A systematic review of waterborne and water-related disease in animal populations of Florida from 1999–2019

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Abstract

Background
Florida’s waters are a reservoir for a host of pathogens and toxins. Many of these microorganisms cause water-related diseases in people that are reportable to the Florida Department of Health. Our objective in this review was to ascertain which water-related pathogens and toxins of public health importance have been found in animal populations in Florida over the last twenty years.

Methods
Nineteen databases were searched, including PubMed and Web of Science Core Collection, using keywords and search terms for the waterborne diseases, water-related vector-borne diseases, and water-based toxins reportable to the Florida Department of Health. For inclusion, peer-reviewed journal articles were to be written in English, published between January 1, 1999 and December 31, 2019, and contain primary research findings documenting at least one of the water-related pathogens or toxins of interest in an animal population within Florida during this same time frame.

Results
Of over eight thousand initial search results, 65 studies were included for final analysis. The most common animal types implicated in the diseases of interest included marine mammals, fish and shellfish, wild birds, and livestock. Toxins or pathogens most often associated with these animals included toxin-producer Karenia brevis, vibriosis, Escherichia coli, and Salmonellosis.

Discussion/conclusion
Findings from this review elucidate the water-related disease-causing pathogens and toxins which have been reported within animal populations in recent Florida history. As most of these diseases are zoonotic, our results suggest a One Health approach is necessary to support and maintain healthy water systems throughout the state of Florida for the protection of both human and animal populations.
Introduction

The state of Florida is a peninsula with a unique environment consisting of hundreds of miles of coastline on the Atlantic Ocean and Gulf of Mexico, along with many inland freshwater bodies. Florida’s waters are an important source of economic revenue for the state, in both recreational and commercial sectors. In 2016 these combined industries brought in $27.8 billion dollars and supported over 170,000 jobs [1]. Freshwater-based recreational tourism from just the St. Johns River basin alone is estimated to bring in over $200 million dollars a year [2]. Florida’s beaches and lakes are hotspots for water activities such as fresh and saltwater fishing, boating, surfing, diving and kayaking for both local residents and out-of-state visitors alike. Each year, the state boasts over 130 million visitors [3].

Florida is home to over 20 million people and numerous species of novel, native and imperiled wildlife [4, 5]. Some of these animals include the American alligator, the American crocodile, alligator snapping turtle, sea turtles (i.e. leatherback, Hawksbill, Kemp’s Ridley, green sea turtle, and loggerhead), whales (i.e. North Atlantic Right, Finback, Sei, sperm, and humpback), many types of birds such as brown pelicans and burrowing owls, various fresh and saltwater fish, amphibians, and coral (i.e. staghorn coral), snakes and other land reptiles (i.e. gopher tortoise), land mammals (i.e. Everglades mink, red wolf, Florida bonneted bat, key deer, and Florida panther), and marine mammals (i.e. Florida manatee) [5]. Preserving and protecting the biodiversity of Florida is critical to maintaining the health of the environment, animals and residents and vital to the recreation and hospitality sectors [6, 7].

The environmental conditions of Florida and its many waterways create favorable ecosystems and transmission opportunities for various water-related infections that affect both humans and animals. Waterborne infectious diseases are primarily spread through the ingestion of contaminated water, often due to poor human and animal waste management, and can cause negative symptoms in both humans and animals if ingested [8]. Water-related vector-borne diseases are also caused by pathogenic microbes but transmission to humans or animals requires a vector that uses water in its life cycle, such as a mosquito. Finally, water-related toxins are harmful substances which are naturally produced by organisms that reside in the water and have the ability to contaminate water bodies [8]. Water-related pathogens are often zoonotic, meaning they can be transmitted between an animal and a person, and create significant public health challenges for prevention, detection and control [9].

Because some zoonotic water-related pathogens and toxins can cause serious, sometimes fatal, human disease and have the potential for person-to-person transmission, cases of human infections are reportable to the Florida Department of Health by the documenting physician [10]. In addition, several of these same diseases discovered in animal populations are also reportable to the Florida Department of Agriculture and Consumer Services by attending veterinarians [11]. Yet these reportable water-related diseases vary widely in their exposure risks, their transmission routes, and their disease presentations. These factors make it difficult to coordinate surveillance efforts between state public health and veterinary professionals or develop a universally-applicable approach to decrease their burden. The objective of this study is to identify which waterborne diseases, water-based toxins, and water-related vector-borne diseases of public health importance have been reported in animal species of Florida over the last twenty years. Although the included studies do not correlate directly to human disease risk or prevalence, understanding which water-related pathogens and toxins impact Florida’s animals in recent years can illuminate ways to prevent transmission in both populations.

Methods

Florida statute (Rule 64D-3.029. Florida Administrative Code) mandates that over 60 human diseases are reportable to the state Department of Health [10, 12]. Of these, 33 are infectious
pathogens which can be identified as either a waterborne disease, water-related vector-borne disease, or water-based toxin. Based on these designations, these diseases were identified to be of public health importance, and are investigated here to ascertain whether they are found in animal populations in Florida. The diseases of interest for this study have been sorted according to their categorial classification (Table 1).

Search strategy and inclusion criteria

Predefined PRISMA guidelines [13] were used to identify, screen, and assess publications for eligibility. The PRISMA Statement provides a flow diagram (Fig 1) and checklist (S1 File) which can be used to map the systematic process of screening titles for inclusion in either a systematic review or meta-analysis [13]. Nineteen online databases were searched. These included PubMed, Web of Science Core Collection, Google Scholar, ProQuest databases of ABI/INFORM, Agriculture Collection, Agricola, Aquatic Science Collection, Biological Sciences, Agricultural and Environmental Science Collection, Health & Medicine, MEDLINE, and TOXLINE, GALE databases of Nursing and Allied Health Outcomes and Environmental Studies and Policy, SAGE Journals, Science Direct, SpringerLink Journals, BioOne Complete, and Environment Complete. Search strings were developed for each database containing keywords related to the waterborne, water-based toxins, and water-related vector-borne diseases reportable to the Florida Department of Health [FDOH; 10] using Boolean Operators and wildcard symbols(*) as appropriate for each database. An example of a search string is included below:

a. (“waterborne disease” OR “water-based vector” OR “water-related toxin” OR “Amebic encephalitis” OR “Naegleria fowleri” OR “Primary amebic meningoecephalitis” OR arbovir” OR “California serogroup virus disease” OR “Chikungunya fever” OR Dengue fever” OR “Eastern equine encephalitis” OR “Malaria” OR “St. Louis encephalitis” OR “Venezuelan equine encephalitis” OR “Viral hemorrhagic fevers” OR “West Nile virus disease” OR “Yellow fever” OR “Zika fever”)

Table 1. Select reportable water-related diseases in Florida analyzed in this study.

| Waterborne | Water-Related Vector-Borne | Water-Based Toxins |
|------------|-----------------|-------------------|
| • Amebic encephalitis | • Arboviral diseases not otherwise listed | • Ciguatera fish poisoning |
| • Campylobacteriosis | • California serogroup virus disease | • Neurotoxic shellfish poisoning |
| • Cholera (Vibrio cholerae type O1) | • Chikungunya fever | • Saxitoxin poisoning (paralytic shellfish poisoning) |
| • Cryptosporidiosis | • Dengue fever | |
| • Cyclosporiasis | • Eastern equine encephalitis | |
| • Escherichia coli infection, Shiga toxin producing | • Malaria | |
| • Giardiasis | | |
| • Hepatitis A | | |
| • Hepatitis E | | |
| • Legionellosis | | |
| • Leptospirosis | | |
| • Melioidosis | | |
| • Poliomyelitis* | | |
| • Salmonellosis | | |
| • Shigellosis | | |
| • Tularemia | | |
| • Typhoid fever (Salmonella serotype Typhi) | | |
| • Vibriois (Vibrio species and closely related organisms, not Vibrio cholerae type O1) | | |

*Humans are the only known reservoir

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b. AND (Florid OR "Southeastern United States")

A full list of the search strings designed for each database, including the total number of results returned for each, is available (S2 File). Publications were restricted to peer-reviewed journal articles written in English and published between January 1, 1999 and December 31, 2019. Articles were determined to be eligible if they contained primary study findings documenting a naturally-derived water-related pathogen of interest in animals or animal samples collected in Florida, USA during the same time frame. Such primary findings would include, for example, samples or specimens collected directly from live or deceased animals that are native to Florida with analysis conducted by the author(s). Secondary data analysis, reviews, and modeling only papers were excluded. The search was conducted between April 2nd and April 8th, 2020.

Screening process

Results from each database search were saved using a citation management program. These results were then copied into a master folder and three researchers removed duplicates by
hand to reach unanimity. The non-duplicate titles were then screened to search each available title and abstract to retain publications that were: a) a journal article; b) written in English due to co-author language limitations; c) primary studies on animal samples collected in Florida; d) primary studies on a pathogen or toxin of interest; and e) naturally occurring contamination or infection. Journal articles that remained went through a full-text review using the same parameters. At least two researchers read the full-text of each article to determine inclusion or exclusion and when necessary, the third researcher was the tie-breaker.

Results
The initial search resulted in 8,363 articles across the multiple databases (Fig 1). Of these, 2,944 were duplicate titles and were removed. From the remaining 5,419 articles, 251 met the necessary criteria for a full-text review, based on title and abstract screening. After assessment of each full-text title by at least two of the co-authors, 186 articles were removed based on predetermined exclusion criteria. These titles were: a publication type other than peer-reviewed journal article, research not on a pathogen or toxin of interest, findings from experimental infection or did not demonstrate prevalence data in a Florida animal population, study samples were collected outside of the date range, or an additional duplicate article. This resulted in 65 articles accepted for analysis in this review.

The included studies spanned the full date range from 1999–2019 with the majority of publications in the year 2009 (n = 7; Table 2). Study sites were located across the state of Florida with the bulk identified in Brevard county (n = 10), followed by Indian River county (n = 9), Volusia county (n = 8), and Sarasota county (n = 7; Fig 2). Research topics included: disease prevalence study in an animal population, case report or case series on animal morbidity or mortality, case report or case series on human morbidity or mortality associated with animal contact, or sentinel surveillance for vector-borne pathogens. While most studies were specifically focused on waterborne disease(s), water-related vector-borne disease(s) or water-based toxin(s), several studies investigated multiple categories at the same time (Fig 2A). There was also diversity in the types of animal species sampled across the studies (Fig 2B). Animal categories included: marine and aquatic species; wildlife, reptiles, and birds; and livestock, poultry and companion animals.

Pathogens and toxins by category
While the search criteria included many waterborne pathogens, water-related vector-borne pathogens and water-based toxins, fewer studies focused on vector-borne agents (n = 12) and toxins (n = 33) than waterborne diseases (n = 39). Waterborne pathogens included: Escherichia coli (E. coli), Salmonella spp., Cryptosporidium spp., Giardia spp., Leptospira spp., Campylobacter spp., and Vibrio spp. Water-related vector-borne pathogens included: Venezuelan equine encephalitis virus (VEEV), Eastern equine encephalitis (EEE), Western equine encephalitis, West Nile virus (WNV), and St. Louis encephalitis virus (SLEV). Water toxins included: brevetoxins produced by Karenia brevis (K. brevis) and toxins saxitoxin, tetrodotoxin, and ciguatoxin. The most frequently examined pathogens and toxins overall included: Toxin-producer K. brevis (n = 17), West Nile virus (n = 9), and Cryptosporidium spp., Giardia spp., and Vibrio spp. (each n = 8).

Marine and aquatic animal studies
The majority of study results centered on diseases of interest in marine and aquatic animal populations (n = 35). These animal populations included: wild fish (n = 10), dolphins (n = 9), manatees (n = 5), oysters (n = 5), sea turtles (n = 2), clams (n = 4), other bivalves or snails
Table 2. Summary of studies from 1999–2019 that found waterborne disease, water-related vector-borne disease, and water-based toxins and toxin-producers of public health importance in Florida animals (n = 65) by positive samples only.

| Reference                                    | Animal Population | Pathogen, Toxin, or Toxin-Producer Analyzed and Animal(s)                  | Florida County (If Specified) |
|----------------------------------------------|-------------------|---------------------------------------------------------------------------|-------------------------------|
| Poli et al., 1999 [14]                       | Clams             | • *Karenia brevis*                                                        | Sarasota, Manatee             |
|                                              | Whelks            |                                                                           |                               |
| Trainer & Baden, 1999 [15]                   | Manatees          | • *Karenia brevis* (formerly known as *Gymnodinium breve*) • Saxitoxin     | -                             |
| Ellison et al., 2001 [16]                    | Oysters           | • *Vibrio parahaemolyticus*                                               | Alachua                       |
| Centers for Disease Control and Prevention, 2002 [17] | Pufferfish       | • Saxitoxin                                                               | Brevard                       |
| Fayer et al., 2003 [18]                      | Oysters           | • *Cryptosporidium* spp. • 5 (20%)                                        | Indian River, Brevard, Volusia |
|                                              | Clams             | • *Cryptosporidium* spp. • 25 (4%)                                       | St. Johns, Sarasota, Manatee  |
| Buck et al., 2006 [19]                       | Dolphins          | • *Vibrio alginolyticus* • 189 (70%)                                     | Sarasota, Manatee             |
|                                              |                   | • *Vibrio damsela* • 189 (64%)                                           |                               |
|                                              |                   | • *Vibrio fluvialis* • 189 (18%)                                         |                               |
|                                              |                   | • *Vibrio furnissi* • 189 (7%)                                           |                               |
|                                              |                   | • *Vibrio parahaemolyticus* • 189 (17%)                                   |                               |
| Landsberg et al., 2006 [20]                  | Pufferfish        | • Saxitoxin                                                               | Indian River, Brevard, Volusia |
| Greig et al., 2007 [21]                      | Dolphins          | • *E. coli* • 33 (48%)                                                   | St. Lucie, Indian River, Brevard, Volusia |
| Naar et al., 2007 [22]                       | Wild Fish         | • *Karenia brevis*                                                        | Gulf                          |
| Fire et al., 2008 [23]                       | Dolphins          | • *Karenia brevis* • 30 (63%)                                            | Sarasota, Manatee             |
| Fire et al., 2008 [24]                       | Wild Fish         | • *Karenia brevis*                                                        | Sarasota, Manatee             |
| Pierce & Henry, 2008 [25]                    | Oysters           | • *Karenia brevis*                                                        | Sarasota, Manatee             |
|                                              | Clams             |                                                                           |                               |
| Deeds et al., 2008 [26]                      | Pufferfish        | • Saxitoxin                                                               | Indian River, Brevard, Volusia |
|                                              |                   | • Tetrodotoxin                                                            |                               |
| Abbott et al., 2009 [27]                     | Pufferfish        | • Saxitoxin                                                               | -                             |
| Schaefer et al., 2009 [28]                   | Dolphins          | • *Vibrio alginolyticus* • *E. coli* • 115 (8.7%) • 116 (1.7%) • WNV • 118 (4.24%) • WEE • 116 (3.34%) | Indian River, Brevard, Volusia |
| Schaefer et al., 2009 [29]                   | Dolphins          | • VEEV • 115 (8.7%) • EEE • 116 (1.7%) • WNV • 118 (4.24%) • WEE • 116 (3.34%) | Indian River, Brevard, Volusia |
| Nam et al., 2010 [30]                        | Lemon Sharks      | • *Karenia brevis*                                                        | Brevard                       |
| Wetzel et al., 2010 [31]                     | Manatees          | • *Karenia brevis*                                                        | -                             |

(Continued)
Table 2. (Continued)

| Reference                          | Animal Population | Pathogen, Toxin, or Toxin-Producer Analyzed and Animal(s) Positive n (%) (If Specified) | Florida County (If Specified) |
|-----------------------------------|-------------------|----------------------------------------------------------------------------------------|-------------------------------|
| Morris et al., 2011 [32]          | Dolphins          | • V. alginolyticus • E. coli                                                          | • Indian River • Brevard • Volusia |
| Twiner et al., 2011 [33]          | Dolphins          | • Karenia brevis                                                                      | • Sarasota • Manatee          |
| Snails                            |                   |                                                                                       |                               |
| Wild Fish                         |                   |                                                                                       |                               |
| Twiner et al., 2012 [34]          | Dolphins          | • Karenia brevis o 12 (100%)                                                           | • Gulf                        |
| van Deventer et al., 2012 [35]    | Wild Fish         | • Karenia brevis                                                                      | • Sarasota                    |
| Capper et al., 2013 [36]          | Manatees           | • Karenia brevis and/or Saxitoxin o 14 (64%)                                           | • Pinellas                    |
| Green Sea Turtles                 |                   | • Karenia brevis and/or Saxitoxin o 13 (85%)                                           |                               |
| Staley et al., 2013 [37]          | Oysters            | • Vibrio spp.                                                                          | • Hillsborough                |
| Unger et al., 2014 [38]           | Black Tip Sharks   | • Vibrio alginolyticus                                                                 | • Martin • Palm Beach         |
| McFarland et al., 2015 [39]       | Green Mussels      | • Karenia brevis                                                                      | • Lee                         |
| Walsh et al., 2015 [40]           | Manatees           | • Karenia brevis                                                                      | • Citrus                      |
| Perrault et al., 2016 [41]        | Loggerhead Sea Turtles | • Karenia brevis o 34 (100%)                                                 | • Monroe                      |
| Vorbach et al., 2017 [42]         | Manatee            | • Salmonella spp. o 1 (100%)                                                           | • Martin                      |
| Kemp et al., 2017 [43]            | Coral              | • Vibrio spp.                                                                          | • Monroe                      |
| Hardison et al., 2018 [44]        | Lionfish           | • Ciguatoxin o 20 (25%)                                                               | • Monroe                      |
| Martony et al., 2018 [45]         | Sea Urchins        | • Vibrio spp. o 70 (33%)                                                              | • Monroe                      |
| Rolton et al., 2018 [46]          | Clams              | • Karenia brevis                                                                      | • Lee                         |
| Fire et al., 2019 [47]            | Dolphins           | • Karenia brevis o 119 (12%) • Saxitoxin o 119 (13%)                                 | • Indian River • Brevard • Volusia |
| Fang et al., 2019 [48]            | Oysters            | • Vibrio cholerae o 60 (48%) • Vibrio parahaemolyticus o 60 (100%) • Vibrio vulnificus o 60 (100%) | • Franklin                    |
| Wild Fish                         |                   | • Vibrio parahaemolyticus o 38 (83%) • Vibrio vulnificus o 38 (67%)                  |                               |

Terrestrial Wildlife, Reptile, and Bird Studies

| Reference                          | Animal Population | Pathogen, Toxin, or Toxin-Producer Analyzed and Animal(s) Positive n (%) (If Specified) | Florida County (If Specified) |
|-----------------------------------|-------------------|----------------------------------------------------------------------------------------|-------------------------------|
| Hudson et al., 2000 [49]          | Wild Birds        | • Salmonella spp.                                                                     | -                             |
| Blackmore et al., 2003 [50]       | Wild Birds        | • WNV o 7,669 (14.4%)                                                                  | -                             |
| Jacobson et al., 2005 [51]        | Alligators        | • WNV o 3 (100%)                                                                       | -                             |
| Godsey et al., 2005 [52]          | Wild Birds        | • WNV o 152 (10.5%) • SLEV o 152 (1.3%)                                                | • Jefferson                   |

(Continued)
Table 2. (Continued)

| Reference            | Animal Population       | Pathogen, Toxin, or Toxin-Producer Analyzed and Animal(s) Positive n (%) (If Specified) | Florida County (If Specified) |
|----------------------|-------------------------|------------------------------------------------------------------------------------------|-------------------------------|
| Allison et al., 2005 [53] | Double Crested Cormorants | • WNV ○ 2 (50%)                                                                          | • Monroe                      |
| Gibbs et al., 2006 [54] | Feral Pigs              | • WNV ○ 35 (17%)                                                                         | -                             |
| Nemeth et al., 2009 [55] | Crested Caracaras       | • SLEV ○ 80 (3%)                                                                         | • Collier                     |
|                      |                         | • EEE ○ 80 (3%)                                                                           | • DeSoto                      |
|                      |                         | • WNV ○ 80 (9%)                                                                           | • Hardee                      |
|                      |                         |                                                                                          | • Hendry                      |
|                      |                         |                                                                                          | • Highlands                   |
|                      |                         |                                                                                          | • Martin                      |
| Charles-Smith et al., 2009 [56] | Gopher Tortoises     | • Salmonella spp. ○ 60 (10%)                                                             | • St. Johns                   |
|                      |                         |                                                                                          | • Orange                      |
| Landolfi et al., 2010 [57] | Green Snakes           | • Cryptosporidium spp. ○ 5 (100%).                                                       | -                             |
| van Deventer et al., 2012 [35] | Shorebirds            | • Karenia brevis ○ 16 (100%)                                                            | • Pinellas                    |
| Chatfield et al., 2013 [58] | Feral Pigs             | • Leptospira spp. ○ 324 (33%)                                                            | -                             |
| Grigione et al., 2014 [59] | Coyotes                | • Cryptosporidium spp. ○ 40 (13%)                                                         | • Pinellas                    |
| Hernandez et al., 2016 [60] | White Ibis             | • Salmonella spp. ○ 333 (16.5%)                                                          | • Palm Beach                  |
|                      |                         |                                                                                          | • Broward                    |
|                      |                         |                                                                                          | • Miami-Dade                  |
| Huffman et al., 2018 [61] | Gopher Tortoises       | • Cryptosporidium spp. ○ 123 (1%)                                                         | • Indian River                |
|                      |                         |                                                                                          | • Martin                      |
|                      |                         |                                                                                          | • Palm Beach                  |
| **Livestock and Companion Animal Studies** | | | |
| Blackmore et al., 2003 [50] | Chickens               | • WNV ○ 2.128 (9%)                                                                        | -                             |
|                      | Horses                 | • WNV ○ 948 (52%)                                                                         | -                             |
| Riley et al., 2003 [62] | Beef Cattle            | • E. coli ○ 296 (9%)                                                                       | • Hernandez                   |
| Trout et al., 2004 [63] | Dairy Cattle           | • Giardia duodenalis                                                                      | -                             |
| Godsey et al., 2005 [52] | Domestic Birds         | • WNV ○ 201 (11.4%)                                                                       | • Jefferson                   |
|                      |                        | • SLEV ○ 201 (1%)                                                                          |                              |
| Trout et al., 2005 [64] | Dairy Cattle           | • Giardia duodenalis                                                                      | -                             |
| Centers for Disease Control and Prevention, 2005 [65] | Cattle Sheep Goats | • E. coli ○ 36 (16.7%)                                                                     | -                             |
| Trout et al., 2006 [66] | Dairy Cattle           | • Giardia duodenalis ○ 86 (24.4%)                                                         | -                             |
| Coffey et al., 2006 [67] | Domestic Dogs          | • VEEV ○ 633 (4%)                                                                         | -                             |
| Trout et al., 2007 [68] | Dairy Cattle           | • Giardia duodenalis                                                                      | -                             |
| Fayer et al., 2007 [69] | Dairy Cattle           | • Cryptosporidium spp. ○ 93 (5.4%)                                                         | -                             |

(Continued)
The most frequent pathogens and toxins found in marine and aquatic animal populations in Florida were toxin-producer *K. brevis* (n = 17), *Vibrio spp.* (n = 8), and saxitoxin (n = 7). The most frequent locations for these studies were the counties of Brevard (n = 10), Indian River (n = 8), Volusia (n = 8), Sarasota (n = 7), and Manatee (n = 6). Most of these studies investigated disease prevalence in a marine animal population, although not as part of any sentinel surveillance program for public health.

![Density of the number of published studies by Florida county and the percentage of studies by type of disease or toxin (A) and category of animals sampled (B).](https://doi.org/10.1371/journal.pone.0255025.g002)
Terrestrial wildlife, reptile and bird studies
Publications were also found regarding land animal populations including reptile and bird species (n = 14). These animal populations included: various wild birds (n = 7), feral pigs (n = 2), gopher tortoises (n = 2), coyotes (n = 1), green snakes (n = 1), and alligators (n = 1). The most frequent pathogens found in terrestrial animal and wild bird populations included: West Nile Virus (n = 6), Cryptosporidium spp. (n = 3), Salmonella spp. (n = 3). The most frequent locations for these studies named throughout the state of Florida were Pinellas county (n = 2), Martin county (n = 2), and Palm Beach county (n = 2). These studies investigated disease prevalence in land animal populations as well as cases regarding land animal morbidity and mortality as a result of diseases of interest.

Livestock and companion animal studies
Studies were also identified in the search that investigated diseases of interest in livestock (including poultry) and companion animals (n = 19). These animal populations included: cattle (n = 9), companion dogs (n = 3), companion cats (n = 2), chickens (n = 2), goats (n = 2), and horses (n = 2), and other domestic or captive birds (n = 1). The most frequent pathogens found in these domestic animal populations were: Giardia spp. (n = 7), E. coli (n = 4), Cryptosporidium spp. (n = 4), and West Nile virus (n = 4). Many of these studies regarding domestic animal populations did not specify a Florida county where data collection occurred (n = 12). Of those with a reported study site, the most frequent locations were Hernando county (n = 2) and Alachua county (n = 2). Several of the results in livestock and companion animal populations were from investigations into the prevalence of waterborne and sanitation-related diseases among livestock populations such as beef and dairy cattle throughout the state of Florida.

Discussion
Between 1999 and 2019, sixteen water-related pathogens of human health importance were documented in Florida’s animal populations. Of the included studies in this review, most focused on zoonotic waterborne diseases such as E. coli, Salmonella spp., Cryptosporidium spp., Giardia spp., Leptospira spp., Vibrio spp., and Campylobacter spp. [16, 18, 19, 21, 28, 32, 37, 38, 42, 43, 45, 48, 49, 56–66, 68–70, 72–74, 76–78]. Waterborne diseases are associated with agricultural runoff, stormwater and flooding, trash, and poorly managed sewage [79–81]. Fecal shedding of zoonotic enteric pathogens can pollute natural habitats and water systems which can lead to human exposure [82, 83].

Waterborne disease
Escherichia coli (E. coli) was reported in marine mammal populations such as dolphins and manatees, as well as in livestock populations like cattle and goats, typically in their fecal samples [21, 28, 32, 62, 65, 70, 72, 78]. While E. coli is a broad species of bacterial subtypes, most of which is harmless and naturally occurring in human and animal intestinal flora, at least six pathotypes are known as diarrheagenic E. coli and can cause disease [84]. The FDOH has included the STEC pathotype, or Shiga toxin-producing E. coli, as one of the reportable waterborne diseases in Florida. The larger subset of E. coli studies included in this analysis did not indicate the subtype detected and therefore the pathogenicity could not be determined. However, the presence of E. coli as a fecal indicator may demonstrate proximal waste contamination and exposure potential for other waterborne zoonotic diseases. Confirmed outbreaks of E. coli in this study were often associated with environments with high levels of human and
animal interaction, such as petting zoos and agricultural areas [62, 65, 70, 72, 78]. The indiscriminate water-focused fecal shedding of zoonotic pathogens, such as pathogenic *E. coli*, from marine mammals is a point of concern since the state thrives on water-based tourism and recreation. There is a potential risk of humans encountering a diseased animal or their feces in or near the beach environments [85]. Waterborne diseases have been found in multiple marine mammals and shorebirds, including seals that spend significant time in shared spaces with beachgoers [85–87]. Further research into waterborne disease transmission and exposure risks in marine animals and humans in Florida is warranted.

*Cryptosporidium* spp. was primarily found in terrestrial animals such as coyotes and tortoises but was also associated with outbreaks in livestock and companion animals (i.e. shelter animals) [57, 59, 61, 69, 73, 74, 76]. Animals in veterinary care, shelters, pet stores, petting zoos or wildlife rehabilitation centers may harbor disease [88–91]. Because of the high level of human contact associated with animal shelters and wildlife rehabilitation centers, it is important to monitor the ongoing health of these animals. If an animal is infected with a disease of significance to human or veterinary health, practitioners should determine whether the animal had the disease prior to their stay, contracted it because of unhygienic containment conditions, or developed it after exposure to another infected animal or human handler [92]. Employees and animal health providers should maintain a high level of hygiene and health screenings for animals in their care as well as their human visitors [89, 90, 93]. Any rehomed, purchased, traded, or released animal should be healthy and disease-free to avoid further transmission to the environment [85, 91, 92].

Livestock are a prevalent source of water and foodborne illness, especially when animal waste is not safely managed and personal hygiene measures are not adhered [79, 80, 88]. Florida houses approximately 47,000 commercial farms and ranches [94]. As agricultural animals and animal products are transported in and out of Florida, preventing and responding to zoonotic waterborne disease can hinder the potential economic and herd loss associated and impede multi-state outbreaks [95]. Transporting live animals who may be under duress due to high-volume agricultural facilities can increase the risk for transmission of waterborne disease within herds and to humans [96]. Care and concern should be taken for the conditions of livestock food, water, and confinement areas in order to prevent potential contamination [88, 96]. Many of our results pertaining to water-related pathogens found in Florida livestock populations did not disclose which counties the data were collected, most likely to protect the agricultural facility from negative consumer opinion [50, 67, 71, 97]. It is important to mitigate the risk of transmission to animals and humans by implementing preventive measures and continuing monitoring and surveillance in the environment. Ensuring a safe built environment and habitat for domestic animals can help mitigate the risk of illness for animals and people [71].

Companion animals also have frequent interactions and close contact with humans of all ages [98]. People who may be immunocompromised or otherwise at risk for severe morbidity due to a water-related disease may be unaware of the risk that unsafe contact with their pet may pose [93]. Vaccinating animals that have frequent contact with humans, cleaning pet areas and items regularly, washing hands after contact with pets or pet waste, monitoring the health of pets and household members with routine veterinary care, and feeding animals safe feed are some of the ways to prevent zoonotic transmission [99]. Pet animals who freely roam outside may be at risk for contact with infected companion or wild animals, who can transmit pathogens via water, feces, or direct contact [100]. This is especially true in areas where urban and natural landscapes overlap, as wild animals such as coyotes have been shown to pass waterborne disease to companion and domestic animals [59].
**Water-based toxins and toxin-producers**

Water-based toxins included brevetoxin produced by overgrowth of *Karenia brevis* and the toxins saxitoxin, tetrodotoxin, ciguatoxin, and others. The most prevalent water-based toxin in the studies analyzed was brevetoxin produced by *K. brevis*, which is associated with harmful algal blooms (HABs), known as "red tides", that can plague the coastline of Florida [14, 15, 22–25, 30, 31, 33, 34, 36, 39–41, 46, 47, 101, 102]. Red tide events have led to die-offs in fish, turtles, dolphins, and manatees while cyanobacteria or blue-green algae has killed birds, wildlife, livestock, dogs and cats [103]. During Florida’s red tides or other HAB events, many species of marine animals and shellfish are at risk of being affected by toxin-producer *K. brevis* and other paralytic toxins, ciguatoxins, tetrodotoxins, brevetoxins, which can contribute to human exposure through consumption of contaminated seafood or contact with the toxins through water or aerosolized particles [104, 105]. It is important to remain aware of red tide seasons, inform the public, and exercise caution when entering affected areas or bringing pets or livestock near water presenting with a harmful algal bloom [102, 103].

Most of the studies included in our analysis were conducted in marine and aquatic animal populations and concentrated in South Florida, especially the Sarasota Bay and the Indian River Lagoon area [14, 18–21, 23–26, 28, 29, 32, 33, 47]. Water-based toxins were the most frequently documented disease-causing agent in this group [14, 15, 17, 20, 22–27, 30, 31, 33, 34, 36, 39–41, 44, 46–48]. Research and prevention efforts to curb HABs and other water toxin effects in Florida and along its coast are ongoing and must consider the dangers these organisms present to human, environmental and animal health. Collaborative efforts such as the Bottlenose Dolphin HERA (Health and Risk Assessment) Project have been instrumental in fostering interdisciplinary research efforts for marine mammals [28]. HAB surveillance and response efforts in Florida are a joint One Health collaboration between the Florida Department of Health, Florida’s Poison Control Centers and hospitals, the National Ocean and Atmospheric Administration (NOAA), Florida Fish and Wildlife Conservation Commission, Mote Marine’s Beach Conditions Report, the Florida Department of Environmental Protection, Fish and Wildlife Research Institute, the Centers for Disease Control and Prevention, Florida Water Management Districts, and the Gulf of Mexico Coastal Ocean Observing System [106]. There are opportunities for further research on water-based toxins in marine animal populations of Florida with priority given to regions with warmer air and water temperatures and greater risk for human-animal contact or exposure to shared water environments.

Human cases of Neurotoxic and Paralytic Shellfish Poisoning are most often caused by the consumption of shellfish and other seafood that contains water-based toxins, typically sourced from contaminated water bodies [104]. Animal cases of algal toxin poisoning can be the result of direct contact in the water or subsequent grooming behaviors, inhalation of aerosolized particles, and bioaccumulation in the foodweb [105]. Water-based toxins and their resulting HABs can be found in freshwater, saltwater, and within a mix of salt water and freshwater (brackish water) [107]. In South and Southwest Florida, a majority of the natural water environments are considered brackish, both a natural condition as coastal waterways originate from inland freshwater springs that flow out to the saltwater ocean and a result of saltwater intrusion [108]. These specialized marine ecosystems are ideal habitats for commercially harvested fish and shellfish. However, the unique salinity and warm temperatures of the waterways may also serve to proliferate ciguatoxins, which can result in Ciguatera fish poisoning [109].

**Water-related vector-borne disease**

Water-related vector-borne diseases Venezuelan Equine Encephalitis Virus (VEEV), Eastern Equine Encephalitis (EEE), West Nile Virus (WNV), and St. Louis Encephalitis Virus (SLEV)
were each documented in Florida animals in this search. Publications included in our study were largely concerned with bird populations such as wild birds and Crested Caracaras due to their migratory patterns and characteristics as effective hosts for arboviral diseases [52, 55, 75]. However, evidence of arboviral infection was also found in chicken, horse, and alligator populations [50, 51, 54, 67]. Sentinel surveillance is an important tool in Florida used to monitor the occurrence of water-related vector-borne disease prevalence in chickens, horses, and mosquitoes collected and tested in different counties across the state [110]. In particular, sentinel surveillance using chickens has been a successful method for monitoring the presence of emerging or reemerging arboviral diseases and to provide early public health warnings [110]. While WNV can cause bird die-offs among corvids, chickens do not effectively amplify arboviruses and are not a considered a risk to people for mosquito-borne viruses [110]. Like chickens, horses are also an important sentinel species to indicate rates of water-related vector-borne and arboviral diseases, such as EEE and WNV, circulating in an area however they tend to show more signs and symptoms of infection [110].

The climate of Florida with higher temperatures and precipitation coupled with abundance water bodies provide excellent environments for water-related disease vector (i.e. mosquitoes) to proliferate [111, 112]. Between 1999 and 2019, Florida maintained a yearly average temperature of 71.5˚F with 52.9 inches of rain [113]. Expected climatic changes such as increased temperatures, flooding and extreme weather events, and rainfall over the coming years will mean a need for increased monitoring and sentinel surveillance for arboviral and vector-borne diseases and their vectors [112]. Monitoring the health of wild birds is also vital to determine the disease burdens of migratory species which serve as hosts for arboviral disease [114]. Research is still needed on vector-borne pathogen trends and seasonality among wild birds and the effects of avian amplification of these diseases in Florida [114–116]. Avian amplification is a phenomenon in which coexistence of mosquito vectors and avian hosts can increase the risk of transmission of important arboviral diseases [115].

**One health recommendations.** Surveillance efforts should expand to a greater diversity of animals to better meet the needs of inland regions of Florida, where loss of natural wildlife habitats due to human development and climate change is likely to increase the risk of contact and transmission with vector hosts and disease reservoirs [7, 117]. Human and terrestrial animal interactions occur either directly or by using shared environments and freshwater sources, which can result in increased risk of transmission of zoonotic diseases [118]. Future efforts should advocate for increased disease surveillance and protection of Florida’s diverse avian, marine and terrestrial animal populations and their natural range through a One Health coordinated approach [118, 119]. New research could spur novel findings on water-related disease and transmission risks in these populations, while also advocating for the protection and preservation of the environments in which they live. More research on safe and healthy coexistence with natural wildlife is needed, both today and in the future [59, 115, 120].

Using a One Health approach to simultaneously strengthen the safety and well-being of humans, animals and the environment is prudent in Florida. Research surrounding water-borne, water-based, and water-related diseases and toxins that affect human and animal populations in Florida should take advantage of opportunities for collaboration geared towards prevention efforts and education of the public. This holistic approach could also be considered when designing a study for these water-related pathogens and toxins as resources such as field staff, sampling and laboratory equipment, and even specimens could be multi-purpose by investigating the disease-causing agents from animal, human, and environmental angles with joint teams of professionals from a variety of fields and public health interests. Sharing data-sets, locations for collection, research findings and funding opportunities between human and veterinary public health teams is the best way to move forward under a united approach to
conserving and protecting Florida’s health. In addition, researchers who are publishing their findings in public health, veterinary, wildlife, and zoological journals would benefit a wider-ranging audience if they consider how the presentation of their data and study results could be utilized by colleagues in complementary fields.

Further research on a wider variety of water-related pathogens and toxins in more animal populations can help inform policy and health promotion efforts. The research presented by this study demonstrates regions of the state which are lacking information related to these pathogens and toxins of public and veterinary importance. For example, while Brevard county had many published studies on aquatic and marine animal populations, no studies were done to examine these disease agents in terrestrial wildlife, birds, reptiles, or domestic animals or livestock. The interest in marine mammal health assessments and publications may correspond with local research programs and centers within the counties such as the Hubbs Sea-world Research Institute in Brevard county or the Sarasota Dolphin Research Program in Sarasota county. However, the maps of the published studies also show that single studies have been done for many counties while large portions of the state do not have any works from the past twenty years, particularly in regions that lack university connections or research centers.

Yet disease surveillance efforts by county health departments track and record each reported human case of these conditions and the FDOH has created a public repository of these frequencies through the website FLHealthCHARTS (http://www.flhealthcharts.com/charts/default.aspx). Animal prevalence data could be shared in a similar manner so that zoonotic diseases and toxins could be searched by several health response or research teams. Information sharing should be encouraged across all counties in Florida and facilitated through formal surveillance channels that are open to experts and field professionals from multiple sectors. It is important to consider input and expertise from all silos in order to best serve our Florida communities.

This study is not without its limitations. Utilizing search databases more commonly available to public health researchers may have unintentionally excluded discipline-specific animal science, veterinary, ecology, or zoology journals. These journals may have published research which met our criteria and would have resulted in an even greater understanding of water-related pathogen and toxin presence in Florida’s animals. Further research on this topic is warranted to investigate potential risk associations of water-related pathogens and toxins as they pertain to Florida’s animals, as this objective falls outside the scope of this systematic review. Moreover, without *E. coli* pathotypes provided by many of the included studies, the role of this microorganism as a zoonotic disease risk could not be fully assessed. Due to the language limitations of the co-authors, journal articles written in any language other than English were also excluded, which could have meant a loss in key findings. And finally, as with many systematic review screenings conducted by hand, there is room for human error. In assessing over 8,000 articles for duplication and adherence to inclusion criteria, it is possible that a publication was misidentified which should have been analyzed in the final results. The researchers attempted to combat these potential errors with regular laboratory team meetings and at-length discussion on the merits of each titles for inclusion.

**Conclusion**

Florida’s environmental conditions present a unique opportunity for water-related pathogens and toxins to spread but also provides the chance to conduct collaborative research on how to prevent infection in humans and animals. This review highlights what water-related diseases of public health importance have been found over the past twenty years among animals in Florida but also demonstrates where research is lacking for specific pathogens and aquatic
toxins, regions, and animal populations. Prevention and protection efforts for Florida’s people, animals, and environment necessitates a One Health approach to tackle waterborne disease, water-related vector-borne disease, and water-bases toxins in a successful, interdisciplinary manner.

Supporting information
S1 File. PRISMA checklist.
(DOC)
S2 File. Search strings and results by database.
(DOC)

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References
1. Fisheries Economies of the United States, 2016 [Internet]. NOAA Fisheries. 2018 [cited 11 August 2020]. Available from: https://www.fisheries.noaa.gov/content/fisheries-economics-united-states-2016
2. Borisova T, Oehlbeck K, Bi X, Wade T, Hodges A. [FE1067] Economic Value of Florida Water Resources: Value Derived by Tourists and Recreationists from Freshwater-Based Recreation. EDIS. 2019 Oct 14; 2019(5):8.
3. Research, Florida Visitor Estimates [Internet]. Visit Florida. 2020 [cited 11 August 2020]. Available from: https://www.visitflorida.org/resources/research/
4. United States Census Bureau QuickFacts: Florida [Internet]. QuickFacts: Florida. 2019 [cited 11 August 2020]. Available from: https://www.census.gov/quickfacts/FL
5. Species Profiles [Internet]. Myfwc.com. [cited 2020 Oct 8]. Available from: https://myfwc.com/wildlifehabitats/profiles/
6. Office of resilience and coastal protection programs [Internet]. Floridadep.gov. [cited 2020 Oct 8]. Available from: https://floridadep.gov/programs/RCP
7. Pecl GT, Araújo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, et al. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science. 2017 Mar 31; 355(6332). https://doi.org/10.1126/science.aai9214 PMID: 28360268

8. World Health Organization. Environmental Management for Vector Control: Training and information materials [Internet]. 1988. Available from: https://www.who.int/water_sanitation_health/resources/envmanparta.pdf?ua=1

9. Bartram J, Craun GF. Waterborne zoonoses: identification, causes, and control. World Health Organization; 2004. Available from: https://www.who.int/water_sanitation_health/publications/zoonoses/en/

10. Disease Reporting Information for health care providers and laboratories [Internet]. Floridahealth.gov. [cited 2020 Oct 8]. Available from: http://www.floridahealth.gov/diseases-and-conditions/disease-reporting-and-management/index.html

11. Reportable animal diseases / veterinarians / business services / home—Florida department of agriculture & consumer services [Internet]. Fdacs.gov. [cited 2020 Oct 8]. Available from: https://www.fdacs.gov/Business-Services/Veterinarians/Reportable-Animal-Diseases

12. Control of Communicable Diseases and Conditions Which May Significantly Affect Public Health—Florida administrative rules, law, code, register—FAC, FAR, eRulemaking [Internet]. Flrules.org. [cited 2020 Oct 8]. Available from: https://www.flrules.org/gateway/ChapterHome.asp?Chapter=64D-3

13. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009 Jul 21; 6(7):e1000097. https://doi.org/10.1371/journal.pmed.1000097 PMID: 19621072

14. Trainer VL, Baden DG. High affinity binding of red tide neurotoxins to marine mammal brain. Aquat Toxicol. 1999 Jul 1; 46(2):139–48. https://doi.org/10.1016/S0166-445x(98)00125-8

15. Ellison RK, Malnati E, DePaola AN, Bowers J, Rodrick GE. Populations of Vibrio parahaemolyticus in retail oysters from Florida using two methods. J Food Prot. 2001 May; 64(5):682–6. https://doi.org/10.4315/0362-028x-64.5.682 PMID: 11348000

16. Centers for Disease Control and Prevention (CDC). Update: Neurologic illness associated with eating Florida pufferfish, 2002. MMWR Morb Mortal Wkly Rep. 2002 May 17; 51(19):414. PMID: 12033478

17. Fayer R, Trout J, Lewis E, Santin M, Zhou L, Lal A, et al. Contamination of Atlantic coast commercial shellfish with Cryptosporidium. Parasitol Res. 2003 Jan 1; 89(2):141–5. https://doi.org/10.1007/s00436-004-0734-0 PMID: 12489014

18. Buck JD, Wells RS, Rhinehart HL, Hansen LJ. Aerobic microorganisms associated with free-ranging bottlenose dolphins in coastal Gulf of Mexico and Atlantic Ocean waters. J Wildl Dis. 2006 Jul; 42(3):536–44. https://doi.org/10.7589/0090-3558-42.3.536 PMID: 17092884

19. Landsberg JH, Hall S, Johannessen JN, White KD, Conrad SM, Abbott JP, et al. Saxitoxin puffer fish and brevetoxins, like ciguatoxins, are potent ichthyotoxic neurotoxins that accumulate in fish. Toxicon. 2007 Oct 1; 50(5):707–23. https://doi.org/10.1016/j.toxicon.2007.06.005 PMID: 17675204

20. Fire SE, Flewelling LJ, Wang Z, Naar J, Henry MS, Pierce RH, et al. Florida red tide and brevetoxins: association and exposure in live resident bottlenose dolphins (Tursiops truncatus) in the eastern Gulf of Mexico, USA. Mar Mamm Sci. 2008 Oct; 24(4):831–44. https://doi.org/10.1111/j.1748-7692.2008.00221.x

21. Fire SE, Flewelling LJ, Naar J, Twinner MJ, Henry MS, Pierce RH, et al. Prevalence of brevetoxins in prey fish of bottlenose dolphins in Sarasota Bay, Florida. Mar Ecol Prog Ser. 2008 Sep 25; 368:283–94. https://doi.org/10.3354/meps07643

22. Pierce RH, Henry MS. Harmful algal toxins of the Florida red tide (Karenia brevis): natural chemical stressors in South Florida coastal ecosystems. Ecotoxicology. 2008 Oct 1; 17(7):623–31. https://doi.org/10.1007/s10646-008-0241-x PMID: 18758951

23. Deeds JR, White KD, Etheridge SM, Landsberg JH. Concentrations of saxitoxin and tetrodotoxin in three species of puffers from the Indian River Lagoon, Florida, the location for multiple cases of
Systematic review of water-related disease in Florida animals

Abbott JP, Flewelling LJ, Landsberg JH. Saxitoxin monitoring in three species of Florida puffer fish. Harmful Algae. 2009 Jan 1; 8(2):343–8.

Schaefer AM, Goldstein JD, Reif JS, Fair PA, Bossart GD. Antibiotic-resistant organisms cultured from Atlantic bottlenose dolphins (Tursiops truncatus) inhabiting estuarine waters of Charleston, SC and Indian River Lagoon, FL. Ecohealth. 2009 Mar 1; 6(1): 33. https://doi.org/10.1007/s10393-009-0221-5 PMID: 19415386

Schaefer AM, Reif JS, Goldstein JD, Ryan CN, Fair PA, Bossart GD. Serological evidence of exposure to selected viral, bacterial, and protozoal pathogens in free-ranging Atlantic bottlenose dolphins (Tursiops truncatus) from the Indian River Lagoon, Florida, and Charleston, South Carolina. Aquat Mamm. 2009 Apr 1; 35(2): 163. https://doi.org/10.1578/am.35.2.2009.163

Nam DH, Adams DH, Flewelling LJ, Basu N. Neurochemical alterations in lemon shark (Negaprion brevirostris) brains in association with brevetoxin exposure. Aquat Toxicol. 2010 Sep 1; 99(3): 351–9. https://doi.org/10.1016/j.aquatox.2010.05.014 PMID: 20542580

Wetzel DL, Reynolds JE III, Sprinkel JM, Schwacke L, Mercurio P, Rommel SA. Fatty acid profiles as a potential lipidomic biomarker of exposure to brevetoxin for endangered Florida manatees (Trichechus manatus latirostris). Sci Total Environ. 2010 Nov 15; 408(24): 6124–33. https://doi.org/10.1016/j.scitotenv.2010.08.043 PMID: 20880571

Morris PJ, Johnson WR, Pisan J, Bossart GD, Adams J, Reif JS, et al. Isolation of culturable microorganisms from free-ranging bottlenose dolphins (Tursiops truncatus) from the southeastern United States. Vet Microbiol. 2011 Mar 24; 148(2–4): 440–7. https://doi.org/10.1016/j.vetmic.2010.08.025 PMID: 20888150

Twiner MJ, Fire S, Schwacke L, Davidson L, Wang Z, Morton S, et al. Concurrent exposure of bottlenose dolphins (Tursiops truncatus) to multiple algal toxins in Sarasota Bay, Florida, USA. PLoS One. 2011 Mar 10; 6(3): e17394. https://doi.org/10.1371/journal.pone.0017394 PMID: 21423740

Twiner MJ, Flewelling LJ, Fire SE, Bowen-Stevens SR, Gaydos JK, Johnson CK, et al. Comparative analysis of three brevetoxin-associated bottlenose dolphin (Tursiops truncatus) mortality events in the Florida panhandle region (USA). PLoS One. 2012 Aug 15; 7(8): e42974. https://doi.org/10.1371/journal.pone.0042974 PMID: 22916189

Van Deventer M, Atwood K, Vargo GA, Flewelling LJ, Landsberg JH, Naar JP, et al. K. saxitoxin puffer poisoning from 2002 to 2004. Trans Am Fish Soc. 2008 Sep 1; 137(5):1317–26. https://doi.org/10.1577/t07-204.1

Abbott JP, Flewelling LJ, Landsberg JH. Saxitoxin monitoring in three species of Florida puffer fish. Harmful Algae. 2009 Jan 1; 8(2):343–8.

McFarland K, Jean F, Soudant P, Volety AK. Uptake and elimination of brevetoxin in the invasive green mussel, Perna viridis, during natural Karenia brevis blooms in southwest Florida. Toxicon. 2015 Apr 1; 97: 46–52. https://doi.org/10.1016/j.toxicon.2015.02.005 PMID: 25681577

Walsh CJ, Butawan M, Yordy J, Ball R, Flewelling L, de Wit M, et al. Sublethal red tide toxin exposure in free-ranging manatees (Trichechus manatus) affects the immune system through reduced lymphocyte proliferation responses, inflammation, and oxidative stress. Aquat Toxicol. 2015 Apr 1; 161:73–84. https://doi.org/10.1016/j.aquatox.2015.01.019 PMID: 25678466

Perrault JR, Bauman KD, Greenan TM, Blum PC, Henry MS, Walsh CJ. Maternal transfer and sublethal immune system effects of brevetoxin exposure in nesting loggerhead sea turtles (Caretta caretta) from western Florida. Aquat Toxicol. 2016 Nov 1; 180: 131–40. https://doi.org/10.1016/j.aquatox.2016.09.020 PMID: 27716578

Vorbach BS, Rotstein DS, Stacy NI, Mavian C, Salemi M, Waltzek TB, et al. Fatal Systemic Salmonellosis in a Florida Manatee (Trichechus manatus latirostris). J Wildl Dis. 2017 Oct; 53(4): 930–3. https://doi.org/10.7589/2017-01-012 PMID: 28463629

Kemp KM, Westrich JR, Alabady MS, Edwards ML, Lipp EK. Abundance and multilocus sequence analysis of Vibrio bacteria associated with diseased elkhorn coral (Acropora palmata) of the Florida Keys. Appl Environ Microbiol. 2018 Jan 15; 84(2). https://doi.org/10.1128/AEM.01035-17 PMID: 29079623
44. Hardison DR, Holland WC, Darius HT, Chinain M, Tester PA, Shea D, et al. Investigation of ciguatera in invasive lionfish from the greater Caribbean region: Implications for fishery development. PLoS One. 2018 Jun 20;13(6):e0198358. https://doi.org/10.1371/journal.pone.0198358 PMID: 29924826

45. Martony M, Poudre D, Yanong R, Kryy Y, Landsberg JH, Isaza R, et al. Establishing a Diagnostic Technique for Coelomocytosis in the Long-Spined Sea Urchin Diadema antillarum. J Aquat Anim Healt. 2018 Dec;30(4):325–31. https://doi.org/10.1002/aah.10443 PMID: 30336511

46. Rolton A, Vignier J, Volety A, Shumway S, Bricelj VM, Soudant P. Impacts of exposure to the toxic dinoflagellate Karenia brevis on reproduction of the northern quahog, Mercenaria mercenaria. Aquat Toxicol. 2018 Sep 1;202:153–62. https://doi.org/10.1016/j.aquatox.2018.07.007 PMID: 30031906

47. Fire SE, Browning JA, Durden WN, Stolen MK. Comparison during-bloom and inter-bloom brevetoxin and saxitoxin concentrations in Indian River Lagoon bottlenose dolphins, 2002–2011. Aquat Toxicol. 2020 Jan 1;218:105371. https://doi.org/10.1016/j.aquatox.2019.105371 PMID: 31790399

48. Fang L, Ginn AM, Harper J, Kane AS, Wright AC. Survey and genetic characterization of Vibrio cholerae in Apalachicola Bay, Florida (2012–2014). J Appl Microbiol. 2019 Apr;126(4):1265–77. https://doi.org/10.1111/jam.14199 PMID: 30629784

49. Hudson CR, Quit C, Lee MD, Keyes K, Dodson SV, Morales C, et al. Genetic relatedness of Salmonella isolates from nondomestic birds in Southeastern United States. J Clin Microbiol. 2000 May 1;38(5):1860–8. https://doi.org/10.1128/JCM.38.5.1860-1865.2000 PMID: 10790113

50. Blackmore CG, Stark LM, Jeter WC, Oliver RL, Brooks RG, Conti LA, et al. Surveillance results from the first West Nile virus transmission season in Florida, 2001. Am J Trop Med Hyg. 2003 Aug 1;69(2):141–50.

51. Jacobson ER, Ginn PE, Troutman JM, Farina L, Stark L, Klenk K, et al. West Nile virus infection in farmed American alligators (Alligator mississippiensis) in Florida. J Wildl Dis. 2005 Jan;41(1):96–106. https://doi.org/10.7589/0090-3558-41.1.96 PMID: 15827215

52. Godsey MS Jr, Blackmore MS, Panella NA, Burkharter K, Gottfried K, Halsey LA, et al. West Nile virus epizootiology in the southeastern United States, 2001. Vector Borne Zoonotic Dis. 2005 Mar 1;5(1):82–9. https://doi.org/10.1089/vbz.2005.5.82 PMID: 15815153

53. Allison AB, Gottdenker NL, Stallknecht DE. Wintering of neurotropic velogenic Newcastle disease virus and West Nile virus in double-crested cormorants (Phalacrocorax auritus) from the Florida Keys. Avian Dis. 2005 Jun;49(2):292–7. https://doi.org/10.1637/7278-091304R PMID: 16094838

54. Gibbs SE, Marlenee NL, Romines J, Kavanaugh D, Corn JL, Stallknecht DE. Antibodies to West Nile virus in feral swine from Florida, Georgia, and Texas, USA. Vector Borne Zoonotic Dis. 2006 Sep 1;6(3):261–5. https://doi.org/10.1089/vbz.2006.6.261 PMID: 16989565

55. Nemeth NM, Dwyer JF, Morrison JL, Fraser JD. Prevalence of antibodies to West Nile virus and other arboviruses among Crested Caracaras (Caracara cheriway) in Florida. J Widl Dis. 2009 Jul;45(3):817–22. https://doi.org/10.7589/0090-3558-45.3.817

56. Charles-Smith LE, Lewbart GA, Aresco MJ, Cowen P. Detection of Salmonella in Gopher Tortoises (Gopherus polyphemus) during two relocation efforts in Florida. Chelonian Conserv Biol. 2009 Dec;8(2):213–6.

57. Landolfi JA, Terio KA, Kinsel MJ, Langan J, Zachariah TT, Childress AL, et al. Orthoreovirus infection and concurrent cryptosporidiosis in rough green snakes (Opheodrys aestivus): pathology and identification of a novel orthoreovirus strain via polymerase chain reaction and sequencing. J Vet Diagn Invest. 2010 Jan;22(1):37–43. https://doi.org/10.1177/104063871002200106 PMID: 20093680

58. Chatfield J, Millerson M, Stoddard R, Bui DM, Galloway R. Serosurvey of leptospirosis in feral hogs (Sus scrofa) in Florida. J Zoo Wildl Med. 2013 Jun;44(2):404–7. https://doi.org/10.1637/2012-0258R2.1 PMID: 23803559

59. Grigione MM, Burman P, Clavio S, Harper SJ, Manning DL, Sarno RJ. A comparative study between enteric parasites of Coyotes in a protected and suburban habitat. Urban Ecosyst. 2014 Mar 1;17(1):1–0. https://doi.org/10.1007/s11252-013-0302-7

60. Hernandez SM, Welch CN, Peters VE, Lipp EK, Curry S, Yabsley MJ, et al. Urbanized white ibises (Eudocimus albus) as carriers of Salmonella enterica of significance to public health and wildlife. PLoS One. 2016 Oct 21;11(10):e0164402. https://doi.org/10.1371/journal.pone.0164402 PMID: 27768705

61. Huffman JN, Haizlett KS, Elhassani DK, Cooney BT, Frazier EM. A survey of Gopherus polyphemus intestinal parasites in South Florida. J Parazitol Res. 2018 Dec 6;2018. https://doi.org/10.1155/2018/3048795 PMID: 30687545

62. Riley DG, Gray JT, Loneragan GH, Barling KS, Chase CC Jr. Escherichia coli O157: H7 prevalence in fecal samples of cattle from a southeastern beef cow-calf herd. J Food Prot. 2003 Oct;66(10):1778–82. https://doi.org/10.4315/0362-028x-66.10.1778 PMID: 14572213
63. Trout JM, Santín M, Greiner E, Fayer R. Prevalence of Giardia duodenalis genotypes in pre-weaned dairy calves. Vet Parasitol. 2004 Oct 5; 124(3–4): 179–86. https://doi.org/10.1016/j.vetpar.2004.07.010 PMID: 15381298

64. Trout JM, Santín M, Greiner E, Fayer R. Prevalence and genotypes of Giardia duodenalis in pre-weaned dairy calves. Vet Parasitol. 2005 Jun 30; 130(3–4): 177–83. https://doi.org/10.1016/j.vetpar.2005.03.032 PMID: 15925721

65. Centers for Disease Control and Prevention (CDC). Outbreaks of Escherichia coli O157: H7 associated with petting zoos—North Carolina, Florida, and Arizona, 2004 and 2005. MMWR Morb Mortal Wkly Rep. 2005 Dec 23; 54(50):1277. PMID: 16371942

66. Trout JM, Santín M, Greiner EC, Fayer R. Prevalence and genotypes of Giardia duodenalis in 1–2 year old dairy cattle. Vet Parasitol. 2006 Sep 10; 140(3–4): 217–22. https://doi.org/10.1016/j.vetpar.2006.03.025 PMID: 16647818

67. Coffey LL, Crawford C, Dee J, Miller R, Freier J, Weaver SC. Serologic evidence of widespread Everglades virus activity in dogs, Florida. Emerg Infect Dis. 2006 Dec; 12(12):1873. https://doi.org/10.3201/eid1212.060446 PMID: 17326938

68. Trout JM, Santín M, Fayer R. Prevalence of Cryptosporidium species and genotypes in mature dairy cattle on farms in eastern United States compared with younger cattle from the same locations. Vet Parasitol. 2007 Apr 30; 145(3–4):260–6. https://doi.org/10.1016/j.vetpar.2006.12.009 PMID: 17287086

69. Riley DG, Loneragan GH, Phillips WA, Gray JT, Fedorka-Cray PJ. Fecal shedding of foodborne pathogens by Florida-born heifers and steers in US beef production segments. J Food Prot. 2008 Apr; 71(4): 807–10. https://doi.org/10.4315/0362-028x-71.4.807 PMID: 18468037

70. Rios LM, Sheu JJ, Day JF, Maruniak JE, Seino K, Zaretksy H, et al. Environmental risk factors associated with West Nile virus clinical disease in Florida horses. Med Vet Entomol. 2009 Dec; 23(4): 357–66. https://doi.org/10.1111/j.1365-2915.2009.00821.x PMID: 19941601

71. Alelis KA, Borkowski PE, Fiorella P, Nasir J, Middaugh J, Blackmore C, et al. Outbreak of shiga toxin-producing Escherichia coli O157 infection associated with a day camp petting zoo—Pinellas County, Florida, May–June 2007. MMWR Morb Mortal Wkly Rep. 2009; 58(16):426–8. PMID: 19407735

72. Sabshin SJ, Levy JK, Tupler T, Tucker SJ, Greiner EC, Leutenegger CM. Enteropathogens identified in cats entering a Florida animal shelter with normal feces or diarrhea. J Am Vet Med Assoc. 2012 Aug 1; 241(3): 331–7. https://doi.org/10.2460/javma.241.3.331 PMID: 22812469

73. Tupler T, Levy JK, Sabshin SJ, Tucker SJ, Greiner EC, Leutenegger CM. Enteropathogens identified in dogs entering a Florida animal shelter with normal feces or diarrhea. J Am Vet Med Assoc. 2012 Aug 1; 241(3): 338–43. https://doi.org/10.2460/javma.241.3.338 PMID: 22812470

74. Estep LK, McClure CJ, Vander Kelen P, Burkett-Cadena ND, Sickerman S, Hernandez J, et al. Risk of exposure to eastern equine encephalomyelitis virus increases with the density of northern cardinals. PLoS One. 2013 Feb 28; 8(2):e57879. https://doi.org/10.1371/journal.pone.0057879 PMID: 23469095

75. Wyrosdick HM, Chapman A, Martinez J, Schaefer JF. Parasite prevalence survey in shelter cats in Citrus County, Florida. Vet Parasitol Reg Stud Reports. 2017 Dec 1; 10: 20–4. https://doi.org/10.1016/j.vprsr.2017.07.002 PMID: 31014592

76. Montgomery MP, Robertson S, Koski L, Salehi E, Stevenson LM, Silver R, et al. Multidrug-resistant Campylobacter jejuni outbreak linked to puppy exposure—United States, 2016–2018. MMWR Morb Mortal Wkly Rep. 2018 Sep 21; 67(37): 1032. https://doi.org/10.15585/mmwr.mm6737a3 PMID: 30235182

77. Baker CA, De J, Bertoldi B, Dunn L, Chapin T, Jay-Russell M, et al. Prevalence and concentration of stx+ E. coli and E. coli O157 in bovine manure from Florida farms. PLoS One. 2019 May 24; 14(5): e0217445. https://doi.org/10.1371/journal.pone.0217445 PMID: 31125367

78. Tyrrel SF, Quinton JN. Overland flow transport of pathogens from agricultural land receiving faecal wastes. J Appl Microbiol. 2003 May; 94: 87–93. https://doi.org/10.1046/j.1365-2672.94.s1.10.x PMID: 12675940

79. Murphy HM, Prioleau MD, Borchardt MA, Hynds PD. Epidemiological evidence of groundwater contribution to global enteric disease, 1948–2015. Hydrogeol J. 2017 Jun 1; 25(4): 981–1001.

80. Kristosik A, Njoroge G, Odhiambo L, Forsyth JE, Mutuku F, LaBeaud AD. Solid wastes provide breeding sites, burrows, and food for biological disease vectors, and urban zoonotic reservoirs: a call to action for solutions-based research. Front Public Health. 2020 Jan 17; 7:405. https://doi.org/10.3389/fpubh.2019.00405 PMID: 32010659
82. Brankston G, Boughe C, Ng V, Fisman DN, Sargeant JM, Greer AL. Assessing the impact of environmental exposures and Cryptosporidium infection in cattle on human incidence of cryptosporidiosis in Southwestern Ontario, Canada. PLoS One. 2018 Apr 26; 13(4):e0196573. https://doi.org/10.1371/journal.pone.0196573 PMID: 29698463

83. Caffarena RD, Meireles MV, Carrasco-Letelier L, Picasso-Rizzo C, Santana BN, Riet-Correa F, et al. Dairy calves in Uruguay are reservoirs of zoonotic subtypes of Cryptosporidium parvum and pose a potential risk of surface water contamination. Front Vet Sci. 2020 Aug 21; 7:562. https://doi.org/10.3389/fvets.2020.00562 PMID: 32974408

84. Questions and Answers [Internet]. Centers for Disease Control and Prevention. Centers for Disease Control and Prevention. 2014 [cited 2020 Oct 8]. Available from: https://www.cdc.gov/ecoli/general/index.html

85. Bogomolni AL, Gast RJ, Ellis JC, Dennett M, Pugliaras KR, Lentell BJ, et al. Victims or vectors: a survey of marine vertebrate zoonoses from coastal waters of the Northwest Atlantic. Dis Aquat Org. 2008 Aug 19; 81(1):13–38. https://doi.org/10.3354/dao01936 PMID: 18828560

86. Hughes-Hanks JM, Rickard LG, Panuska C, Saucier JR, O'hara TM, Dehn L, et al. Prevalence of Cryptosporidium spp. and Giardia spp. in five marine mammal species. J Parasitol. 2005 Oct; 91(5):1225–8. https://doi.org/10.1645/GE-545R.1 PMID: 16419775

87. Waltzek TB, Cortés-Hinojosa G, Wellehan JF Jr, Gray GC. Marine mammal zoonoses: A review of disease manifestations. Zoonoses Public Health. 2012 Dec; 59(8): 521–35. https://doi.org/10.1111/j.1863-2378.2012.01492.x PMID: 22697432

88. Conrad CC, Stanford K, Narvaez-Bravo C, Callaway T, McAllister T. Farm fairs and petting zoos: a review of animal contact as a source of zoonotic enteric disease. Foodborne Pathog Dis. 2017 Feb 1; 14(2):59–73. https://doi.org/10.1089/fpd.2016.2185 PMID: 27992253

89. Sapp SG, Rascoe LN, Wilkins PP, Handali S, Gray EB, Eberhard M, et al. Baylisascaris procyonis roundworm seroprevalence among wildlife rehabilitators, United States and Canada, 2012–2015. Emerg Infect Dis. 2016 Dec; 22(12): 2128. https://doi.org/10.3201/eid2212.160467 PMID: 27869612

90. Wright JG, Jung S, Holman RC, Marano NN, McQuiston JH. Infection control practices and zoonotic disease risks among veterinarians in the United States. J Am Vet Med Assoc. 2008 Jun 15; 232(12): 1863–72. https://doi.org/10.2460/javma.232.12.1863 PMID: 18598158

91. Raza A, Rand J, Qamar AG, Jabbar A, Kopp S. Gastrointestinal parasites in shelter dogs: Occurrence, pathology, treatment and risk to shelter workers. Animals. 2018 Jul; 8(7): 108. https://doi.org/10.3390/ani8070108 PMID: 30004469

92. Steele CM, Brown RN, Botzler RG. Prevalences of zoonotic bacteria among seabirds in rehabilitation centers along the Pacific Coast of California and Washington, USA. J Wildl Dis. 2005 Oct; 41(4): 735–44. https://doi.org/10.7589/0090-3558-41.4.735 PMID: 16456162

93. Stull JW, Stevenson KB. Zoonotic disease risks for immunocompromised and other high-risk clients and staff: promoting safe pet ownership and contact. Vet Clin North Am Small Anim Pract. 2015 Mar 1; 44(2): 377–92. https://doi.org/10.1016/j.cvsm.2014.11.007 PMID: 25953453

94. Florida agriculture overview and statistics [Internet]. Fdacs.gov. [cited 2020 Oct 8]. Available from: https://www.fdacs.gov/Agriculture-Industry/Florida-Agriculture-Overview-and-Statistics

95. Häslor B, Gilbert W, Jones BA, Pfeiffer DU, Rushton J, Otte MJ. The economic value of One Health in relation to the mitigation of zoonotic disease risks. In One Health: The Human-Animal-Environment Interfaces in Emerging Infectious Diseases 2012 (pp. 127–151). Springer, Berlin, Heidelberg.

96. Greger M. The long haul: risks associated with livestock transport. Biosecur Bioterror. 2007 Dec; 5(4):301–12. https://doi.org/10.1089/bsp.2007.0028 PMID: 18081490

97. Keusch GT, Pappasianou M, Gonzalez MC, Scott KA, Tsai P, National Research Council. Governance Challenges for Zoonotic Disease Surveillance, Reporting, and Response. Sustaining Global Surveillance and Response to Emerging Zoonotic Diseases 2009. National Academies Press (US). Available from: https://pdf.usaid.gov/pdf_docs/pandq645.pdf

98. O’Haire M. Companion animals and human health: Benefits, challenges, and the road ahead. J Vet Behav. 2010 Sep 1; 5(5): 226–34.

99. Stull JW, Brophy J, Weese JS. Reducing the risk of pet-associated zoonotic infections. CMAJ. 2015 Jul 14; 187(10): 736–43. https://doi.org/10.1503/cmaj.141020 PMID: 25897046

100. Gerhold RW, Jessup DA. Zoonotic diseases associated with free-roaming cats. Zoonoses Public Health. 2013 May; 60(3):189–95. https://doi.org/10.1111/j.1863-2378.2012.01522.x PMID: 22830565

101. Kirkpatrick B, Fleming LE, Squicciarini D, Backer LC, Clark R, Abraham W, et al. Literature review of Florida red tide: implications for human health effects. Harmful Algae. 2004 Apr 1; 3(2):99–115. https://doi.org/10.1016/j.hal.2003.08.005 PMID: 20411030
102. Fleming LE, Kirkpatrick B, Backer LC, Walsh CJ, Nierenberg K, Clark J, et al. Review of Florida red tide and human health effects. Harmful Algae. 2011 Jan 1; 10(2):224–33. https://doi.org/10.1016/j.hal.2010.08.006 PMID: 21218152

103. Backer LC, Landsberg JH, Miller M, Keel K, Taylor TK. Canine cyanotoxin poisonings in the United States (1920s–2012): Review of suspected and confirmed cases from three data sources. Toxins. 2013 Sep; 5(9):1597–628. https://doi.org/10.3390/toxins5091597 PMID: 24064718

104. Vilariño N, Louzao MC, Abal P, Cagide E, Carrera C, Vieytes MR, et al. Human poisoning from marine toxins: Unknowns for optimal consumer protection. Toxins. 2018 Aug; 10(8): 324. https://doi.org/10.3390/toxins10080324 PMID: 30096904

105. Van Dolah FM, Doucette GJ, Gulland FM, Rowles TL, Bossart GD. Impacts of algal toxins on marine mammals. In: Vos J, Bossart G, Fournier M, O’Shea T, ed. by. Toxicology of Marine Mammals. 3rd ed. London: Taylor & Francis; 2003. p. 247–269.

106. HAB Updates [Internet]. Floridahealth.gov. [cited 2020 Oct 8]. Available from: http://www.floridahealth.gov/environmental-health/aquatic-toxins/updates-report-and-contact/index.html

107. Illness & Symptoms [Internet]. Cdc.gov. 2018 [cited 2020 Oct 8]. Available from: https://www.cdc.gov/habs/illness.html

108. Gramling C. A freshwater, saltwater tug-of-war is eating away at the Everglades [Internet]. Science-news.org. 2018 [cited 2020 Oct 8]. Available from: https://www.sciencenews.org/article/florida-everglades-freshwater-saltwater-sea-level-rise

109. Radke EG, Reich A, Morris JG Jr. Epidemiology of ciguatera in Florida. Am J Trop Med Hyg. 2015 Aug 5; 93(2): 425–32. https://doi.org/10.4269/ajtmh.14-0400 PMID: 26123957

110. Mosquito-Borne Disease Guidebook [Internet]. Floridahealth.gov. [cited 2020 Oct 8]. Available from: http://www.floridahealth.gov/diseases-and-conditions/mosquito-borne-diseases/guidebook.html

111. Leisnham PT, LaDeau SL, Juliano SA. Spatial and temporal habitat segregation of mosquitoes in urban Florida. PLoS One. 2014 Mar 12; 9(3): e91655. https://doi.org/10.1371/journal.pone.0091655 PMID: 24621592

112. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. Ann N Y Acad Sci. 2019 Jan; 1436(1):157: https://doi.org/10.1111/nyas.13950 PMID: 30120891

113. Climate at a Glance: Statewide Time Series [Internet]. NOAA. 2010 [cited 11 August 2020]. Available from: https://www.ncdc.noaa.gov/cag/

114. Komar N. West Nile virus surveillance using sentinel birds. Ann N Y Acad Sci. 2001 Dec; 951(1):58–73. https://doi.org/10.1111/j.1749-6632.2001.tb02685.x PMID: 11797805

115. Bingham AM, Burkett-Cadena ND, Hassan HK, McClure CJ, Unnasch TR. Field investigations of winter transmission of eastern equine encephalitis virus in Florida. Am J Trop Med Hyg. 2014 Oct 1; 91 (4):685–93. https://doi.org/10.4269/ajtmh.14-0091 PMID: 25070997

116. Shaman J. Amplification due to spatial clustering in an individual-based model of mosquito–avian arbovirus transmission. Trans R Soc Trop Med Hyg. 2007 May 1; 101(5): 469–83. https://doi.org/10.1016/j.trstmh.2006.11.007 PMID: 17270229

117. Eisenberg JN, Desai MA, Levy K, Bates SJ, Liang S, Naumoff K, et al. Environmental determinants of infectious disease: A framework for tracking causal links and guiding public health research. Environ Health Perspect. 2007 Aug; 115(8):1216–23. https://doi.org/10.1289/ehp.9806 PMID: 17687450

118. Rabinowitz P, Conti L. Links among human health, animal health, and ecosystem health. Annu Rev Public Health. 2013 Mar 18; 34: 189–204. https://doi.org/10.1146/annurev-publichealth-031912-114426 PMID: 23330700

119. World Health Organization. Taking a Multisectoral One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries. Food & Agriculture Org.; 2019 Mar 11. Available from https://apps.who.int/iris/bitstream/handle/10665/235620/9789241514934-eng.pdf

120. Bossart GD. Marine mammals as sentinel species for oceans and human health. Vet Pathol. 2011 May; 48(3):676–90. https://doi.org/10.1177/0300985810389525 PMID: 21160025