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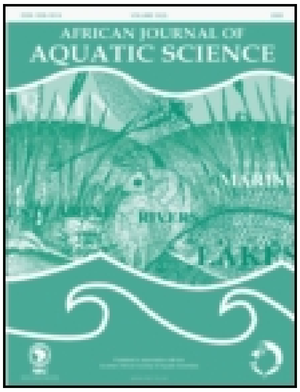

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Fish health status, research and management in East Africa: past and present

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Fish health status, research and management in East Africa: past and present

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This paper reviews the state of research on fish pathogens in Burundi, Kenya, Rwanda, Tanzania and Uganda from the early 1900s, the period when fisheries management started in the region, to date, and evaluates the current policy, regulatory frameworks, management practices and frameworks for addressing fish health issues in East African Community countries. Host pathogens and their distributions are listed. To date, fish health research has focused on the occurrence and taxonomy of parasites mainly in wild hosts. Very limited research output and knowledge exist on bacterial, viral and fungal disease agents and on fish culture systems, as well as on parasites' life cycles and/or vectors, epidemiology, pathogenicity, prevention and control. The current fish disease control and preventive strategies and diagnostic facilities are basic and non-specific. Although the five countries have legislation for the management of fisheries that clearly mention the restriction of movement of fish and fish products, they lack comprehensive policy and regulatory provisions to ensure an appreciable level of disease prevention and control. With the intensifying fish farming in the region, the research gaps in fish pathology, the potential impacts of the pathogens and the lack of appropriate management framework for fish diseases highlight the need to strengthen aquatic biosecurity.

Keywords: aquaculture, aquatic health management, disease, East African Community

Introduction

Risks of pathogen introduction and the virulence of the opportunistic pathogens in aquatic systems are on the increase (Kent 2000, Subasinghe et al. 2001, Subasinghe 2005). In addition, the recent outbreak of epizootic ulcerative syndrome (EUS) in southern Africa has heightened concern about aquatic animal disease management in Africa in general (FAO 2009a). Although fish culture has remained predominantly for subsistence purposes, the efforts to promote and develop this sector have resulted in wider acceptance of the practice throughout the East African Community (EAC) (LVFO 2005, MINAGRI 2009, MOFK 2010, NPA 2010). In addition, the increase in demand for fish, related to rapid population growth and dwindling wild fish stocks in the major lakes, also provides opportunity to invest in aquaculture. Concomitant with aquaculture development and expansion, the movement of live fish within countries and across borders poses serious aquatic animal health concerns (Subasinghe et al. 2001, Bondad-Reantaso 2004). Therefore, there was a critical need to evaluate disease management practices and aquatic biosecurity regulatory frameworks for the EAC to protect both the developing aquaculture industry and the vital fisheries sector of the member countries.

This paper reviews the state of knowledge and research on fish pathogens, highlights the importance of fish diseases to aquaculture and natural stocks, and evaluates the respective national policies and regulatory frameworks for aquatic animal health management in Burundi, Kenya, Rwanda, Tanzania and Uganda.

Fish health status and research

An in-depth literature review was conducted on East African aquatic ecosystems, fisheries and aquaculture management reports, media articles and books, emphasising fish health, pathogens and aquatic biosecurity in East Africa. There may be many additional records of fish pathogens in the region in inaccessible literature. A total of 121 species of parasites (20 Protozoa, 24 Monogenea, 17 Digenea, 14 Cestoda, 21 Nematoda, two Acanthocephala, eight Branchiura and 15 Copepoda), five bacteria, three fungi and one virus were reported infesting fish from East African water bodies (Table 1). Most studies focused on parasites, mainly in wild populations of the two most widely farmed fish species, *Oreochromis niloticus* and *Clarias gariepinus*, and the indigenous species *O. variabilis*, *O. esculentus*, *O. leucostictus* and *Tilapia zillii*. The pathogen fauna of other native freshwater fishes, and of commercial fisheries species such as *Lates niloticus* and *Labeo victorianus*, remains largely unknown or has not been studied. In addition, the studies focused on pathogen descriptions, with brief discussion of their biology and pathology. Descriptions of the parasites' life cycles and population dynamics were generally lacking, although such information is essential in understanding epidemiology and for designing environmental-based control measures (Georgiadis et al. 2001, Subasinghe 2005). There was very limited research on bacterial, fungal and viral diseases in the region. This could be related to the lack of diagnostic infrastructure, the high cost of diagnosing and identifying such pathogens and the

Table 1: Pathogens infecting freshwater fishes, and their distribution in East Africa. Only currently acceptable scientific names are given

Parasite	Host	Location/country	Reference
PROTOZOA			
Apiosoma sp.	*Clarias gariepinus*	Fish farms, Uganda	Florio et al. (2009)
Babesiosoma mariae	*Astatoreochromis alluaudi*, *Labeo victorianus*, *Oreochromis esculentus*, *O. niloticus*, *O. variabilis*	Lake Victoria, Uganda	Baker (1960)
Chilodonella sp.	*Oreochromis variabilis*	Lake Victoria, Uganda	Fryer (1961)
Coccidia sp.	*Oreochromis niloticus*	Reservoirs and Sagana fish farm, Kenya	Florio et al. (2009)
Cryptobia sp.	*Oreochromis niloticus*	Reservoirs and Sagana fish farm, Kenya	Florio et al. (2009)
Epistylis sp.	*Clarias gariepinus*	Fish farms, Uganda	Akoll et al. (2012)
Goussia cichlidarum	*Oreochromis niloticus*, *Sarotherodon galilaeus*	Lakes George and Victoria, Uganda	Landsberg and Paperna (1985)
Ichthyobodo sp.	*Oreochromis niloticus*	Fish ponds, cages and reservoirs in Uganda and Kenya; Sagana fish farm, Kenya	Florio et al. (2009)
Ichthyophthirius multifiliis	*Barbus paludinosus*, *Lebistes reticulatus*, *Oreochromis niloticus*	Lake Victoria, Uganda	Paperna (1972)
Myxobolus brachysporus	*Oreochromis esculentus*, *O. variabilis*	Lake Victoria, Uganda	Baker (1963)
Myxobolus heterosporus	*Haplochromis* sp., *Oreochromis esculentus*, *O. niloticus*, *O. variabilis*	Lakes George and Victoria, Uganda	Baker (1963)
Myxobolus homeospora	*Oreochromis esculentus*, *O. variabilis*	Lake Victoria, Uganda	Baker (1963)
	Oreochromis niloticus, *O. variabilis*, *Sarotherodon galilaeus*, *Tilapia zillii*	Lake Victoria, Uganda	Paperna (1973a)
Myxobolus kainjiae	*Haplochromis angustifrons*, *H. elegans*	Lake George, Uganda	Paperna (1973a)
Myxobolus stenosus	*Synodontis schall*	Lake Victoria, Uganda	Paperna (1973a)
Plistophora sp.	*Haplochromis angustifrons, H. elegans*	Lake George, Uganda	Paperna (1996)
Sphaerospora sp.	*Oreochromis niloticus*	Fish ponds and reservoirs, Uganda and Kenya	Florio et al. (2009)
Trichodina spp.	*Clarias gariepinus*, *Oreochromis niloticus*	Fish ponds and reservoirs, Uganda; reservoirs and Sagana fish farm, Kenya	Akoll et al. (2012), Florio et al. (2009)
	Oncorhyncus mykiss	Trout farm, slopes of Mount Kenya	Ogara et al. (1998)
Trichodinella spp.	*Clarias gariepinus*, *Oreochromis niloticus*	Reservoirs, Uganda and Kenya	Florio et al. (2009)
Trypanosoma mariae	*Astatoreochromis alluaudi*, *Labeo victorianus*, *Oreochromis esculentus*, *O. niloticus*, *O. variabilis*	Lakes George and Victoria, Uganda	Baker (1960)
Trypanosoma mukasai	*Astatoreochromis alluaudi*, *Bagrus docmac*, *Mormyrus kannume*, *Oreochromis esculentus*, *O. niloticus*, *O. variabilis*, *Haplochromis* sp.	Lakes George and Victoria, Uganda	Baker (1960)
MONOGENEA			
Ancyrocephalus synodontii	*Synodontis victoriae*	Uganda	Khalil (1971)
Annulotrema elongata	*Alestes baremoze*	Uganda	Khalil (1971)
Annulotrema gravis	*Brycinus nurse*	Uganda	Khalil (1971)
Characidotrema elongata	*Brycinus nurse*	Uganda	Khalil (1971)
Cichlidogyrus arthracanthus	*Tilapia zillii*	Uganda	Khalil (1971), Pariselle and Euzet (2009)
Cichlidogyrus dionchus	*Haplochromis guiarti*	Lake Victoria, Uganda	Pariselle and Euzet 2009

Table 1: (cont.)

Parasite	Host	Location/country	Reference
Cichlidogyrus halli	*Oreochromis leucostictus*, *O. niloticus*, *Sarotherodon galilaeus*	Lakes George and Albert and Kajjansi fish farm, Uganda	Pariselle and Euzet (2009)
Cichlidogyrus haplochromii	*Haplochromis* spp., *Oreochromis leucostictus*, *Tilapia* sp.	Lakes Albert, Victoria, George, Nabugabo, Bunyoni and Mulehe, Uganda; Ruaha River, Tanzania	Pariselle and Euzet (2009)
Cichlidogyrus longipenis	*Astatoreochromis alluaudi*	Lake Victoria, Uganda	Pariselle and Euzet (2009)
Cichlidogyrus sclerosus	*Oreochromis niloticus*	Kajjansi fish ponds, reservoirs, Uganda; reservoirs and Sagana fish farm, Kenya	Akoll et al. (2012), Florio et al. (2009)
	Haplochromis sp.,*Oreochromis leucostictus*, *O. mossambicus*, *O. niloticus*, *Tilapia zillii*	Lakes George and Victoria, Kajjansi fish ponds, Uganda	Pariselle and Euzet (2009)
Cichlidogyrus thurstonae	*Oreochromis esculentus*, *O. niloticus*, *O. variabilis*, *Haplochromis longirostris*	Uganda	Pariselle and Euzet (2009)
Cichlidogyrus tiberianus	*Tilapia rendalli*, *T. zillii*	Uganda	Pariselle and Euzet (2009)
Cichlidogyrus tilapiae	*Oreochromis niloticus*	Kajjansi fish ponds, reservoirs, Uganda; reservoirs, Sagana fish farm, Kenya	Akoll et al. (2012), Florio et al. (2009)
	Haplochromis macrognathus, *Oreochromis leucostictus*, *O. mossambicus*, *O. niloticus*, *Tilapia zillii*	Lakes George and Victoria, Kajjansi fish farm, Uganda	Pariselle and Euzet (2009)
Diplectanum lacustris	*Lates niloticus*	Lake Albert, Uganda	Thurston and Paperna (1969)
	Lates niloticus	Uganda	Khalil (1971)
Enterogyrus hemihaplochromii	*Pseudocrenilabrus multicolor*	East Africa (no specific locality)	Pariselle and Euzet (2009)
Gyrodactylus sp.	*Tilapia* sp.	Intensive fish farm, Kenya	Paperna (1996)
	Clarias alluaudi, *C. gariepinus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Macrogyrodactylus congolensis	*Clarias gariepinus*	Fish farms in Uganda	Akoll et al. (2012)
Neodactylogrus spinicirrus	*Barbus altinalis*	Uganda	Khalil (1971)
Neodiplozoon polycotyleus	*Barbus neumayeri*	Intermittent stream in Kibale Forest, Uganda	Chapman et al. (2000)
Quadriacanthus clariadis	*Bagrus docmac*, *Clarias gariepinus*	Uganda	Khalil (1971)
Schilbetrema acornis	*Schilbe mystus*	Uganda	Khalil (1971)
Schilbetrema quadricornis schilbe	*Schilbe mystus*	Uganda	Khalil (1971)
Scutogyrus gravivaginus	*Oreochromis leucostictus*, *O. variabilis*	Lakes Victoria and Albert, Uganda	Pariselle and Euzet (2009)
Scutogyrus longicornis	*Oreochromis niloticus*, *Sarotherodon galilaeus*, *Tilapia zillii*	Lakes George and Albert, Uganda	Pariselle and Euzet (2009)
DIGENEA			
Allocredium mazoensis	*Bagrus docmac, Clarias alluaudi*, *C. gariepinus*, *C. liocephalus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Astiotrema reniferum	*Clarias gariepinus*, *C. liocephalus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Astiotrema sp.	*Clarias gariepinus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Bolbophorus sp.	*Oreochromis niloticus*	Reservoirs and fish ponds, Lake Victoria, Uganda	Akoll et al. (2012), Paperna (1996)
Cladocystis tanganyikae	Unidentified cichlid	Lake Tanganyika, Tanzania	Khalil (1971)
Clinostomum cutaneum	*Oreochromis niloticus*	Reservoirs and fish ponds, Uganda; reservoirs and Sagana fish farm, Kenya	Akoll et al. (2012), Florio et al. (2009), Gustinelli et al. (2010)
Clinostomum phalacrocoracis	*Oreochromis niloticus*	Reservoirs in Uganda and Kenya; Sagana fish farm, Kenya	Florio et al. (2009)
Clinostomum sp.	*Clarias alluaudi*, *C. gariepinus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Diplostomum mashonense	*Clarias gariepinus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)

Table 1: (cont.)

Parasite	Host	Location/country	Reference
Euclinostomum heterostomum	*Oreochromis niloticus*	Reservoirs in Uganda and Kenya; Sagana fish farm, Kenya	Florio et al. (2009)
	Clarias liocephalus	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Eumasenia bangweulensis	*Bagrus docmac*, *Clarias alluaudi*, *C. gariepinus*, *C. liocephalus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Heterochis crumenifer (syn. *Distoma protopterii*)	*Protopterus aethiopicus*	Uganda	Khalil (1971)
Neascus sp.	*Oreochromis niloticus*	Lake Victoria	Paperna (1996)
Ornithodiplostomum sp.	*Clarias gariepinus*	Fish ponds, Uganda	Akoll et al. (2012)
Phyllodistomum folium	*Bagrus docmac*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Tylodelphys spp.	*Clarias gariepinus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Zoogonoides sp.	*Clarias gariepinus*	Fish ponds, Uganda	Akoll et al. (2012)
CESTODA			
Amirthalingamia macracantha	*Oreochromis niloticus*	Reservoirs and fish ponds in Uganda and Kenya	Akoll et al. (2012), Florio et al. (2009)
	Tilapia zillii	Lake Naivasha, Kenya	Aloo (2002)
Amphilinidae	*Clarias gariepinus*	Fish ponds, Uganda	Akoll et al. (2012)
Caryophyllaeus leticeps	*Barbus tropidolepis*	Tanzania	Khalil (1971)
Ligula intestinalis	*Barbus* spp., *Haplochromis* spp., *Rastrineobola argentea*	Lake Victoria, Uganda and Kenya	Paperna (1996)
Lytocestoides tangayikae	*Alestes* sp.	Tanzania	Khalil (1971)
Marsypocephalus tanganyikae	*Clarias lazera*	Tanzania	Khalil (1971)
Monobothrioides cunningtoni	*Auchenoglanis occidentalis*	Tanzania	Khalil (1971)
Monobothrioides woodlandi	*Clarias gariepinus*, *C. liocephalus*, *C. werneri*,	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Monobothrioides sp.	*Clarias gariepinus*	Fish ponds, Uganda	Akoll et al. (2012)
Polyonchobothrium clarias	*Clarias gariepinus*, *C. liocephalus*, *C. mossambicus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Proteocephalus beauchampi	*Chrysichthys brachynema*	Tanzania and Burundi	Khalil (1971)
Proteocephalus cunningtoni	*Dinotopterus cunningtoni*	Tanzania	Khalil (1971)
Proteocephalus dinotopteri	*Dinotopterus cunningtoni*	Tanzania	Khalil (1971)
Proteocephalus sp.	*Clarias gariepinus*, *Heterobranchus longifilis*	Lake Victoria and Malagarasi River, Tanzania	Mwita and Nkwengulila (2008)
NEMATODA			
Afrophilometra hydrocyoni	*Hydrocynus forskahlii*	Lake Turkana, Kenya	Moravec et al. (2009b)
Camallanus kirandensis	*Barbus* sp.	Tanzania	Khalil (1971)
Comephoronema sp.	*Clarias liocephalus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Contracaecum larvae	*Tilapia leucostictus*	Lake Naivasha, Kenya	Paperna (1996)
	Oreochromis niloticus	Lake Baringo, Kenya; Lake George, Uganda	Paperna (1996)
	Alcolapia grahami	Lake Magadi, Kenya	Paperna (1996)
	Oreochromis leucostictus	Lake Naivasha, Kenya	Aloo (2002)
	Clarias alluaudi, *C. gariepinus*, *C. liocephalus*, *C. werneri*, *Heterobranchus longifilis*	Lake Victoria and Malagarasi swamp, Tanzania	Mwita and Nkwengulila (2008)
	Clarias gariepinus	Fish ponds, Uganda	Akoll et al. (2012)
Dujardinascaris helicina	*Lates microlepis*	Tanzania	Khalil (1971)
Eustrongylides sp.	*Dinotopterus cunningtoni*, *Oreochromis niloticus*	Tanzania	Khalil (1971)
	Bagrus docmac	Lake Victoria, Uganda	Mbahinzireki (1980)
	Haplochromis spp.	Lake Victoria, Uganda	Paperna (1996)
	Clarias gariepinus	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Gendria tilapiae	*Clarias gariepinus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Mexiconema africanum	*Auchenoglanis occidentalis*	Lake Turkana, Kenya	Moravec et al. (2009a)
Neogoezia sp.	*Clarias alluaudi*, *C. liocephalus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Paracamallanus cyathopharynx	*Clarias alluaudi*, *C. gariepinus*, *C. liocephalus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)

Table 1: (cont.)

Parasite	Host	Location/country	Reference
Philometra bagri	*Bagrus bayad*	Lake Turkana, Kenya	Moravec et al. (2009b)
Philometra lati	*Lates niloticus*	Lake Turkana, Kenya	Moravec et al. (2009b)
Philometra spiriformis	*Lates niloticus*	Lake Turkana, Kenya	Moravec et al. (2009b)
Procamallanus laevionchus	*Clarias alluaudi*, *C. gariepinus*, *C. liocephalus*, *C. werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Procamallanus sp.	*Clarias gariepinus*, *Oreochromis niloticus*	Fish pond, Uganda	Akoll et al. (2012)
Quimperia sp.	*Bagrus docmac*, *Clarias liocephalus*, *Heterobranchus longifilis*	Lake Victoria and Malagarasi River, Tanzania	Mwita and Nkwengulila (2008)
Rhabdochona congolensis	*Clarias gariepinus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Rhabdochona paski	*Alestes macrophthalmus*	Tanzania	Khalil (1971)
Spinitectus petterae	*Clarias werneri*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
Spinitectus thrustonae	*Mormyrus* sp.	Uganda	Khalil (1971)
Travnema sp.	*Clarias liocephalus*	Lake Victoria, Tanzania	Mwita and Nkwengulila (2008)
ACANTHOCEPHALA			
Acanthogyrus tilapiae	*Oreochromis niloticus*	Reservoirs and fish ponds in Uganda and Kenya	Akoll et al. (2012), Florio et al. (2009)
	Oreochromis niloticus, *Tilapia zillii*	Lake Naivasha, Kenya	Aloo (2002)
Polyacanthorhynchus kenyensis	*Micropterus salmoides*, *Oreochromis niloticus*, *Tilapia zillii*, *Tilapia* sp.	Lake Naivasha, Kenya	Schmidt and Canaris (1967), Aloo and Dezfuli (1997)
CRUSTACEA (Branchiura)			
Argulus africanus	*Bagrus docmac*, *Barbus altianalis*, *Clarias gariepinus*, *Haplochromis* spp.,*Oreochromis esculentus*, *O. variabilis*, *Protopterus aethiopicus*	Lake Victoria, Uganda	Fryer (1962)
Argulus cunningtoni	*Auchenoglanis occidentalis*, *Bagrus bayad*, *Clarias gariepinus,* *Distichodus niloticus*, *Lates niloticus*, *Synodontis schall*	Lake Albert, Uganda	Fryer (1965)
Argulus monodi	*Heterobranchus longifilis*	Malagarasi River, Tanzania	Mwita and Nkwengulila (2008)
Argulus rhipidiophorus	*Clarias gariepinus*	Lakes Turkana (Rudolf) and Naivasha, Kenya	Fryer (1960)
	Oreochromis niloticus	Lake Kivu, Rwanda	Fryer (1965)
	Haplochromis sp., *Oreochromis niloticus*	Lake Edward and Kazinga Channel, Uganda	Fryer (1965)
	Alestes baremoze, *Bagrus bayad*, *Clarias gariepinus*, *Hydrocynus forskahlii*, *H. lineatus*, *Lates niloticus, Synodontis schall*	Lake Albert, Uganda	Fryer (1965)
Chonopeltis brevis	*Barbus altianalis radcliffi, Labeo victorianus*	Lake Victoria, Uganda; River Tana, Kenya; River Mugambuzi, Tanzania	Fryer (1962)
Chonopeltis flaccifrons	*Marcusenius welwerthi*	Malagarasi swamps, Tanzania	Fryer (1960)
Chonopeltis schoutedeni	*Mormyrus* sp.	Malagarasi swamps, Tanzania	Fryer (1960)
Dolops ranarum	*Auchenoglanis occidentalis*, *Bagrus bayad*, *B. docmac*, *Clarias gariepinus*, *Lates niloticus*, *Oreochromis esculentus*, *O. variabilis*	Lake Victoria, Uganda and Tanzania	Mwita and Nkwengulila (2008), Mbahinzireki (1980)
		Lake Albert, Uganda	Fryer (1965)
		Kivirondo Gulf, Lake Victoria, Kenya	Benda (1979)
CRUSTACEA (Copepoda)			
Afrolernaea longicollis	*Mormyrus* sp.	Malagarasi swamps, Tanzania	Fryer (1960)
Ergasilus kandti	*Lates niloticus, Lates* spp.	Lake Albert, Uganda; Lake Tanganyika, Tanzania	Paperna (1996)
Ergasilus lamellifer	*Haplochromis* sp.	Lake Victoria, Uganda	Fryer (1962)
Ergasilus lates	*Oreochromis niloticus*, *Sarotherodon galileus*	Lake Turkana (Rudolf), Kenya	Fryer (1960)
Lamproglena barbicola	*Barbus altianalis radcliffi*	Lake Victoria, Uganda	Fryer (1962)
Lamproglena clariae	*Clarias gariepinus*	Lake Victoria, Uganda	Fryer (1962)
	Heterobranchus longifilis	Malagarasi swamps, Tanzania	Fryer (1962)

Table 1: (cont.)

Parasite	Host	Location/country	Reference
Lamproglena monodi	*Haplochromis* spp., *Oreochromis esculentus*, *O. variabilis*	Lake Victoria, Uganda	Fryer (1962)
	Oreochromis niloticus	Malagarasi swamps, Tanzania; Lake Albert, Uganda	Fryer (1965)
Lernaea barnimiana	*Lates niloticus*	Lake George, Uganda	Thurston (1969)
	Barbus altianalis radcliffi, *Labeo victorianus*, *Oreochromis esculentus*, *O. variabilis*	Lake Victoria, Uganda	Fryer (1962)
Lernaea cyprinacea	*Bagrus docmac*, *Oreochromis esculentus*, *O. variabilis*	Lake Victoria, Uganda	Fryer (1962)
Lernaea haplocephala	*Polypterus congicus*	Malagarasi swamps, Tanzania	Fryer (1960)
Lernaea inflata	*Rastrineobola argentea*	Lake Victoria, Uganda	Fryer (1962)
Lernaea longa	*Lates niloticus*	Lake Turkana (Rudolf), Kenya	Fryer (1960)
Opistholernaea laterobrachialis niloticus	*Oreochromis niloticus*	Nile system	Fryer (1965)
Opistholernaea longa	*Lates niloticus*	Nile system	Fryer (1965)
BACTERIA			
Aeromonas caviae	*Oncorhyncus mykiss*	Trout farm, slopes of Mount Kenya	Ogara et al. (1998)
Aeromonas hydrophila	*Oreochromis niloticus*	Fish farm in Mombasa, Kenya	Roberts and Sommerville (1982)
	Oncorhyncus mykiss	Trout farm, slopes of Mount Kenya	Ogara et al. (1998)
Chlamydiales bacteria	*Clarias gariepinus*	Fish farms, Uganda	Akoll (2005)
Edwardsiella tarda	*Oreochromis niloticus*	Fish farm in Mombasa, Kenya	Roberts and Sommerville (1982)
Flavobacterium columnare	*Oreochromis niloticus*	Fish farm, Kenya	Roberts and Sommerville (1982)
Mycobacterium fortuitum	*Oreochromis niloticus*	Fish farm, Kenya	Roberts and Sommerville (1982)
FUNGI			
Aspergillus sp.	*Sarotherodon* spp.	Fish farm in Mombasa, Kenya	Olufemi et al. (1983)
Branchiomyces sp.	*Oreochromis niloticus*	Sagana fish farm, Kenya	Florio et al. (2009)
Saprolegnia sp.	*Oreochromis* spp.	Uganda	Paperna (1996)
VIRUS			
Lymphocystis virus	*Oreochromis amphimelas*, *O. esculentus*	Lake Kitangiri, Tanzania	Paperna (1973b)
	Haplochromis sp., *Oreochromis variabilis*	Lake Victoria, Uganda	Paperna (1973b)
	Haplochromis sp., *H. elegans*, *Oreochromis variabilis*	Lake George, Uganda	Paperna (1973b)

absence of outbreak reports owing to poor record keeping in the subsistence aquaculture practised and to the socio-economic setting within the EAC.

Fish disease management and institutional capacity

A review of the existing statutory and policy instruments for the management and development of fisheries and aquaculture in the five countries showed limited coverage for fish health management. The legal provisions for controlling fish diseases lack management provisions for their practical control and management.

Simple disease outbreaks are managed locally by farmers. Unlike in grow-out systems, disinfection of farm equipment and culture facilities are routinely included in fish health management schemes in hatcheries. The choice of management options and the application of drugs are based on the farmers' knowledge and experience. Therefore, in most cases the application of drugs and chemicals is done without identification of the etiological agent. Frequently, formalin, potassium permanganate and copper sulphate are used for suspected ectoparasites and fungi infections, and oxytetracycline for apparent bacterial infections. Since most infections exhibit similar gross manifestation, there is a high potential for administering the incorrect treatment. The indiscriminate use of chemicals and drugs is likely to result in residue problems and the development of drug resistance among pathogens (Samuelsen et al. 1992, Dixon 1994, Serrano 2005, Sapkota et al. 2008, Defoirdt et al. 2011). In addition, most chemicals and drugs used are not officially approved, and no legislation spells out the prohibition of specific chemicals, except for that in Burundi. Lack of legislation on drug and chemical use in most countries can be related to the developmental stage and small size of the aquaculture sector, which does not necessitate the establishment of the required controls and measures, as well as to the need for approval of chemicals. In addition, national records show that there is limited use of quarantine facilities and the risk analysis process is rarely conducted regarding the trade in live aquatic animals and the introduction of new species for farming. The continuation of these practices may result in the rapid spread of disease pathogens within and between countries (Subasinghe et al. 2001, Bondad-Reantaso 2004). These may lead to a challenging aquatic animal disease situation in East African aquaculture, particularly where disease prevention is difficult.

With regard to institutional capacity, there are no specialised fish diagnostic laboratories in the five countries recognised by the Organisation of World Animal Health (known by its French name *Office International des Epizooties* — OIE). In the event of a disease outbreak, diagnoses are performed at those universities and public research organisations that conduct research on fisheries. However, these organisations were found to be largely academic in approach and their results may not be legally admissible because of the differences in laboratory management practices for academic and purely management-focused laboratories. In Tanzania, such centres for fish disease diagnosis include the University of Dar es Salaam (USDM), Sokoine University of Agriculture (SUA), and institutions such as Tanzania Fisheries Research Institute (TAFIRI), the National Institute for Medical Research (NIMR), National Fisheries Training Institutes (NFTI), and the National Fish Quality Laboratory. In Uganda, Makerere University, particularly the Department of Biological Sciences and the Faculty of Veterinary Medicine, and Kajjansi Aquaculture Research and Development Centre of the National Fisheries Resources Research Institute (NaFIRRI) under National Agriculture Research Organisation (NARO), are involved in fish health management and research. Kenya has several universities, including Moi, Kenyatta, Egerton and Maseno, as well as the Kenya Marine and Fisheries Research Institute, that offer some fish disease diagnoses. In Rwanda, the organisations with some capability for fish disease diagnosis include the National University of Rwanda and the designated fish stations in Rwanda, such as the National Fisheries Training Centre at Kigembe and the Rwasave Demonstration station at Butare. Nonetheless, these centres are currently not involved in fish health management. In Burundi, the centres with capacity for fish disease diagnosis include the University of Burundi and Kazuri Fish Centre. However, these centres have inadequate infrastructure and capacity to handle all fish diseases. Although efforts are being made in the region to train specialised staff in fish health, the rate of retaining those personnel is low (FAO 2009b).

Policy and regulatory frameworks related to fish health

Almost all East African countries have developed fisheries policies and a legal system for the management and development of both capture fisheries and aquaculture. In Burundi, the Bill on health policy of pets, wild and aquaculture animals and bees, Law No. 1/28 of 24 December 2009, stipulates that fish diseases, including yersiniosis, herpes virus infections, corynebacteriosis and *Pseudomonas* infections, should be monitored and defines their diagnostic procedures and management options. This is the only Act in East Africa that provides a list of diseases listed by OIE for monitoring within a country and comprehensive control and prevention strategies.

In Kenya, the fishery resources are managed by the Department of Fisheries through the Fisheries Act and Maritime Act (Cap 378 and Cap 250 of the Laws of Kenya, respectively). Kenya also has a fisheries policy to guide the sustainable development and management of the fishery sector including aquaculture. The policy objectives are pursued through the implementation of 10 broad policies, of which four statements (2.1, 2.4, 2.6 and 2.7) are of importance to aquatic animal health management. However, these statements neither provide a comprehensive list of pathogens for consideration nor a disease management plan. Statement 2.1 requires that fisheries activities provide for environmental integrity, but there is no mention of specific pathogens for control through fish introductions. Statement 2.6 empowers the ministry to establish an accredited laboratory system for the fisheries sector.

The Fisheries Act 1989 (Cap 378, revised 1991) and Maritime Act (Cap 250) empower the Director of Fisheries to make and issue regulations to promote the development of fisheries and aquaculture and to ensure the proper management of fisheries. The law further empowers fisheries authorities to prevent and control fish introductions and restrict the cross-border importation of live fish, as well as permitting the authorities to destroy infected fish under Article 57. The law does not, however, specify the pathogens requiring monitoring.

Since 2001, the Republic of Rwanda has embarked on a major legal reform to repeal obsolete laws and update others so as to make existing laws consistent with the new Constitution (Mugisha 2009). This included the review and updating of the fisheries legislation in 2008 (Rutaisire 2011). However, even in the new legislation there were limited provisions for fish health management, probably due to the insignificant contribution of fisheries to the national economy.

In Tanzania, the National Fisheries Policy is guided by the Fisheries Act 2003. Policy Statement No. 11 focuses on fish health and mandates the ministry together with relevant stakeholders to establish a code of conduct for aquaculture and to provide guidelines to address issues such as site selection, construction, suitable species, water abstraction, spread of disease and effluent control. This should ensure effective management practices that favour hygienic measures and implementation strategies that comprehensively address fish health issues. The statement also provides for the undertaking of appropriate environmental assessment and monitoring to minimise adverse ecological changes related to the discharge of effluent, use of drugs and chemicals and other aquaculture activities, as well as ensuring safe, effective and minimum use of therapeutants and drugs, antibiotics and other chemicals used to control diseases.

The Tanzania Fisheries Act (2003) empowers the Director to issue and monitor implementation/enforcement of fisheries regulations. Articles 13, 15 and 25 of the Act are pertinent to fish health management. The articles put restrictions on the movement of eggs, fingerlings, seed, exotic adult fish, genetically modified species and genetic materials from one water body to another, the importation of fish and fishery products, and the introduction of exotic species, unless permission is granted by an authorised officer. The Act also empowers local authorities, among others, to monitor and control fish disease and, in the case of a disease outbreak, to destroy the fish stocks. Further, the Act requires the authorities to guarantee hygienic conditions including making sure that there are no pathogens within the fish and fishery products. Generally, the Tanzanian laws and regulations have attempted to address fish health management. However, implementation or enforcement of, and adherence to, the rules remain problematic, as the range of diseases for monitoring is not indicated and there is no contingency plan provided in the policy and the Act.

Uganda has a national fisheries policy which sought to support the fisheries sector to achieve sustainable exploitation of the fishery resources without degrading the environment. The policy does not, however, provide strategies for fish health management. The Uganda Crocodile and Fish Act (1964) was revised and renamed as the Fish Act (Cap 197) in 2000, and provides rules and regulations for the control of fishing, conservation and other transactions in the fishing industry. Article 12 of this Act prohibits introductions or transfers of fish and their eggs, except with written permission from the 'Chief Fisheries Officer', in an attempt to prevent the spread of fish disease or pathogens, including parasites. Other laws relevant to aquatic animal health available in Uganda include the Animal Disease Act (1964) of Uganda, but this law requires modification to accommodate aquatic animals.

Importance of different pathogens in East Africa

In relation to aquaculture, the potential importance of each parasite group will be discussed.

Protozoa

Protozoans are ubiquitous in fish. Highly pathogenic protozoa reported in or on fish belong to three main phyla: Myxosporea, Sarcomastigophora and Ciliophora, especially trichodinids, *Chilodonella*, *Tetrahymena*, *Ichthyophthirius* and several Sessilina species (Lom and Dykova 1992, Lio-Po and Lim 2002). Protozoan infections are usually aggravated by environmental deterioration and crowding of the hosts (Lom and Dykova 1992, Paperna 1996). Although significant outbreaks have not been reported in East Africa, myxosporeans are prevalent, with *Myxobolus* infections in *Oreochromis* species reaching 100%, and 25% in *Haplochromis* spp. (Paperna 1996). There is limited knowledge on the pathology of protozoans, with the exception of *Myxobolus kainjiae* infecting *Haplochromis angustifrons* and *H. elegans* in Lake George, which appeared to have potential for destroying the gonads (Paperna 1973a). Ciliates are a major problem in hatcheries and sometimes in fish grow-out systems (Lom and Dykova 1992, Lio-Po and Lim 2002). Reports from the region indicate high prevalence of ciliates in various aquaculture systems (Florio et al. 2009, Akoll et al. 2012). The shift from subsistence to commercial aquaculture in East Africa may promote protozoan infections due to crowding of fish and other aquatic animals.

Monogeneans

Monogenean trematodes are common parasites of fish. Although some monogeneans are endoparasites, most are ectoparasitic on the gills, buccal cavity, body surface and fins (Pariselle and Euzet 2009). These parasites proliferate rapidly in a short time under the crowded and stressful conditions common in culture facilities because of their short generation time and a life cycle requiring only one host. Thus monogeneans pose a great threat to fish culture (Nowak 2004, Mansell et al. 2005, Hutson et al. 2007). In wild hosts, these parasites rarely cause significant impact because they usually occur in low numbers on fish (Ogawa 2002). Fish infected with monogeneans are also highly susceptible to bacterial and fungal secondary infections (Xu et al. 2007). In East Africa, monogenetic species belonging to *Cichlidogyrus* in cichlids and *Gyrodactylus* and *Macrogyrodactylus* in catfish are prevalent (Paperna 1996, Florio et al. 2009, Akoll et al. in press). Members of *Cichlidogyrus* and *Gyrodactylus* are very pathogenic and responsible for massive mortalities in fish (Kabata 1985, Cone 1995, Akoll 2005).

Digeneans

The most abundant digeneans in the region are the diplostomids and clinostomatids (Florio et al. 2009, Akoll et al. 2012). In the eyes, *Tylodelphys* spp. and *Apharyngostrigea* spp. have been isolated from the vitreous humour. In the skin, metacercariae associated with 'black spots' and yellow grubs have been recorded in several fish species in East African waters (Table 1). Three species of clinostomatids, *Clinostomum cutaneum, C. phalacrocoracis* and *Euclinostomum heterostomum*, have been reported in cichlids and silurids in the region. Generally, the clinical effects of digenean infections are not obvious. The pathological alterations are in most cases localised to the infected area. However, a high number of parasites may cause body deformities (Paperna 1996), intensive inflammation and mortalities (Hoffman and Hutcheson 1970, Mitchell et al. 1982), cataracts and blindness (Seppälä et al. 2005a). Such severe infections, especially cysts on the opercula and gill-associated cysts, may reduce foraging ability of the fish, which may result in stunting and weight loss (Karvonen and Seppälä 2008). The metacercariae, forming coloured cysts on the skin and infecting the eyes, predispose fish to predators by increasing visibility and altering their cryptic behaviour (Seppälä et al. 2005a, 2005b). Overall, the threats associated with digenetic trematodes to aquaculture range from low to moderate (Hutson et al. 2007). With regard to economic and public health concerns, heavily infected fish, particularly those with cutaneous infections, may be rejected by consumers (Kabunda and Sommerville 1984). Digenetic trematodes also have zoonotic potential. Although no records are available in East Africa, there are reports of clinostomatids infecting humans (Chung et al. 1995, Kakizoe et al. 2004, Park et al. 2009) and human *Heterophyes*, *Opisthorchis* and *Haplorchis* infections (Ko 1995, Chai et al. 2005).

Cestodes

Of the 10 orders, six consist of the most prevalent species infecting fishes (Benz et al. 2002). These include Caryophyllidea occurring mainly in freshwater siluriforms and cypriniforms and Spathebothridea infesting freshwater teleosts. Pseudophyllidea infest a variety of marine and freshwater teleosts, Proteocephalidea are commonly found in salmonids while Tetraphyllidea and Trypanorhyncha occur mainly in elasmobranchs. Generally, fish mortalities attributed to cestode infestations are rare (Dick and Choudhury 1995a, Loot et al. 2002, Shields et al. 2002). Nonetheless, haemorrhage, necrosis, fibrosis, oedema, abdominal distension and reduced reproductive capacity are associated with plerocercoids (Dick and Choudhury 1995a, Loot et al. 2002, Shields et al. 2002, Molnár 2005). In East Africa, histopathology examination of two cestodes, *Amirthalingamia macracantha* in *O. niloticus* (Florio et al. 2009) and *Polyonchobothrium clarias* in *Clarias gariepinus* (Wabuke-Bunoti 1980), revealed fibrosis, haemorrhage, pronounced nodules, inflammation, infiltration of the fibroblasts and lymphocytes as well as cellular exfoliation due to mechanical erosion and hypertrophy. *Ligula intestinalis* significantly reduced the reproductive capacity of *Rastrineobola argentea* in Lake Victoria (Cowx et al. 2008). Although heavy infestations are possible, with devastating effects (Dick and Choudhury 1995a), the complex life cycle requiring two or three hosts to complete, may lower the rate of accumulation of cestodes in the host. Good farm husbandry, especially limiting bird access to culture facilities, is essential in preventing infections. Although the adverse effects on the host may be minimal, fish rejections by consumers are possible due to heavy plerocercoids infestations in muscles (Dick and Choudhury 1995a). Some cestodes such as *Diphyllobothrium* sp. are zoonotic (Ko 1995, Scholz et al. 2009), although there are no records available in East Africa.

Nematodes

Adult nematodes occur mainly in fish intestines, while larval stages occur in the viscera, muscles and other organs, especially the swim bladder. Generally, adult parasites cause low pathology (Dick and Choudhury 1995b). Larval nematodes, particularly migratory species like *Anisakis*, *Contracaecum*, *Eustronglides*, *Philometra* and *Philenoma* can inflict severe pathology on the host (Dick and Choudhury 1995b, Noga 2000). Nematodes with a direct life cycle, such as *Capillaria* or live-bearing species like *Camallanus* and *Philometra*, can lead to proliferation of infective stages in the fish culture systems. The mortalities reported in tilapia hybrids caused by *Contracaecum* sp. in East Africa (Paperna 1991) highlight the importance of this nematode species in the fisheries sector. Haemorrhage, inflammation due to cysts, attachment or migration through tissues, granuloma and fibrosis are the major consequences of infections (Dick and Choudhury 1995b). Although little is known about the pathogenicity of the nematode species reported in East Africa (Table 1), reports on related species such as *Camallanus oxycephulus* and *Philometra cephalus* suggest that their occurrence may impact negatively on intensive fish culture (Molnár et al. 1991, Dick and Choudhury 1995b). Therefore management options, especially for commercial production systems, must also focus on the control of nematodes. With regard to public health, nematodes, especially *Contracaecum* sp., pose a serious threat to humans (Ko 1995) and may cause significant economic loss to fish farming due to consumer rejection (Dick and Choudhury 1995b, Paperna 1996).

Acanthocephalans

Acanthocephalans have variable pathogenicity, with localised tissue reactions, characterised by strong reddening at the site of parasite attachment, being most common. Histologically, focal inflammation and necrosis, fibrosis, infiltration of macrophages and other phagocytic cells are frequently reported pathological changes (Taraschewski 1988, Paperna 1996, Florio et al. 2009, Sanil et al. 2011). Occasionally, there is gut obstruction, though with limited pathology (Amin and Heckmann 1992). A few studies have reported severe hyperplasia and hypertrophy as well as inflammatory reaction at the submucosa, oedema and infiltration of macrophages into inflamed areas (Martins et al. 2001). Generally, host mortalities associated with acanthocephalan infections are uncommon (Nickol 1995). Pathogen risk assessments revealed that acanthocephalans pose negligible to very low threats to aquaculture (Hutson et al. 2007). However, high stocking density of fish may increase stress among cultured fish and this may increase fish susceptibility to parasite infestations. Hence, control mechanisms focusing on reducing stress factors should be put in place.

Crustaceans

Several crustaceans are parasitic to fish and have caused losses in wild fish and aquaculture hosts (Pike 1989, Lester and Roubal 1995, Molnár and Székely 2004, Taylor et al. 2006). Most commonly reported and important species infesting freshwater fishes belong to the Copepoda, e.g. Ergasilidae, Lernaea, Caligidae, Lamproglena and Branchiura, especially *Argulus*, *Chonopeltis* and *Dolops* (Lester and Roubal 1995). Representative species of these families, except Caligidae, occur in East Africa (Table 1). The widely distributed fish parasitic crustaceans in Africa belong to the genus *Lamproglena* (Fryer 1962). However, the impact of these parasites on the host species remain poorly known, due to limited knowledge about the pathogens. Nonetheless, crustaceans are known to induce mortalities (Lester and Roubal 1995) and increase susceptibility of infected hosts to secondary infections (Bandilla et al. 2006). A report of higher infection levels in lakes than streams (Fryer 1962) highlights the potential for the high intensities in culture systems with intermittent water flow, particularly, when fish are stressed due to crowding of fish and water deterioration.

Bacteria

The major bacterial infections among tropical fish are caused by species of *Aeromonas*, *Pseudomonas*, *Edwardsiella*, *Flavobacterium*, *Mycobacterium* and *Streptococcus* (Lio-Po and Lim 2002). Among the most important bacterial diseases in tropical fish culture systems are haemorrhagic septicaemia caused by *Aeromonas* sp. (Cipriano 2001), edwardsiellosis associated with *Edwardsiella tarda* (Meyer and Bullock 1973, Francis-Floyd et al. 1993, Sahoo et al. 2000, Mohanty and Sahoo 2007) and columnaris disease caused by *Flavobacterium columnare* (Durborow et al. 1998). A number of virulent bacteria, including *Streptococcus iniae* associated with significant mortalities of cultured tilapia (Shoemaker and Klesius 1997) and epitheliocystis in *Clarias gariepinus* caused by Chlamydiales bacteria (Meijer et al. 2006), have been reported in East Africa. Although ubiquitous in water, most bacteria are merely opportunistic pathogens. Therefore, the onset and severity of bacterial infections are primarily triggered by environmental stressors such as high temperature, low dissolved oxygen, high ammonia concentration, etc. (Plumb et al. 1976, Walters and Plumb, 1980) and heavy parasite infections (Xu et al. 2007). Therefore, as a result of transformation of small-scale aquaculture into commercial production ventures, bacterial infections may increase, concomitant with the frequency and intensity of environmental deterioration and parasite infections. However, there is little information regarding the occurrence, distribution, pathology and epidemiology of bacterial diseases in the region.

Fungi

Fungal diseases are caused by members of the family Saprolegniaceae in the class Oomycetes, (Khoo 2000). The species of this family belong to seven genera, i.e. *Saprolegnia*, *Achyla*, *Aphanomyces*, *Leptolegnia*, *Dictyuchus*, *Tsoachyla* and *Branchiomyces*. Global records indicate that *Saprolegnia*, *Achyla*, *Aphanomyces* and *Branchiomyces* are the most pathogenic species (Khoo 2000). Occasionally, members of *Ichthyophonus* belonging to the class Zygomycetes (Wolf and Smith 1999) and *Aspergillus* in the class Hypomycetes (Olufemi et al. 1983) are associated with fish diseases. In East Africa, *Saprolegnia* and *Branchiomyces* (Table 1) remain a challenge, especially in hatcheries (Paperna 1996) and newly stocked fish production systems (Florio et al. 2009). The recent outbreak of epizootic ulcerative syndrome (EUS) caused by *Aphanomyces invadans* in the Zambezi–Chobe river basin, killing a wide range of fish species (FAO 2009a), highlights the importance of this fungal disease. Although some species are primary pathogens, most fungi are opportunists (Khoo 2000). The infections are common in stressed or immuno-compromised hosts caused by unfavourable environmental conditions, injury and excessive handling, or they are secondary to bacterial or viral infections.

Viruses

Viral infections are difficult to control, and thus prevention is recommended. Although older fish may develop resistance to infections, viruses cause significant losses in the fisheries sector, especially in fry and fingerlings (Lio-Po and Lim 2002). Among the OIE-listed fish diseases, seven out of nine conditions are caused by viruses. In East Africa, lymphocystis caused by iridovirus is the only viral infection reported in tilapiines (Paperna 1973b). The paucity of viral infection records in the region could be related to the limited diagnostic infrastructure in region and the lack of accessories such as cell lines and electron microscopes in the existing facilities. The risk factors that may facilitate the development of viral diseases include handling stress, poor water quality, and rapid fluctuation of water temperature, high stocking density and poor nutrition. These conditions may prevail in intensive aquaculture systems, which are usually densely stocked with fish.

Future research and management

Although the list of pathogens so far recorded provides insight into their occurrence in the EAC, and can aid the drafting of management schemes for intensive systems, up-to-date surveys are required. In order to develop comprehensive aquatic health management frameworks, detailed research into the ecological and epidemiological aspects of these pathogens is necessary. Continuous monitoring of these pathogens is also required, to assist in the detection of new/introduced parasites. Institutional infrastructure and human capacity enhancement in fish disease diagnosis must be undertaken, and these can be done at sub-regional level to cut down on management costs. Policies and laws in most countries provide only the precautionary measures for disease prevention and control. The gaps in the respective countries' legislation and policies highlight the weak institutional and policy frameworks for the management of fish disease. Most importantly, all countries, with the exception of Burundi, neither provide a list of pathogens for monitoring nor a comprehensive disease management plan. However, this may have been due to the lack of information about the pathogens and limited reports on disease outbreaks and their significance at farm, country or ecosystem levels. Therefore, unless governments are informed about the implications of fish diseases for the development of the fisheries and aquaculture sectors, having limited and increasingly less support for fish health management creates a potentially dangerous situation which can result in massive fish mortalities. Besides, under the umbrella of the EAC, stakeholders should emphasise forming a regional forum to design fish health management strategies that must lead into establishing of a regional aquatic biosecurity strategy and management framework. Initiatives to establish and support national and regional centres for networking expertise, resources and information, as well as the designing of a common regional reporting system for fish diseases, akin to that of the Network of Aquaculture Centres in Asia-Pacific (NACA), are essential for sustainable aquaculture development in East Africa.

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