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REVIEW

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.

Türkiye'de Görülen Bakteriyel ve Viral Balık Hastalıkları

Özet

Bu derlemede Türkiye'de bulunan başlıca bakteriyel ve viral balık patojenleri hakkında ki bilgi durumu özetlenmiştir. Bu bağlamda 1976 ve 2013 yılları arasında yayımlanan bilimsel makaleler, yüksek lisans ve doktora tezleri, sempozyum bildirileri, resmi kayıtlar ve kitaplarda dağınık olarak bulunan kayıtlar bir araya getirilmiştir. Türkiye'de bu dönemdeki bakteriyel ve viral hastalıkları incelenmiş ve toplam 48 patojenik bakteri ve 5 virüs türü rapor edilmiştir. Her yıl yeni hastalık etkenleri izole edilmesinden dolayı bu çalışmanın mevcut tüm bakteri ve virüsleri kapsadığı anlamı ortaya çıkmamalıdır. En yüksek salgınlar balıkların larval ve yavru dönemlerinde meydana gelmektedir. Bu makalede, patojenik bakteri ve virüs türlerinin coğrafik dağılımı, konakçı ve ortaya çıktıkları yıllara odaklanmıştır. Rapor edilen hastalıklar arasında en sık bildirilen balık hastalıkları Vibriosis, Furunkulosis, Hareketli Aeromonas Septisemi, Yersiniosis, Photobakteriosis ve Flavobakteriosis olarak yer almaktadır. Bu arada *Vagococcus salmoninarum*, *Renibacterium salmoninarum*, *Piscirickettsia salmonis* ve *Pseudomonas luteola* nadiren karşılaşılan patojenler olmasına rağmen balıklarda sorunlar oluşturabileceği düşünülmektedir. Son olarak, mevcut balık hastalıklarını önleme ve tedavi stratejileri de ele alınmıştır.

Anahtar Kelimeler: Hastalık transferi, aşılar, hastalıkların tedavisi, hastalıklardan korunma.

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 (*Oncorhynchus mykiss*), Gilt-head sea bream (*Sparus aurata*), and Sea bass (*Dicentrarchus labrax*) are the most predominant fish species cultured in Turkey (TUIK, 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 (Cagirgan, 1993a; Korun and Gokoglu, 2007a; Tanrikul, 2007). 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 (Korun 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 (Korun 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.

Common name of the disease	Etiological agents	Host	Geographical distribution	References
Red-pest, Vibriosis, Salt-water furunculosis, Boil disease	*Listonella anguillarum (Vibrio anguillarum)*	*Sparus aurata*	Mugla	Candan (1991)
		Dicentrarchus labrax	Aegean Sea	Cagirgan (1993a)
		Salmo salar	Black Sea	Candan (2000)
		Dicentrarchus labrax	Izmir, Mugla, Aydin	Tanrikul *et al.* (2004)
		Dicentrarchus labrax	Antalya	Korun (2004a)
		Dicentrarchus labrax	Ordu	Savaş *et al.* (2006)
		Pagrus pagrus	Mugla	Korun and Gokoglu (2007a)
		Aulonocara maylandi	Istanbul (Aquarium)	Akayli (2007)
		Oncorhynchus mykiss	Mugla, Aydin, Denizli	Aksit and Kum (2008)
		Sparus aurata	Izmir, Mugla	Canak (2011)
		Oncorhynchus mykiss	Black Sea	Timur *et al.* (2011)
Vibriosis, Eye disease, Septicemia	*Vibrio alginolyticus*	*Dicentrarchus labrax*	Aegean Sea	Cagirgan (1993a)
		Sparus aurata	Aegean Sea	Cagirgan (1993a)
		Oncorhynchus mykiss	Ordu	Savaş *et al.* (2006)
		Dicentrarchus labrax	Ordu	Savaş *et al.* (2006)
		Trachurus trachurus	Mersin	Ozer *et al.* (2008a)
		Trachurus mediterraneus	Trabzon	Boran *et al.* (2013)
Vibriosis	*Vibrio ordalii*	*Sparus aurata*	Mugla	Akayli (2001)
		Dicentrarchus labrax	Aegean Region	Turk (2002)
		Dicentrarchus labrax	Izmir	Korun (2004a)
		Dicentrarchus labrax	Canakkale	Tanrikul *et al.* (2004)
		Dicentrarchus labrax	Antalya	Korun (2004a)
Vibriosis	*Vibrio vulnificus*	*Sparus aurata*	Aegean Region	Turk (2002)
		Dicentrarchus labrax	Aegean Region	Turk (2002)
		Trachurus mediterraneus	Trabzon	Boran *et al.* (2013)
Vibriosis, Eye disease, Granuloma	*Vibrio harveyi*	*Dicentrarchus labrax*	Mugla	Korun and Akayli (2004)
		Sparus aurata	Mugla, Izmir	Canak (2011)
Vibriosis	*Vibrio parahaemolyticus*	*Oncorhynchus mykiss*	Aydin	Aydin (2000a)

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. *achromogens*, 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 (*Acipencer 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.*

Table 2. Distribution and host range of *A. salmonicida*

Common name of the disease	Etiological agent	Host	Geographical distribution	References
Ulcerative Disease	*A. salmonicida* subsp. *achromogenes*	*Oncorhynchus mykiss* *Dicentrarchus labrax* *Psetta maxima*	Balikesir Black Sea Eastern Black Sea	Korun and Timur (2001) Karatas *et al.* (2005) Savas and Ture (2008)
Furunculosis	*A. salmonicida* subsp. *salmonicida*	*Oncorhynchus mykiss*	Marmara Region Aegean Region Ankara Black sea Mugla, Aydin, Denizli Trabzon, Rize	Timur *et al.* (1999) Kirkan *et al.* (2003) Ozkok (2005) Timur *et al.* (2008) Aksit and Kum (2008) Kayis *et al.* (2009)

Table 3. Distribution and host of motile *Aeromonas* species

Common name of the disease	Etiological agents	Host	Geographical distribution	References
Motile Aeromonas septicemia (MAS), Red fin disease, Red pest, Infectious abdominal dropsy	*Aeromonas hydrophila*	*Oncorhynchus mykiss*	Eskisehir	Baran *et al.* (1980)
		Anguilla anguilla	Eskisehir	Timur (1983)
		Ornimental Fish spp.	Istanbul (Aquarium)	Guvener (2001)
		Sparus aurata	Aegean Region	Turk (2002)
		Dicentrarchus labrax	Aegean Region	Turk (2002)
		Ctenopharyngodon idella	Ankara	Uzbilek and Yildiz (2002)
		Oncorhynchus mykiss	Erzurum	Aydin and Ciltas (2004)
		Xiphophorus hellerii	Istanbul (Aquarium)	Akayli and Zeybek (2005)
		Oncorhynchus mykiss	Ordu	Savaş *et al.* (2006)
		Dicentrarchus labrax	Ordu	Savaş *et al.* (2006)
		Cyprinus carpio	Sanliurfa	Tel *et al.* (2007)
		Carassius auratus	Antalya (Aquarium)	Korun and Toprak (2007b)
		Cyprinus carpio	Burdur	Ozturk *et al.* (2007)
		Oncorhynchus mykiss	Mersin	Ozer *et al.* (2009)
		Oncorhynchus mykiss	Eastern Black Sea	Durmaz and Turk (2009)
		Oncorhynchus mykiss	Elazig	Aksoy (2009)
		Acipencer gueldenstaedtii	Istanbul	Timur *et al.* (2010)
		Oncorhynchus mykiss	Antalya	Korun and Toprak (2010)
		Trachurus mediterraneus	Trabzon	Boran *et al.* (2013)
	Aeromonas sobria	Unknown	Elazig	Muz *et al.* (1995)
		Salmo salar	Black Sea	Karatas (1996)
		Oncorhynchus mykiss	Ankara	Ozkok (2005)
		Oncorhynchus mykiss	Erzurum	Saglam *et al.* (2006)
		Carassius auratus	Antalya (Aquarium)	Korun and Toprak (2007b)
		Oncorhynchus mykiss	Black Sea	Timur *et al.* (2008)
		Oncorhynchus mykiss	Trabzon, Rize	Kayis vd. (2009)
		Oncorhynchus mykiss	Mersin	Ozer *et al.* (2009)
		Oncorhynchus mykiss	Antalya	Korun and Toprak (2010)
		Sparus aurata	Aegean Region	Avsever *et al.* (2012)
		Dicentrarchus labrax	Aegean Region	Avsever *et al.* (2012)
	Aeromonas caviae	-	Elazig	Muz *et al.* (1995)
		Salmo salar	Black Sea	Candan *et al.* (1995)
		Poecilia reticulata	Istanbul (Aquarium)	Timur *et al.* (2003)
		Carassius auratus	Antalya (Aquarium)	Korun and Toprak (2007b)
		Oncorhynchus mykiss	Trabzon, Rize	Kayis *et al.* (2009)
		Oncorhynchus mykiss	Antalya	Korun and Toprak (2010)
	Aeromonas schubertii	*Oncorhynchus mykiss*	Mediterranean Region	Akayli *et al.* (2011)

schubertii was occurred in Mediterranean region and pathogen was isolated from rainbow trout (Akayli *et al.*, 2011). This bacteria also belongs to motile *Aeromonas* species and might cause MAS.

Yersiniosis

It is one of the most important diseases in salmonids causing serious economic losses both in freshwater and marine salmonid aquaculture (Austin and Austin, 2012; Bullock and Snieszko, 1975; Toranzo, 2004). It also known as enteric red mouth disease (ERM), or yersiniosis. Causative agent of the disease is *Yersinia ruckeri*. It was first isolated from rainbow trout in Hagerman Valley, USA in 1950s (Ross *et al.*, 1966). Yersiniosis is commonly observed from all over the world where salmonids are cultured (Plumb and Hanson, 2011).

In Turkey, first outbreak of this disease occurred in one of the rainbow trout farm in southern Anatolia (Timur and Timur, 1991b). Disease agent came from Africa with imported rainbow trout summer eggs. After two decades, it became one of the widest distributed fish pathogen in Turkey (Table 4). Like the rest of the world, it was mostly seen in salmonids but it was also isolated from sea bass (Savaş *et al.*, 2006)). Recently, number of *Y. ruckeri* isolation ware decreased may be due to vaccination of fish with *Y. ruckeri* bacterin.

Photobacteriosis

The disease is also known as pseudotuberculosis (formerly pasteurellosis) which is caused by *Photobacterium damsela* subsp. *piscicida*. The causative agent of the disease was first observed in white perch (*Morone americanus*) and striped bass (*M. saxatilis*) in Chesapeake Bay, USA (Snieszko and

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 (Toronzo *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^{0}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

Table 4. Distribution and host range of *Yersinia ruckeri*

Common name of the disease	Etiological agent	Host	Geographical distribution	References
		Oncorhynchus mykiss	Mediterranean Region	Timur and Timur (1991b)
		Oncorhynchus mykiss	Marmara Region	Karatas and Candan (1997)
		Oncorhynchus mykiss	Mugla	Diler *et al.* (1998)
		Oncorhynchus mykiss	Aydin	Kirkan *et al.* (2000)
		Oncorhynchus mykiss	Black Sea	Karatas *et al.* (2004)
		Oncorhynchus mykiss	Malatya	Seker *et al.* (2005)
		Dicentrarchus labrax	Ordu	Savaş *et al.* (2006)
		Oncorhynchus mykiss	Erzurum	Saglam *et al.* (2006)
Enteric red mouth		*Oncorhynchus mykiss*	Adana, Antalya, Burdur, Isparta Mersin and Kahramanmaras	Mefut *et al.* (2007)
	Yersinia ruckeri	*Oncorhynchus mykiss*	Elazig	Kilic *et al.* (2007)
Yersiniosis		*Dicentrarchus labrax*	Eastern Black Sea	Savas and Ture (2008)
		Oncorhynchus mykiss	Mugla, Aydin, Denizli	Aksit and Kum (2008)
		Oncorhynchus mykiss	Mersin	Ozer *et al.* (2008b)
		Oncorhynchus mykiss	Isparta, Bilecik, Denizli, Kirklareli Bolu, Tekirdag, Canakkale, Elazig Aydin, Bursa, Yalova, Trabzon, Rize Kutahya, Kayseri, Urfa, Ordu Manisa, Denizli	Altun *et al.* (2010)
		Oncorhynchus mykiss	Malatya and Elazig	Seker *et al.* (2012)

Table 5. Distribution and host range of *Ph. damsella subsp. P iscicida*

Common name of the disease	Etiological agent	Host	Geographical distribution	References
Photobacteriosis		*Sparus aurata*	Aegean Sea	Cagirgan (1993b)
	Photobacterium	*Dicentrarchus labrax*	Canakkale	Candan *et al.* (1996)
	damsella subsp.	*Mugil sp.*	Aegean Sea	Tanrikul and Cagirgan (2001)
Pseudotuberculosis	*piscicida*	*Dicentrarchus labrax*	Aegean Region	Turk (2002)
	(*Pasteurella*	*Dicentrarchus labrax*	Antalya	Korun (2004b)
	piscicida)	*Oncorhynchus mykiss*	Eastern Black Sea	Savaş *et al.* (2006)
Pasteurellosis		*Dicentrarchus labrax*	Eastern Black Sea	Savaş *et al.* (2006)

Table 6. Distribution and host range of *Flavobacterium* species

Common names of the disease	Etiological agents	Host	Geographical distribution	References
Cold-water disease Rainbow trout fry syndrome (RTFS)	*Flavobacterium psychrophilum*	*Oncorhynchus mykiss*	Aydin, Canakkale, Bilecik, Manisa, Samsun, Ordu, Kayseri,	Balta and Cagirgan (1998)
		Oncorhynchus mykiss	Sakarya	Korun and Timur (2001)
		Oncorhynchus mykiss	Mediterranean Region	Diler *et al.* (2003)
		Oncorhynchus mykiss	Marmara Region	Timur *et al.* (2004)
		Oncorhynchus mykiss	Elazig, Malatya, Erzincan	Ispir *et al.* (2004)
		Dicentrarchus labrax	Mugla	Ayaz (2006)
		Oncorhynchus mykiss	Aegean Sea	Kum *et al.* (2008)
		Oncorhynchus mykiss	Trabzon, Rize	Kayis *et al.* (2009)
Columnaris disease Saddleback disease Cotton wool disease Mouth fungus	*Flavobacterium columnare (Flexibacter columnaris, Cytophaga columnaris)*	*Oncorhynchus mykiss*	Rize, Trabzon, Aydın, Kayseri, Ordu, Manisa, Denizli	Balta and Cagirgan (1998)
		Oncorhynchus mykiss	Isparta	Kubilay *et al.* (2008)
		Oncorhynchus mykiss	Mugla	Kubilay *et al.* (2009)
		Oncorhynchus mykiss	Mersin	Yildirim and Ozer (2010)
Gill and skin disease	*Flavobacterium johnsoniae*	*Oncorhynchus mykiss*	Mersin	Yildirim and Ozer (2010)
		Acipencer gueldenstaedtii	Sakarya	Karatas *et al.* (2010)
Bacterial gill disease (BGD)	*Flavobacterium branchiophilum*	*Oncorhynchus mykiss*	Mersin	Yildirim ve Ozer (2010)
-	*Flavobacterium hydatis*	*Acipencer gueldenstaedtii*	Sakarya	Timur *et al.* (2010)

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^{0}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 15ºC.

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

Japan (Wakabayashi *et al.*, 1980).

In Turkey, it was claimed that the pathogen was isolated from rainbow trout hatcheries and caused mortalities up to %50 with other *Flavobacterium spp*. (Yildirim and Ozer, 2010) (Table 6). However, some of the biochemical test results reported in this particular study does 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 (*Acipencer 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 tapiriña*), 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

Streptococcosis stands for a common name of a disease caused by different genera and species. The disease which is known as "warm water" streptococcosis (causes morbidity and mortality above 15ºC) is caused by *Lactococcus garvieae*, *Streptococcus iniae*, *Streptococcus parauberis* and *Streptococcus agalactiae.* The other one, vagococcosis, (causes morbidity and mortality below 15ºC) 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 (Casrson *et al.*, 1993), Italy (Ghittino 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 (Akayli *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. aeroginasa* and *Ps. luteola* (Muroga and Nakajima, 1981; Prosyanaya, 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

Common names of the disease	Etiological agent	Host	Geographical distribution	References
Lactococcosis "Warm-water" Streptococcosis	*Lactococcus garvieae*	*Oncorhynchus mykiss*	-	Cagirgan and Tanrikul (1995)
		Oncorhynchus mykiss	Aegean Region	Diler *et al.* (2002)
		Oncorhynchus mykiss	Mugla, Denizli, Antalya, Konya	Altun *et al.* (2005)
		Oncorhynchus mykiss	Konya, Antalya, Isparta,	Kubilay *et al.* (2005)
		Psetta maxima	Eastern Black Sea	Savas and Ture (2008)
		Oncorhynchus mykiss	Eastern Black Sea	Savas and Ture (2008)
		Dicentrarchus labrax	Eastern Black Sea	Savas and Ture (2008)
		Oncorhynchus mykiss	Aydin, Mugla, Denizli	Aksit and Kum (2008)
		Oncorhynchus mykiss	Mersin	Ozer *et al.* (2008b)
		Oncorhynchus mykiss	Marmara Region	Timur *et al.* (2011)
		Oncorhynchus mykiss	Kutahya, Bilecik, Isparta, Bursa, Samsun, Mugla, Antalya	Altun *et al.* (2013b)
Vagococcosis, "Cold-water" Streptococcosis	*Vagococcus salmoninarum*	*Oncorhynchus mykiss*	Mediterranean Region	Didinen *et al.* (2011)
Staphylococcosis	*Staphylococcus epidermidis*	*Dicentrarchus labrax*	Aegean Region	Turk (2002)
		Sparus aurata	Aegean Region	Kubilay and Ulukoy (2004)
		Dicentrarchus labrax	Black Sea	Timur *et al.* (2008)
Staphylococcosis	*Staphylococcus cohnii subsp. cohnii*	*Dentex dentex*	Aegean Region	Akayli *et al.* (2011)
		Oncorhynchus mykiss	Aegean Region	Akayli *et al.* (2011)

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-byo) (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 Altinok *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 M*ycobacterium 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

Table 8. Distribution and host range of *Pseudomonas spp*

Common names of the disease	Etiological agents	Host	Geographical distribution	References
	Pseudomonas sp.	*Stizostedion lucioperca*	Eğirdir	Timur and Timur (1985)
Haemorrhagic septicaemia, Fin Rot	*Pseudomonas fluorescens*	*Sparus aurata*	Aegean Region	Turk (2002)
		Dicentrarchus labrax	Aegean Region	Turk (2002)
		Oncorhynchus mykiss	Sakarya	Akayli and Timur (2004)
		Poecilia reticulata	Istanbul (Aquarium)	Akayli and Korun (2004)
		Oncorhynchus mykiss	Ankara	Ozkok (2005)
		Dicentrarchus labrax	Adana	Matyar (2007)
		Oncorhynchus mykiss	Trabzon, Rize	Kayis *et al.* (2009)
		Oncorhynchus mykiss	Black Sea	Timur *et al.* (2011)
Ulcerative disease, Haemorrhagic ascites	*Pseudomonas putida*	*Cyprinus carpio*	-	Aydin *et al.* (1998)
		Carassius auratus	-	Aydin *et al.* (1998)
		Oncorhynchus mykiss	Ankara	Ozkok (2005)
		Oncorhynchus mykiss	Trabzon	Altinok *et al.* (2006)
		Dicentrarchus labrax	Adana	Matyar (2007)
Red spot disease, Sekiten-byo	*P. anguilliseptica*	*Dicentrarchus labrax*	Aegean Sea	Turk (2002)
		Sparus aurata	Izmir, Mugla	Canak (2011)
Gill disease	*P. aeroginasa*	*Dicentrarchus labrax*	Mugla	Ayaz (2006)
		Oncorhynchus mykiss	Mersin	Yildirim and Ozer (2010)
		Oncorhynchus mykiss	Trabzon, Rize	Kayis *et al.* (2009)
-	*P. chlororaphis*	*Dicentrarchus labrax*	Aegean Region	Turk (2002)
Haemorrhagic ascites	*P. plecoglossicida*	*Oncorhynchus mykiss*	-	Akayli *et al.* (2010)
-	*P. luteola*	*Oncorhynchus mykiss*	Trabzon	Altinok *et al.* (2007)

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 Chao, 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 (Rimaila, 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 labrax*) 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). Edwardsiellosis 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. damselae subsp. damselae Infection

The disease caused by *Photobacterium damselae subsp. damselae* (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

Common name of the disease	Etiological agent	Host	Geographical distribution	References
-	*Arcobacter cryaerophilus (Campylobacter cryearophila)*	*Oncorhynchus mykiss*	Marmara Region	Bulut and Aydin (2004)
-	*Aerococcus viridans*	*Oncorhynchus mykiss*	Mersin	Ozet el al. (2008)
-	*Burkholderia cepacia*	*Oncorhynchus mykiss* *T. mediterraneus*	Trabzon, Rize Trabzon	Kayis *et al.* (2009) Boran *et al.* (2013)
Necrotic kidney, Hyperemia of the mouth	*Citrobacter braakii*	*Oncorhynchus mykiss*	Bursa	Altun *et al.* (2013c)
-	*Citrobacter freundii*	*Oncorhynchus mykiss* *Oncorhynchus mykiss*	Erzurum Trabzon, Rize	Saglam *et al.* (2006) Kayis *et al.* (2009)
Enteric septicemia of catfish, hole in the head disease	*Edwardsiella ictaluri*	*Oncorhynchus mykiss*	Ankara	Keskin *et al.* (2004)
	Enterobacter cloacae	*Oncorhynchus mykiss*	Trabzon, Rize	Kayis *et al.* (2009)
Septicemia	*Escherichia vulneris*	*Oncorhynchus mykiss, Carassius Carassius, Poecilia sp.*	Erzurum	Aydin *et al.* (1997)
Hemorrhagic septicemia	*Hafnia alvei*	*Oncorhynchus mykiss* *Oncorhynchus mykiss*	Ankara Trabzon, Rize	Ozkok (2005) Kayis *et al.* (2009)
Vibriosis	*Photobacterium damselae subsp. damselae (Vibrio damselae)*	*Sparus aurata* *Dicentrarchus labrax* *Dicentrarchus labrax* *Oncorhynchus mykiss* *Oncorhynchus mykiss* *T. mediterraneus*	Mugla Aegean Region Antalya Black Sea Trabzon, Rize Trabzon	Akayli (2001) Turk (2002) Korun (2004b) Timur *et al.* (2008) Kayis *et al.* (2009) Boran *et al.* (2013)
-	*Plesiomonas shigelloides*	*Poecilia reticulata* *Oncorhynchus mykiss*	Istanbul (Aquarium) Trabzon, Rize	Akayli and Zeybek (2005) Kayis *et al.* (2009)
Septicemia	*Serratia liquefeciens*	*Oncorhynchus mykiss* *Oncorhynchus mykiss*	Erzurum Trabzon, Rize	Aydin *et al.* (2001) Kayis *et al.* (2009)
Ulcer, Hemorrhage	*Shewanella putrefaciens grp*	*Dicentrarchus labrax* *Oncorhynchus mykiss* *Carassius auratus auratus*	Aegean Region Trabzon, Rize Bursa (Aquarium)	Korun *et al.* (2009) Kayis *et al.* (2009) Altun *et al.* (2013a)

bacterium is not only a fish pathogen but also human pathogen. It effects variety of marine fish spp. Damsel fish seems to be most susceptible to this pathogen.

It is one of the most important diseases in cultured European sea bass (Korun, 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 reticulate*) 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 liquefeciens Infection

Serratia liquefeciens 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 (Starliper, 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).

Korun *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 clocae 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 is icosahedral 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 *Rhabdoviridae*, 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 Kinkelin, 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 (Kalayci *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 Ogut, 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 (Niggrelli 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 papillosum, 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.

Table 10. Distribution and host range of viral diseases

Virus	Abbreviation	Genome	Classification	Identified host	Geographical distribution	References
Infectious pancreatic necrosis virus	IPNV	*dsRNA*	*Birnaviridae, Aquabirnavirus*	*Oncorhynchus mykiss*	Different parts of Turkey	Candan (2002)
				Oncorhynchus mykiss	Ordu, Samsun, Tokat, Trabzon	Albayrak and Ozan (2010)
				Oncorhynchus mykiss	Eastern Black Sea	Ogut and Altuntas (2012
				Oncorhynchus mykiss	Adana, Adiyaman, Ankara, Antalya, Artvin, Aydin, Bilecik, Bolu, Burdur, Denizli, Duzce, Elazig, Eskisehir, Gumushane, Hatay, Izmir, Kahramanmaras, Kayseri, Mugla, Ordu, Sakarya, Samsun, Tokat, Trabzon, Usak, Zonguldak,	Kalayci *et al.* (2012)
				Dicentrarchus labrax	Antalya, Mugla, Ordu	Kalayci *et al.* (2012)
				Oncorhynchus mykiss	Elazig, Malatya, Sivas, Erzincan, Sanliurfa, Kahramanmaras, Erzurum	Gurcay *et al.* (2013)
Viral haemorrhagic septicemia virus	VHSV	ssRNA	*Rhabdoviridae, Novirhabdovirus*	*Psetta maxima*	Trabzon	Nishizawa *et al.* (2006)
				Scopthalmus maximus	Trabzon	Kalayci *et al.* (2006)
				Merlangius merlangus	Eastern Black Sea	Altuntas and Ogut (2010)
				Oncorhynchus mykiss	Bolu	Kalayci *et al.* (2012)
				Sparus aurata	Izmir	Kalayci *et al.* (2012)
				Dicentrarchus labrax	Antalya, Mugla, Izmir	Kalayci *et al.* (2012)
				Psetta maxima	Trabzon, Mugla	Kalayci *et al.* (2012)
Lymphocystis disease virus	-	dsDNA	*Iridoviridae, Lymphocystis virus*	*Sparus aurata*	Mugla	Candan (1991b)
Erythrocytic necrosis virus	ENV	dsDNA	*Iridoviridae*	*Dicentrarchus labrax*	Black Sea	Timur *et al.* (2008)
Cyprinid herpes virus 1(Carp pox)	CHV-1	ssRNA	*Rhabdoviridae*	*Cyprinus carpio*	-	Timur (1991a)

Since it is restricted to cyprinids and carp production rates are low in Turkey, it is not considered as a serious disease problem in Turkey. It was first reported by Timur (1991a) from mirror carp in Antalya (Table 10).

Prevention and Treatment

The ideal way to control infectious fish diseases is to prevent exposure to pathogenic agents whenever possible, thus avoiding most devastating health problems through biosecurity (Plumb and Hanson, 2011). However, when dealing with the aquatic environment, it is virtually impossible to define all disease-causing agents and keep them isolated from the fish host. Water provides an excellent medium for transfer of many communicable agents from fish to fish or from locality to locality. Moreover, many disease-causing organisms are endemic to the aquatic environment and are opportunistic, facultative pathogens that remain viable under various conditions (Plumb and Hanson, 2011).

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 factor 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 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, tetramycine, 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 Both 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, 2006).

Novel live attenuated vaccines have been developed against pathogenic *L. anguillarum* and *Y. ruckeri* by deleting their *aro*A and *aro*C genes. Therefore bacteria are incapable of expressing *aro*A and *aro*C 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 *aro*A and *aro*C mutant as a live vaccine conferred significant protection (relative percentage survival≥92%) against the pathogenic wild-type strain of *L. anguillarum* or *Y. ruckeri*. *aro*A and *aro*C mutant *L. anguillarum* and *aro*A and *aro*C 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. 110O886).

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