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Tilapia lake virus (TiLV): Literature review

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Summary

Tilapia lake virus (TiLV) is an emerging infectious agent that has recently been identified in diseased tilapia on three continents. At the time of writing, scientific publications have reported TiLV in samples collected from Colombia, Ecuador, Egypt, Israel and Thailand. While the link between TiLV and disease outbreaks in Israel and Thailand are well documented, further investigations are being undertaken to determine the significance of TiLV in the other countries. Israel and Taiwan Province of China have made a notification of TiLV as an emerging disease to the World Organisation for Animal Health (OIE). Studies have shown that populations infected with TiLV show variable levels of morbidity and mortality. This report summarizes the currently available scientific information on TiLV, including clinical signs, diagnostics and epidemiology. While of no concern to human health, the consequences of infection with TiLV in tilapia populations may potentially result in socio economic losses and impacts on food security.

Executive summary

TiLV has recently been noted as an important infectious agent that may threaten the worldwide tilapia industry. According to the Food and Agriculture Organization of the United Nations (FAO), global production of tilapia is estimated at 6.4 million metric tons (MMT), with the top three producers in 2015 being the People's Republic of China (1.78 MMT), Indonesia (1.12 MMT) and Egypt (0.88 MMT) (FAO 2017a). Bangladesh, Vietnam and the Philippines are other leading producers (FAO 2017a).

At the time of writing, TiLV has been reported to be present on three continents: Asia, Africa and South America. With increased screening, the list of affected countries is likely to increase in the near future. Although the virus does not represent any direct risk to human health, its known distribution gives significant cause for concern regarding the potential impacts on livelihoods and food security. As a result, international organizations have released information to heighten awareness of the current situation. At time of writing, two countries (Israel and Taiwan Province of China) have made an OIE notification of TiLV as an emerging disease to the OIE. A technical disease card for TiLV has been released by the OIE (OIE 2017). In addition, a Network of Aquaculture Centres in Asia-Pacific (NACA) disease alert (NACA 2017), a CGIAR Research Program on Fish Agri-food Systems (CGIAR 2017) factsheet, an FAO Global Information and Early Warning System (GIEWS) special alert 388 (FAO 2017b), as well as several website warnings, have been released. Together these publications highlight the urgent need for further knowledge regarding TiLV and its implications, as well as the importance of international collaboration. The disease associated with TiLV infection is currently known under two different names, tilapia lake virus disease (TiLVD) as in the OIE technical disease card (OIE 2017) and syncytical hepatitis of tilapia (SHT) as first referred to by Ferguson et al. (2014). This report summarizes the information on TiLV currently available from scientific publications. These include the aetiological agent, host factors, disease patterns and risk factors, pathology and diagnostic tests, and socio economic impact. The main recommendations for knowledge generation and collaboration have been summarized in the final section of this report.

Review of scientific publications on tilapia lake virus (TiLV)

Aetiological agent

Viral properties

According to scientific publications, TiLV has been identified from samples collected in Israel (Eyngor et al. 2014), Egypt (Fathi et al. 2017), Ecuador (Tsofack et al. 2017), Colombia (Tsofack et al. 2017) and Thailand (Dong et al. 2017a; Surachetpong et al. 2017).

The virus has been described as an enveloped, negative-sense, single-stranded RNA virus with 10 segments encoding 10 proteins (Eyngor et al. 2014; Bacharach et al. 2016; Surachetpong et al. 2017) and a diameter between 55 and 100 nm (Ferguson et al. 2014; Eyngor et al. 2014; del-Pozo et al. 2017; Surachetpong et al. 2017). All 10 segments contain an open reading frame (ORF), with the largest segment, segment 1, containing an open reading frame with weak sequence homology to the influenza C virus PB1 subunit (Bacharach et al. 2016). The remaining segments show no homology to other known viruses (Eyngor et al. 2014; Bacharach et al. 2016); however the conserved complementary sequences at the 5' and 3' termini are consistent with the genome organization found in orthomyxoviruses (Bacharach et al. 2016).

Viral particles have been found to be sensitive to organic solvents (ether and chloroform), due to their lipid membrane (Eyngor et al. 2014). Duration of survival outside the host has not been determined; however

horizontal, waterborne spread has been demonstrated under experimental conditions (Eyngor et al. 2014). Experimental infection (both intraperitoneal injection and cohabitation challenge) has produced clinical disease resembling that of natural outbreaks, including high levels of mortality (up to 80%) within 10 days post infection (Eyngor et al. 2014). A recent challenge study (intraperitoneal injection) in Thailand produced high mortality in both Nile (86%) and red (66%) tilapia within 4 to 12 days post infection and resulted in clinical signs and histopathological lesions similar to that seen in natural outbreaks (Tattiyapong et al. 2017). Fish surviving disease outbreaks have been found to be resistant to subsequent outbreaks (Eyngor et al. 2014).

Results from *in situ* hybridization indicate that TiLV replication and transcription occurs at sites of pathology (i.e. the liver in samples with liver lesions and the central nervous system in samples with central nervous system lesions) (Bacharach et al. 2016). In samples collected from Thailand, *in situ* hybridization yielded positive signals in multiple organs (liver, kidney, brain, gills, spleen and muscle connective tissue), with the strongest signals found in the liver, kidney and gills (Dong et al. 2017a). In samples originating from Ecuador, a viral predilection to the liver and gastrointestinal tract was suggested, with an apparent tropism for hepatic epithelium (del-Pozo et al. 2017).



Naturally TiLV-infected Nile tilapia fingerlings revealed discoloration and scale protrusion.

Gene bank accession numbers and nucleotide/ amino acid identities

Several TiLV sequences originating from Egypt, Israel and Thailand are available in the GenBank database (<https://www.ncbi.nlm.nih.gov/genbank/>) (Appendix 1).

From samples originating in Israel, available sequences include KJ605629 (clone 7450, ORF) (Eyngor et al. 2014) and KU751814 to KU751823 (whole genome, segments 1 to 10) (Bacharach et al. 2016). From samples originating in Thailand, available sequences

include KY615742 (segment 1), KY615743 (segment 5) and KY615744 to KY615745 (segment 9) (Dong et al. 2017a), as well as KX631921 to KX631930 (whole genome, segments 1-10) and KX631931 to KX631936 (segment 1, originating from different Thailand provinces) (Surachetpong et al. 2017).

Nucleotide and amino acid identity with isolates originating from Israel has been reported for isolates from Egypt, Ecuador and Thailand and are shown in Table 1.

Source	GenBank accession no.	Identity to TiLV from Israel		Reference
		GenBank accession no. of TiLV Israel	% of identify	
Egypt	Not available	KU751816 (segment 3)	93%	Fathi et al. 2017
Egypt	KY817381–KY817390	Segments 3, 4 and 9 (accession numbers not specified)	93%	Nicholson et al. 2017
Ecuador	Not available	full genome sequences KU751814–KU751823	97.2% to 99.0% nucleotide identity; 98.7% to 100% amino acid identity	Bacharach et al. 2016
Ecuador	Not available	KJ605629 (ORF)	98% to 100%	del-Pozo et al. 2017
Thailand	KY615742	KU751814 (segment 1)	96.3% to 97.5% nucleotide identity; 97.4% to 98.8% amino acid identity	Dong et al. 2017a
Thailand	KY615743	KU751818 (segment 5)		
Thailand	KY615744–KY615745	KU751822 (segment 9)		
Thailand	KX631921–KX631930–KX631936	full genome sequences KU751814–KU751823	95.6% to 99.1% nucleotide identity; 96.7% to 99.5% amino acid identity	Surachetpong et al. 2017

Table 1. Published TiLV GenBank accession numbers and reported nucleotide and amino acid identities.

Host factors

Susceptible species

Affected farmed species include hybrid tilapia (*Oreochromis niloticus* x *O. aureus* hybrids) in Israel (Eyngor et al. 2014); Nile tilapia (*O. niloticus*) in Egypt (Fathi et al. 2017), Ecuador (Ferguson et al. 2014) and Thailand (Dong et al. 2017a; Surachetpong et al. 2017); and red tilapia (*Oreochromis* sp.) in Thailand (Dong et al. 2017a; Surachetpong et al. 2017). In Israel, TiLV has additionally been identified from various species of wild tilapines (including *Sarotherodon galilaeus*, *Tilapia zilli*, *Oreochromis aureus*, and *Tristramellasimonis intermedia*) in the Sea of Galilee (Eyngor et al. 2014).

A possible strain susceptibility of *O. niloticus* has been observed in an outbreak in Ecuador, with a 60–70% difference in observed mortality levels between two different fish strains (Ferguson et al. 2014) (see section 3.2).

Co-cultivated grey mullet (*Mugil cephalus*) and carp (*Cyprinus carpio*) have not shown mortality during disease outbreaks in Israel (Eyngor et al. 2014). Similarly, co-cultivated grey mullet and thin-lipped mullet (*Liza ramada*) were found to be unaffected during Egyptian outbreaks (Fathi et al. 2017).

Susceptible life stages

In Israel, mortalities have been observed over a wide weight range (Eyngor et al. 2014). Fingerlings have been affected in Ecuador (Ferguson et al. 2014) and Thailand (Dong et al. 2017a; Surachetpong et al. 2017). Additionally, small fish (up to 50 g) were affected in Thailand (Surachetpong et al. 2017). Furthermore, a recent study in Thailand using archived and fresh samples collected between 2012 and 2017 from four hatcheries found fertilized eggs, yolk sac larvae, fries

and fingerlings to be positive for TiLV (Dong et al. 2017b). In Egypt, medium (>100 g) and large-sized fish have been affected by an unknown cause of mortality during the summer months, commonly referred to as “summer mortality,” some of which have tested positive for TiLV (Fathi et al. 2017).

Disease pattern and risk factors

Geographical distribution

Scientific publications have reported detections of TiLV in samples originating from Israel (Eyngor et al. 2014), Egypt (Fathi et al. 2017), Ecuador (Bacharach et al. 2016; Tsofack et al. 2017), Colombia (Tsofack et al. 2017) and Thailand (Dong et al. 2017a; Surachetpong et al. 2017).

In Israel between May 2011 and July 2013, TiLV isolates were obtained from sampled wild stocks in the Sea of Galilee, as well as from farmed stock in major aquaculture areas (coastal shore, Jordan Valley and Upper and Lower Galilee) (Eyngor et al. 2014). In Egypt, 37% of randomly selected fish farms in the major aquaculture areas (Kafr el Sheikh, Behera, Sharkia) were affected by summer mortalities when sampled in 2015 (Fathi et al. 2017).

TiLV has been detected at a single farm in Ecuador where fingerlings were sampled in 2011 and 2012 (Ferguson et al. 2014; Bacharach et al. 2016), while no case description has been provided for TiLV-positive samples from Colombia (Tsofack et al. 2017).

Three farms in three Thailand provinces (Phetchaburi and Chai Nat sampled in 2016 and Pathum Thani sampled in 2017) were reported TiLV-positive by Dong et al. (2017a). Surachetpong et al. (2017) reported 22 out of 32 farms, sampled between October 2015 and May 2016, to be TiLV positive (Ang Thong, Chai Nat, Chachoengsao, Kanchanaburi, Khon Kaen, Nakhon Ratchasima, Pathum Thani, Phitsanulok and Ratchbuni provinces), while the 10 TiLV-negative farms were located in three other provinces (Samut Songkhram, Prachin Buri and Nong Khai) (Surachetpong et al. 2017). TiLV has been found in archived samples in Thailand dating from 2012 (Dong et al. 2017).

Clinical signs

Reported clinical signs include lethargy, ocular alterations, skin erosions and discoloration (darkening) in Israel (Eyngor et al. 2014) and exophthalmia, discoloration (darkening), abdominal distension, scale protrusion and gill pallor in Ecuador (Ferguson et al. 2014). In Thailand, loss of appetite, lethargy, abnormal

behavior (e.g. swimming at the surface), pallor, anemia, exophthalmia, abdominal swelling, and skin congestion and erosion have been reported (Dong et al. 2017a; Surachetpong et al. 2017). In Egyptian farms experiencing summer mortality, affected fish showed haemorrhagic patches, detached scales, open wounds, dark discoloration and fin rot (Nicholson et al. 2017).

Mortality levels of above 80% have been observed in affected farmed populations in Israel, while no such level of mass mortality has been reported in wild stocks from which positive samples have been obtained (Eyngor et al. 2014). In Thailand, mortality levels between 20% and 90% have been reported, with mortality usually seen within the first month after transfer to grow-out cages (Dong et al. 2017a; Surachetpong et al. 2017) and peak mortality rates observed within two weeks of onset of mortality (Surachetpong et al. 2017). Similarly, the case in Ecuador showed onset of mortality from four to seven days post transfer to on-growing ponds, with mortality ranging from a low level of 10–20% to a high level of 80%, depending on the fish strain (Ferguson et al. 2014).

In Egypt, the average mortality level at farms experiencing summer mortality has been found to be 9.2% (range 5–15%) in affected farms (Fathi et al. 2017). The mortality level attributable to TiLV infection in Egypt is currently unknown.

Risk factors for disease outbreaks

Clinical outbreaks have been reported during the hot season, namely May to October (at water temperatures of 22°C to 32°C) in Israel (Eyngor et al. 2014), June to October ($\geq 25^\circ\text{C}$) in Egypt (Fathi et al. 2017) and May to November (25°C to 27°C) in Ecuador (Ferguson et al. 2014). Some of the samples yielding positive TiLV detection in Thailand were collected in the months between October and May (Surachetpong et al. 2017).

In Egypt, large farm size, high stocking densities and tilapia-mullet polyculture have been identified as risk factors for TiLV outbreaks (Fathi et al. 2017).

Affected fingerlings in Ecuador were commonly detected within four to seven days post transfer to grow-out ponds, with mortality ranging from a low level of 10–20% to a high level of 80% depending on fish strain (Ferguson et al. 2014). Variations in mortality have been reported from Thailand in farms with different species and production form combinations, ranging from around 20% in farms with mixed stocking of red tilapia and Nile tilapia in earthen ponds in Phetchaburi province to around 90% in farms with

Nile tilapia in Pathum Thani province and farms with red tilapia in open floating cages in Chai Nat province (Dong et al. 2017a).

Co-infections

Reported co-infections in TiLV-positive fish from Thailand were *Flavobacterium*, *Aeromonas* and *Streptococcus* and external monogenean parasites (*Gyrodactylus* and *Dactylogyrus*) and ciliated protozoa (*Trichodina*) (Surachetpong et al. 2017). The relative significance of TiLV and any co-infections have not been determined; however infection experiments have shown mortality levels up to 80% in experimental TiLV-infected populations (Eyngor et al. 2014).

The relationship between summer mortalities in Egypt and TiLV has not yet been determined; however four out of eight farms sampled in 2015 (Nicholson et al. 2017) and three out of seven farms sampled in 2016 (Fathi et al. 2017) in Egypt that had experienced summer mortalities were found to be TiLV positive. In addition, multiple *Aeromonas* spp. (*A. veronii*, *A. ichthiosmia*, *A. enteropelogenes* and *A. hydrophilia*) were also identified from samples collected from Egyptian fish farms during 2015 (Nicholson et al. 2017).

Diagnosics and diagnostic tests

Gross pathology

Observations from affected populations in Israel include ocular alterations, skin erosions and discoloration (darkening) (Eyngor et al. 2014), while in Ecuador, abdominal distension, scale protrusion and gill pallor have been observed in addition to exophthalmia and skin discoloration (darkening) (Ferguson et al. 2014). Affected fish from Thailand showed pallor (Dong et al. 2017a), anemia, exophthalmia, abdominal swelling, skin congestion, erosion, brain congestion and paleness of the gills and liver (Surachetpong et al. 2017).

Histopathology

Briefly, cases in Israel showed the most severe central nervous system lesions (Eyngor et al. 2014) while cases in Ecuador and Colombia had major liver lesions (Ferguson et al. 2014; Tsofack et al. 2017; del-Pozo et al. 2017). Both liver and central nervous system lesions have been reported in cases from Egypt (Fathi et al. 2017).

More specifically, observed lesions in affected fish in Israel include congestion of internal organs (kidneys and brain), foci of gliosis and perivascular cuffing in the brain cortex, and ocular lesions (endophthalmitis and cataractous changes of the lens) (Eyngor et al. 2014).

In affected fish from Egypt, histopathological findings include gliosis, encephalitis and mild perivascular cuffing in the brain, multifocal chronic hepatitis and multifocal interstitial hemorrhage in the kidney (Fathi et al. 2017). The case in Ecuador showed hepatocyte necrosis and syncytial cell formation, necrosis of gastric glands and diffuse congestion in multiple tissues (Ferguson et al. 2014). Syncytial hepatitis was also reported in samples from Colombia (Tsofack et al. 2017) and Thailand (Dong et al. 2017a), with additional observations from Thailand including aggregation of lymphocytes and perivascular cuffing in brain tissue (Surachetpong et al. 2017).

Cell culture

Experiments have shown multiple cell lines to be suitable for TiLV cell culture (Eyngor et al. 2014; Tsofack et al. 2017).

The E-11 cell line was found to show visible cytopathic effect (CPE) five to seven days after inoculation, with cytoplasmic vacuoles and plaque formation followed by disintegration of cell monolayer nine to 10 days after inoculation (Eyngor et al. 2014). Cell lines of primary tilapia brain cells showed swollen, rounded, granulated cells 10 to 12 days after inoculation, with monolayer detachment 14 to 19 days after inoculation (Eyngor et al. 2014). E-11 cells at 25°C have been reported to provide optimal conditions for TiLV replication (Tsofack et al. 2017). The OmB and TmB cell lines showed similar sensitivities to TiLV infection as the E-11 cell line; however the E-11 cultures were deemed superior due to the clear and rapid CPE development (Tsofack et al. 2017). OmB has been suggested as a useful cell line for end-point dilution (TCID₅₀) assays and both OmB and TmB may reportedly be useful for generating pure TiLV strains as they are snakehead reovirus-free (Tsofack et al. 2017). Pooling of two to three samples of brain tissue have yielded positive TiLV culture results (Tsofack et al. 2017).

Other cell lines (CHSE-214, BF-2, BB, EPC, KF-1, RTG-2 and FHM) have been reported to show inconsistent CPE with TiLV (Eyngor et al. 2014).

Molecular methods

Initially, a RT-PCR method for TiLV detection was published together with information on TiLV specific primers (Eyngor et al. 2014). This was followed by the publication of a nested RT-PCR assay, with a reportedly improved sensitivity for segment 3, enabling detection down to seven copies of TiLV (Tsofack et al. 2017). The nested RT-PCR assay was found to detect TiLV in both fresh and preserved (RNA later; QIAGEN) samples

from diseased fish, and identified TiLV RNA in samples from diseased fish from Israel, Ecuador and Colombia (Tsofack et al. 2017). A real-time PCR method, used for quantification, was additionally described (Tsofack et al. 2017). Subsequently an alternative semi-nested RT-PCR method has been described where the primer Nested ext-2 was omitted (Dong et al. 2017a). Pooling of between two to five samples have been reported to yield successful agent identification (Tsofack et al. 2017; Dong et al. 2017a; Fathi et al. 2017; Surachetpong et al. 2017).

Additionally, the *in situ* hybridization method has been described and has been used to reveal TiLV tissue tropism (Bacharach et al. 2016; Dong et al. 2017a).

Serology

A reduced packed cell volume (16% versus the normal 48–50%) has been observed in Ecuador, together with an increased number of immature erythrocytes in blood smears (Ferguson et al. 2014).

Socio economic impact

Fish farms affected by TiLV reported mortality levels that may reach above 80% (Eyngor et al. 2014; Dong et al. 2017a; Surachetpong et al. 2017).

Estimates from Egypt indicate a production loss of 98,000 metric tons, at a value of around USD 100 million, due to the summer mortality syndrome in 2015 (Fathi et al. 2017).

In the Sea of Galilee in Israel, the annual wild catch figures for the main edible fish in the lake, *S. galilaeus*, decreased from 316 metric tons in 2005 to 8 metric tons in 2009, with a subsequent increase to 160 metric tons in 2013 and 140 metric tons in 2014 (Eyngor et al. 2014). The contribution of TiLV infection to this decline has not been determined; however TiLV has been identified in samples from several wild tilapines, including *S. galilaeus* (Eyngor et al. 2014).



Photo credit: Dr. Saengchan Sanabai/Center for Shrimp and Fish Diseases, Mahidol University, Bangkok, Thailand (left); WorldFish (right)

Naturally TiLV-infected red tilapia juveniles (left); skin lesions in TiLV-infected tilapia (right).

Major knowledge gaps – a need for strong international collaboration

As highlighted by multiple publications from international organizations, TiLV is likely to be a global problem for farmed tilapia. Therefore, increasing our knowledge and scientific documentation on multiple aspects of TiLV and the resultant disease are urgently needed (CGIAR 2017; FAO 2017b; NACA 2017; OIE 2017). The main recommendations on closing important knowledge gaps and points for collaboration have been summarized here.

There is an urgent need for increased knowledge on the real geographical distribution of TiLV. Due to the large international trade of tilapia, a more widespread distribution of the virus could be considered likely. Dong et al. (2017b) have released a map of 43 countries that may be at risk due to tilapia imports from TiLV-infected countries.

Instigating screening and surveillance programs in many of the tilapia producing countries should be actively encouraged. According to the FAO, multiple countries have initiated official screening and surveillance programs (FAO 2017b). FAO also recommended biosecurity measures that countries need to follow when translocating live tilapias, for countries found positive for TiLV and for countries with an unknown TiLV status (FAO 2017b). International collaboration on such screening/surveillance efforts may expedite initial knowledge generation while local diagnostic capacity building is being undertaken. Conducting TiLV import risk analysis should be encouraged in countries with significant tilapia production where TiLV has not been detected. Competent authorities of some concerned countries are in the process of collecting more information and conducting laboratory tests to validate the scientific findings that reported the presence of TiLV. An increased awareness of the importance of reporting, recording and mapping any unusual mortality in tilapia is crucial.

Given the importance of tilapia as a protein source in parts of the world, TiLV-associated losses may constitute a significant risk to food security. In addition, its presence is likely to affect international trade in tilapia. Socio-economic impact assessments should be encouraged in order to quantify the current or expected impact of disease as a result of infection with TiLV.

There is little scientific knowledge available regarding important epidemiological aspects of TiLV. Knowledge on factors such as viral properties, methods of transmission, susceptible host life stages, survival of TiLV

outside the host (in water, on fomites, in fresh/frozen products), risk factors for disease outbreaks (including different production systems) and presence of any non-tilapine hosts/carrier species need to be investigated in the countries where TiLV has been detected. Due to varying factors, such as production methods and fish genetics, the possibility of a variation in risk factors between different countries/regions should be evaluated. Given the long-term efforts that have been invested in producing genetically improved strains of tilapia, susceptibilities for TiLV need to be thoroughly investigated under field conditions. Similarly, there is an urgent need to determine the potential for vertical transmission of TiLV, as well as the possibility of a sub-clinical carrier status. Both descriptive, observational and experimental studies should be conducted to address such knowledge gaps. Based on the generated information, improved biosecurity measures, as well as intervention and containment programs, should be designed to minimize the impact of TiLV in the affected countries and regions and reduce the risk of further spread to other areas.

With a multi-continent presence of TiLV, there is a need for regional capacity building within all stakeholder groups. To facilitate rapid dissemination of information, participatory approaches at all stakeholder levels should be encouraged. Strong international collaboration on diagnostic capacity building should be prioritized to increase diagnostic efficiency. The development of new or improved diagnostic methods (e.g. ELISA, rapid antigen strip test and real-time RT-PCR) to increase screening efficiency and sensitivity should be encouraged. Collaborative programs between the private sector and relevant governments should be promoted to limit the impact of TiLV and the associated disease. With ongoing vaccine development efforts, an effective, safe and affordable vaccine could be available in the near future. In the long term, improved biosecurity measures may be possible to combine with an effective TiLV vaccine and possibly also specific-pathogen-free fish.

The potential impact of TiLV, in combination with its multi-continent distribution, calls for close international collaboration to improve the collective knowledge and understanding of TiLV and its consequences. With rapid dissemination of new knowledge and efficient national and international collaboration, improved TiLV mitigation and control strategies should hopefully be within reach.

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Appendix – Genbank accession numbers

GenBank accession number	Segment	Originating country	reference
KY817381	Not specified	Egypt	Nicholson et al. 2017
KY817382	Not specified	Egypt	Nicholson et al. 2017
KY817383	Not specified	Egypt	Nicholson et al. 2017
KY817384	Not specified	Egypt	Nicholson et al. 2017
KY817385	Not specified	Egypt	Nicholson et al. 2017
KY817386	Not specified	Egypt	Nicholson et al. 2017
KY817387	Not specified	Egypt	Nicholson et al. 2017
KY817388	Not specified	Egypt	Nicholson et al. 2017
KY817389	Not specified	Egypt	Nicholson et al. 2017
KY817390	Not specified	Egypt	Nicholson et al. 2017
KJ605629	Clone 7450, ORF	Israel	Eyngor et al. 2014
KU751814	Segment 1	Israel	Bacharach et al. 2016
KU751815	Segment 2	Israel	Bacharach et al. 2016
KU751816	Segment 3	Israel	Bacharach et al. 2016
KU751817	Segment 4	Israel	Bacharach et al. 2016
KU751818	Segment 5	Israel	Bacharach et al. 2016
KU751819	Segment 6	Israel	Bacharach et al. 2016
KU751820	Segment 7	Israel	Bacharach et al. 2016
KU751821	Segment 8	Israel	Bacharach et al. 2016
KU751822	Segment 9	Israel	Bacharach et al. 2016
KU751823	Segment 10	Israel	Bacharach et al. 2016
KY615742	Segment 1	Thailand	Dong et al. 2017a
KY615743	Segment 5	Thailand	Dong et al. 2017a
KY615744	Segment 9	Thailand	Dong et al. 2017a
KY615745	Segment 9	Thailand	Dong et al. 2017a
KX631921	Segment 1	Thailand	Surachetpong et al. 2017
KX631922	Segment 2	Thailand	Surachetpong et al. 2017
KX631923	Segment 3	Thailand	Surachetpong et al. 2017
KX631924	Segment 4	Thailand	Surachetpong et al. 2017
KX631925	Segment 5	Thailand	Surachetpong et al. 2017
KX631926	Segment 6	Thailand	Surachetpong et al. 2017
KX631927	Segment 7	Thailand	Surachetpong et al. 2017
KX631928	Segment 8	Thailand	Surachetpong et al. 2017
KX631929	Segment 9	Thailand	Surachetpong et al. 2017
KX631930	Segment 10	Thailand	Surachetpong et al. 2017
KX631931	Segment 1	Thailand	Surachetpong et al. 2017
KX631932	Segment 1	Thailand	Surachetpong et al. 2017
KX631933	Segment 1	Thailand	Surachetpong et al. 2017
KX631934	Segment 1	Thailand	Surachetpong et al. 2017
KX631935	Segment 1	Thailand	Surachetpong et al. 2017
KX631936	Segment 1	Thailand	Surachetpong et al. 2017



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