controlling and monitoring farming practices is much poorer in most developing countries, restricting the insight we have into both antibiotic use and disease outbreaks. Together, this creates a situation with a high uncertainty compared to industrialized countries, and the more complicated governmental structure also often prevents effective implementation of any mitigation strategies.

24.4.4 Aquaculture

Another food production sector where extensive amounts of antibiotics are used is in aquaculture (Cabello 2006). Infectious diseases cause losses of fish stock, and as aquaculture is globally increasing, so are the risks for diseases (Bostock et al. 2010; Cabello et al. 2016). Most antibiotic use in aquaculture is motivated by preventing stock losses, and in many parts of the world, the use of antimicrobials for these purposes is largely unregulated (FAO/OIE/WHO 2006). There are no reliable estimates of the total use of antibiotics in production of fish and other seafood, but it is likely to be counted in hundreds of thousands or even millions of tons annually (Done et al. 2015). Typically, the antibiotic is applied together with the feed, providing both a selection pressure for resistance and a more nutrient-rich environment at the same time. A wide array of antibiotics, many of which are used in human medicine, are used in aquaculture, including quinolones, sulfonamides, tetracyclines, and beta-lactams. This provides a selective environment for bacteria resistant to clinically relevant antibiotics, and there are indications of resistance being transferred between fish pathogens and human-associated bacteria (Cabello 2006; Ryu et al. 2012). Further complicating the problem is that integrated animal–fish–vegetable farming with antibiotic use is fairly common in Southeast Asia, causing direct antibiotic exposure and potentially selection for resistant bacteria (Suzuki and Hoa 2012).

Since fish farms are typically in contact with surrounding water bodies, both antibiotic residues and resistant bacteria can easily migrate out of the confined areas. In addition, the gut microbiome in the fishes will over time acquire higher degrees of resistance to the used antibiotics, as will the fish pathogens that the antibiotics are supposed to control. Many fish pathogens have relatively close phylogenetic relationships with human pathogens, making it fairly easy for them to transfer their resistance factors to human-associated bacteria. Indeed, a significant proportion of the clinically relevant mobile resistance genes circulating among pathogens today are likely to have originated from fish-associated bacteria (Rhodes et al. 2000; Lupo et al. 2012). At the same time, there seem to be relatively minor effects on the bacterial communities in sediments associated with intensive aquaculture with antibiotic use (Han et al. 2018).