Bacterial and Viral Fish Diseases in Turkey

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Abstract

This review summarizes the state of knowledge about the major bacterial and viral pathogens of fish found in Turkey. It also considers diseases prevention and treatment. In this study, peer reviewed scientific articles, theses and dissertations, symposium proceedings, government records as well as recent books, which published between 1976 and 2013 were used as a source to compile dispersed literature. Bacterial and viral disease problems were investigated during this period in Turkey. Total of 48 pathogen bacteria and 5 virus species have been reported in Turkey. It does mean that all the bacteria and virus present in fish have been covered since every year new disease agents have been isolated. The highest outbreaks occurred in larval and juvenile stages of the fish. This article focused on geographical distribution, host range, and occurrence year of pathogenic bacteria and virus species. Vibriosis, Furunculosis, Motile Aeromonas Septicemia, Yersiniosis, Photobacteriosis and Flavobacteriosis are among the most frequently reported fish diseases. Meanwhile, Vagococcus salmoninarum, Renibacterium salmoninarum, Piscirickettsia salmonis and Pseudomonas luteola are rarely encountered pathogens and might be emerging disease problems. Finally, the current status in fish diseases prevention and their treatment strategies are also addressed.

Keywords: Disease transfer, vaccines, disease treatment, disease prevention.

Introduction

Fish diseases are playing one of the roles as a limiting factor in fish production and causing heavy mortalities especially in hatcheries thus affecting profit negatively. Both researchers and farmers in Aquaculture area are looking for a ways to get maximum amount of yield from per unit volume of water to lower the coast in aquaculture operations. One simple way to get maximum amount of yield from per unit volume of water is basically overcrowding the fish and this condition causes stress in fish which are accustomed to live freely in nature and causes unexpected losses (Toksen, 1999). Therefore, it is essential that proper measurements are taken against stress causing agents such as bad water...
quality, bad feed nutrition, and heavy stocking rate etc. The best way to deal with diseases is to prevent both infectious and noninfectious outbreaks. Beyond that, correct diagnosis and economically acceptable treatment methods should be carried out.

Some of the bacterial species that inhabit the aquatic environment are essential to the balance of nature with no direct consequence in causing disease in fish. However, approximately 125 different bacterial species belonging to 34 different bacterial families have been associated with various fish diseases in the world. Furthermore, nearly 100 fish viruses belonging to 16 virus families have been isolated worldwide while only 5 fish viruses identified in Turkey. The list of viral and bacterial fish pathogens keeps extending. The water used in aquaculture operations provides a natural habitat for growth and proliferation of bacteria which can be influenced by nutrient availability, pH, temperature, and other factors that affect their growth pattern, virulence, and pathogenicity. In order to grow, bacteria need an organic substrate that provide nutrients; some survive as free living organisms or exist as fish pathogens, while others are fastidious and survive indefinitely only within a host (Plumb and Hanson, 2011). Most bacteria responsible for causing disease in fish are gram negative rods but some pathogens that are gram-positive rods or cocci and a few that are acid-fast rods also cause disease in aquatic animals.

Since rainbow trout (*Oncorhyncus mykiss*), Gilt-head sea bream (*Sparus aurata*), and Sea bass (*Dicentrarchus labrax*) are the most predominant fish species cultured in Turkey (TUİK, 2012), most of the diseases agents have been isolated from these tree species. Fish diseases identification or etiological agent isolation is mainly concentrated in certain location where Faculty members or Fisheries Institute employee work on fish diseases. Furthermore, most of the fish diseases agents isolated in Turkey after 2000s because of the increasing number of fish diseases professional.

Compared with bacterial and parasitic diseases of fish, studies about viral diseases of fish in Turkey is relatively new. First proven viral fish disease in Turkey was infectious pancreatic necrosis virus (IPNV). Although comparatively few fish viruses cause severe disease in aquaculture, results can be devastating when viral diseases outbreak. Most known fish viruses have been reported in freshwater cultured species, some occur in marine fish only, and others are found in both environments (Plumb and Hanson, 2011).

Main reason for spreading diseases from one location to another or from country to country is uncontrolled fish transfer. To avoid transferring pathogen from one location to another, specific pathogen free stocks should be developed and fish transfer should be controlled. Unfortunately, fish transferred between fish farms are not controlled in the Turkey. Although transportation of fish is regulated by the state, implementation of the regulations are mostly lacking. Based on regulations imposed, whenever a farmer wants to transport fish, an application must be filed to the provincial directorate of agriculture to appoint a veterinarian to check the fish health for virus, parasite, bacteria and fungus. However, whoever wants to transport fish pays a visit to a veterinarian who works for the provincial directorate of agriculture to obtain transport certificate. In this case veterinarian may give the certificate without seeing fish. Therefore, infectious diseases have been spreading region to region. Yersiniosis caused by *Yersinia ruckeri* and lactococcosis diseases caused by *Lactococcus garvieae* were first reported in Aegean region and they have been spread all over the Turkey where fish cultured. Newly arrived fish or eggs should be given a prophylactic treatment with appropriate drugs to remove any external pathogens. When possible, new fish should be segregated from the residential population until they are shown to be disease free. Certain fish production facilities should produce certified disease-free fish or eggs (Plumb and Hanson, 2011). Because of the production systems, lack of legal restraints to shipping and limited number of pathogens to target, no facilities currently market disease free eggs or fry in the Turkey. Another problem is the fish eggs or ornamental fish import. When live fish are imported from any country, there is no quarantine procedure taken at the port of entry. Therefore, exotic pathogens are directly being imported to country and spread all the regions. These problem have to be solved by responsible government authorities.

Since the most common causative agents of infectious diseases in aquaculture, are bacteria and viruses, in this review only both of them are covered. The other fish diseases caused by parasites and fungi are discarded. This review examines the major bacterial and viral pathogens of fish found in Turkey. It also considers diseases prevention and treatment. For this purpose peer reviewed scientific articles, theses and dissertations, symposium proceedings, government records as well as recent books, which published between 1976 and 2013 were used as a source to compile dispersed literature.

### Bacterial Diseases

#### Vibriosis

Vibriosis is a disease caused by bacteria belonging to the genus *Vibrio*. This disease possesses wide distribution and host range worldwide. Losses associated with it has been reported in many fish species, including sea bass, sea bream, salmonid spp., cod (*Gadus morhua*), European eel (*Anguilla anguilla*), turbot (*Psetta maxima*), and tilapia (*Oreochromis niloticus*) (Toranzo and Barja, 1990).
Although the causative agents of vibriosis are *Listonella anguillarum*, *V. ordalii*, *V. vulnificus*, *V. harveyi*, and *V. alginolyticus* (Austin and Austin, 2012; Toranzo et al., 2005), the main causative agent of the disease is *L. anguillarum*. Ten different serotypes of this pathogen described (O1-O10) so far. Serotype 1 and 2 are responsible for the most of the outbreaks. Among the *Vibrio* species *L. anguillarum* was first described in 1909 by Bergamn as the etiological agent of the ‘red pest of eels’ in the Baltic Sea (Woo and Bruno, 2011). According to published literature in Turkey, *L. anguillarum* was first isolated from diseased sea bream in Mugla (Candan, 1991a) and couple of years later the disease causing agent was also isolated from sea bass, red porgy (*Pagrus pagrus*) and rainbow trout (*Oncorhynchus mykiss*) in USA (Schiewe and Schiewe, 2000). The pathogen possesses wide distribution throughout Turkey (Table 1) because of uncontrolled fish transfer.

*Vibrio ordalii* is another important etiological agent of the vibriosis. It was initially described in coho salmon (*O. kisutch*) in USA (Schiewe and Crosa, 1981). First isolation of *V. ordalii* in Turkey was reported from sea bream in Mugla (Akayli, 2001). It was seven years after when same bacteria was also reported from sea bass in Aegean Sea (Korus and Timur, 2008).

Other identified pathogen species of *Vibrio* causing fish diseases also described in Turkey including *V. alginolyticus*, *V. vulnificus*, *V. harveyi* and *V. parahaemolyticus*. *V. alginolyticus* first reported from both sea bass and sea bream in Mugla (Cagirgan, 1993a). Other susceptible species are rainbow trout and cultured horse mackerel (*Trachurus mediterraneus*) (Savaş et al., 2006; Boran et al., 2013). *V. vulnificus* was first isolated from sea bream in Aegean Sea (Turk, 2002) while *V. harveyi* was first observed in sea bass in Antalya (Korus and Akayli, 2004a). The other *Vibrio* species is *V. parahaemolyticus*, first isolated from rainbow trout in Aydin (Aydin, 2000a).

Some of the vibrio species can be isolated in freshwater fish. It does not mean that *Vibrio* species can infect fish in fresh water or facultative vibrio species can live in fresh water. In Black Sea region, especially North East cost of the Turkey, rainbow trout have been cultured in freshwater raceways and when fish weight reached to 50 g or more especially fish farmers prefer 150 g or more and water temperature decrease to 18°C in October or November, they are transferred to sea cages. They are kept there until the water temperature reached to 20°C

### Table 1. Distribution and host range of *Vibrio* spp.

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<thead>
<tr>
<th>Common name of the disease</th>
<th>Etiological agents</th>
<th>Host</th>
<th>Geographical distribution</th>
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## References

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or until the harvest to sell. Sometimes, some farmer cannot sell their fish when water temperature increase in April or May; Therefore, they transfer their fish from sea cages to freshwater tank or raceways. Meanwhile, *Vibrio* species can also transferred from seawater to freshwater with the fish. Although *Vibrio* species cannot stay in freshwater for a long time, they can be isolated from fish since fish osmolality closed to 9‰ salinity. It does not mean that *vibrio* species can infect fresh water fish in fresh water.

**Furunculosis**

*Aeromonas salmonicida* subsp. *salmonicida* is known as an etiologic agent of furunculosis, one of the oldest known diseases and its origin is unclear and questionable. Etiological agent is also known as “typical *A. salmonicida*” and it should not be confused with “atypical *A. salmonicida***. The early isolation of the etiologic agent was made in 1930s (Mackie et al., 1930; Austin and Austin, 2012). Furunculosis is a prevalent disease of cultured salmonids, which causes serious economic crisis in the industry. Although salmonids seem to be most susceptible species, this particular disease has been reported more than 50 different fish species worldwide (McFadden, 1970; Bernoth, 1977; Barker and Kehoe, 1995; Kirkan et al., 2003).

The pathogen bacterium was first isolated from rainbow trout fry in Marmara Region, Turkey (Timur et al., 1999). Following reports have been documented from different parts of Turkey (Table 2) but so far, only it has been observed in rainbow trout. The outbreaks generally occurred in hatcheries and ended up with high mortalities (Timur et al., 1999; Kirkan et al., 2003).

**Goldfish Ulcer Disease**

The causative agent of the disease is *Aeromonas salmonicida* subsp. *achromogenes*, which is also known as atypical *A. salmonicida*. Ulcer disease was initially diagnosed in the early 1960s in trout in U.K. (Smith, 1963). Atypical *A. salmonicida* has become a major disease in cyprinids (Plumb and Hanson, 2011). The disease has been confirmed in many countries including European countries, USA and Australia (Plumb and Hanson, 2011).

Few outbreaks of atypical *A. salmonicida* occurred in Turkey (Table 2), Korun and Timur (2001) were first reported the pathogen from rainbow trout in Balikesir. Subsequently, it was reported from sea bass and turbot in Black Sea region (Karatas et al., 2005; Savas and Ture, 2008).

**Motile Aeromonas Septicemia (MAS)**

MAS is associated with infections caused by *Aeromonas hydrophila*, *A. sobria*, *A. veronii*, and *A. caviae*. *Aeromonas hydrophila* is the predominant causative agent of MAS. These pathogens exist worldwide in fresh and brackish waters and occasionally in salt waters and they have a diverse host range. Motile *Aeromonas* spp. are considered as opportunistic pathogens and could easily found in organically rich waters. Thus, stress and poor water quality play a key role in occurrence. *A. hydrophila* has been recognized as a pathogen of fish since early 1960s in Europe (Levis and Bender, 1960) and in USA (Snieszko and Bullock, 1965). *A. sobria* has been recognized as a fish pathogen since 1987. Toranzo et al. (1989) was first reported it from wild gizzard shad (*Dorosoma cepedianum*) in USA.

In Turkey, *A. hydrophila* was first isolated from rainbow trout in Eskisehir (Baran et al., 1980). The pathogen was subsequently isolated from other fish species such as sea bass, sea bream, eel, carp (*Cyprinus carpio*), sturgeon (*Acipenser gueldenstaedtii*), horse mackerel (*T. mediterraneus*) and from some ornamental fish species from different parts of Turkey (Table 3).

The other etiological agent of the disease, *A. sobria*, was reported from Atlantic salmon (*Salmo salar*) in Black Sea (Karatas, 1996). It also has a wide host range such as rainbow trout, sea bass and sea bream. Initially, *A. caviae* was isolated from different fish species in Keban Dam (Muz et al., 1995). Afterwards, etiological agent was also isolated from rainbow trout, Atlantic salmon and some ornamental fish species (Candan et al., 1995; Timur et al., 2003; Korun and Toprak, 2010).

The only incidence of mortality caused by *A.
The disease Yersiniosis is caused by Yersinia ruckeri, which was first isolated from rainbow trout in 1950s (Ross et al., 1966). Other Yersiniosis strains have been isolated from salmonids in different geographical regions (Fleminger et al., 1995; Korun and Toprak, 2007b). The disease was first seen in the Mediterranean Region of Turkey (Korun and Toprak, 2007b) and has been reported from many other countries (Korun and Toprak, 2010). The disease is known to cause pseudotuberculosis in salmonids and is one of the most important diseases in freshwater and marine salmonid aquaculture (Austin et al., 1975; Toranzo, 2004). The disease has a worldwide distribution, with outbreaks reported from Europe, North America, and Asia (Baran et al., 1980; Öztürk and Altınoğlu, 2011). The disease is caused by Yersinia ruckeri, which is an aerobic, non-motile, Gram-negative bacterium. It is highly pathogenic to salmonids and can cause significant economic losses (Austin et al., 2008). The disease is transmitted by water, feed, and direct contact with infected fish (Baran et al., 1980; Öztürk and Altınoğlu, 2011). The disease can be treated with antibiotics, but prophylactic measures are recommended to prevent the disease (Baran et al., 1980; Öztürk and Altınoğlu, 2011). The disease is a significant challenge for the salmonid aquaculture industry, and ongoing research is needed to develop effective management strategies.
Bullock, 1965). Until now, the bacteria has been isolated from diseased fish in England (Ajmal and Hobbs, 1967), Norway (Hastein and Bullock, 1976), Taiwan (Toranzo et al., 1989), Spain (Torozono et al., 1991), Greece (Baudin et al., 1991) and Italy (Ceschia et al., 1991).

Photobacterium damsela subsp. piscicida has been observed in numerous fish species in Turkey (Table 5). It was first isolated from diseased sea bream in Aegean Sea (Cagirgan, 1993a). Subsequent isolations were reported from sea bass (Candan, 1996), Mugil sp. (Tanrikul and Cagirgan, 2001) and rainbow trout (Savas and Ture, 2008).

Flavobacteriosis

There are three main Flavobacterium spp. that are primary pathogen of freshwater fish within the genus. These are, F. psychrophilum, the causative agent of cold-water disease, F. columnare, the causative agent of columnaris disease and F. branchiophilum, the causative agent of bacterial gill disease (BGD). Other Flavobacterium species including F. scophtalmum, F. balustinum, F. hydatis, F. johnsoniae and F. oncorhynchi were also recognized as a fish pathogens (Austin and Austin, 2012). Among them, F. psychrophilum, F. columnare, F. branchiophilum, F. johnsoniae and F. hydatis were identified in Turkey (Table 6).

Bacterial Cold-water Disease (BCD)

Flavobacterium psychrophilum (Cytophaga psychrophilum or Flexibacter psychrophilum) is the etiological agent of the rainbow trout fry syndrome (RTFS) and also known as the causative agent of bacterial cold-water disease in larger cultured fish. The disease had this name because it particularly occurs in low temperatures when water temperature decrease to below 12°C. The first outbreak occurred in coho salmons and isolated from diseased fish in USA in 1948 (Lehmann et al., 1991). RTFS has been confirmed in many countries. During last twenty years, it had economically devastating impact on

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Table 4. Distribution and host range of Yersinia ruckeri

Table 5. Distribution and host range of Ph. damsella subsp. P. piscicida
cultivated fish, especially on rainbow trout in Europe and considered as a serious disease in farmed rainbow trout fry and fingerlings (Austin and Stobie, 1992; Bernardet et al., 1988; Santos et al., 1992; Toranzo and Barja, 1993).

The pathogen was confirmed in most of the rainbow trout hatcheries in Turkey and caused heavy mortalities. First isolation of F. psychrophilum was from rainbow trout which sampled from different farms in 1990 (Balta and Cagirgan, 1998) (Table 6). Especially, when fish are small (0.1-4 g) and water temperature decrease to below 10°C, BCD or RTFS causes high mortality.

### Columnaris Disease

Causative agent of the columnaris disease was described as Flavobacterium columnare (formerly Flexibacter columnaris, Cytophaga columnaris, Chondrococcus columnaris). It also referred to as cotton wool disease, saddleback disease, or mouth fungus. The disease was first reported from different fish species in Mississippi River and named Bacillus columnaris (Davis, 1922). After two decades, Ordal and Rucker (1944) isolated and described the causative agent. Unlike cold-water disease, columnaris disease generally occurs when the water temperature gets above 15°C.

Although F. columnare was isolated in Aegean, Mediterranean and Black Sea regions of Turkey, initial isolation of columnaris disease was from farmed rainbow trout in Mugla (Balta and Cagirgan, 1998) (Table 6).

### Bacterial Gill Disease

*Flavobacterium branchiophilum* is the causative agent of the Bacterial Gill Disease (BGD). It was first described in 1926 (Davis, 1926). Afterwards, it was isolated from salmonids in USA (Kimura et al., 1978). Subsequently it was also isolated in Korea (Ko and Heo, 1997), Canada (Ostland et al., 1994) and

<table>
<thead>
<tr>
<th>Common names of the disease</th>
<th>Etiological agents</th>
<th>Host</th>
<th>Geographical distribution</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-water disease</td>
<td><em>Flavobacterium</em> psychrophilum</td>
<td>Oncorhynchus mykiss</td>
<td>Aydin, Canakkale, Bilecik, Manisa, Samsun, Ordu, Kayseri, Sakarya</td>
<td>Balta and Cagirgan (1998)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Mediterranean Region</td>
<td>Diler et al. (2003)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Marmara Region</td>
<td>Timur et al. (2004)</td>
</tr>
<tr>
<td>Rainbow trout fry syndrome (RTFS)</td>
<td><em>Flavobacterium</em> columnare</td>
<td>Oncorhynchus mykiss</td>
<td>Elazig, Malatya, Erzincan</td>
<td>Ispir et al. (2004)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dicentrarchus labrax</td>
<td>Mugla</td>
<td>Ayaz (2006)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Aegean Sea</td>
<td>Kum et al. (2008)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Trabzon, Rize</td>
<td>Kayis et al. (2009)</td>
</tr>
<tr>
<td>Columnaris disease</td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Rize, Trabzon, Aydin, Kayseri, Ordu, Manisa, Denizli</td>
<td>Balta and Cagirgan (1998)</td>
</tr>
<tr>
<td>Saddleback disease</td>
<td><em>Flavobacterium columnare</em> (Flexibacter columnaris, Cytophaga columnaris)</td>
<td>Oncorhynchus mykiss</td>
<td>Isparta</td>
<td>Kubilay et al. (2008)</td>
</tr>
<tr>
<td>Cotton wool disease</td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Mugla</td>
<td>Kubilay et al. (2009)</td>
</tr>
<tr>
<td>Mouth fungus</td>
<td></td>
<td>Oncorhynchus mykiss</td>
<td>Mersin</td>
<td>Yildirim and Ozer (2010)</td>
</tr>
<tr>
<td>Gill and skin disease</td>
<td><em>Flavobacterium johnsoniae</em></td>
<td>Oncorhynchus mykiss</td>
<td>Mersin</td>
<td>Yildirim and Ozer (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acipenser gueldenstaedtii</td>
<td>Sakarya</td>
<td>Karatas et al. (2010)</td>
</tr>
<tr>
<td>Bacterial gill disease (BGD)</td>
<td><em>Flavobacterium branchiophilum</em></td>
<td>Oncorhynchus mykiss</td>
<td>Mersin</td>
<td>Yildirim ve Ozer (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acipenser gueldenstaedtii</td>
<td>Sakarya</td>
<td>Timur et al. (2010)</td>
</tr>
</tbody>
</table>
In Turkey, it was claimed that the pathogen was isolated from rainbow trout hatcheries and caused mortalities up to 65% with other Flavobacterium spp. (Yildirim and Ozer, 2010) (Table 6). However, some of the biochemical test results reported in this particular study do not match with F. branchiophilum (Austin and Austin, 2012; Plumb and Hanson, 2011; Woo and Bruno, 2011). Therefore, there might be a misidentification of F. branchiophilum.

Other Flavobacterium spp.

Two other Flavobacterium species were also isolated from diseased fish in Turkey. One of them is F. johnsoniae which causes disease in gills and skin. The etiological agent was first isolated from Russian sturgeon (Acipenser gueldenstaedtii) in Sakarya (Karatas et al., 2010). Diseased sturgeons were characterized by hemorrhages and erosions in the ventral part of the body. At the same year, pathogen was also reported from rainbow trout cultured in fish farm, located in Mersin (Yildirim and Ozer, 2010). The other Flavobacterium species is F. hydatis. It was also first isolated from Russian sturgeon in Sakarya (Table 6). Mixed infection with F. hydatis and A. hydrophila caused low mortalities in sturgeon (Timur et al., 2010). Findings suggest that F. hydatis might be playing a role as secondary pathogen.

Flexibacteriosis

Flexibacteriosis is a severe disease caused by Tenacibaculum maritimum (formerly Flexibacter maritimus). Several other names, such as tenacibaculosis, marine columnaris, eroded mouth syndrome, black patch necrosis, and gliding bacterial disease were used to designate the disease caused by this bacterium. It has been recognized as a pathogen of fish since 1979 (Hikida et al., 1979). The pathogen has been isolated in Australia (Handlinger et al., 1997), USA (Chen et al., 1985), Canada (Ostland et al., 1999) and Europe (Pazos et al., 1996). Many fish species would appear to be susceptible to infections by T. maritimum. To date, it has been isolated from sea bass, Dover sole (Solea solea), turbot (Scophthalmus maximus), salmonids, striped trumpeter (Latris lineata), greenback flounder (Rhombosolea tapirini), sardine (Sardinops sagax), anchovy (Engraulis mordax) (Santos et al., 1999).

The first report of T. maritimum infection in Turkey was in sea bass and sea bream from Aegean Region (Turk, 2002). Timur et al. (2011) isolated the pathogen from Black Sea Region from rainbow trout.

Coccal Infections

Streptococciosis stands for a common name of a disease caused by different genera and species. The disease which is known as “warm water” streptococciosis (causes morbidity and mortality above 15°C) is caused by Lactococcus garvieae, Streptococcus iniae, Streptococcus parauberis and Streptococcusagalactiae. The other one, vagococciosis, (causes morbidity and mortality below 15°C) is caused by Vagococcus salmoninarum. Hoshina et al. (1958) was reported Streptococcus spp. as a fish pathogen in 1950s in Japan.

Lactococcus garvieae (formerly Enterococcus seriolicida) was initially isolated from a trout farm in 1988 in Spain (Palacios et al., 1993). Subsequently, it was reported from many other countries such as, South Africa (Carrson et al., 1993), Italy (Ghiotto and Prearo, 1992), Iran (Soltani et al., 2008) and USA (Evas et al., 2009). L. garvieae was first isolated from rainbow trout in Aegean region of Turkey (Diler et al., 2002). Subsequently, the outbreaks have been reported from rainbow trout, turbot and sea bass (Table 7) in different parts of the country.

Vagococcus salmoninarum was first isolated from diseased rainbow trout in USA in 1968 and named as lactobacillus (Austin and Austin, 2012). In Turkey, Didinen et al. (2011) was performed the first isolation from rainbow trout farmed in Mediterranean region. No following outbreak or isolation was reported since.

Staphylococcus epidermidis was first reported from farmed yellowtail and red sea bream in Japan (Kusuda and Sugiyama, 1981). In Turkey, initial isolation was performed by Turk (2002) from sea bass cultured in cage, located at the coastal region of the Aegean Sea. Subsequently, Timur et al. (2008) proved the existence of the pathogen in Turkey by isolating it from sea bass in cage farm, located in the coastal region of the Black Sea. Staphylococcus cohnii subsp. cohnii was first isolated from farmed rainbow trout and common dentex (Dentex dentex) in Aegean region of Turkey (Akyali et al., 2011).

Pseudomoniasis

Pseudomonas infections or Pseudomoniasis refer to a disease caused by Pseudomonas species. Pseudomonas spp. are found in normal microbial flora of both freshwater and saltwater fish. It was believed that these bacteria could be opportunistic pathogens. Most of the time, Pseudomonas spp. isolated with other bacteria. For instance, when rainbow trout is infected with Y. ruckeri, both Ps. pseudoalcaligenes and Y. ruckeri were isolated from the fish (Austin and Stobie, 1992). Findings suggest that Pseudomonas spp. can be secondary infections. Confirmed pathogenic species of this genus are Ps. chlororaphis, Ps. anguilliseptica, Ps. fluorescens, Ps. putida, Ps. plecoglossicida, Ps. aeruginosa and Ps. luteola (Muroga and Nakajima, 1981; Prosyaya, 1981; Toranzo and Barja, 1993; Altinok et al., 2006; Kayis et al., 2009). Among these pathogens, Ps. anguilliseptica is considered the most significant
Table 7. Distribution and host of some gram positive pathogens

<table>
<thead>
<tr>
<th>Common names of the disease</th>
<th>Etiological agent</th>
<th>Host</th>
<th>Geographical distribution</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactococcosis</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Aegean Region</td>
<td>-</td>
<td>Cagirgan and Tanrikul (1995)</td>
</tr>
<tr>
<td></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Mugla, Denizli, Antalya, Konya</td>
<td>-</td>
<td>Diler et al. (2002)</td>
</tr>
<tr>
<td></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Konya, Antalya, Isparta</td>
<td>-</td>
<td>Altun et al. (2005)</td>
</tr>
<tr>
<td></td>
<td><em>Ps. maxima</em></td>
<td>Eastern Black Sea</td>
<td>-</td>
<td>Kubilay et al. (2005)</td>
</tr>
<tr>
<td></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Eastern Black Sea</td>
<td>-</td>
<td>Savas and Ture (2008)</td>
</tr>
<tr>
<td>&quot;Warm-water&quot; Streptococcosis</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Aydin, Mugla, Denizli</td>
<td>-</td>
<td>Aksit and Kurn (2008)</td>
</tr>
<tr>
<td></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Marmara Region</td>
<td>-</td>
<td>Ozer et al. (2008b)</td>
</tr>
<tr>
<td></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Kutahya, Bilecik, Isparta</td>
<td>-</td>
<td>Timur et al. (2011)</td>
</tr>
<tr>
<td></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Bursa, Samsun, Mugla, Antalya</td>
<td>-</td>
<td>Altun et al. (2013b)</td>
</tr>
<tr>
<td>Vagococcosis, &quot;Cold-water&quot; Streptococcosis</td>
<td><em>Vagococcus salmoninarum</em></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Mediterranean Region</td>
<td>Didinen et al. (2011)</td>
</tr>
<tr>
<td></td>
<td><em>Dicentrarchus labrax</em></td>
<td>Aegean Region</td>
<td>-</td>
<td>Turk (2002)</td>
</tr>
<tr>
<td></td>
<td><em>Sparus aurata</em></td>
<td>Aegean Region</td>
<td>-</td>
<td>Kubilay and Ulukoy (2004)</td>
</tr>
<tr>
<td></td>
<td><em>Dicentrarchus labrax</em></td>
<td>Black Sea</td>
<td>-</td>
<td>Timur et al. (2008)</td>
</tr>
<tr>
<td>Staphylococcosis</td>
<td><em>Staphylococcus epidermidis</em></td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Aegean Region</td>
<td>Akayli et al. (2011)</td>
</tr>
<tr>
<td></td>
<td><em>Dentex dentex</em></td>
<td>Aegean Region</td>
<td>-</td>
<td>Akayli et al. (2011)</td>
</tr>
</tbody>
</table>

Pathogen for fish and causes winter disease when the water temperature gets below 15°C. *Ps. anguilliseptica* was first reported from Japanese eel in Japan in 1972 (Wakabayashi and Egusa, 1972). It mainly affects Japan and European eels, causes red spot disease (also known as sekiten-hyo) (Plumb and Hanson, 2011). In Turkey, initial isolation of this pathogen was performed by Turk (2002) from sea bass from Aegean Sea. Recognized hosts of the disease are sea bass and sea bream.

*Ps. fluorescens* is the causative agent of the pseudomonas septicemia. As it was mentioned earlier, it is an opportunistic pathogen. It shows similar clinical signs of *Aeromonas* septicemia. In Turkey, the pathogen was first reported from sea bream in Aegean Sea (Turk, 2002). Afterwards, it was also isolated from sea bass, rainbow trout and from some ornamental fish species (Table 8).

The first outbreak of a disease caused by *Ps. luteola* was recorded by Altinkok et al. (2007) in cultured rainbow trout. To date, it is the only report implicating *Ps. luteola* as a fish pathogen in the world. Diseased fish were externally characterized by exophthalmia, dark pigmentation, and ulcerative lesions near dorsal fin.

*Ps. aeroginasa* is known as a causative agent of gill disease. It was reported from sea bass in Aegean Sea and rainbow trout in Mersin, Trabzon and Rize (Ayaz, 2006; Kayis et al., 2009). *Ps. chlororaphis* was first reported from sea bream in Aegean Sea but biochemical properties of the isolate was not mentioned (Turk, 2002). *P. plecoglossicida* was first reported from rainbow trout fries in Turkey (Akayli et al., 2010). *P. putida* causes ulcerative infection in fish. It was first isolated from common carp in Turkey (Aydin et al., 1998). It was also isolated from rainbow trout and sea bass (Table 8).

**Mycobacteriosis**

Mycobacteriosis (Fish Tuberculosis) is severe disease known to affect wide range of freshwater and saltwater fish. Primary etiological agent of the disease is *Mycobacterium marinum* but other *Mycobacterium* spp. were also described as a fish pathogen (Bragg et al., 1990; Chinabut, 1999; Talaat et al., 1999). It was reported initially by Aronson (1926) from tropical aquarium fish in USA.

*Mycobacterium* can be found in the water and sediment and it has worldwide distribution. Until now, two outbreaks of the mycobacteriosis from different hosts were reported in Turkey. Candan (1991a) was first who mentioned existence of *Mycobacterium* sp. in sea bream in Mugla. Pathogen was diagnosed as a *Mycobacterium* sp. based on clinical signs of the disease and no biochemical or other tests were carried out to identify bacteria.

Korun et al. (2005) was claimed the first isolation of mycobacteriosis. The outbreak of the disease was occurred in sea bass farm located in Aegean coast of Canakkale. The etiological agent of the disease was reported as a *Mycobacterium* sp. Acid-fast rods in granulomas were seen in histological section but authors failed to isolate the pathogen.

**Piscirickettsiosis**
Piscirickettsiosis is a bacterial infection that caused by *Piscirickettsia salmonis*. The disease was also known as salmonid rickettsial septicemia. It primarily affects salmonids reared in sea cages. The disease has been known since 1939 (Plumb and Hanson, 2011). After half decade of piscirickettsiosis outbreaks, it has been observed in cultured coho salmon in Chile and caused heavy mortalities (Bravo and Campos, 1989). Subsequently, the bacterium was isolated from Atlantic salmon in Norway, Canada and Ireland (OIE, 2013; Olsen et al., 1997; Rodger and Drinan, 1993) and tilapia in Taiwan (Chern and Cao, 1994).

During 2003, first outbreak of the disease occurred in sea bass farm on the coast of the Black Sea in Turkey. Isolated bacterium was described as rickettsia-like organism (RLO) (Timur et al., 2005). Different pathogen species, *L. anguillarum* and *P. damselae* subsp. *piscicida* were also isolated from examined fish. To date, it is the only confirmed report of the pathogen in Turkey.

### Bacterial Kidney Disease (BKD)

Bacterial kidney disease is a chronic disease that causes high mortalities particularly in salmonids. Etiological agent of the disease is *Renibacterium salmoninarum* (syn. *Corynebacterium salmonis*) which targets the fish kidney and causes white spots. Thus, it was named as kidney disease. The disease is generally observed in salmonids and first reported in Atlantic salmon in 1990 in Scotland (Austin and Austin, 2012), but etiological agent was first isolated in 1956 (Ordal and Earp, 1956). Subsequently, BKD occurred in Finland (Rimala, 2002), Japan (Kimura and Awakura, 1977) and Canada (Evelyn et al., 1973).

In Turkey, first attempt was made to isolate *R. salmoninarum* from diseased rainbow trout in Bayindir Dam, Ankara (Halici et al., 1977) but biochemical tests used to isolate the bacterium did not match with *R. salmoninarum*. Therefore, it should be misidentification of *R. salmoninarum*. Later, mixed colonies of *Y. ruckeri* and *R. salmoninarum* were isolated from cultured Black Sea salmon (*Salmo trutta lacbras*) in the Eastern Black Sea Region and results were confirmed by sequencing 501 base pairs of DNA fragment from 16s rDNA gene of the *R. salmoninarum* (Savas et al., 2006).

### Other Bacterial Fish Pathogens

Some bacteria are well-studied by scientists and known as fish pathogens. Most of the bacteria classified as well-recognized pathogens are economically important and causes heavy mortalities or has a wide host range and distribution. For other bacterial fish pathogens there are limited information available. Whenever there is limited information...
available, it could be possible that either the disease is new emerging disease or it is rarely encountered. It is also possible that some of them are recognized as secondary or opportunistic pathogens and unusual stress factors may play a key role in their occurrence. Bacteria, which were reported as a fish pathogens in Turkey without adequate information were also discussed (Table 9).

**Edwardsiella Infections (Enteric Septicemia)**

Two species of genus Edwardsiella are recognized as fish pathogens. These are *E. ictaluri* and *E. tarda*. *E. tarda* is not only a fish pathogen but also human pathogen. *E. tarda* causes red disease of eels and fish gangrene of catfish. The disease was first isolated from cultured eel in Asia (Hoshina, 1962). Edwardsielliosis caused by *E. tarda* which causes serious mortality in marine and freshwater fish, including catfish, carp, eel, flounder, seabream tilapia, and yellowtail (Plumb and Hanson, 2011). It has not been isolated from any fish species in the Turkey.

On the other hand, *E. ictaluri* is the causative agent of enteric septicemia of catfish or hole in the head disease was first reported in catfish in USA (Hawke et al., 1981). Subsequently, the disease, was observed in Australia (How et al., 1983) and Taiwan (Chung and Kou, 1983).

*E. ictaluri* was first isolated from rainbow trout in Ankara in Turkey (Keskin et al., 2004), however, infected fish didn’t show any clinical sign. To date, it remains as the only *E. ictaluri* isolation in Turkey (Table 9).

**Ph. damsela subsp. damsela Infection**

The disease caused by *Photobacterium damsela subsp. damsela* (Formerly known as *Vibrio damsela*) is skin ulcer. It was initially isolated from blacksmith (*Chromis punctipinnis*) (Love et al., 1981). The

### Table 9. Distribution and host range of other bacterial pathogens

<table>
<thead>
<tr>
<th>Common name of the disease</th>
<th>Etiological agent</th>
<th>Host</th>
<th>Geographical distribution</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>-</strong></td>
<td><em>Arcobacter cryaerophilus</em> (Campylobacter cryaerophilica)</td>
<td>Oncorhynchus mykiss</td>
<td>Marmara Region</td>
<td>Bulut and Aydin (2004)</td>
</tr>
<tr>
<td><strong>-</strong></td>
<td><em>Aerococcus viridans</em></td>
<td>Oncorhynchus mykiss</td>
<td>Mersin</td>
<td>Ozet el al. (2008)</td>
</tr>
<tr>
<td><strong>-</strong></td>
<td><em>Burkholderia cepacia</em></td>
<td>Oncorhynchus mykiss</td>
<td>Trabzon, Rize</td>
<td>Kayis et al. (2009)</td>
</tr>
<tr>
<td><strong>Necrotic kidney, Hyperemia of the mouth</strong></td>
<td><em>Citrobacter braakii</em></td>
<td>Oncorhynchus mykiss</td>
<td>Bursa</td>
<td>Altun et al. (2013c)</td>
</tr>
<tr>
<td><strong>-</strong></td>
<td><em>Citrobacter freundii</em></td>
<td>Oncorhynchus mykiss</td>
<td>Erzurum</td>
<td>Saglam et al. (2006)</td>
</tr>
<tr>
<td><strong>-</strong></td>
<td><em>Enterobacter cloacae</em></td>
<td>Oncorhynchus mykiss</td>
<td>Trabzon, Rize</td>
<td>Kayis et al. (2009)</td>
</tr>
<tr>
<td><strong>Septicemia</strong></td>
<td><em>Escherichia vulneris</em></td>
<td>Oncorhynchus mykiss, Carassius Carassius, Poecilia sp.</td>
<td>Erzurum</td>
<td>Aydin et al. (1997)</td>
</tr>
<tr>
<td><strong>Hemorrhagic septicemia</strong></td>
<td><em>Hafnia alvei</em></td>
<td>Oncorhynchus mykiss</td>
<td>Ankara</td>
<td>Ozkok (2005)</td>
</tr>
<tr>
<td><strong>Vibriosis</strong></td>
<td><em>Photobacterium damsela subsp. damsela</em> (Vibrio damsela)</td>
<td>Oncorhynchus mykiss</td>
<td>Trabzon, Rize</td>
<td>Akayli (2001)</td>
</tr>
<tr>
<td><strong>-</strong></td>
<td><em>Plesiomonas shigelloides</em></td>
<td>Poecilia reticulata</td>
<td>Istanbul (Aquarium)</td>
<td>Akayli and Zeybek (2005)</td>
</tr>
<tr>
<td><strong>Septicemia</strong></td>
<td><em>Serratia liquefeciens</em></td>
<td>Oncorhynchus mykiss</td>
<td>Erzurum</td>
<td>Aydin et al. (2001)</td>
</tr>
<tr>
<td><strong>Ulcer, Hemorrhage</strong></td>
<td><em>Shewanella putrefaciens</em> grp</td>
<td>Oncorhynchus mykiss, Carassius auratus, auratus</td>
<td>Trabzon, Rize</td>
<td>Korun et al. (2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Kayis et al. (2009)</td>
</tr>
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<td></td>
<td></td>
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<td></td>
<td>Altun et al. (2013a)</td>
</tr>
</tbody>
</table>
bacterium is not only a fish pathogen but also human pathogen. It effects variety of marine fish spp. Damselfish seems to be most susceptible to this pathogen.

It is one of the most important diseases in cultured European sea bass (Koron, 2004b). Initial isolation was fulfilled from sea bream in Mugla, Turkey (Akayli, 2001). In same region, it was also isolated from sea bass (Turk, 2002). Subsequently, the pathogen was reported from rainbow trout and horse mackerel in Black Sea (Timur et al., 2008; Kayis et al., 2009; Boran et al., 2013) (Table 9). It should be noted that only mixed bacteria colonies were isolated in all of these disease cases. Thus, pathogenicity of the bacterium is unclear in Turkey and the causative agent probably plays secondary pathogen role in most of the cases.

**Plesiomonas shigelloides Infection**

*Plesiomonas shigelloides* was first isolated from rainbow trout in Portugal in 1984 (Cruz et al., 1986). Subsequently, pathogen also isolated from catfish, sturgeon, rainbow trout, eel and gourami in Germany (Klein et al., 1993). Hemorrhages around the vent and protruded anus generally occur after infection (Austin and Austin, 2012). The pathogen is also the etiological agent of diarrhea in humans (Klein et al., 1993).

Akayli and Zeybek (2005) was first reported the isolation of *P. shigelloides* from guppies (*Poecilia reticulata*) which were collected from different aquarium stores. After four years, the pathogen was reported from rainbow trout in Trabzon (Kayis et al., 2009) (Table 9).

**Serratia liquefaciens Infection**

*Serratia liquefaciens* is recognized as a potential fish pathogen belonging to *Enterobacteriaceae* family and it is the causative agent of bacterial septicemia (Woo and Bruno, 2011). The bacterium was isolated in different countries, for instance, from turbot in France (Vigneulle and Baudin, 1995), arctic char (*Salvelinus alpinus*) in U.S.A (Starilper, 2001) and from Atlantic salmon in Scotland (McIntosh and Austin, 1990).

It was first isolated from rainbow trout in 2001 in Erzurum, Turkey (Aydin et al., 2001). Following isolation was reported in Trabzon from rainbow trout (Kayis et al., 2009). So far, the pathogen has never associated with serious outbreaks in Turkey (Table 9).

**Citrobacter Infection**

*Citrobacter freundii* was first reported as an emerging fish pathogen from sunfish (*Mola mola*) in Japan (Sato et al., 1982). After initial isolation, it was also isolated from Atlantic salmon in USA (Baya et al., 1990), rainbow trout in Spain which caused high mortalities with IPNV (Sanz, 1991) and from carp in India (Karunasagar et al., 1992). *C. freundii* is an opportunistic pathogen. Thus, stress, and pollution play a key role in infection occurrence (Sanz, 1991; Whalen et al., 2007).

In Turkey, it was isolated from rainbow trout in Erzurum (Saglam et al., 2006) but there is no clear information about bacterial pathogenicity. After few years, it was also isolated from rainbow trout in Trabzon (Kayis et al., 2009). In both events, no heavy mortalities were observed. Besides that, another *Citrobacter* species, *Citrobacter breakii* was first reported as a fish pathogen in Bursa (Altun et al., 2013c) (Table 9).

**Arcobacter cryaerophilus Infection**

The bacterium is part of the normal micro flora of freshwater fish (Aydin et al., 2000b). Since the bacterium is ubiquitous in the environment and fish, it is not surprising that it might be opportunistic fish pathogen. It was first described as an emerging fish pathogen and isolated from rainbow trout in Balikesir and Canakkale (Aydin et al., 2000). After that, pathogenicity of the bacterium was confirmed by experimental infections which were performed on rainbow trout, and albino crosses (Bulut and Aydin, 2004) (Table 9). Infected fish showed pale gills, watery spleens, hemorrhages and bloody fluid in intestine.

**Shewanella putrefaciens Infection**

Disease caused by *S. putrefaciens* was first occurred in farmed rabbit fish (*Siganus rivulatus*) in Red Sea in 1985 and caused heavy mortalities (Saeed et al., 1987). After initial report, it was isolated from both common carp (*Cyprinus carpio*) and rainbow trout farms located in Poland (Kozinska and Pekala, 2004).

Koron et al. (2009) was first reported the outbreak of a disease caused by *S. putrefaciens* from European sea bass in Aegean Region of Turkey. In the same year, the bacterium was also reported from rainbow trout in Trabzon (Kayis et al., 2009) (Table 9).

**Aerococcus viridans**

The bacterium was described as a pathogen and caused low mortalities in lobsters (*Homarus gammarus* L.) (Gjerde, 1984). Ozer et al. (2008) isolated *A. viridans* from cultured rainbow trout in Mersin (Table 9). Fish infected with *A. viridans* showed darkened skin, exophthalmia and hemorrhages in liver.

**Hafnia alvei**

*Hafnia alvei* is one of the causative agents of the hemorrhagic septicemia. It was first reported as a fish
pathogen from rainbow trout in Bulgaria (Gelev and Gelev, 1988). Subsequent outbreak occurred in cherry salmon (O. masou) in Japan and confirmed its pathogenicity. If API Biochemical Test System is used for identification, the bacterium could be misidentified as Y. ruckeri or vice versa. The pathogen was isolated from rainbow trout in Ankara, Rize and Trabzon (Ozkok, 2005; Kayis et al., 2009) (Table 9).

Enterobacter cloacae

Enterobacter cloacae was isolated from mullet (Mugil cephalus) in India. Bath challenge was performed and pathogenicity was determined (Sekar et al., 2008). In Turkey, Kayis et al. (2009) recovered the disease organism from rainbow trout in Trabzon and Rize (Table 9).

Viral Fish Diseases

IPNV

The causative agent is Infectious pancreatic necrosis virus (IPNV) which belongs to Birnaviridae group. It isicosahedral in shape, unenveloped and has a double stranded RNA genome. IPN is an infectious systemic disease that has been recognized to have worldwide distribution in a wide range of fish. It causes high mortalities especially in fry and fingerling salmonids. The virus can be vertically and horizontally transmitted. Thus, the only way to get rid of the virus is the destruction of the stock (Olson and Thomas, 1994). Wood et al. (1955) was first described the IPNV.

In Turkey, first IPNV particles were reported from rainbow trout organs after histopathological examination (Timur et al., 1993). After a decade, existence of IPNV was proved by RT-PCR (Candan, 2002). Subsequently, IPNV has been reported from different parts of Turkey and findings suggest wide distribution of the virus in Turkey (Table 10).

VHSV

Viral hemorrhagic septicemia (VHS) is a severe viral disease caused by VHS virus. The virus belongs to the family Birnaviridae, genus Novirhabdovirus. The disease was first occurred in rainbow trout in Germany (Schaperclaus, 1938). It is responsible for severe economic losses in rainbow trout farms in Europe (Woo and Bruno, 2011). VHSV was thought to have a predilection for salmonids, especially rainbow trout. Over the years, host range of the pathogen has expanded. For instance, Atlantic cod, pike, turbot, sea bass, Coho salmon, brown trout (Castric and Kinkelín, 1980; Jensen et al., 1979; Meier and Vestergard, 1980; Rasmussen, 1965; Winton et al., 1989). Unlike IPNV, there is no clear evidence about vertical transmission of the virus, but it is likely that, it can be transmitted horizontally and in many cases survivors become asymptomatic carriers. Salmonid fries are the most susceptible fish species to the virus. Mortality rates can reach up to 80-90%.

VHSV was first isolated in Trabzon, Turkey from cultured turbot fry and brood stock in 2004 (Kalaycı et al., 2006; Nishizawa et al., 2006). Subsequent isolations (Table 10) of VHSV in the Black Sea Region proved the existence of VHSV in Turkey (Altuntas and Oğut, 2010).

Viral Erythrocytic Necrosis (VEN)

The etiological agent of the disease is an iridovirus, named as erythrocytic necrosis virus (ENV). It was first reported in 1969 and identified as piscine erythrocytic necrosis (Laird and Bullock, 1969). Since its initial recognition, the virus has been recovered as a pathogen from a wide variety of fish species from different countries, for instance, sea bass in Spain (Pinto et al., 1989), coho salmon in Japan (Takahashi et al., 1982), pacific herring in Alaska (Meyers et al., 1986), coho salmon in Chile (Reyes and Campalans, 1987) and eel in Taiwan (Chen et al., 1985). Unlike VHSV and IPNV, VEN has not been recognized as a severe disease, it causes nominal mortalities in regard to other viral infections.

In 2008, viral erythrocytic infection occurred in cultured Mediterranean sea bass in Black Sea (Timur et al., 2008). It is the only recorded report that has been made to date in Turkey (Table 10).

Lymphocystis

Lymphocystis is caused by a lymphocystis virus. It has been reported from wide variety of both freshwater and marine fish species from all over the world. It is one of the oldest and the best known fish virus. It has been known as a causative agent of a disease since 1874 (Plumb and Hanson, 2011). It was reported from ornamental fish in USA (Nigrelli and Ruggieri, 1965), Red Sea, Bering Sea, Mediterranean Sea (Anders, 1989) and Korea (Hossain et al., 2007). The causative agent of the virus was isolated from Sea Bream in Mugla, Turkey (Candan, 1991b). There is not any report of severe disease outbreak associated with Lymphocystis in Turkey (Table 10).

Carp Pox

It is also known as a fish pox or epithelioma papillomatosum, caused by a herpes virus. Like lymphocystis, it is one of oldest known fish disease. The virus was first recorded in 15th century (Hedrick and Sano, 1989). It was mainly reported from carp producer countries such as European countries, United States and Far East countries. Sano et al. (1985) was reported that, the most susceptible hosts of the virus are common carp and koi carp.
and viral origins, became one of the most important conditions resulting from intensive fish farming and stressful fast-growing animal food-producing sectors. As a consequence, pathogens that remain viable under various environmental conditions and are opportunistic, facultative disease causing organisms are transferred from fish to fish or from locality to locality. Moreover, many communicable agents from fish to terrestrial animals. Fish respond quickly any kind of environmental change than homothermic terrestrial animals. Fish respond quickly to environmental change than homothermic terrestrial animals. Fish respond quickly to environmental change than homothermic terrestrial animals. Fish respond quickly to environmental change than homothermic terrestrial animals. Fish respond quickly to environmental change than homothermic terrestrial animals. Fish respond quickly to environmental change than homothermic terrestrial animals.

Aquaculture is a vital source of food and still the fastest-growing animal food-producing sector. As a result of intensive fish farming and stressful conditions, infectious diseases, especially bacterial and viral origins, became one of the most important limiting factors in aquaculture facilities. Some diseases do not always reveal themselves in a clinical form. These types of diseases, e.g. BKD, furunculosis and ERM pose real risk of transferring the pathogen with fish movements (Hirvela et al., 2006). Therefore, it is obligatory to apply transportation restrictions. These may prevent the spread of the diseases or slow down the transmission. It may require efficient monitoring, dissuasive and financial sanctions. In some instances, it is really hard to get rid of the disease. Complete disposition of infected fish and disinfection of related facilities, especially hatcheries, may be more economical than the losses associated with mortalities. The best practice for the elimination of IPNV, VHSV, BKD and furunculosis is prevention by the use of disease-free stocks if possible.

Since fish are poikilothermic, they react more quickly to environmental change than homothermic terrestrial animals. Fish respond quickly any kind of environmental changes such as temperature change, excessive or insufficient dissolved gasses in the water, metabolites, or chemical additives, and so forth, to which they are unable to adapt. These factors increase fish susceptibility to infectious agents and compromise their immune response (Plumb and Hansen, 2011).

In aquaculture, the usage of antimicrobial...
compound was started in 1940s against furunculosis (Austin and Austin, 2012; Gutsell, 1946). Intensive fish farming is the main reason for the use of high amount of antimicrobial drugs. Incorrect usage of antimicrobials in veterinary medicine and in aquaculture as a growth promoter, prophylaxis and therapeutic purposes leads to bacterial resistance to the antibiotics and also, accumulation antibiotic residue in fish. Bacteria may develop resistance to antimicrobials if used too often, over an extended period of time, or if applied improperly. Oxytetracycline, sulfadimethoxine, tetracycline, tetracycline are among the most frequently used antibiotics (Plumb and Hanson, 2011). Consequently, most of the bacteria has already acquired resistance against these antibiotics (unpublished data). On the other hand, florfenicol is a newly introduced antibiotic to aquaculture (Kayis, 2009). Therefore most of the bacteria strains are susceptible against it. In EU member states and the USA, limited antimicrobial agents are licensed for use in finfish and their use in aquaculture products that are for human consumption is very limited (Matyar, 2007). In contrast, in most of the developing countries, antimicrobial drug usage regulations are virtually absent, inadequate or unrestrained.

Several different kinds of antibiotics are used around the world in aquaculture for the control of bacterial diseases by adding them directly to the water or incorporating them into the feed. High frequencies of bacteria that are resistant to the antimicrobial agent have been found in aquaculture, including multiple resistant bacteria, found in fish farms and the surrounding aquatic environment. Accumulation of surplus antimicrobials and antimicrobial residues may occur in fish farms. Antimicrobial build up could establish selective pressure favoring selection and growth of antimicrobial-resistant bacteria. There is a potential risk that antimicrobial resistance genes could be disseminated into a wide range of aquatic environmental bacteria. There is also a possible flow of antimicrobial resistance genes between animal and human pathogens (Petersen et al., 2002).

Initial effectiveness of using antibiotics against various fish diseases somewhat decreased the interest in vaccine development for particular diseases. However, with the emergence of antibiotic-resistant strains of bacteria as a result of antibiotics use has drawn significant attention back to vaccines. Under intensive rearing conditions, vaccines can provide protection against specific disease when fish are the most susceptible and provides long-term immunoprotection (Plumb and Hanson, 2011). Unlike antibiotics, vaccines do not leave any residue and they are safe for applied fish. Depending on the fish and environmental conditions, vaccination can be performed orally, by immersion or by injection. Like antibiotics, vaccines cannot totally eliminate all of the disease organism. Vaccinated fish can become carriers and can play role as a disease reservoir. That might have an impact on wild stocks, which interact with vaccinated fish especially in sea cages.

Antibiotics are commonly used for treatment of these diseases but bacteria develop antibiotic resistant. To overcome these problems, fish should be vaccinated. Many attempts have been made to vaccinate fish against vibriosis and yersiniosis by using simple killed bacterin preparations. Immunization with killed bacteria has been attempted and protection obtained by immersion by feeding as a feed additive or by injection with the killed bacteria has been minimal. Better protection has been obtained by administering the killed bacteria by injection in combination with an emulsified adjuvant (Cane, 2013). However, immune responses to live vaccines are generally of greater magnitude and of longer duration than those produced by killed or subunit vaccines. Attenuated vaccines have some advantages over killed bacterin vaccines. They are living and invasive, thereby facilitating vaccine uptake and they establish low-grade infections resulting in the stimulation of cellular immunity and typically establish longer-lasting immunity (unpublished data).

Nowadays, live attenuated bacterial vaccines have been developed to immunize fish against several bacterial diseases. Direct and random approaches can be used to induce mutations into bacterial pathogens to achieve attenuation. Direct approaches include mutation or deletion of genes involved in metabolic pathways and/or pathogenesis, while random approaches include genetic methods such as transposon mutagenesis or the use of chemicals such as antibiotics (Cane, 2013). Sometime mutations are reversible especially when bacteria mutated by chemicals or by passages. This situation poses a risk for both host and environment. To encounter such problems, bacteria should be mutated by inactivation of genes involved in the metabolic pathways which are necessary for bacterial growth and survival in vivo. Examples of biochemical pathways targeted to produce attenuated strains include the following: aromatic amino acid biosynthesis, purine biosynthesis, capsule biosynthesis, galactose epimerase and adenylate cyclase (Tatum and Briggs, 2005). These mutant bacteria were unable to increase their number to make disease; therefore they cannot survive long enough to create diseases (Roberts et al., 1990). Bacteria have a linear biochemical network for the synthesis of aromatic amino acid. The biosynthesis of aromatic amino acids from core primary metabolism initiates via the shikimate pathway, leading to the synthesis of chorismate. Shikimate pathway is catalyzed by 5-enolpyruvylshikimate 3-phosphate synthase, which leads to the synthesis of enolpyruvylshikimate 3-phosphate (EPSP) encoded by aroA gene. The final step in the shikimate pathway is catalyzed by chorismate synthase which converts EPSP to chorismate encoded by aroC gene (Oyston et al., 1996; Kitzing et al., 2004; Johansson and Liden,
Novel live attenuated vaccines have been developed against pathogenic L. anguillarum and Y. ruckeri by deleting their aroA and aroC genes. Therefore bacteria are incapable of expressing aroA and aroC metabolic genes. This mutation is a deletion that the mutation leads to the failure to chorismate synthase that catalyzes the last step in the common shikimate pathway leading to aromatic compounds. The vaccination of rainbow trout with the aroA and aroC mutant as a live vaccine conferred significant protection (relative percentage survival≥92%) against the pathogenic wild-type strain of L. anguillarum or Y. ruckeri, aroA and aroC mutant L. anguillarum and aroA and aroC mutant Y. ruckeri can be used as a live vaccine to protect fish from vibriosis and yersiniosis, respectively when fish are 3 grams or older (TUBITAK, Project no. 1100886).

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