

1 Aquatic biota is not exempt from Coronavirus infections: An overview

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6

7 Abstract

8 Coronaviruses are pathogens recognized for having an animal origin and commonly associated with terrestrial
9 environments. However, although in few cases, there are reports of their presence in aquatic organisms like fish,
10 crustaceans, waterfowls and marine mammals. None of these cases have even led to human health effects, when contact
11 with these infected organisms, whether they are alive or dead. Aquatic birds seem to be the main group in carrying and
12 circulating these types of viruses in healthy bird populations and play an important role in these environments.
13 Although the route of infection for CoVID-19 (Coronavirus disease 2019) by water or aquatic organisms, has not yet
14 been observed in the wild, the relevance of its study is highlighted, because there are cases of other viral infections
15 (no coronavirus), which are known to have been transferred to the human by aquatic biota. What is even better, it
16 becomes encouraging to know that aquatic species shows very few cases in fishes, marine mammals, and crustaceans,
17 and some other aquatic animals may also be a possible source of cure or treatment against coronaviruses, as some
18 evidence with algae and marine sponges suggests.

19

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21

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36

37 **1. Introduction**

38 The current Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV-2) or CoVID-19 pandemic, as it is
39 commonly known, brought society's interest in one of the families of high-risk pathological-infectious viruses, known
40 as Coronavirus (CoVs)[1]. The impact that the CoVID-19 has had on human dynamics is undoubtedly enormous. The
41 mortality and public health impacts caused by CoVID-19, caught the attention of scientists to try to slow down its
42 effects and look for a vaccine. This virus is already present in every continent, and as previous events with other viruses
43 such as SARS or HIV (Human Immunodeficiency Virus), humans will have to learn how to live with it. However, this
44 situation also makes us wonder about what other organisms may be subject to coronavirus infection? Which organisms
45 can be vectors or reservoirs? That is that they may have the virus in their body, transport it and spread it in other areas
46 or to other organisms, without suffering the symptoms of the infection. Moreover, can the coronavirus infect and affect
47 aquatic organisms? These questions, indeed some present in the scientific and non-scientific communities may
48 eventually be answered in a particular way over time for SARS-CoV-2. However, at the moment, scientific efforts are
49 focused on the public health aspects at the global level [2,3]. Thanks to previous studies on the subject, we can have
50 access to information that allows us to understand more about the possible scenarios associated with these questions.
51 Moreover, to be able to make more specific approaches to the impact of SARS-CoV-2 on aquatic organisms, based on
52 the general knowledge that is available on coronaviruses.

53

54 **1.2 Coronavirus features**

55 CoVs are pathogens associated with epithelial cells infections such as gastrointestinal (gastroenteritis) and respiratory
56 (respiratory infections) [4–6]. Its structure consists of three components: 1) genetic material with which it replicates
57 or reproduces within infected cells, known as RNA (ribonucleic acid of a chain between 26 and 32 kb in length), 2) an
58 external protein that surrounds it known as caps (viral wrap) and 3) a membrane that surrounds and envelops the protein
59 cover, which is covered in turn, with spicules that give the shape of a "crown", from which they are called coronavirus,
60 and that allows them to recognize and come into contact with the membrane of the cell that will infect [7,8]. These
61 spicules are called the "S" protein [7].

62

63 It is recognized that CoVs have its origin in bats, with several varieties or viral species depending on poly-protein or
64 full genome analyses [8,9], which include some of the most toxic and lethal strains of recent decades. CoVs mainly
65 affect terrestrial organisms, such as humans, bats, felines, camels and birds [8,10]; however, their potential to infect
66 the aquatic life has been demonstrated.

67

68 Coronaviruses are part of the Family Coronaviridae of the Order Nidovirals, which in addition to infecting mammals
69 and birds, have also been found in crustaceans, fish and marine mammals [6,8]. Four genera are recognized based on
70 their phylogeny and genomic structure, from the subfamily Orthocoronavirinae, of which *Alphacoronavirus*,

71 *Betacoronavirus*, *Gammacoronavirus* and *Deltacoronavirus* stand out, for their ability to infect humans and non-
72 human respiratory tracts, and other organisms at the digestive level (enteritis) [8]. Within this group of Nidovirals, we
73 find viruses such as the widely known SARS-CoV and MERS-CoV (Middle East Respiratory Syndrome), both
74 belonging to the genus *Betacoronavirus* and subgenus *Sarbecovirus* and *Merbecovirus*, respectively [6,8]. These two
75 types of viruses are recognized as infectious of zoonotic origin, that implies a transmission from an animal, as a result
76 of direct interactions with an animal carrying the infection. The other subfamily within the Coronaviridae is the
77 Torovirinae, formed in turn by two genera, *Torovirus* and *Bafinivirus*, respectively. *Bafinivirus*, in fact, has been
78 identified in a teleost fish [11,12].

79

80 **2. Coronavirus and aquatic environments**

81 Interest in virus transmissions in aquatic media focuses on those with public health relevance, which often enter natural
82 water from treated and untreated wastewater discharges [4,13]. In the 1980s, it was recognized that as far as pathogenic
83 viruses are concerned, more than 100 different types are excreted by man or by animals through their faeces [14]. The
84 stool is one of the main materials for viruses transfer to water bodies. The transfer to the mouth as a result of poor
85 hygiene, or the intake of contaminated water, allows viruses to enter the digestive system, infecting and replicating
86 itself in the gastrointestinal tract, and then being expelled in large numbers again in the faeces produced by infected
87 people or animals [15]. It is estimated that about 10 billion viral particles are present for every gram of excrement [16].
88 Sewages, especially in countries with limited capacities for treatment and adequate sanitization, poses a risk of
89 contamination when discharged or overflowing into the bodies of natural water occurs [16]. Unfortunately, this
90 scenario becomes more complicated considering that also hospital waste, biological-infectious and sanitary waste
91 (intimate towels, mouth covers, gauze, body protectors among others), can eventually reach lakes, lagoons, rivers and
92 seas, due to their mishandling as solid waste, becoming vectors of viruses towards the aquatic environment. Recently,
93 a study has shown the presence of SARS-CoV-2 from the waste discharge activities of infected communities [17]. For
94 CoVs in general, it is reported that they can continue active or infectious for up to several weeks in water, including
95 wastewaters [18]. Thus, viruses can come into contact with free-living aquatic organisms or in aquaculture farms and
96 then be transmitted to humans when they become pets or food, and that, in the near future, it could be the way for new
97 coronavirus outbreaks, which will need to be evaluated particularly for CoVID-19.

98

99 Some CoVs transmitted through contaminated food or water include *Alphacoronaviruses* such as 229E and NL63 or
100 *Betacoronaviruses* such as OC43 and HKU1 (not well-known frequencies) and SARS (with occasional frequencies)
101 [5]. Infections related to contaminated water can have various routes of contagion that may include aspiration,
102 inhalation of aerosol droplets, penetration by the skin or mucous membranes, as well as by intake [19].

103

104 The presence of CoVs in natural waters has been determined with low percentages, compares to another type of viruses;
105 however, they have been detected recently, as is the case of the Ilé river basin in Kazakhstan [20].

106

107

108 **2.1 CoVs and aquatic organisms**

109 Studies focusing on viral infections in aquatic organisms have targeted mainly those species of commercial importance
110 and especially those of aquaculture exploitation [21], or those associated with captivity and tourism industry, such as
111 marine mammals in aquariums and water parks [22].

112
113 Within the CoVs that have been identified in aquatic organisms and also associated to important pathological
114 infections, we find those that affect crustaceans, fish, marine mammals (Table 1) and waterfowl (Table 2 and 3). No
115 mollusc infections by CoVs have been reported so far.

116
117 **2.1.1 Crustaceans**

118 Crustaceans are recognized as a group capable of accumulating in their exoskeleton or body cover human pathogens.
119 However, their role in the transmission of diseases to humans has not been proven [23], perhaps by the culinary habits
120 and customs of removing body covers before ingesting them. In shrimps, the "Yellow head virus" or YHV [24], was
121 reported in 1990 (Table 1) in East and Southeast Asia, affecting *Penaeus monodon* shrimp farmed. There are
122 unconfirmed reports in Mexico for *P. Stylirostris* and *P. vannamei* [24–26]. Genetic studies showed that YHV had
123 undergone significant recombination processes, apparently attributable to international trade with wild and farmed
124 shrimp in the Asia-Pacific region, promoting a faster genetic diversity of the virus, as a result of several recombination
125 events [27].

126
127 **2.1.2 Fishes**

128 In the case of fish, viruses of the *Bafinivirus* group have been reported [6,12,28,29]. There are cases since the late
129 1980s, where CoVs have been identified, particularly in Japan by 1988, in the common carp (*Cyprinus carpio*), widely
130 cultivated and consumed in the world [30,31]. Production involvements reached 70% mortality within 20 days, with
131 pathological damage including renal and hepatic tubular necrosis, as well as damage to renal hematopoietic tissue [28],
132 skin and abdomen bleeding [12]. However, *Bafiniviruses*, together with *Gammacoronaviruses* detected in marine
133 mammals, are usually found mainly in the digestive tract of the host or infected organisms [5]. It is also recognized
134 that the first report of CoVs was in another European cyprinid known as white brema (*Blicca bjoerkna*), which showed
135 a bacilliform structure, related to the viruses of the subfamily Torovirinae, giving rise to a new genus defined as
136 *Bafinivirus* [12]. Most recently this genus has been reported in *Pimephales promelas* or bighead face fish [32,33] and
137 on the salmon *Oncorhynchus tshawytscha* [34], identified as two different types of *Bafinivirus* (Table 1).

138
139 Some Chinese electronic media have stated that CoVID-19 cannot be transmitted through fish, under the argument of
140 the virus's thermo-tolerance and the low body temperature of fish, compared to those of mammals [35]. However, this
141 must be confirmed. Recent and specific tests of SARS-CoV-2 tolerance to thermal gradients have demonstrated
142 tolerance between 4°C and 20°C in the air [36]. This temperature range is below the human body temperature (36.6°C),
143 which are resisted and tolerated by SARS-CoV-2 during human infections. In drinking water, its dispersion seems to
144 decrease at 23°C [37]. In addition, we must recognize that this would have relevant implications for tolerance, if we

145 consider that fish and crustaceans are ectothermic (some fishes can be heterothermic, like tuna), that is, their body
146 temperature is equal to that of the environment around them [38], and fish that have shown the presence of CoVs have
147 a tolerance to a wide range of temperatures, from temperate to warm conditions (like cyprinid fish that lives or
148 reproduces between 17 °C and 30°C [39]), which in the case of the CoVID-19, could allow its incorporation by fish,
149 just considering their body temperature as a limit factor for its infection. On the other hand, Peneid shrimps are tropical
150 (between 24 °C and 32°C [40]), and marine mammals regulate body temperatures in a lower range than humans (29-
151 32°C [41]). Despite this, marine mammals have developed CoVs infections, as can be seen in Table 1. Under this
152 evidence, the body temperature would not be a limiting factor on the possible future infection of SARS-CoV-2 to
153 crustaceans, fish and marine mammals, or at least once they have already entered the body of the organism.

154

155 **2.1.3 Waterfowl.**

156 Of the groups of animals associated with aquatic environments, birds appear to be the group with the higher diversity
157 of CoVs, with at least 96 genetically identified varieties found during this review (Table 2 and 3), within two of the
158 four genera (71 *Gammacoronavirus* and 13 *Deltacoronavirus*, respectively) of the subfamily Orthocoronavirinae [42].
159 Different types of birds, such as gulls (*Larus hyperboreus*; *L. galucesceus*), geese (*Branta bernicla*, *Anser*
160 *caerulescens*), spatulas (*Platalea minor*), herons (*Ardea cinerea*, *Ardeola bacchus*), cormorants (*Phalacrocorax*
161 *carbo*) and ducks (*Anas Americana*, *A. crecca*, *A. clypeata*, *A. penelope*, *A. acuta*, *Dendrocygna javanica*) are
162 confirmed carriers of CoVs. The ducks of the genus *Anas* sp. and *Anser* sp. are the most represented and capable of
163 carrying even strains of SARS-CoV. Particularly noteworthy are *Anas domestica*, *Anas platyrhynchos* and *Anser anser*
164 (Table 2).

165

166 Some birds, such as cormorant and ducks are migratory, and that would allow wide geographical distribution of these
167 types of viruses. Although no reports of human infection originated from waterfowl have been detected, the ecological
168 study of these correlation becomes indispensable, to understand better the relationship of birds and CoVs, and their
169 epidemiology among birds and other species within their ecosystems [42].

170

171 **2.1.4 Marine mammals.**

172 Regarding marine mammals, the first report of CoVs dates back to the 1970s associated with the death of several seals
173 (*Phoca vitulina*) in a Florida aquarium [43] and other free-living pinnipeds off the coast of California [44]. This
174 infection was known as HSCoV (Harbor Seal coronavirus), identified as deadly haemorrhagic pneumonia caused by
175 *Alphacoronavirus* group [44]. Years later, in 2008, the presence of other CoVs was detected in a beluga whale
176 (*Delphinapterus leucas*) under captivity (BWCoV SW1) [9,45]. In 2014, the presence of CoVs was detected in faeces
177 from bottlenose dolphins [9], from the Indo-Pacific (*Tursiops aduncus*), which was called BdCoV HKU22 (Bottlenose
178 dolphin CoV). These latter two were recognized within the *Gammacoronavirus* group, which caused viral bronchitis
179 to those infected animals [9]. The gregarious behavior of several marine mammal species may promote the contagion
180 and dispersal of these types of pathogens in wild populations, so their monitoring becomes essential and necessary for
181 their health and avoid further transmission to others aquatic organisms.

182

183 Gammacoronavirus detected in marine mammals, unlike *Bafinivirus* in fish, can also be found in the respiratory tracts
184 of terrestrial and marine mammals and not only in the digestive tracks [5]. Viruses such as influenza A and B have
185 been reported in mammals such as seals and cetaceans [5,22], which have come to be considered as reservoirs and
186 vectors towards humans [5]. This scenario opens up the possibility that other viruses, including CoVs, could be
187 transmitted to humans when interacting and coming into contact with seals, sea lions and dolphins in water parks and
188 aquariums. Working with infected wildlife, or using them as food sources, especially in communities such as Asian
189 ones, might also be another route of transmission. These leads us to one of the main questions in case of the SARS-
190 CoV-2 infects an aquatic ecosystem..., would SARS-CoV-2 from aquatic organisms infect humans?.

191

192 **3.- Virus infections to humans from aquatic organisms**

193 During this review, no published studies on the actual risk of SARS-CoV-2 contagion from aquatic organisms were
194 found. There is a history of other viral respiratory infections transmitted to humans from either wild or captive animals
195 [15,22]. That is the case with influenza-A, caused by the H7N7 virus, in people infected during a necropsy performed
196 to a seal [43], or by coming into contact with the sneeze of a seal in captivity [22], causing conjunctivitis, rather than
197 typical influenza or respiratory disease. A similar case has also been identified for Influenza B [5,22]. Moreover, a
198 historical review carried out by Petrovic et al. [15], has shown numerous viral outbreaks (not CoVs related) associated
199 with shellfish. These outbreaks, included human enteric viruses, mainly those of type NoV (norovirus). HAV (hepatitis
200 virus A), EV (Enterovirus), HAdV (human adenovirus) and HRV (human rotavirus) are reported in shellfish in
201 different countries, but not CoVs. Oysters and clams have been associated with NoV and HAV between 1976 and
202 1999, in the United States alone. The presence of these viruses has also been identified in molluscs in Europe, both in
203 fish and sea markets and in oyster farms associated with human enteric viruses between 1990 and 2006 [46,47] and all
204 are good examples of food as a source of viral infections. For the World Health Organization and the Food and
205 Agriculture Organization Joint Committee, coronaviruses related to Severe Acute Respiratory Syndrome (SARS-CoV)
206 are viruses of concern by contaminated food [48]. There are other types of water-viruses associated with birds, such
207 as H5N1 avian influenza and avian influenza A1, also highly infectious, and recognized for their transmission to
208 humans from duck meat and blood [49,50]. Due to these examples, there are required extensive monitoring studies
209 since ducks are one of the main groups of birds capable of carrying CoVs (Table 2).

210

211 At the moment, as long as there are no more significant scientific elements to be certain of the non-spread of the SARS-
212 CoV-2 pandemic through natural waters and aquatic organisms, it is best to follow the indications that the health
213 authorities have been issuing in this regard. These indications highlight those made by the World Health Organization
214 [51], which recommends avoiding unprotected contact with wild and farm animals, and has even been recommended
215 not to approach public markets where wild animals are under sale, both live and slaughtered [8].

216

217 **4.- Conclusions**

218 The presence of CoVs in aquatic environments is a reality, which has demonstrated its ability to be transmitted to
219 organisms in wildlife, aquaculture farms and animals under captivity. The presence observed in farmed fish such as
220 carp, in farmed and wild populations of peneid shrimp, although they have not reported significant effects or

221 consequences on human health, could be of potential risk in the near future. Knowledge of other cases such as marine
222 mammals, where seals have shown to be carriers of respiratory infections, which have eventually been transmitted to
223 humans, with effects on eye membranes, even in infections as dangerous as influenza diseases, must be taken in
224 consideration. Waterfowl show to be a natural reservoir, mainly ducks, which, due to their migratory behaviors, deserve
225 to be studied in more detail. The high adaptive capacity of viruses, the wide distribution and recombination potential
226 of their genetic material, could be factors that favor their eventual pathogenicity through aquatic environments.
227 Although molluscs are not infected with CoVs, their antecedents as vectors of other viruses, make them suitable for
228 monitoring for possible future infections.

229

230 **5.- Further considerations for CoVs and aquatic biota**

231 The efforts of the scientific community will continue over the coming years to learn more about CoVID-19. Genetic
232 adaptation, including mutation and recombination, identify routes of zoonotic (animal) origin, new vector organisms
233 (birds, mammals, fish, molluscs or crustaceans), animal-human transmission events, wild natural storage and contagion
234 risks, which will allow effective and realistic programmes to control the transmission of coronaviruses, particularly
235 SARS-CoV-2. It is recognized that viral genotypes with epidemiological potential can become very variable, as a result
236 of their genetic characteristics, which allow them to endure and survive, as well as spread and even mutate along
237 trophic chains [23]. It is encouraging to know that even other aquatic organisms, such as seaweed or sponges, could
238 play a key role in the treatment of CoVs infections. It has been observed through laboratory tests with *Halimeda tuna*
239 algae, a natural product known as diterpene aldehyde or halitunal [52], with an antiCoV effect. Other examples are
240 the sponge *Mycale sp*, which produces a substance called micalamide A, both with antiviral capacity against the A59-
241 CoV of murine or rodent origin [53,54]. Another good example is the *Axinella corrugata* sponge that produces an ethyl
242 ester of esculetin-4-carboxylic acid against SARS-CoV [55]. These substances together with other products of natural
243 origin [54,56], could be the sources of some control against to coronavirus like SARS-CoV-2 in the future.

244

245 Although some scientists speculate that CoVs will not last long in the environment, especially in tropical and
246 subtropical environments [57], due to their intolerance to high temperatures, the diversity and presence of CoVs in
247 aquatic organisms should be monitored. Their varieties identified adequately in infected wild populations, to better
248 understand their infectious potential and avoid future outbreaks in the wild, which eventually could also reach humans.

249

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Table 1. Coronavirus found in aquatic organisms. Taxonomical groups, according to de Groot et al. [6] and Kasmi et al. [10].

Group	Genus	CoV type	Host	Health Effects	Year	Reference	
Order Suborder Family	Nidoviales Coronidovirinea Coronaviridae	<i>Coronavirus(?)</i> * <i>Coronavirus(?)</i> *	Carp CoV Carp Viremia- Associated Ana- Aki-Byo	Common carp (Japan) Common carp (Japan)	Erythema, necrosis (abdomen and liver) Dermal ulcerations, necrotic lesion. Found in spleen and hematopoietic tissue	1988 1997- 1998	[21,29] [29,58]
Subfamily	Orthocorona- virinae	<i>Alphacoronavirus</i> <i>HsCoV</i> <i>HsCoV</i>		Harbor seals (Aquatic Park, Florida, USA) Pacific Harbor seals (California, USA)	Acute enteritis, pulmonary edema Pulmonary congestion, consolidation and hemorrhage, pneumonia	1987 2000	[43] [59]
		<i>Betacoronavirus</i> <i>Gammacoronavirus</i> <i>BdCoV HKU22</i>	Not reported BWCoVSW1 BdCoV HKU22				
		<i>Deltacoronavirus</i>	Not reported				
Torovirinae		<i>Torovirus(?)</i> * <i>Bafinivirus</i>	CIVH 33/86 WBV DF24/00	Beluga whale (Aquatic Park, California, USA) Bottlenose Dolphin (Aquatic Park, Hong Kong)	Hepatic necrosis and pulmonary disease Found in faeces	2008	[6,45] [9]
Family	Roniviridae	<i>Okavirus</i>	YHV (Yellow Head Virus)	Grass carp (Hungary) White bream fish (Saxonia- Anhalt, Germany) FHMNV Chinook Salmon Bafinivirus	Not known Not known Fathead minnow fish (Arkansas, USA) Chinook salmon (Ontario, Canada)	1986 2000 1997 2014	[29] [11,29] [32,33] [29,34]

*still unclassified.

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Table 2. Coronavirus found in waterfowl of the Order Anseriformes.

Order	Genus	Species	Type of bird	Type of CoV	References
Anseriformes	<i>Anas</i>	<i>domestica</i>	Duck	Gamma (SARS-CoV)	[60]
		<i>platyrhynchos</i>	Spotbill duck	Gamma (SARS-CoV)	[60]
		<i>americana</i>	American wigeon	Delta (JQ065048.1)	[61]
		<i>crecca</i>	Common teal	Gamma (J0109, J0121, J0126, J0559, J0579, J1393); Delta (J1420)	[42,62,63]
		<i>clypeata</i>	Northern shoveler	Gamma (K547, K554, K561, K589, J0554, J0807, J1300, J0901, J1491); Delta (J0590)	[42,63]
		<i>penelope</i>	Euroasian wigeon	Gamma (K596, J0588, J1561)	[42]
		<i>acuta</i>	Northern pintail	Gamma (J1375, J1393, J1404, J1407, J1435, J1616, J1451, PBA-10, PBA-15, PBA-16, PBA-25, PBA-37, PBA-124)	[42,62,63]
		<i>erythrorhyncha</i>	Red-billed duck	Gamma (KM093874, KM093875, KM093876, KM093877)	[63]
		<i>hottentota</i>	Hottentot teal	Gamma (KM093880)	[61]
	<i>Clangula</i>	<i>hyemalis</i>	Long-tail duck	Gamma (Fin14395)	[62]
	<i>Cygnus</i>	<i>cygnus</i>	Whooper swan	Gamma (Fin4983)	[62]
	<i>Dendrocygna</i>	<i>javanica</i>	Lesser whistling duck	Gamma (KH08-0852)	[42,61]
		<i>viduata</i>	White-faced whistling duck	Gamma (KM093872, KM093873, KM093878)	[63]
	<i>Aythya</i>	<i>fuligula</i>	Tufted duck	Gamma (J1482)	[42]
	<i>Anser</i>	<i>caerulescens</i>	Snow goose	Gamma (WIR-159)	[42,61]
		<i>anser</i>	Greylag goose	Gamma (SARS)	[60]
		<i>cygnoides</i>	Swan goose	Gamma (DPV_16). Delta (DPV_5, DPV_10)	[61]
	<i>Branta</i>	<i>bernicla</i>	Brent goose	Gamma (KR-69, KR-70, KR88)	[42,61,63]

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Table 3. Gammacoronavirus and Deltacoronavirus reported in aquatic birds.

Order	Genus	Species	Type of bird	Type of CoV	References
Pelecaniformes	<i>Ardeola</i>	<i>bacchus</i>	Pond heron	Delta (KH08-1475, KH08-1474)	[42]
	<i>Ardea</i>	<i>cinerea</i>	Gray heron	Delta (K581, K513)	[42]
	<i>Bubulcus</i>	<i>ibis</i>	Heron	Gamma (KM093897)	[61,63]
	<i>Platalea</i>	<i>minor</i>	Black-faced spoonbill	Delta (J0569)	[42]
Gruiformes	<i>Phalacrocorax</i>	<i>carbo</i>	Great cormorant	Delta (J0982, J1517)	[42]
	<i>Rallus</i>	<i>madagascariensis</i>	Madagascar rail	Gamma (KM093896)	[63]
	<i>Porphyrrula</i>	<i>allenii</i>	Allen's gallinule	Gamma (KM093890, KM093891, KM093892, KM093893, KM093894)	[61,63]
	<i>Gallinula</i>	<i>chloropus</i>	Common moorhen	Gamma (KM093881, KM093885, KM093887), Delta (JQ065049.1)	[61,63]
Charadriiformes	<i>Charadrius</i>	<i>pecuarius</i>	Kittlitz's plover	Gamma (KM093879, KM093883, KM093884)	[61,63]
	<i>Gallinago</i>	<i>macrodactyla</i>	Madagascan snipe	Gamma (KM093888, KM093889, KM093895)	[63]
	<i>Calidris</i>	<i>mauri</i>	Wester sandpiper	Gamma (KR-28)	[61]
		<i>ptilocnemis</i>	Rock sandpiper	Gamma (CIR-66187, CIR-665821, CIR-665828)	[42,61,63]
		<i>alba</i>	Sanderling	Gamma (PNLP100)	[61]
	<i>Larus</i>	<i>fuscicollis</i>	White-rumped sandpiper	Gamma (PNLP159)	[61]
		<i>sp</i>	Gull	Delta (JX548304)	[61]
		<i>argentatus</i>	Herring gull	Gamma (Fin9211, Fin10877, Fin10879, Fin12822, Fin13125)	[62]
		<i>hyperboreus</i>	Glaucous gull	Gamma (PBA-173)	[42]
		<i>fuscus</i>	Lesser Black-back gull	Gamma (Fin10059)	[62]
		<i>glaucescens</i>	Glaucous-winged gull	Gamma (CIR-66002, GU396682)	[42]
	<i>Chroicocephalus</i>	<i>ridibundus</i>	Black-headed gull	Gamma (CIR-66187, GU396679, GU396680, GU396683, KX588674, Fin10083)	[42,62]
<i>Rostratula</i>	<i>benghalensis</i>	Greater Painted-snipe	Gamma (KM093883)	[61]	
	<i>Rynchops</i>	<i>niger</i>	Black skimmer	Delta (PNLP115)	[61]