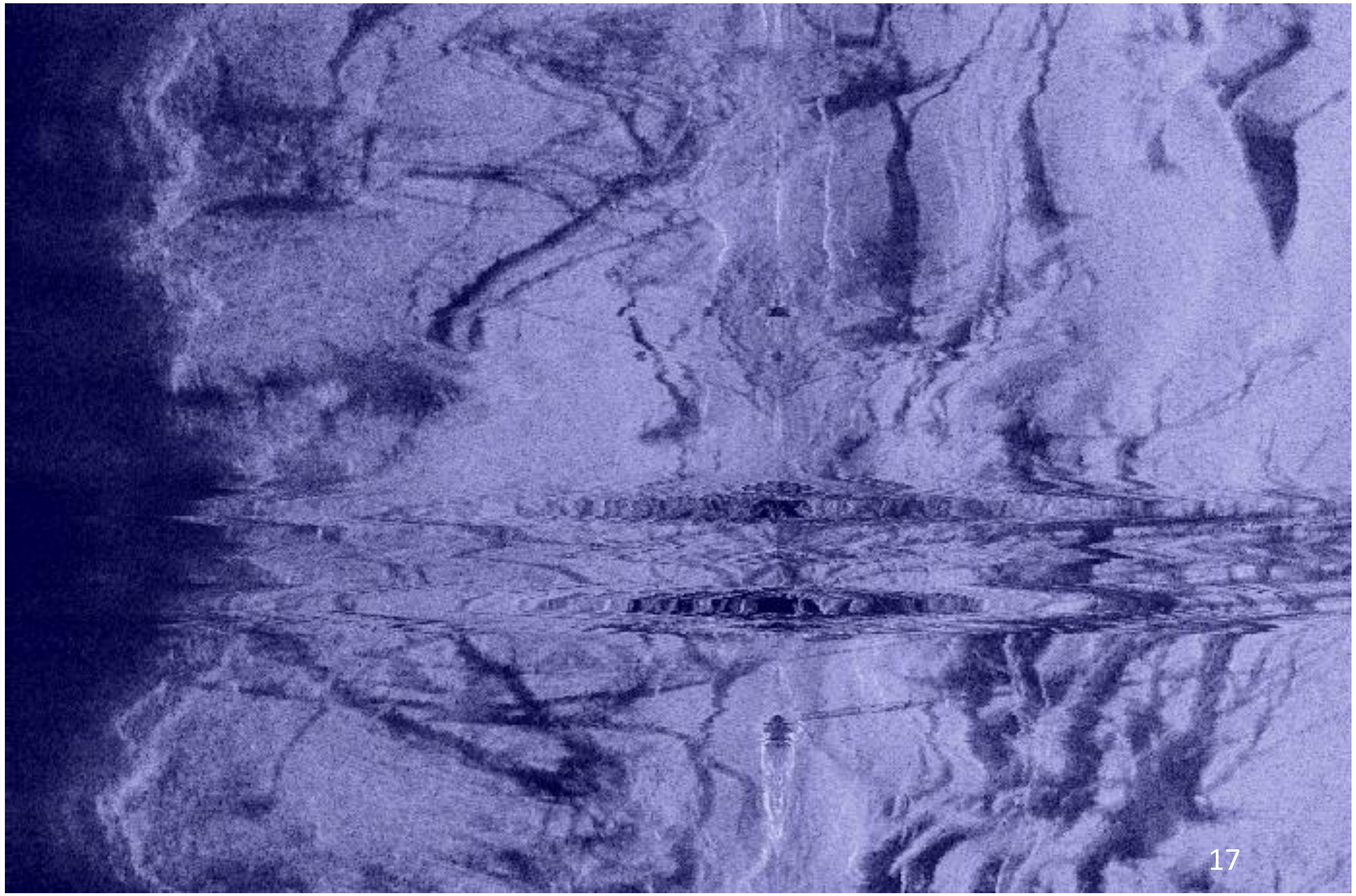
Image distortions

The distortion present in this image is downright horrible. If you had to spend more than a few minutes trying to map habitat from imagery like this you might end up puking on your shoes!

What is going on here, and what might we learn from these examples regarding the judicious use of slant range correction with the Humminbird system?

Strange distortion forms

Deep, outside bend of large Coastal Plain river with large submerged trees



Making sense of distortions

In a simplified channel setting (i.e., flat, open bed), the sonar signal first contacts the bottom directly below the boat (solid black arrow). As a result, the first signal returns to the transducer are also coming from points directly below the boat. This is not the case if you have large woody debris suspended above the bottom, near the boat path. As illustrated on the right, first sonar returns are instead coming from the suspended, lateral branches of the sunken timber (dashed black arrow), rather than from a point directly below the boat.

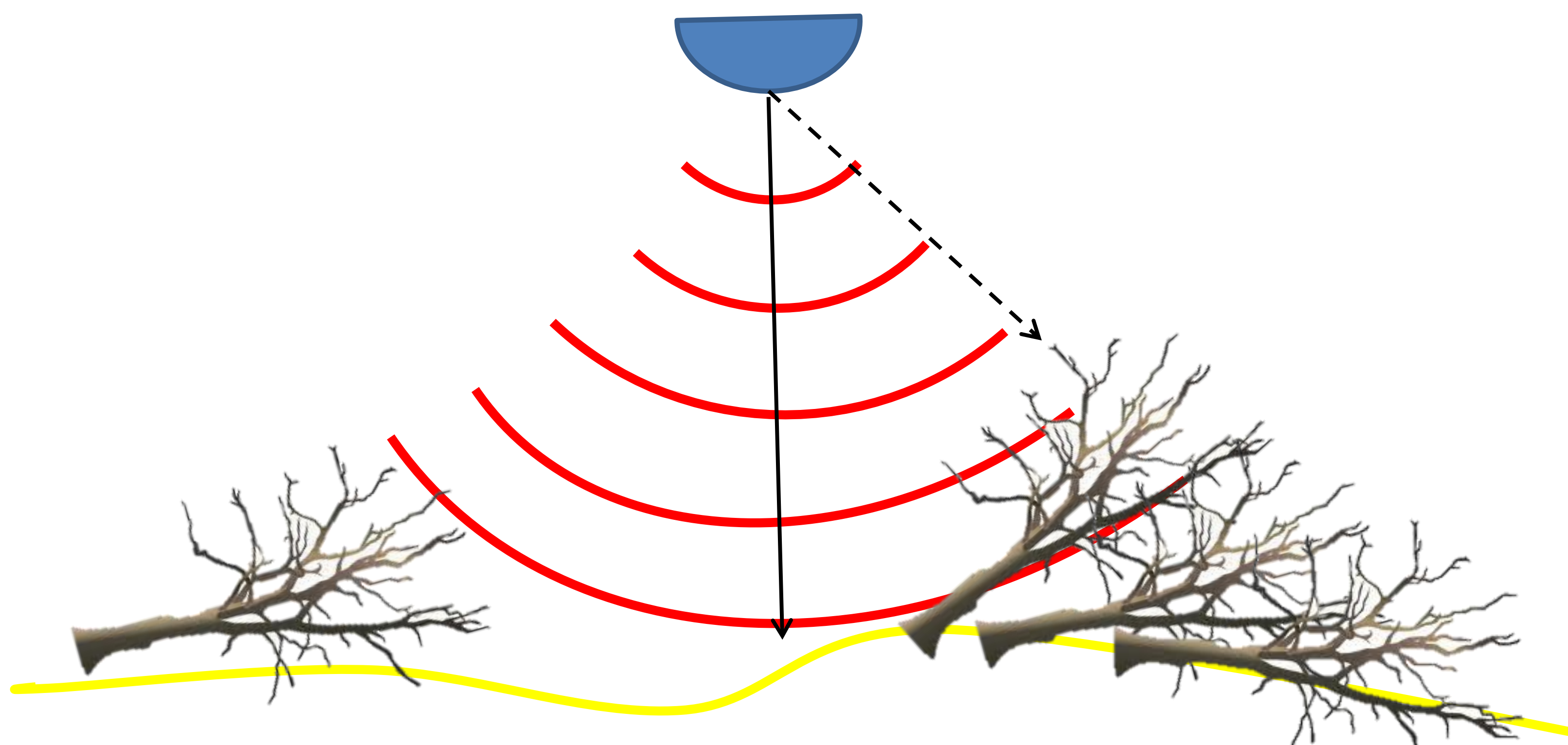
When slant range correction is being applied, the computer assumes the first returns to the transducer are coming from features that should be spatially relocated to a position directly below the boat. Thus, the pixels representing the returns off the branches of the submerged tree on the right are repositioned directly below the boat, and the pixels representing the open, sandy area below the boat are repositioned somewhere out in space to the right or left of the boat path. The result is an image with varying degrees of distortion; an image that does not make sense visually or spatially. (By the way, these issues also plague automated processing routines used by high-end sonar processing software). By preserving the water column in sonar imagery, this source of distortion is eliminated.

When planning a survey it is advisable to perform some field tests of the Contour mode setting to determine whether slant range correction is suitable to your survey situation. In most cases, this author (Adam) prefers not to use this feature.

What is going on here!?

In a simplified setting, first contact occurs directly below boat.

Here, first sonar returns are instead from suspended lateral objects, causing distortions during slant range processing.

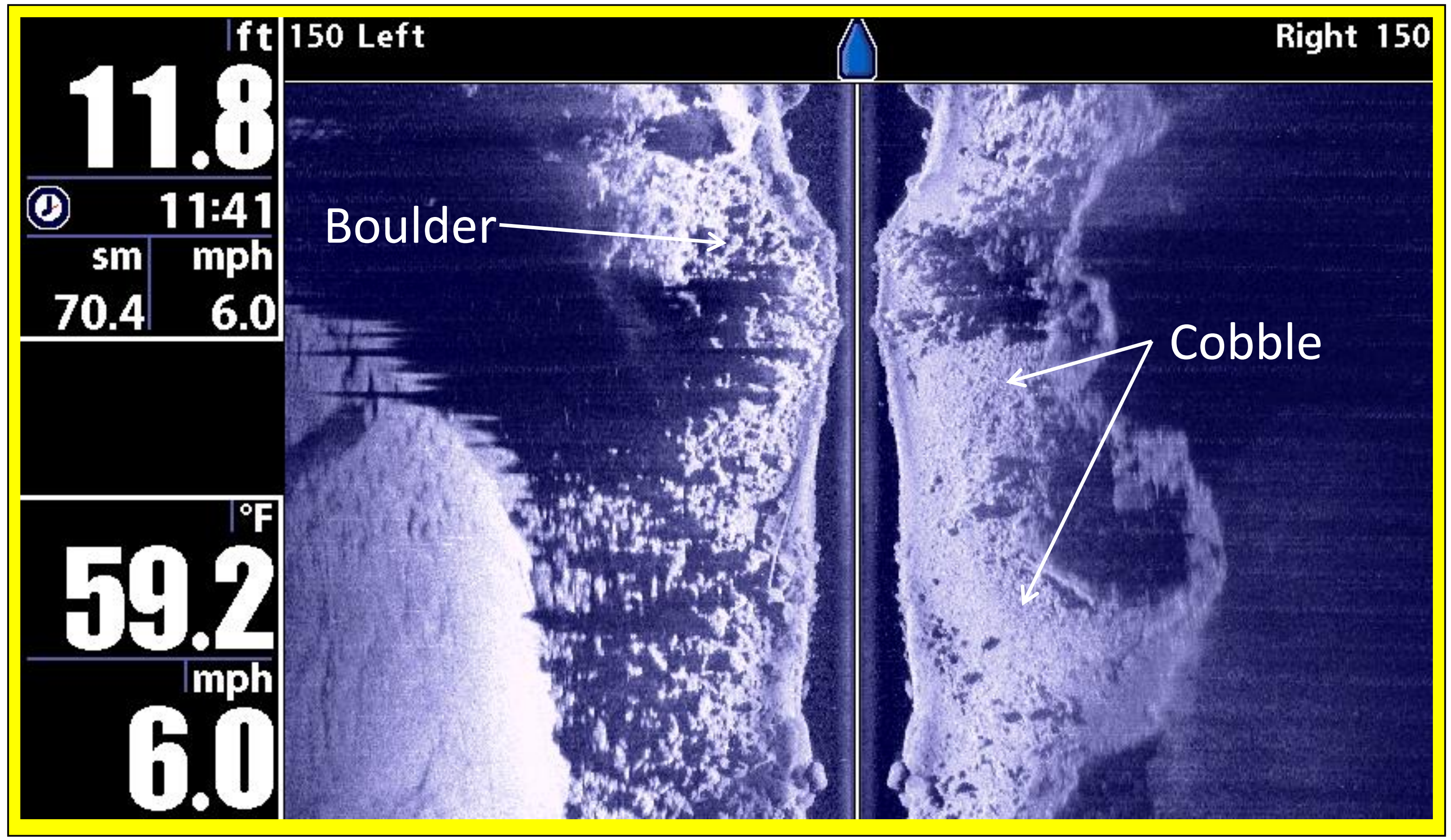


Classic substrates

Now that we've covered some of the bases on water column and slant range correction, let's look at some of the typical substrates we've encountered in surveys of streams of the Southeast Coastal Plain. The image from the right was captured in the lower Flint River. This river is characterized by extensive rocky shoals (primarily cobble to boulder sized material), sand flats, and reaches of flat, limestone bedrock exposures. On the right, we can see that the survey boat approached a rocky shoal, and charted a course over the shoal. The transducer came close, but did not strike, a few of the large, shallow boulders present in the shoal. As the boat approached this shoal, the shallow water and rock pile blocked and reflected the signal back to the boat, casting sonar shadows. These shadowed areas represent missing data that can be quantified during mapping. Note the difference between the large, coarse material predominant along the left side of the image, and the finer (yet still textured) rocky material on the right hand side of the image. This finer textured material is cobble-sized rock (according to the modified Wentworth particle size scheme). In the lower left hand corner of the image appears a smooth sand bar. The boundary between the sand and rocky shoal is strikingly obvious.

Rocky shoals and sand bar

Deep, outside bend of large Coastal Plain river with large submerged trees



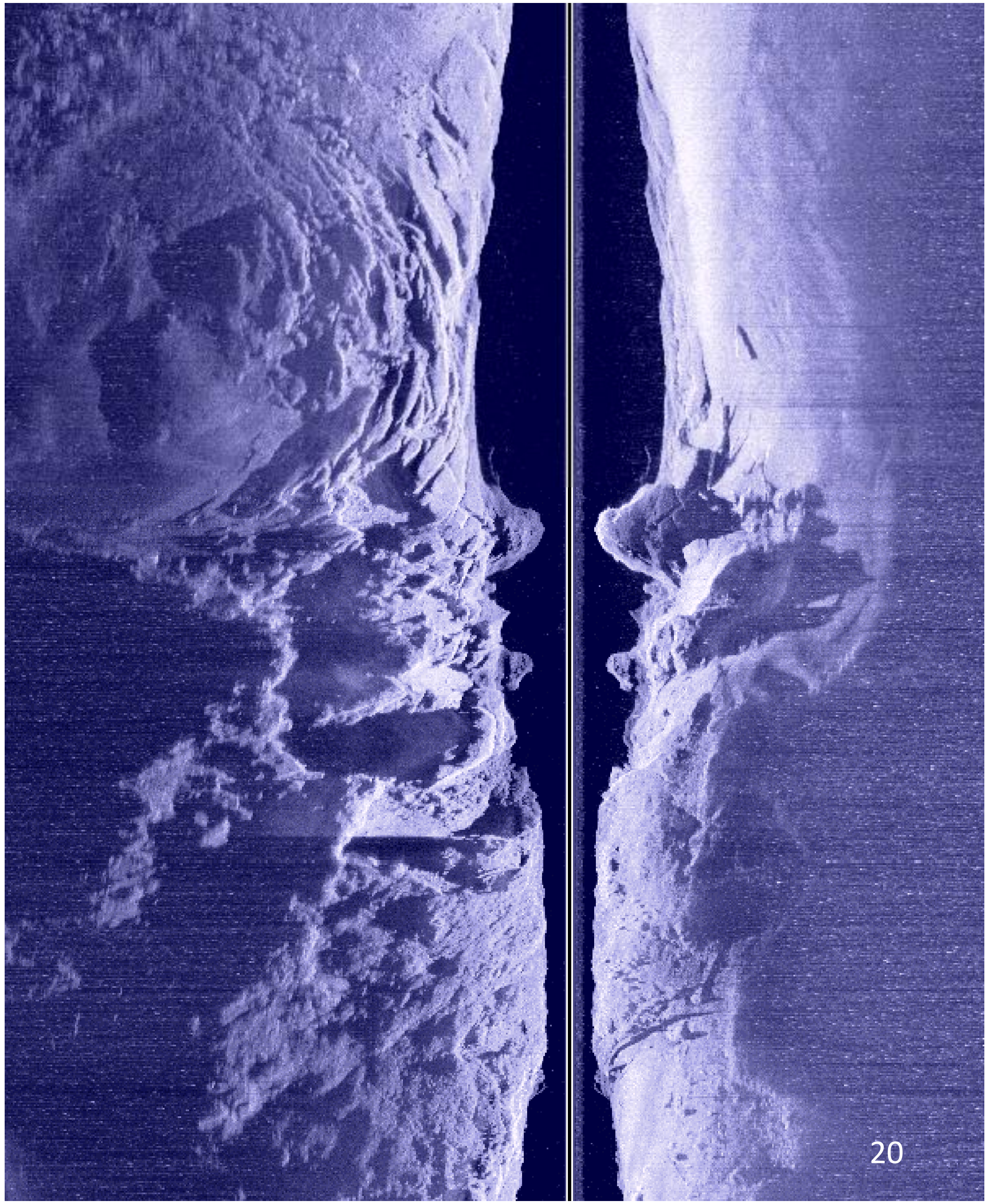
Limestone bedrock

Here's a mosaic of several raw sonar images that reveals an extensive outcropping of hard limestone rock. In several places like this on the Flint River, large pinnacles of limestone emerge from the bottom. During this survey I charted a course directly over one of these pinnacles, though I never knew it existed lurking below in murky water. With some familiarity and experience with sonar signatures from substrates such as limestone, it becomes possible to discriminate this type of material from other rock types.

An interesting side note regarding deep holes containing massive limestone blocks- This reach was known to consistently produce large flathead catfish during annual surveys. Once sonar survey work began in this river, we quickly associated deep holes that contained limestone boulder structure with abundant, large flathead catfish.

Limestone rock formations revealed

An extensive, submerged limestone outcrop

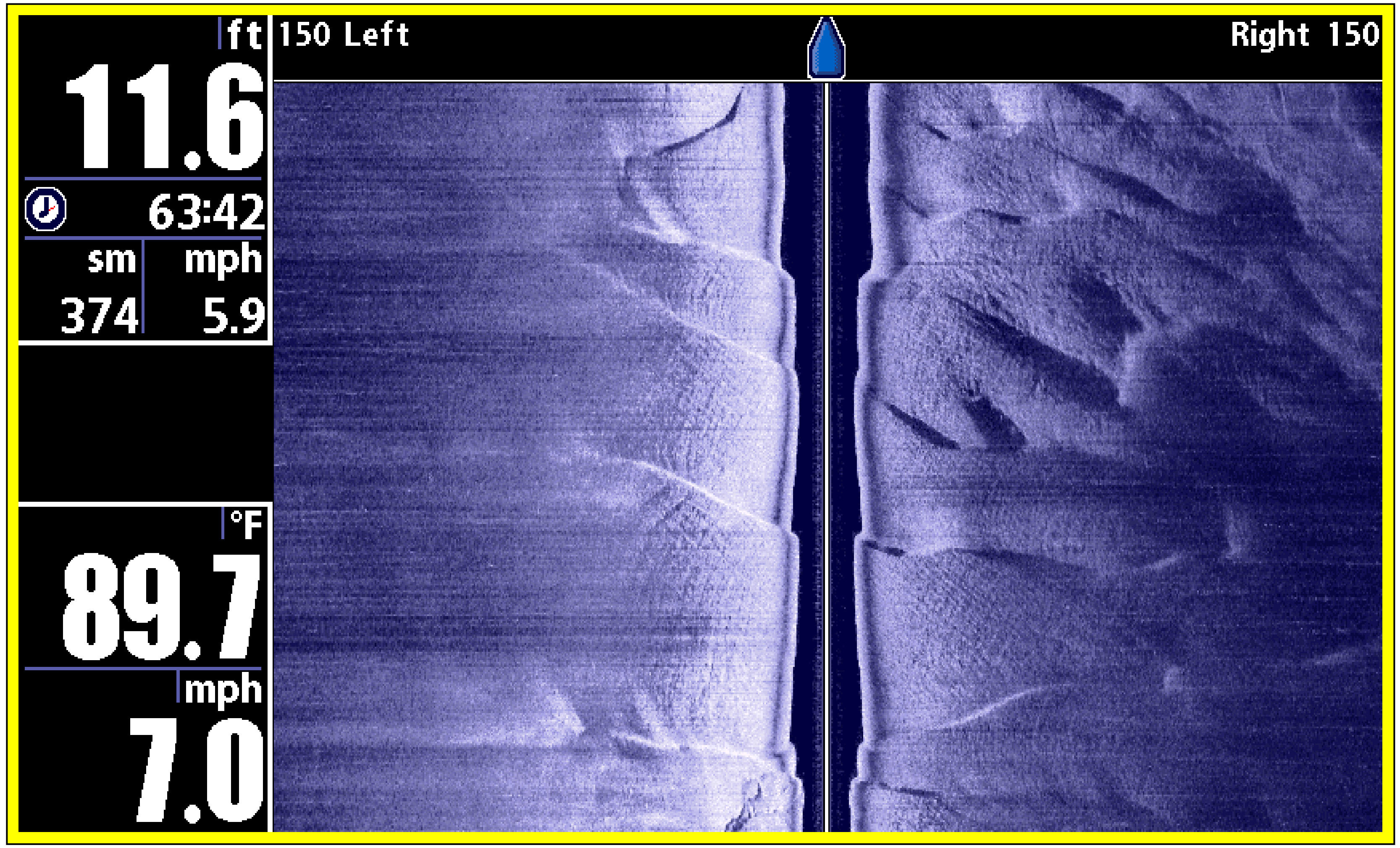


Sand formations

In rivers sandy substrate is often sculpted into beautiful dune and ripple patterns. Like winds that carry sand across the desert, currents carry sand downstream. This process creates characteristic bedforms that reveal the nature of the substrate.

Sand Dunes

Sand dunes along the bottom of the Flint River

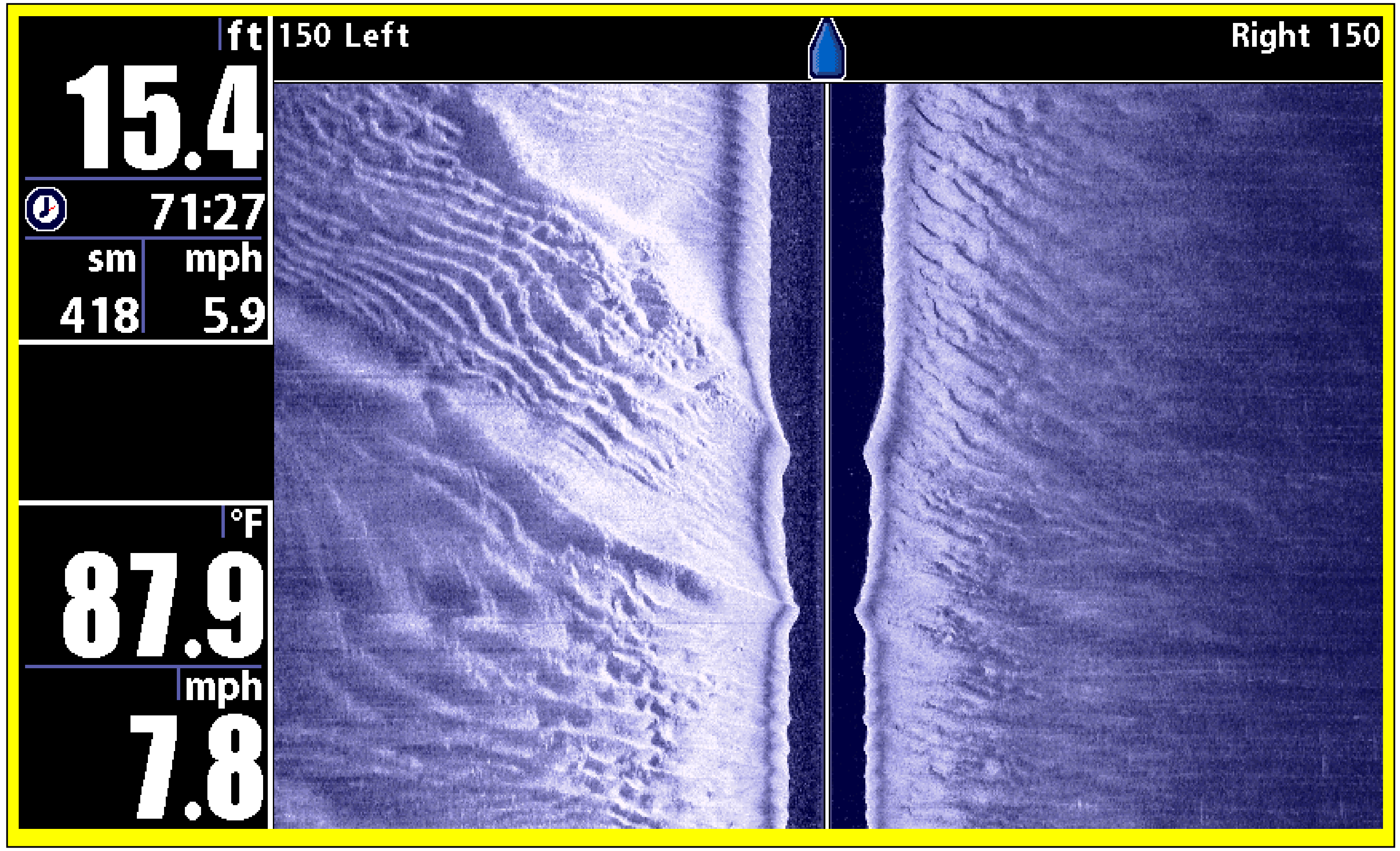


Sand formations

In the adjacent image the sandy bedform might best be described as rippled. Note, however, that within the series of ripples on the left side of the image are 2 very distinct leading edges of what might be called sand waves. Hydrogeomophological processes and mechanisms are responsible for sand dune, ripple, and wave formation. Particle size, stream velocity, and shear stress at the sediment surface are among variables involved. For purposes of habitat mapping, these bedform features are not only common, but also extremely valuable for discrimination of sand in lotic systems.

Sand ripples

Sand ripples along the bottom of the Flint River

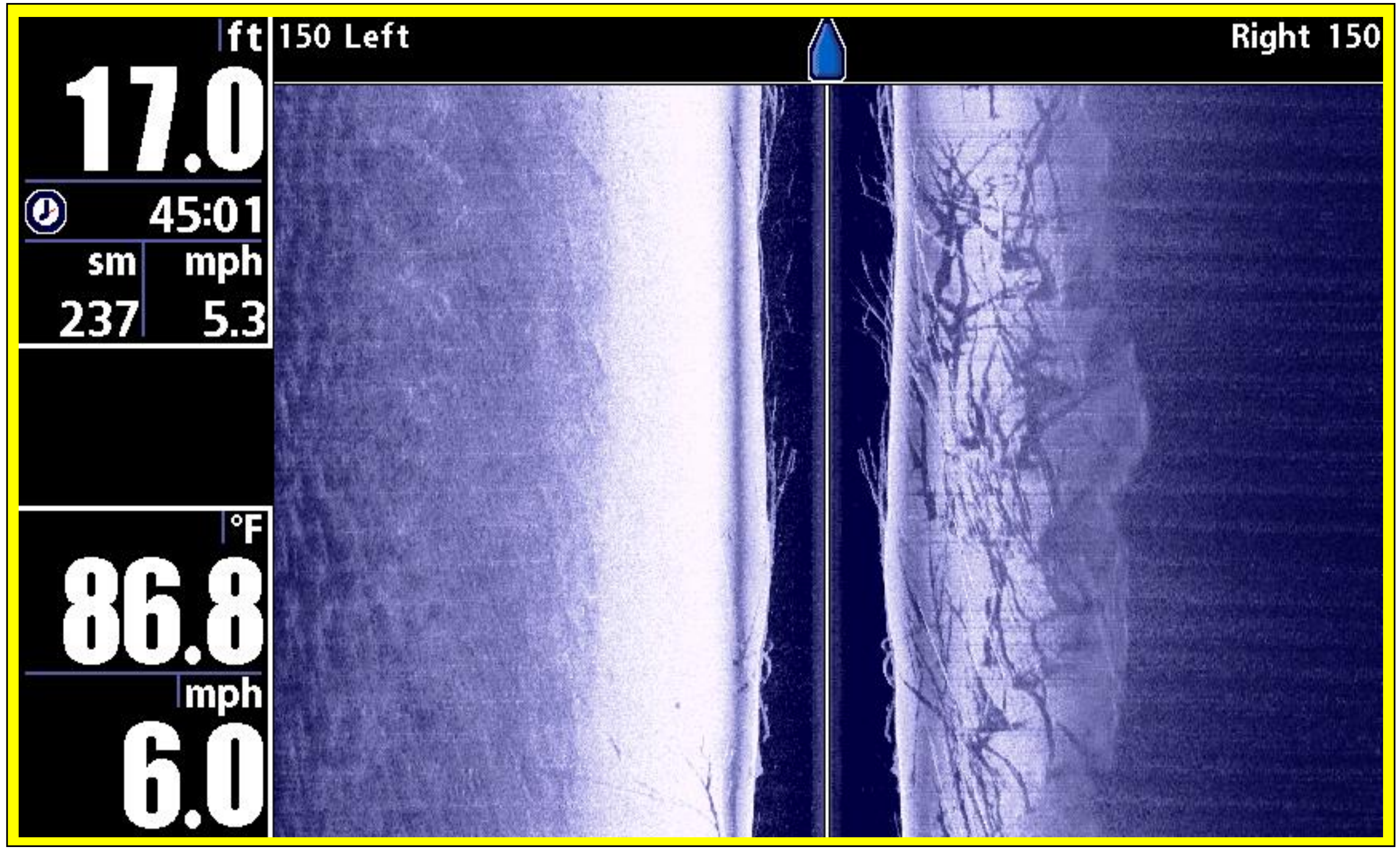


Large Woody Debris

Whether you call it large woody debris, large woody material, coarse woody debris, or something else…submerged wood can be imaged and quantified using side scan sonar. In sand bed, Coastal Plain rivers, wood is found in predictable locations. The adjacent image comes from the Altamaha River in Southeast Georgia. Here, submerged wood has accumulated along the right bank, which happens to be the outer bend, and erosional side of the channel. To the left we have smooth, shallow sand. You might imagine it possible, however painstaking, to attempt to count the individual number of pieces of wood in this image.

Large Woody Debris

Large woody debris along the outside, right bend of the river



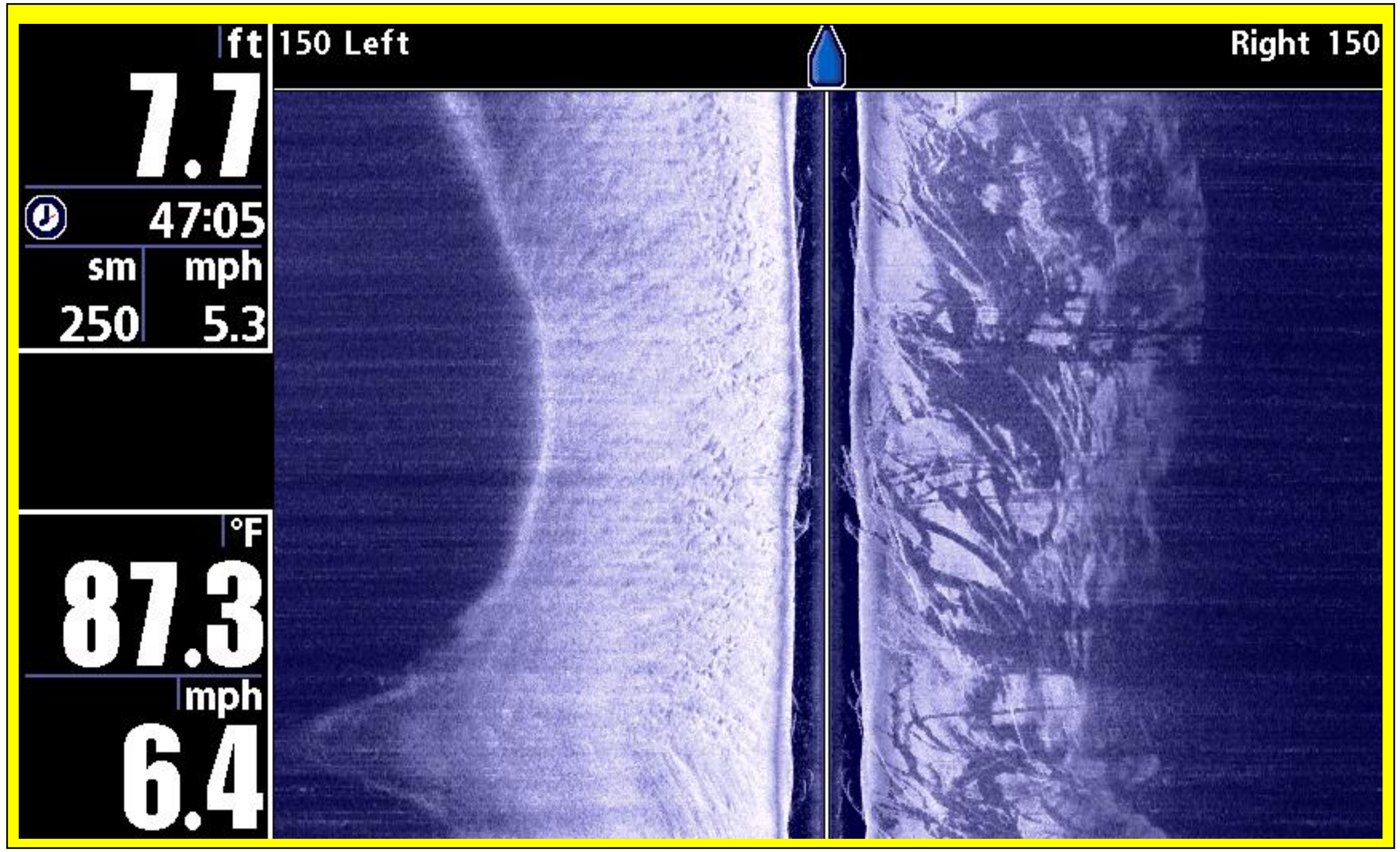
Large Woody Debris

In some systems, the idea of counting pieces of LWD or putting points on the map for each piece may not be feasible due to the large quantity and dense accumulations of wood as seen here along another outer bend of the Altamaha River. Perhaps a more suitable alternative when mapping wood in this case would be to draw a polygon around the accumulation to derive areal estimates of woody cover.

If we were interested in identifying suitable mussel sampling locations within this reach, we might avoid sending divers down into this snag fest.

Wood Accumulations

An accumulation of snags along outside bend of river



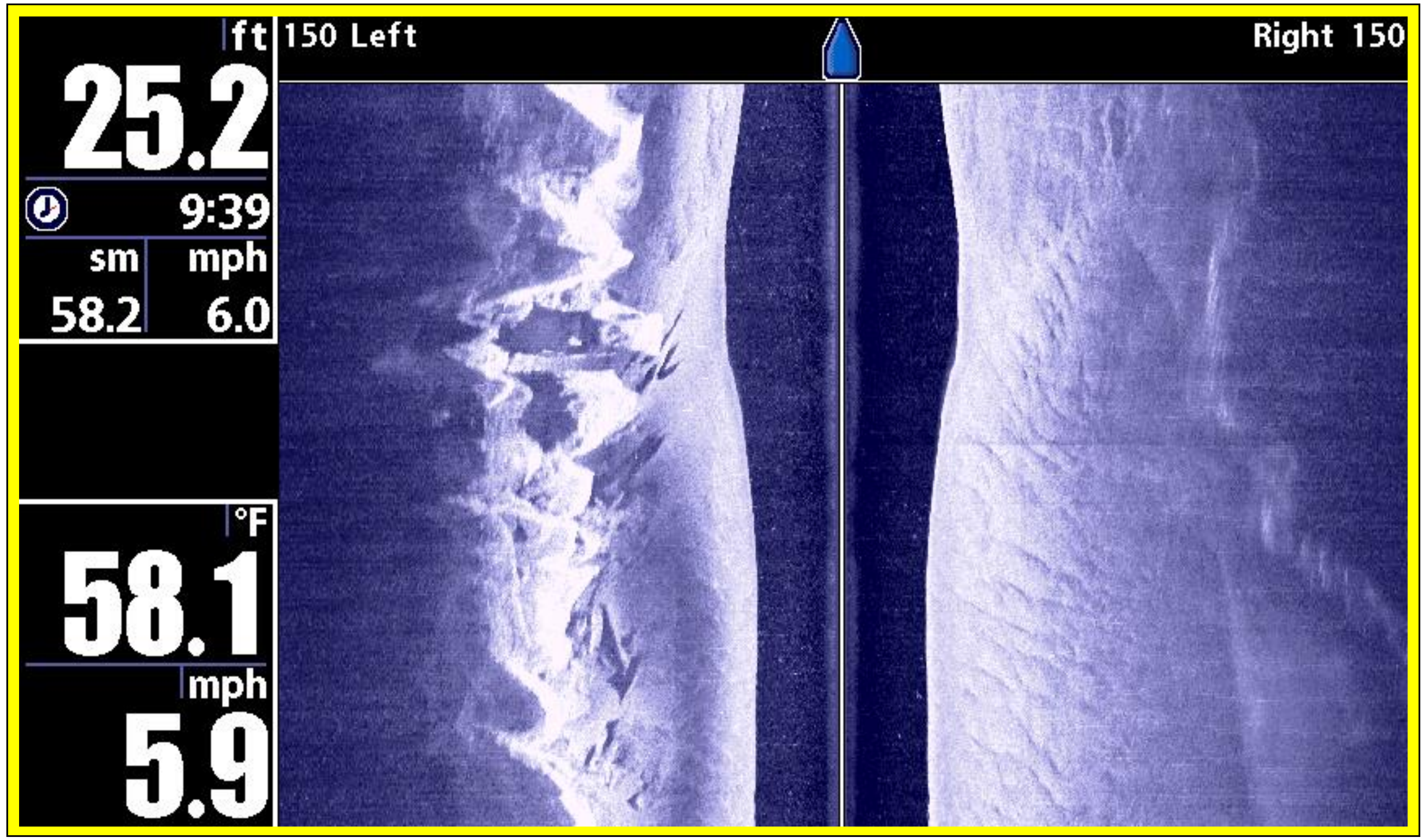
In search of deadheads

Virgin, pre-cut submerged timbers can be found in most navigable Coastal Plain river systems. These logs have rested on the river bottom for 100 years or more in most cases. Deadhead logs are sometimes easily distinguished from other pieces of LWD by their pole-straight, cylindrical forms. Here we see a few potential deadhead logs positioned at the base of a deep, oddly structured bank of the Flint River. These logs are hiding along the base of a towering limestone rock wall. In many places along the Flint River these rock walls are visible above the water's surface during low water conditions. Diving down along these limestone walls is like exploring the dark side of the moon. Now that's truly a gig for a Georgia deadheader!

*Note- removing deadhead logs from state navigable waters in Georgia is unlawful.

Deadhead Logs

Several deadhead logs nested at base of limestone wall



In search of deadheads

Sometimes it's hard to miss a deadhead log when it is perched along the bank of a drought-stricken creek.

Large (Deadhead) Log

A solo deadhead log along the bank of Ichawaynochaway Creek

In search of deadheads

Here's a close-up photo of this same log, with intern Josh Hubbell posing to provide reference on the massive size of this log. The canoe is 16 feet long.

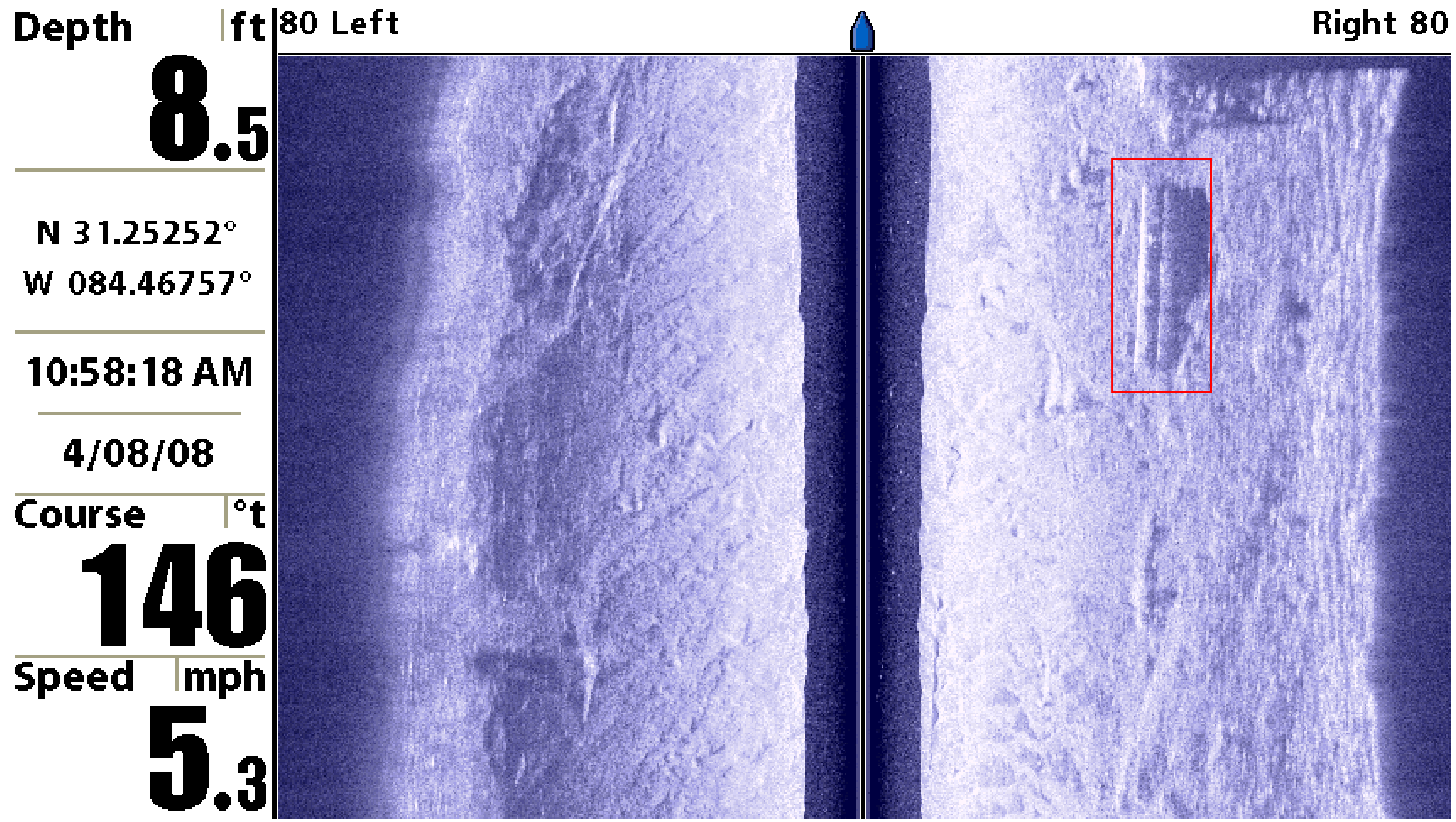
Large (Deadhead) Log

In search of deadheads

Here we show a raw sonar image of the creek where the deadhead log in the previous slide was resting. Of course we created this image when stream flow was much higher and the log was completely submersed. Interestingly, there appear to be two identical log-like objects adjacent to one another. This double image is actually an artifact. In other words, there is only one log present in this location, and the mirrored object does not exist. This example was specifically chosen to demonstrate that artifacts can and do occur in sonar images, just as they do in digital photographs. This type of artifact is sometimes associated with logs, and although the cause is uncertain, we suspect it involves a deflection of some of the sonar signal off of the log and reflection from the water surface above.

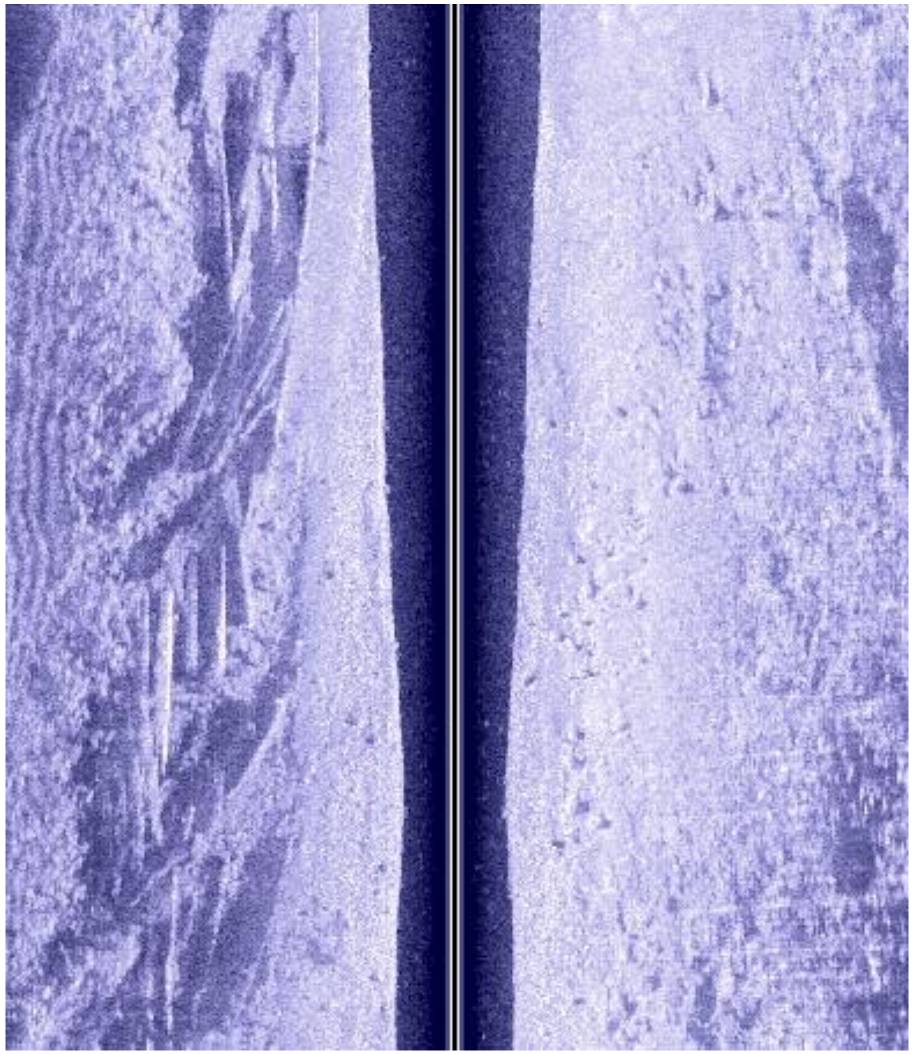
Same log in sonar image

-Double image is an artifact

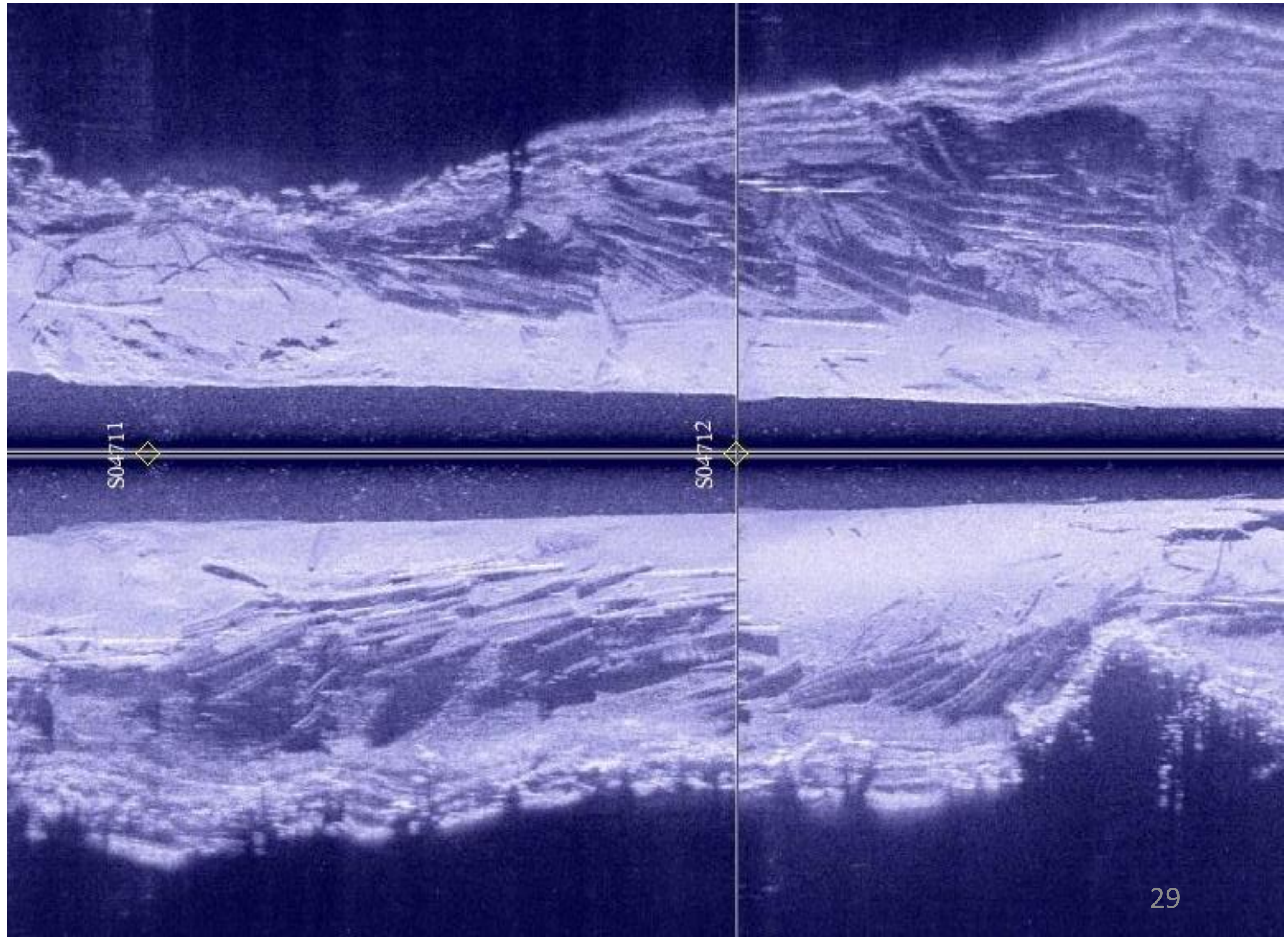


Caches of deadhead logs

Deadhead logs do not always appear as isolated objects. In these examples we find caches (piles) of sunken logs resting on creek bottoms. Caches are common in areas formerly used for launching and landing log rafts.



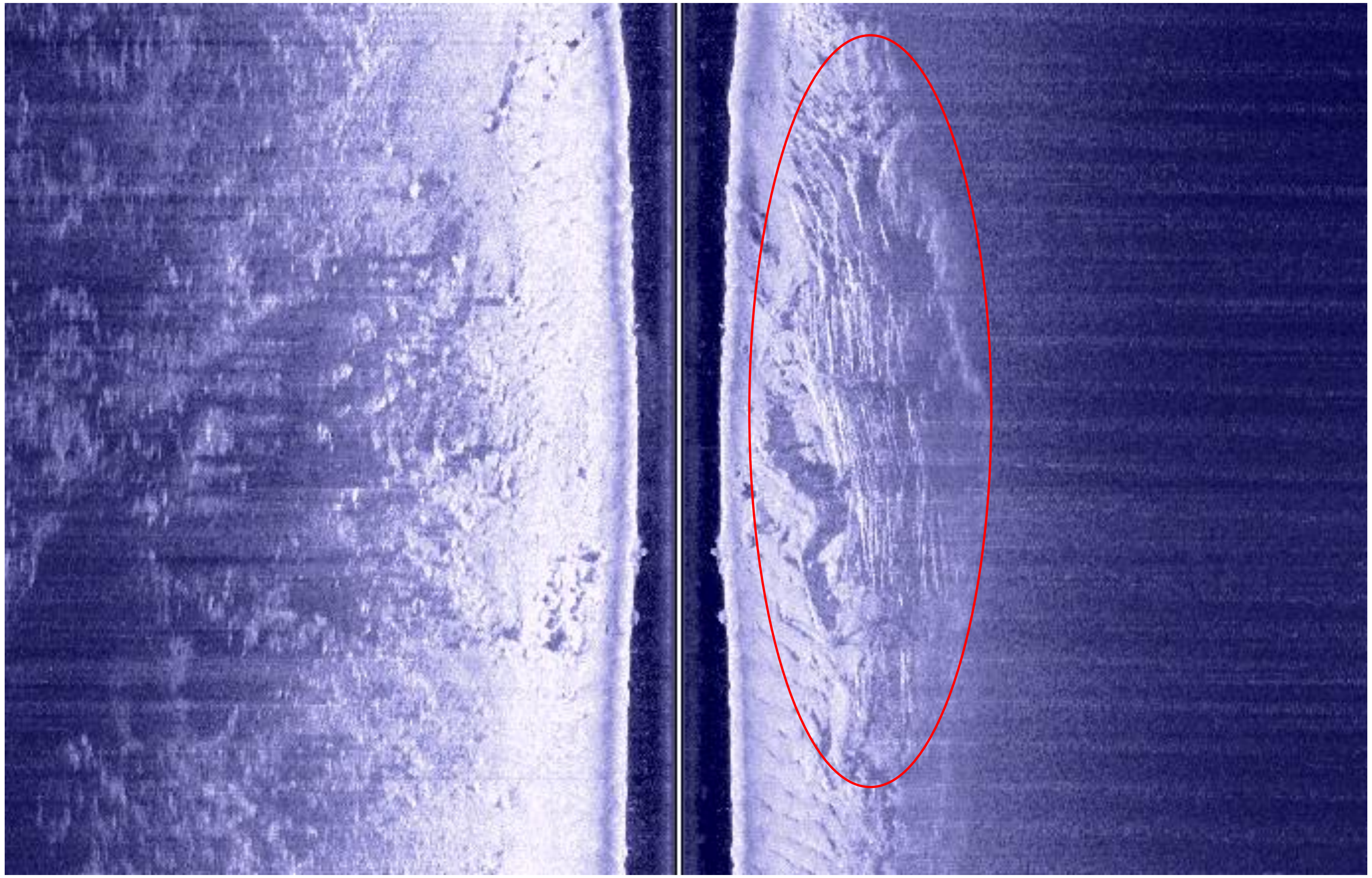
Log Caches



The remains of a raft

During a reconnaissance survey for deadhead logs in the Flint River we encountered the curious feature circled on the right. Although water was too deep and swift at the time to confirm its identity, we returned later that year to have a look.

Log Raft on Flint River



The remains of a raft

What we found during this groundtruthing expedition was a regularly arranged group of logs now exposed along the right bank of the river. Rather than remain preserved underwater, these logs were in various states of decay due to repeated exposure and drying during low flow periods. We suspect this log pile may be the remains of a large log raft that never found its final destination.

Log Raft on Flint River

Features in context

In the following series of slides we will work on interpreting complex features in context. During our early work with sonar mapping we seized the opportunity to visit local creeks during periods of extreme drought and obtain photos, like the one shown here, of study areas. The time spent examining these areas during low, clear water, and the opportunity to study the relationship between field photographs and sonar images of the same areas proved invaluable for honing our skills of interpretation. Let's spend some time doing the same for a few of these images.

In the scene to the right our intern Josh is standing atop a large boulder in the middle of the stream channel, diligently studying the area. To his right an old cypress tree snag stands rooted in the channel. In front of Josh we see another large boulder. Almost touching this boulder is a deadhead log that is oriented parallel to the channel. The topside of this log is just above the water surface. Let's see if we can pick out each of these objects in the corresponding sonar image.

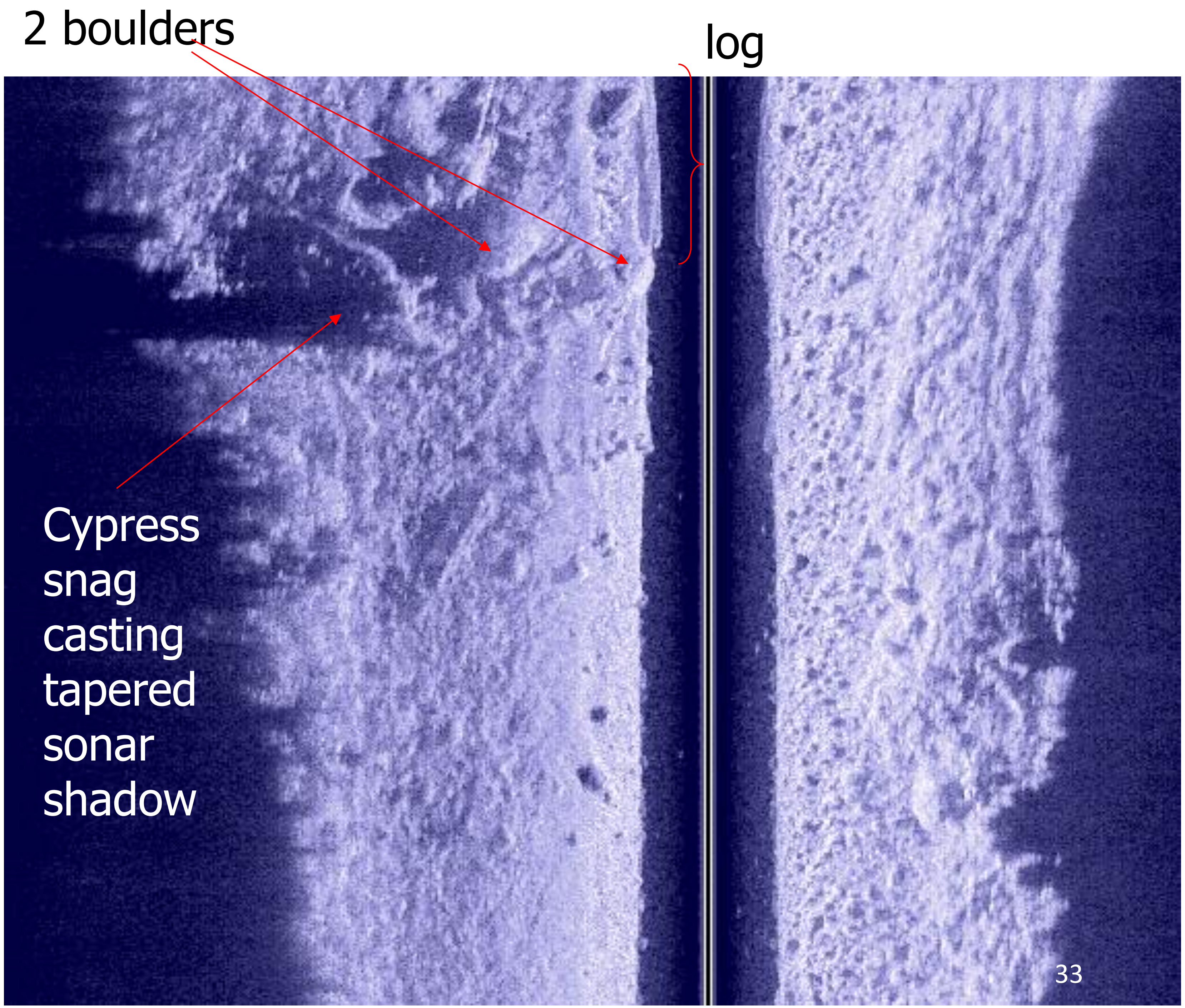
Interpreting Features

Features in this scene

Let's point out the features discussed in the previous slide. The two boulders are located on the left side of the image, just left of the path the boat took during the survey. The rock Josh was standing on was tipped up, and here we see the sonar shadow being cast by this object. The second boulder in front of Josh is identified here as the roundish object located near the edge of the water column. Note that this sonar image boulder appears to be smaller than the one Josh was standing on, yet they appeared to be about the same size in the digital photograph. The reduced size of this second boulder that is close to the center of the image is a good example of the effect of object size compression in this region of the image. The boulder artificially appears smaller than it is in reality.

The cypress tree stump cannot be seen, except for the vertical leading edge that reflected signal back to the transducer. Instead, we clearly see the tapered sonar shadow that was cast by the buttress of this tree. The shadow extends all the way to the bank indicating this object indeed protruded all the way through the water column. The sunken deadhead log is quite difficult to identify in this image, but if we look closely behind the second boulder we find an object that represents this log. The log was almost directly underneath the boat during the survey, as we can almost see part of the object mirrored on the right side of the image.

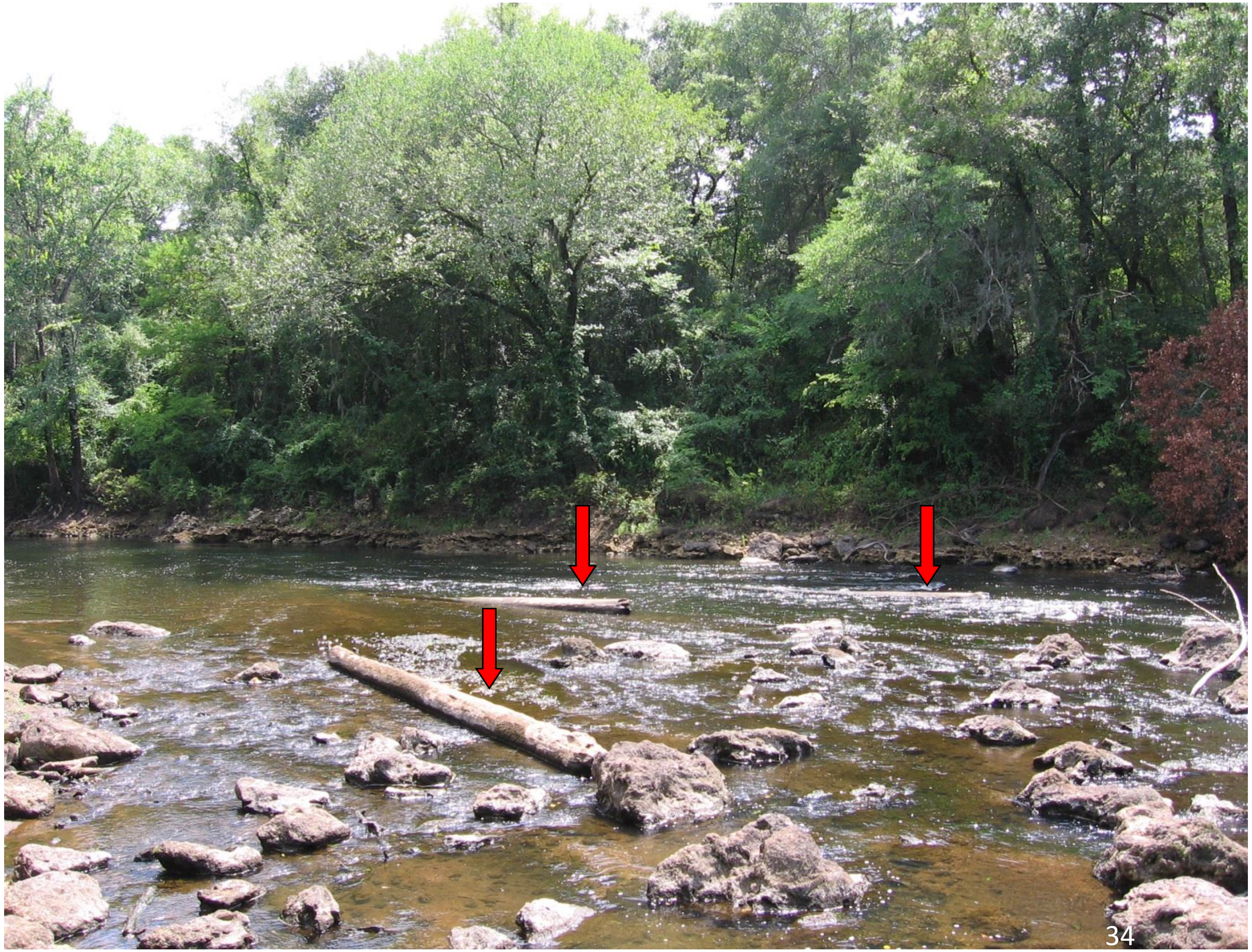
Interpreting Features



Features in this scene

Here's another photograph of a drought-stricken creek in South Georgia. This shoal contains many large boulders, in addition to three noticeable deadhead logs exposed above the water surface. Let's have a look at the sonar image captured for this area during higher water.

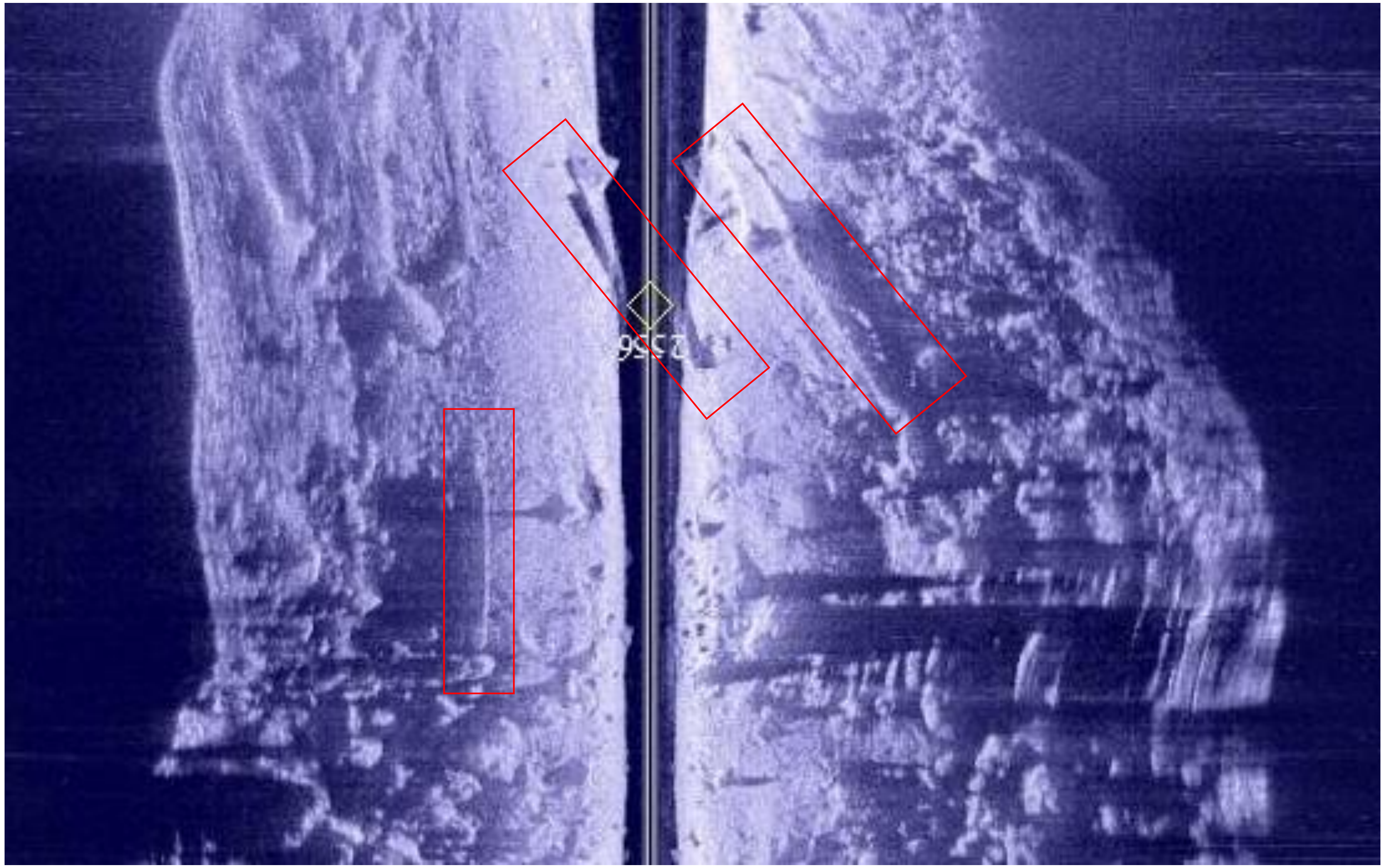
Boulder field with 3 logs



Features in this scene

The field of boulders is quite evident extending across the lower half of this sonar image. Many of these large rocks are casting long shadows, especially because the water was fairly shallow over the shoal during the sonar survey. The three deadhead logs have been identified by red boxes in this image. The survey boat passed over the log in the middle of the image; the log was oriented at an angle to the boat path and as a result we see portions of the log on either side of the image.

Boulder field with 3 logs



Features in this scene

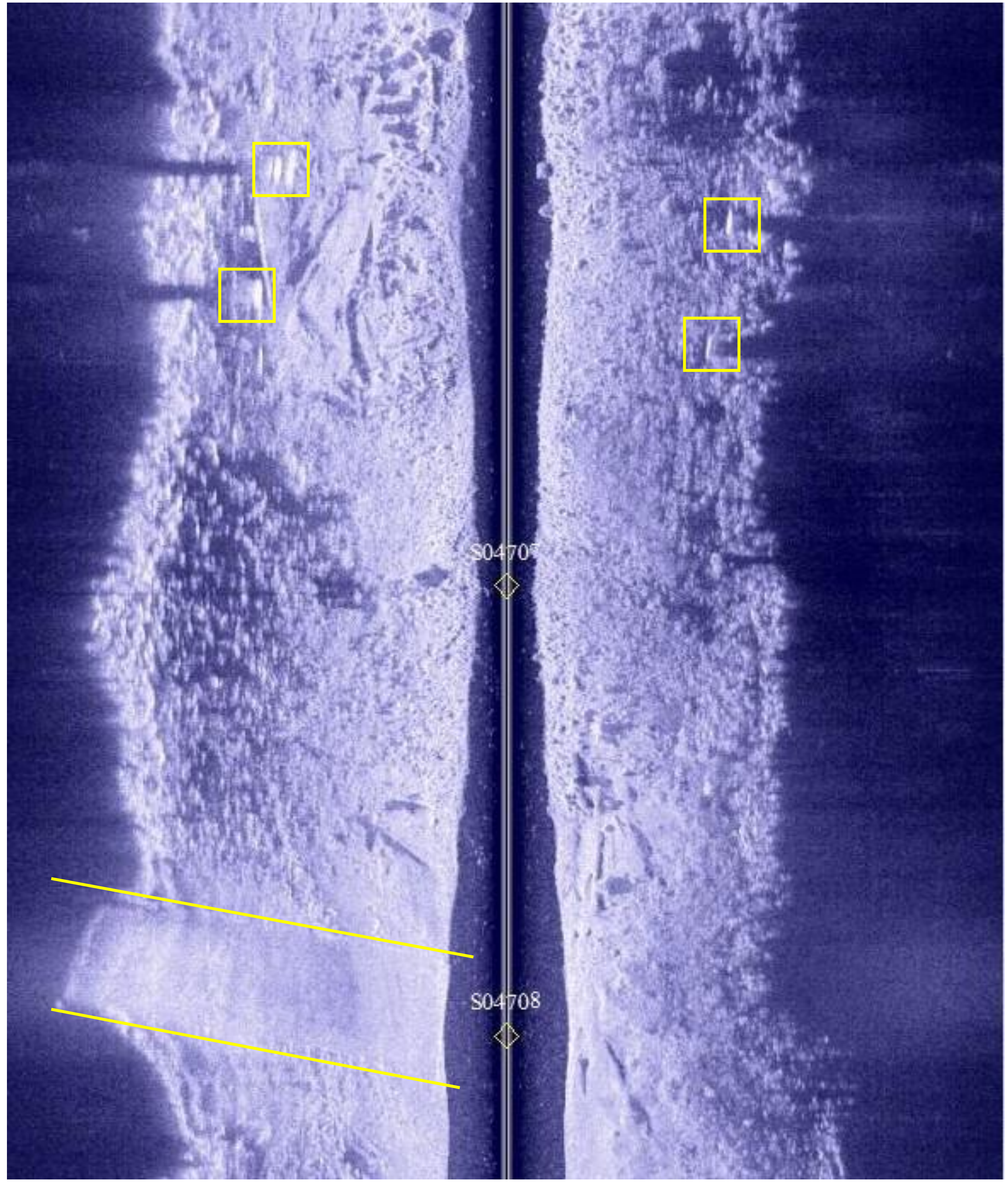
In this scene, our trusty survey vessel sits next to a concrete boat ramp that extends underwater into the creek. Just upstream is a bridge span with submerged narrow abutments. Let's see if we can identify these features in the corresponding sonar imagery.

Bridge pylons and Concrete ramp

Features in this scene

In the upper half of the mosaic we find four submerged bridge pylons. We can only visualize the edge of these structures. Each has a narrow sonar shadow behind that extends all the way to the bank; a tell-tale indication that each pylon fully protrudes through the water column.

In the lower left hand corner of the mosaic we find the submerged concrete boat ramp. In our live program we are able to toggle the yellow lines defining this feature on and off to help illustrate the difference in overall texture and tone of this smooth, hardened area relative to the creek bottom substrate above and below the ramp. These differences are subtle, but with experience these they become more pronounced and recognizable.



Features in this scene

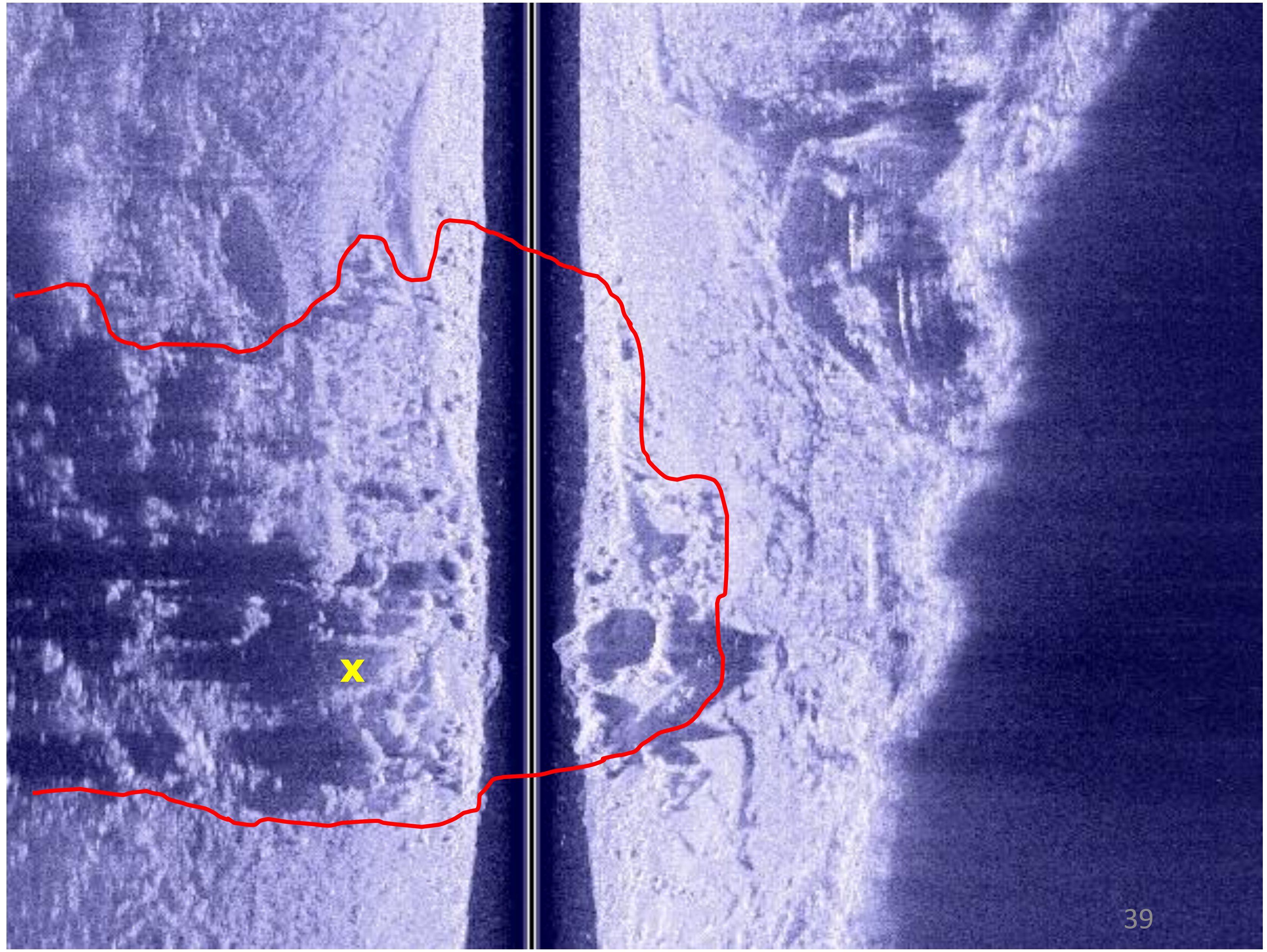
In this scene, intern Wes Tracy and I visited an exposed boulder-strewn shoal along Ichawaynochaway Creek for some groundtruth work. The aspect of this photograph reveals how steep the banks of this entrenched creek were in some places. Would you believe we successfully navigated down the center of this creek during a survey? Not at this flow, of course! The yellow line provides an indication of the downstream path taken by our vessel during the sonar survey.

Mid-channel Boulder Shoal

Features in this scene

Here we show a portion of this shoal as it was imaged during the survey. Note the large boulders that were located along the upstream, leading edge of the shoal. The red, hand-drawn line illustrates the apparent boundaries of this shoal in the sonar image. A yellow X has been placed in the location of the large boulder I believe Wes was standing on in the previous slide.

Mid-channel Boulder Shoal



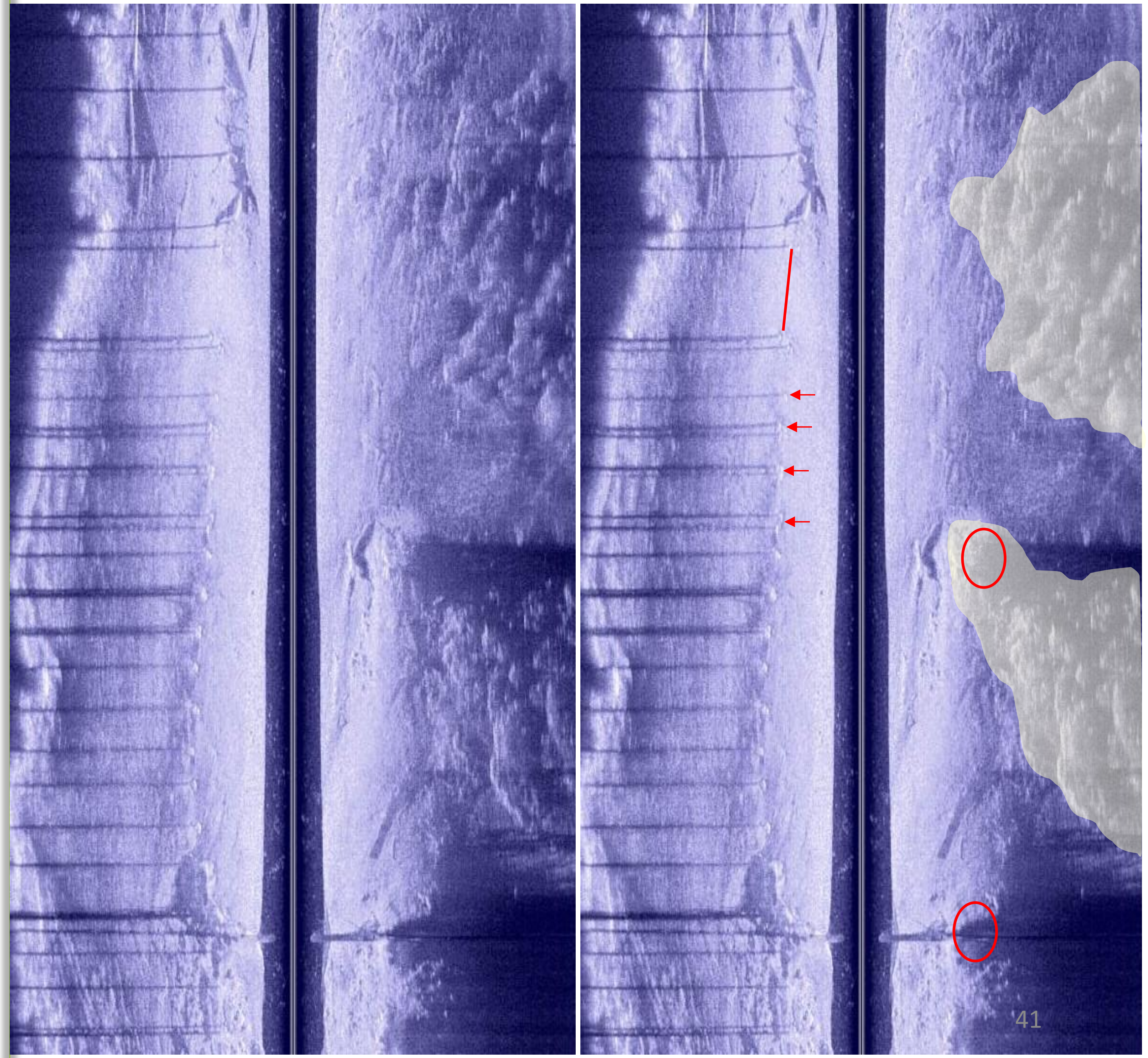
A complex scene

Here is a portion of lower Spring Creek in Southwest Georgia. This area was long ago used as a landing for deadhead logs. A mill and lumber company were located on the adjacent property. Along the far side of the creek we find a series of upright wooden pilings. Note the gap between two adjacent pilings identified with a red line. In the middle of the channel are two small cypress trees identified with red dots. In front of the marked cypress tree closest to the camera is a log oriented perpendicular to the channel (red x). Along the right side of the image (left bank) are two exposed bars or humps. Although it is difficult to tell from this photograph, these bars are actually outcrops of solid limestone bedrock. The surrounding substrate was mud and silt.

Pilings, Cypress, and Humps

Features in this scene

Here we display this reach of the creek in raw sonar image mosaic form. On the left is the raw mosaic, and on the right we have added reference markers for the features identified in the previous slide. Notice how each upright piling casts a long narrow shadow that reaches the right bank. The gap between the two pilings is clearly evident. It is somewhat difficult to identify the two upright cypress trees because each was rooted on a raised portion of the bed. The approximate positions of these trees have been identified with red circles. And lastly, the two limestone outcrops have been identified with the shaded polygons on the right hand mosaic. The difference in texture between these outcrops and the surrounding muddy substrate are quite subtle. Interpreting these substrate distinctions is challenging in this scene.



A popular question

The question of whether fish can be imaged by side scan sonar is relevant and intriguing. Until now we have focused on inert physical features and objects, yet all of the streams we have scanned have resident fish populations. What does it take to image a fish?

Several important factors having to do with operation of the sonar equipment, such as the range setting used, will likely play a role in imaging fish. At higher range settings, smaller objects (fish) are less likely to appear as distinguishable targets in an image. As far as subjects go, fish that are larger and more reflective (hard-bodied) like the Gulf sturgeon to the right, probably stand a better chance of being imaged by side scan sonar. Fish with soft bodies, like catfish, may absorb too much of the sonar signal to be detected, although much work remains to explore differences among fishes.

At least one study demonstrating the use of the Humminbird system for detecting manatees (see reference below) appears in the primary literature, and others are underway examining the effectiveness of detecting and counting sturgeon with side scan sonar.

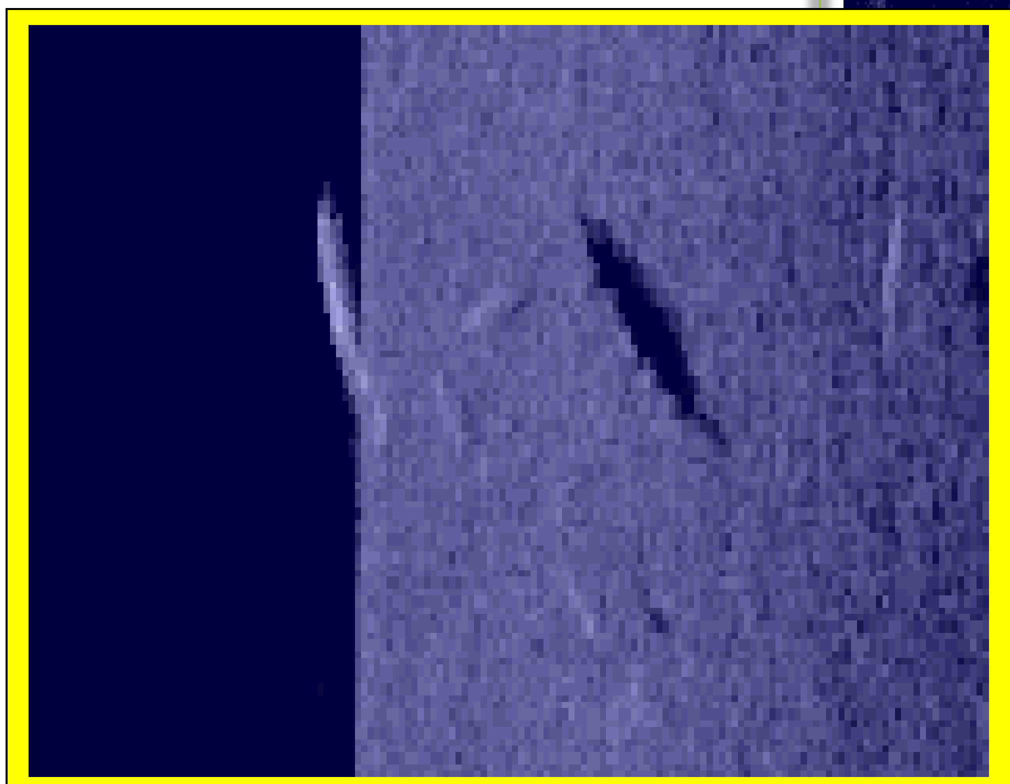
Gonzalez-Socoloske, D., L. D. Olivera-Gomez, and R. E. Ford. 2009. Detection of free-ranging West Indian manatees *Trichechus manatus* using side-scan sonar. Endangered Species Research, 8: 249-257.

Can fish be seen?

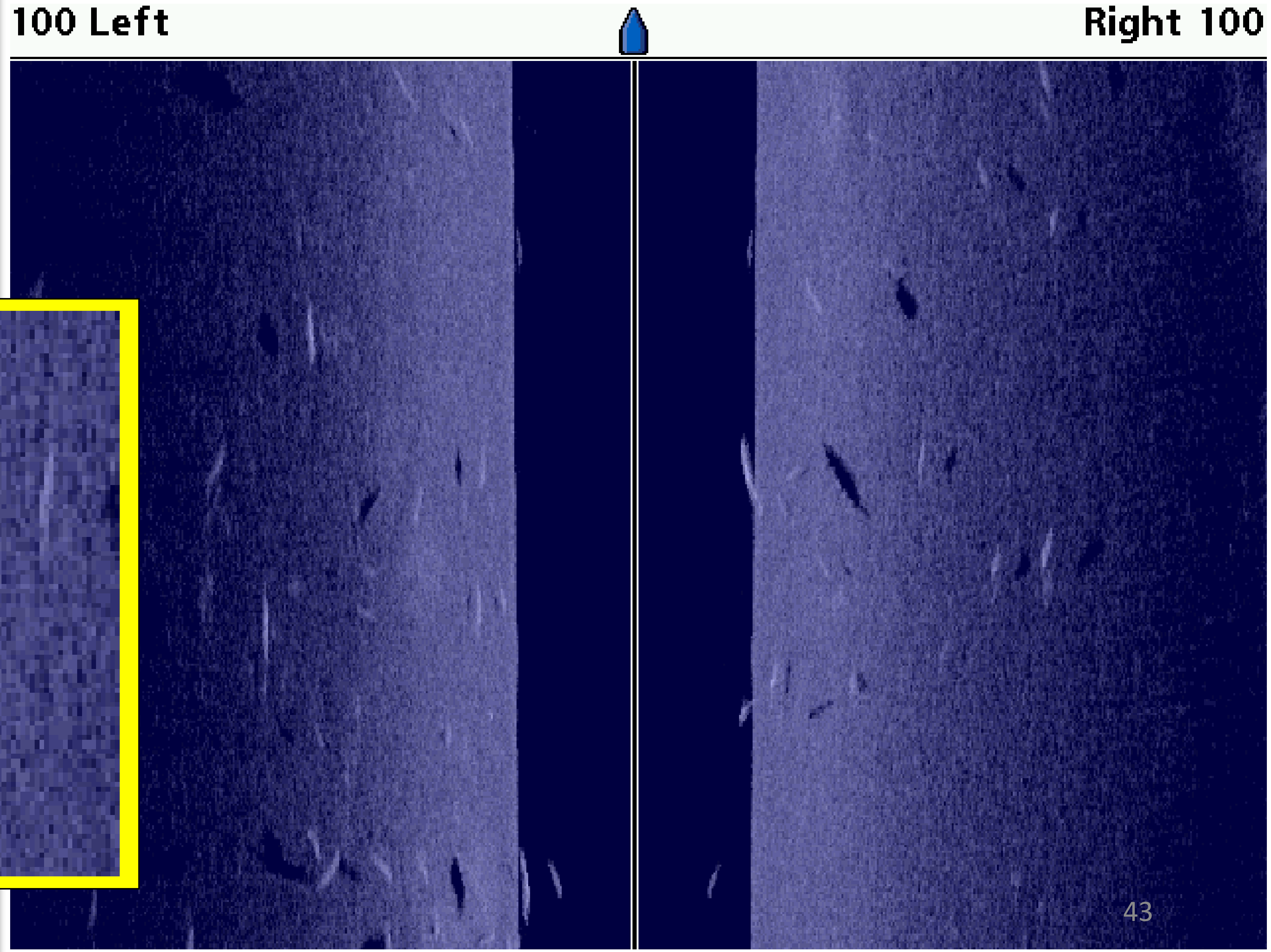
Gulf sturgeon: a large, reflective target

Sturgeon in resting area

Here is a single image captured in a known resting area for Gulf sturgeon that typically holds dozens if not hundreds of sturgeon. Many of the suspended targets seen here are likely sturgeon. Below we zoom in on the target just right of center to examine its shadow profile. Note the sloping forehead, heterocercal tail, pectoral and pelvic fins. Interestingly, it is the shadow of sturgeon rather than the target itself that often appears so well defined in the sonar image.



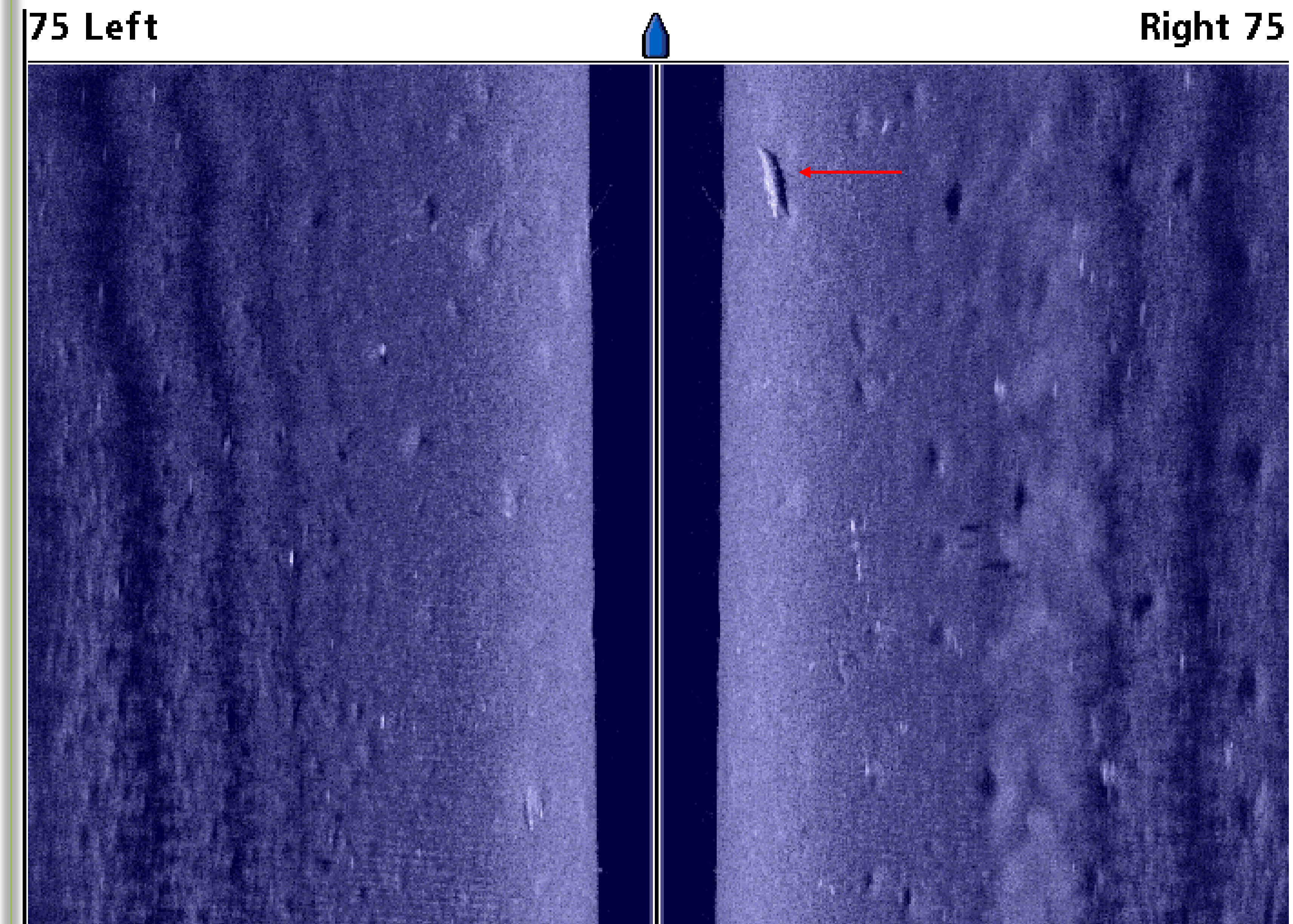
Gulf Sturgeon



What’s lurking below

Here is a sonar image captured from a reservoir cove that harbored a small alligator. This gator was at the water surface until I approached it with the sonar boat. The animal sank down to the bottom and rested there as I passed overhead. It even appears from the shadow that his head was turned up toward the surface, perhaps wondering where I was going. Alligators, like sturgeon, are large, reflective targets.

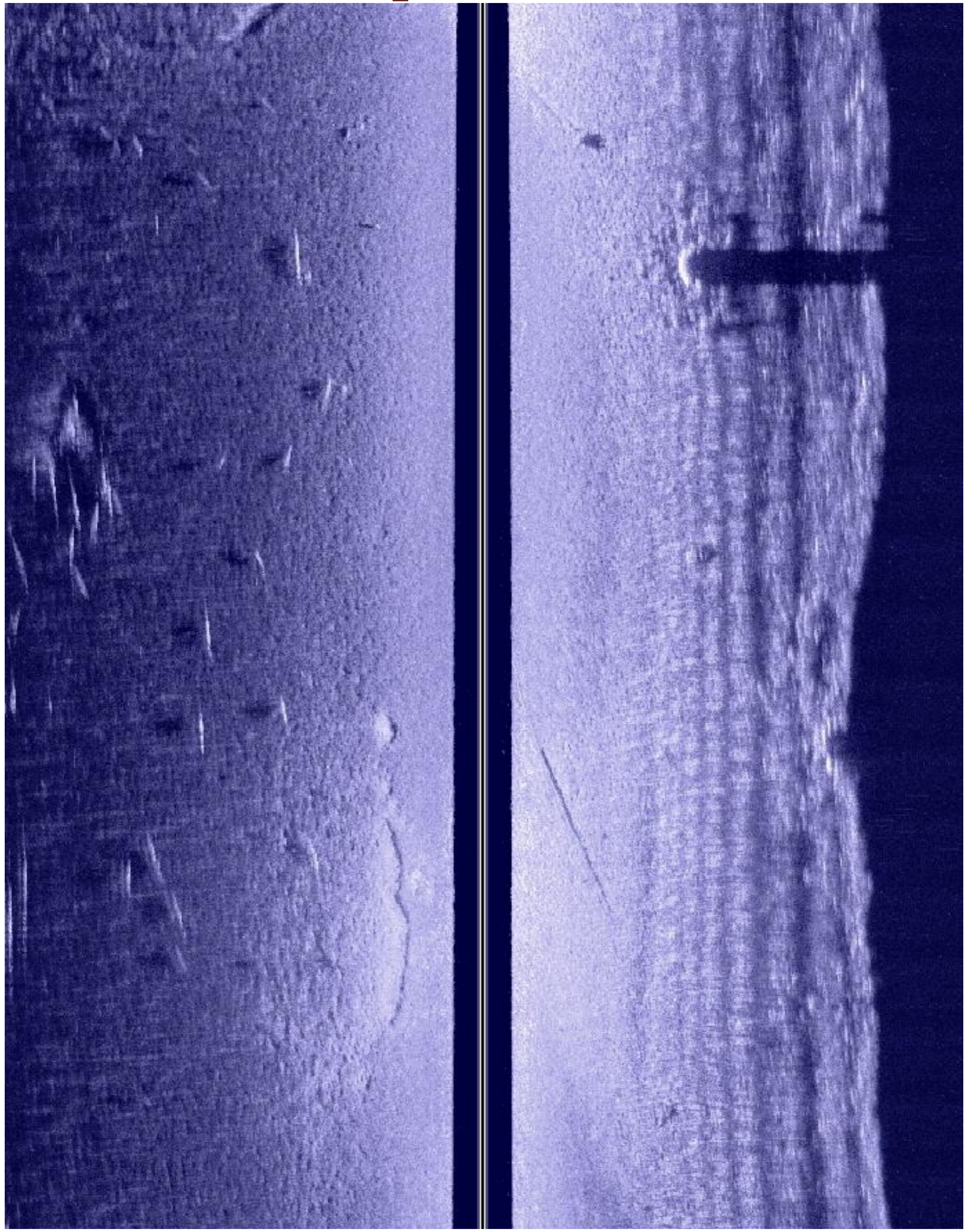
Alligator



Fish on the move

One of the realities of imaging fish is that they can move. If targets are in motion as the sonar beam passes over them, their representative sonar returns can be distorted, either stretched or shrunken or perhaps not visible at all. In the image on the right I believe we see a school of fairly large fish off to one side of the boat (left). Although the targets are close to the bottom, we can see that the shadows are slightly offset from the object, a clear indication that these objects are not logs. To me, these targets appear stretched, or longer than normal. I suspect this effect occurred because the school of fish were moving in the same direction as the boat, however not moving as fast as the survey vessel. Perhaps these fish were common or grass carp. Their identity remains unknown given the water was very muddy and I was unprepared to do any fishing.

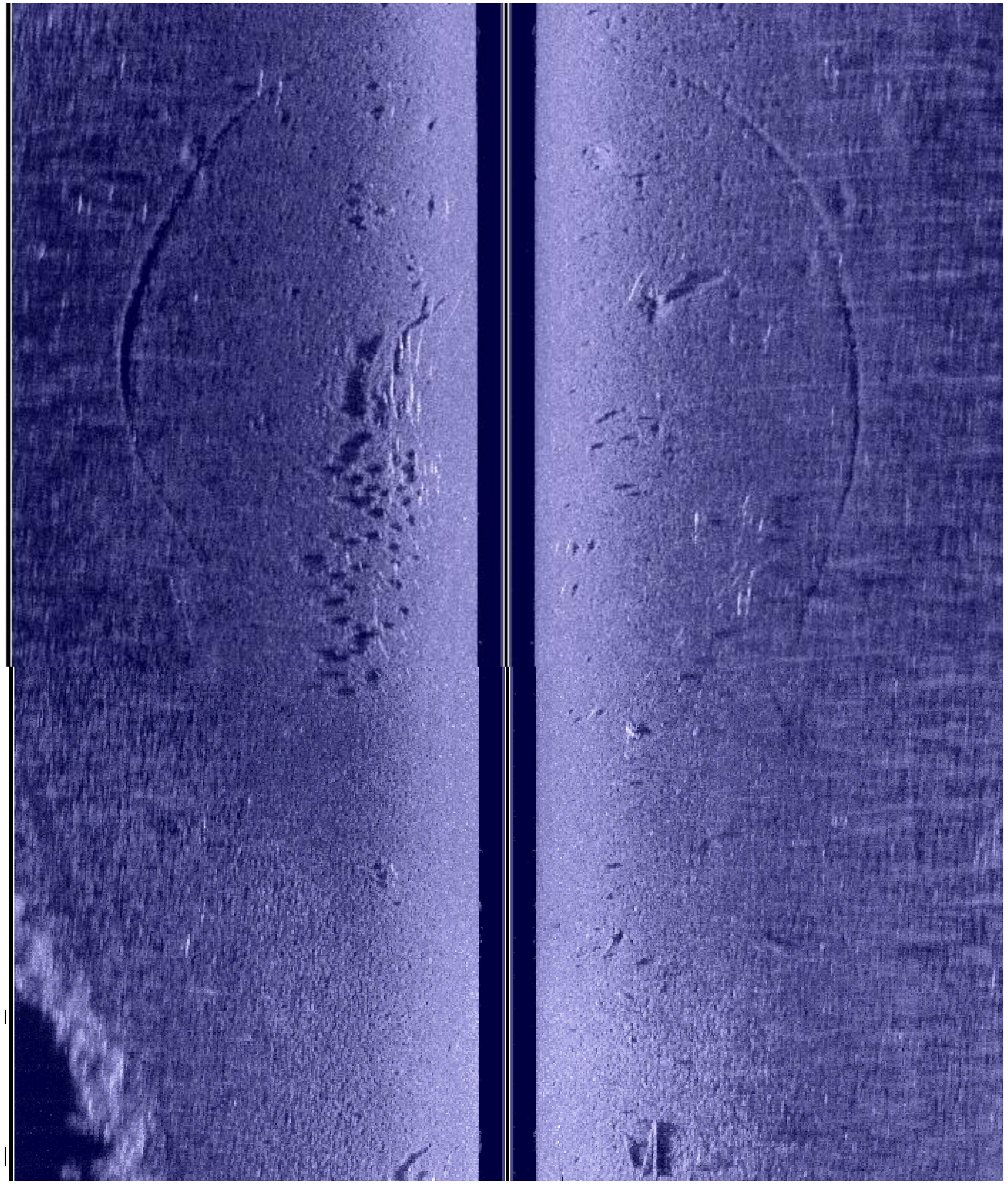
Groups of fish



More fish schools

This is an interesting image that shows another school of fish, located both left and right of the boat. Again, the offset shadows indicate these are suspended objects. The left side school appears to have more fish, and the top end members appear to be on the move as the boat passed over them. The odd circular pattern in this image is something like the sonar equivalent of a crop circle. On this day, several tournament level bass anglers had their shiny boats out on the water for spring test-runs and were doing donuts, leaving nice circular prop scars in the muddy flat.

Groups of fish

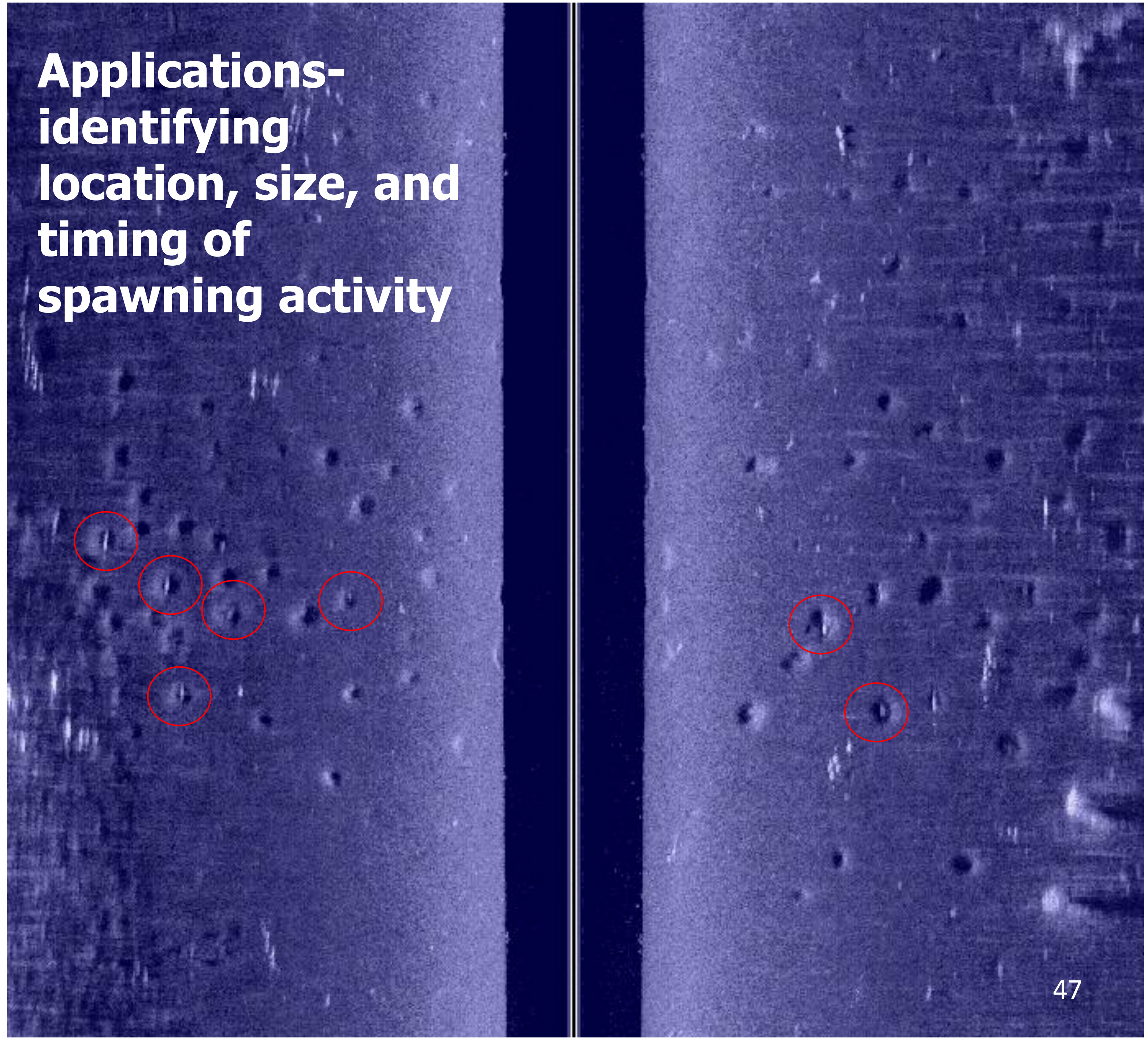


A cratered lakebed

Side scan sonar may not reveal everything that exists underwater, but there seems to be a endless number of potential features and applications that could be explored with this technology. The adjacent image provides a good example of a potential application for validation and development in lentic settings. The crater-like depressions on the bottom of this reservoir cove are centrarchid spawning beds. Not only do we see the beds in this example, but some have male fish guardians (identified with red circles)!

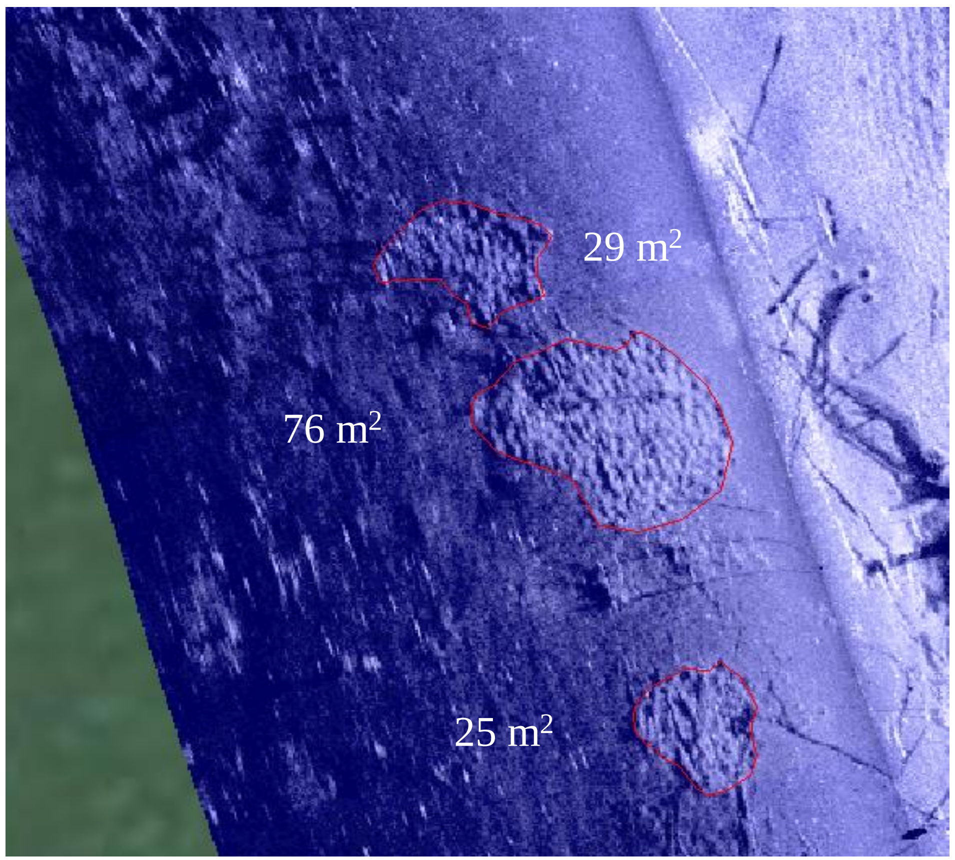
How might this information be used? We once began a pilot study to assess our ability to use side scan sonar to detect and quantify fish beds and monitor trends in the production of fish beds over time in several reservoir coves using time lapse sonar surveys. In a time lapse approach repeat sonar surveys of the same transects are conducted to examine changes in a parameter of interest. This work showed great promise but was never completed. So many potential applications remain for development; we hope to encourage our readers to join the effort!

Fish Beds

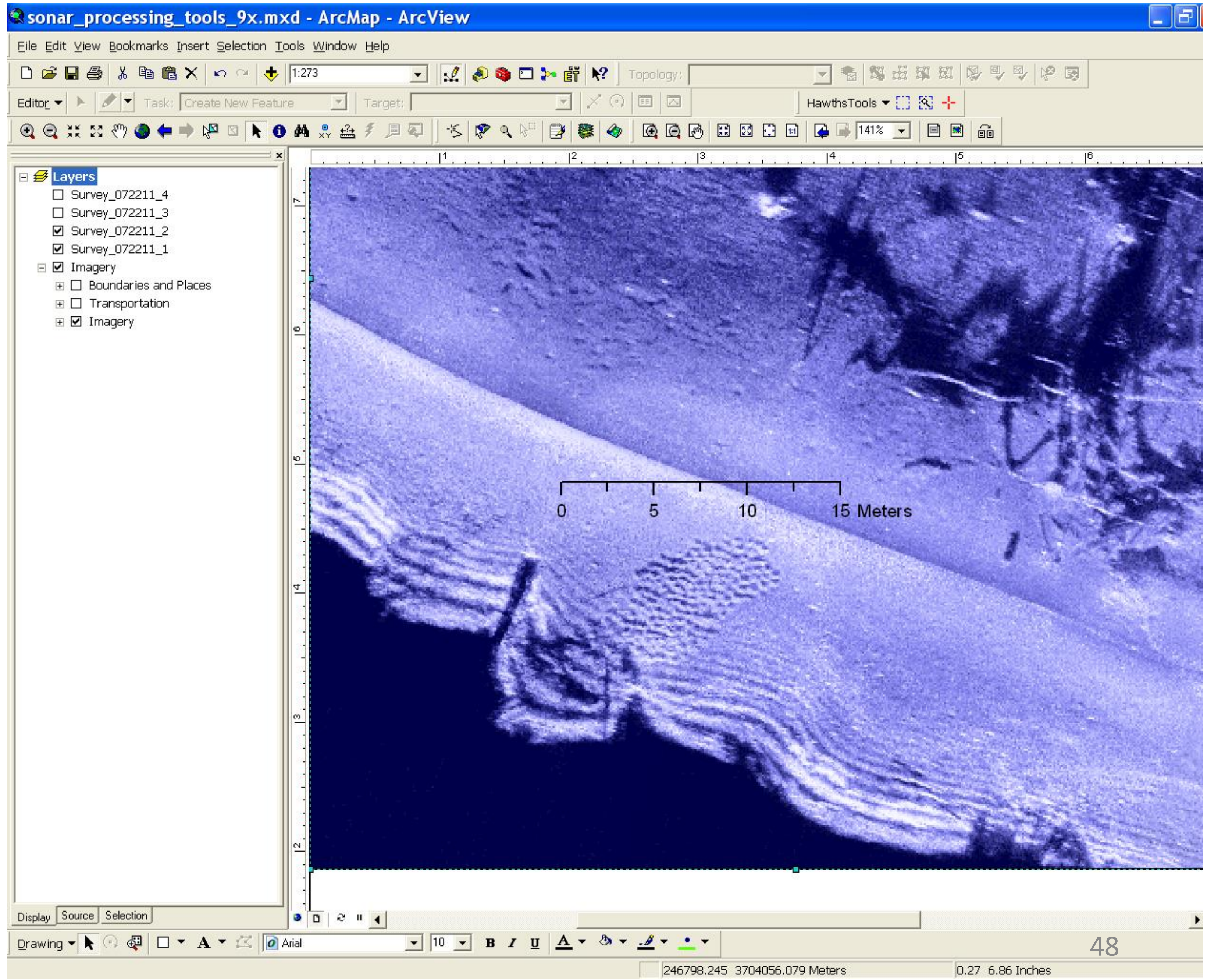


A cratered lakebed

Here are a few other images showing bed aggregations along reservoir shorelines. Unlike the scattered beds in the previous slide these are very tightly spaced, suggesting colonial spawning aggregations of bream.



Colonial bed formations

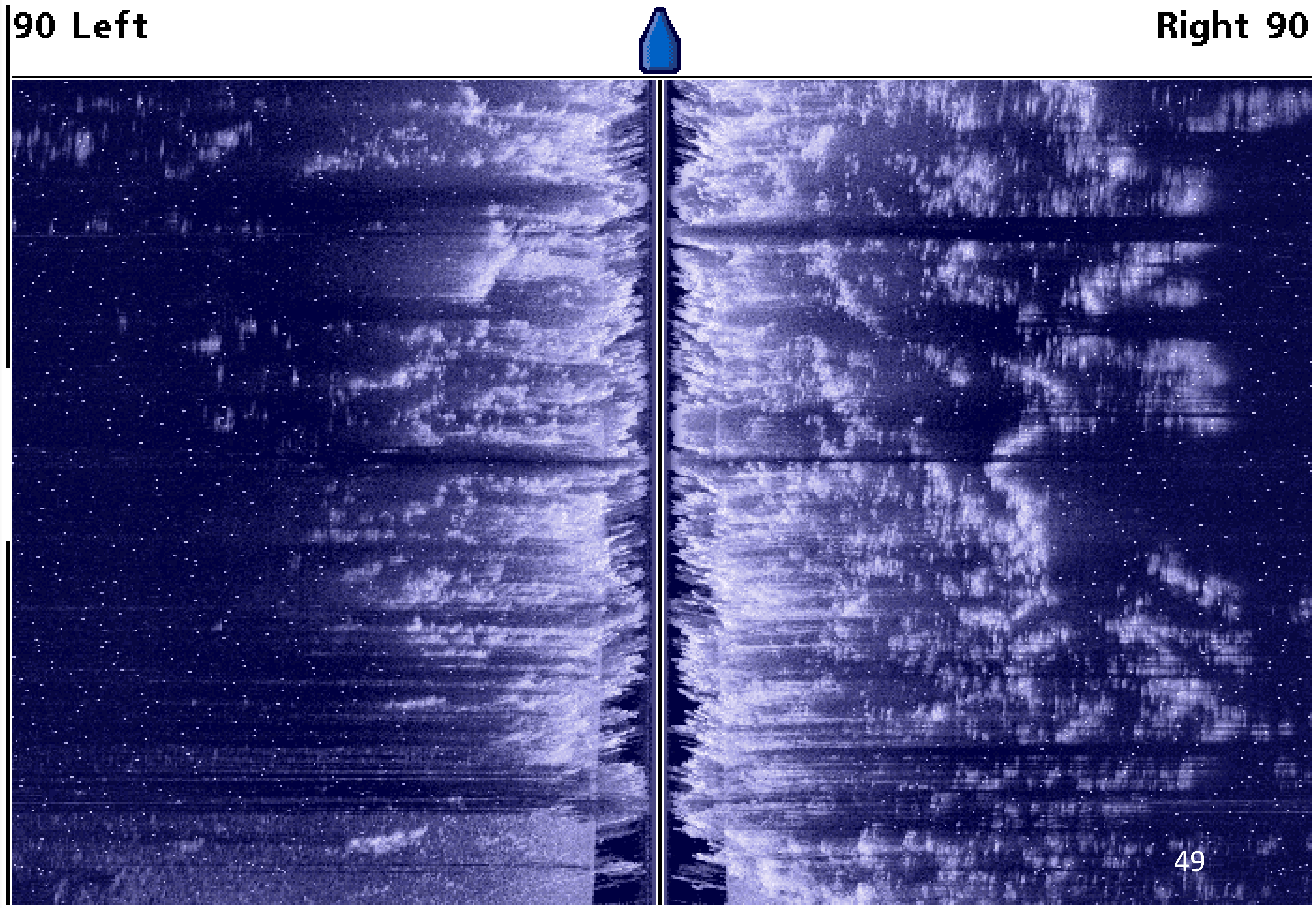


What about plants?

In every workshop we've ever hosted, someone has asked about aquatic vegetation. Does sonar reveal submerged aquatic vegetation and what applications exist for the study of SAV with side scan sonar? Our experience with SAV is limited, having worked primarily in streams where vegetation does not exist. However, when taking sonar into reservoirs and lakes we have captured images like this one. Here, we navigated our sonar boat over a vast bed of hydrilla, a troublesome invasive plant that forms thick colonies in shallow waters. The stems of this plant can grow to reach the water surface, and in doing so these plants block and reflect much of the sonar signal as shown here. This hydrilla bed appears to have a sonar signature unlike any of the "substrates" previously examined in this chapter. If other types of SAV also provide unique or distinguishable sonar signatures in imagery, then the idea of mapping and monitoring SAV with side scan sonar has great promise, and should be investigated.

Submerged Aquatic Vegetation

Plant growth through water column to surface will reflect (block) sound

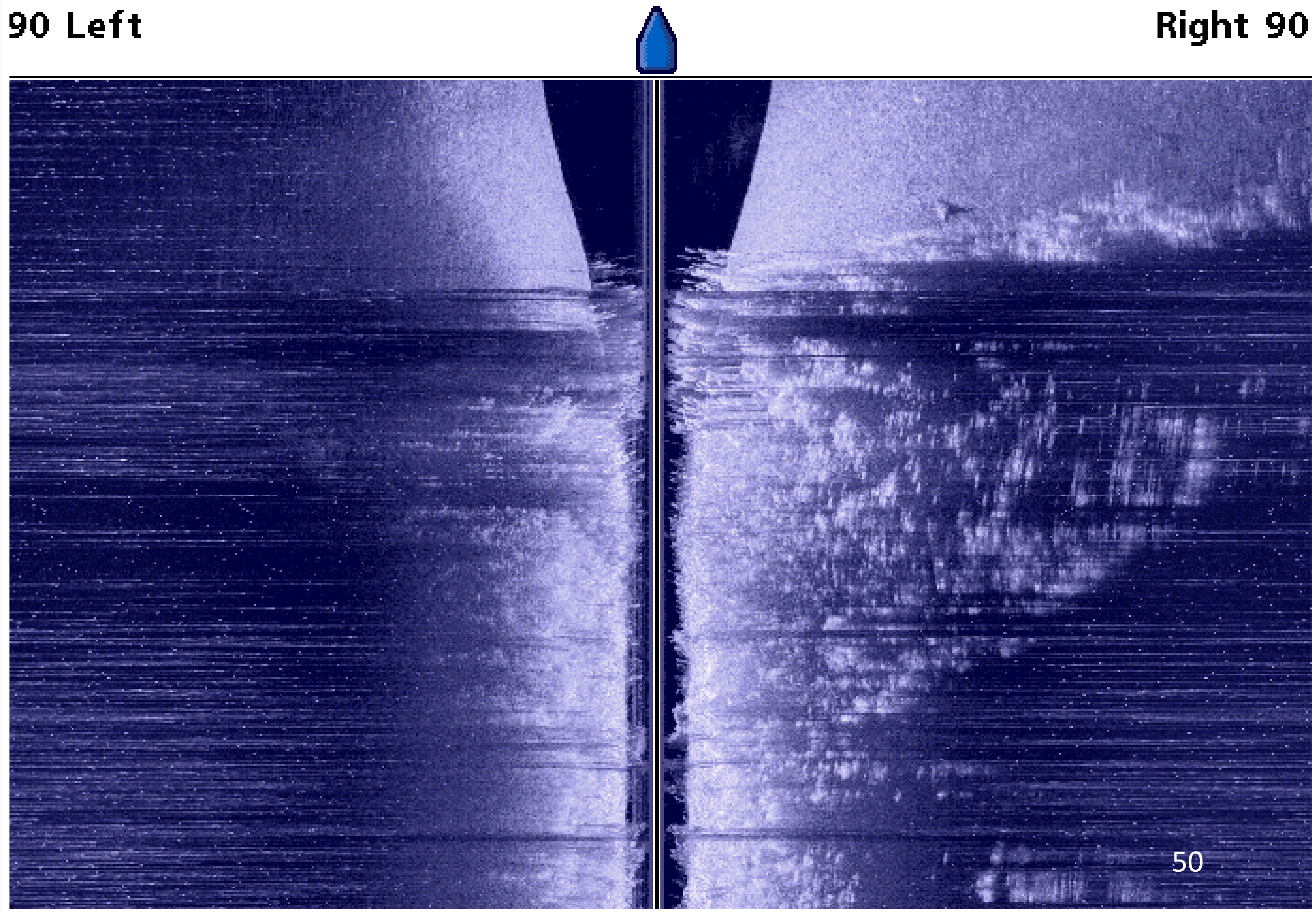


What about plants?

Clearly, one issue with imaging hydrilla or other surface level plants is that signal blocking can occur. Note that as the boat passed beyond the hydrilla bed in the adjacent image, the signal was no longer blocked and the open lake bottom was visible. We can easily delineate the boundary between hydrilla and the open lake bed in this image. Another interesting point about this transition is the change in depth (look at the width of the water column) at the point of transition between hydrilla and open lake bottom. The edge of this hydrilla bed appears to be tracking the bathymetric contour of the lake, where growth is limited beyond a certain depth threshold by light availability.

Submerged Aquatic Vegetation

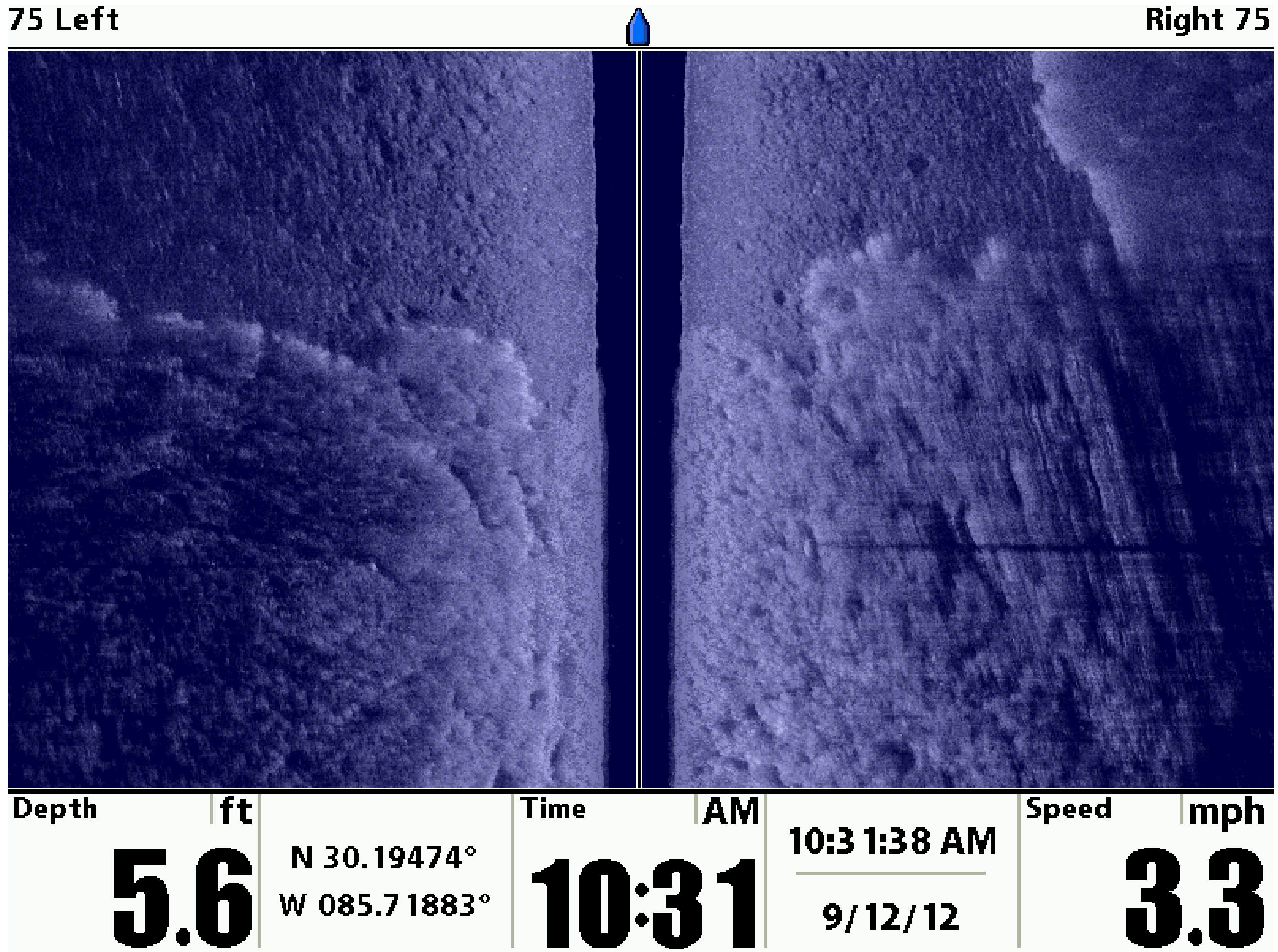
Plant growth through water column to surface will reflect (block) sound



Seagrass signatures

To provide a few other examples of submerged aquatic plants we did some pilot sonar survey work on St. Andrews Bay (Panama City, FL) to take a look at seagrass signatures. Although this bay is often crystal clear, the water this year was very tea stained from the heavy volume of summer rain, and visually locating seagrass beds was not possible. On the right is an image that shows a clear boundary between a seagrass bed known to exist in the survey area and the sand/mud bottom.

Seagrass Beds



Seagrass prop scarring

Unfortunately, this seagrass bed was located near a shallow, high traffic area of the bay. Note the transition from deeper, sand/mud bottom to the shallower flat inhabited by seagrasses. When the tide is low at this location, boaters apparently plow right through the seagrass bed as evidenced by the many crossing prop scars left behind.

This concludes Session I-Part B on sonar image interpretation. A groundtruthed image library can be an invaluable training and reference tool for a sonar mapping workgroup. We encourage you to consider developing a library specific to aquatic systems of your region.

Seagrass Scarring