19. There is no net horizontal force on the dog-boat system, so their center of mass does not move. Therefore by Eq. 9-16,

$$M\Delta x_{\rm com} = 0 = m_b\Delta x_b + m_d\Delta x_d$$

which implies

$$|\Delta x_b| = \frac{m_d}{m_b}\ |\Delta x_d|\ .$$

Now we express the geometrical condition that *relative to the boat* the dog has moved a distance $d = 2.4$ m:

$$|\Delta x_b| + |\Delta x_d| = d$$

which accounts for the fact that the dog moves one way and the boat moves the other. We substitute for $|\Delta x_b|$ from above:

$$\frac{m_d}{m_b}\,|\Delta x_d| + |\Delta x_d| = d$$

which leads to

$$|\Delta x_d| = \frac{d}{1+\frac{m_d}{m_b}} = \frac{2.4}{1+\frac{4.5}{18}} = 1.92\ \text{m}\ .$$

The dog is therefore 1.9 m closer to the shore than initially (where it was 6.1 m from it). Thus, it is now 4.2 m from the shore.