Essential veterinary education in fish health and disease: a global perspective

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Summary
Fish are the largest class of vertebrates, with over 25,000 estimated species and subspecies. Fish have evolved unique anatomical and physiological adaptations, when compared to terrestrial vertebrates, for life in a range of aquatic environments. Interest in aquatic animal health has been recorded in Eastern and Western cultures for more than 2,000 years. In recent times, there has been an increase in the numbers of aquatic animals being used as companion animals or pets, for food and in laboratories, as well as in restoration and conservation programmes. There has also been a corresponding increase in concern for their health and welfare. Moral and ethical considerations require the optimisation of husbandry practices and advances in aquatic animal health for these animals. As with other vertebrates, veterinarians are best equipped to meet the challenges for aquatic animal health from clinical, scientific and legal perspectives. To accomplish this goal, veterinary education must incorporate aquatic animal health throughout graduate curricula, create advanced post-graduate training opportunities, and support a continuum of professional development opportunities for all levels of aquatic animal health expertise.

Keywords
Aquatic animal health – Aquatic animals – Curriculum – Fish – Fish health – Vertebrates.

Introduction

Fish are the most species-rich group of vertebrates. There are more than 25,000 described species, which possess a wide range of physical and physiological adaptations for a diverse range of aquatic habitats (16). Fish have played a prominent role in society for centuries. Aquatic animals:

– provide an important food source from both fisheries and aquaculture

– are one of the most common laboratory animal models for a variety of toxicological, infectious disease, immunologic and genetic research programmes

– are the most numerous companion animals, as pets in bowls, aquariums and ponds

– represent the fastest-growing vertebrate taxa used for education in public displays at aquariums and zoos

– serve as a vital indicator group for marine and freshwater eco-system evaluation, habitat assessment, conservation medicine and environmental health.

Thus, an understanding of fish health and disease is crucial to a veterinary education that strives to encompass a wide range of animal taxa and to incorporate a pro-active approach when addressing current and future needs in veterinary medicine and public health.

An interest in fish health has been documented for over 2,000 years. The first reports on fish health in Western literature are attributed to Aristotle in 350 BC, who recorded the presence of crustacean ectoparasites near the fins of swordfish and tuna (2). Reports on carp culture in China during the Han Dynasty (206 BC to 220 AD) noted the presence of white spot, a common protozoan parasite of many fish. In the United States of America (USA), the first recorded discoveries in the field of fish health began in the early 1600s, and these annals have been preserved in archives at the Philadelphia and California Academies of Science. Mitchell compiled several of these accounts to create a comprehensive historical summary from 1609 to 1969 (15). Many of these early references for diagnoses and disease treatments are still used today.

Although more systematic veterinary involvement began in the late 1970s and early 1980s, when many veterinary schools began hiring faculty staff with expertise in fish health, veterinary involvement in this field was largely dependent on individual participation and achievement until the 1990s. Several veterinarians and aquatic animal health specialists have written papers encouraging greater veterinary involvement in finfish and shellfish health, recognising the potential opportunities for the veterinary profession in a dynamic aquatic animal industry. Purchase *et al.* (19) addressed the need for veterinarians to train in aquatic specialities to meet the growing demands of aquaculture in the USA.

Although most US veterinary schools have at least one and, in some cases, several faculty members directing clinical and/or research programmes in fish health, these programmes rarely receive the same financial, developmental or administrative support afforded to programmes on more traditional mammalian species. Sometimes these aquatic health programmes are relegated to research and clinical sites which are off campus or located away from general veterinary operations. More often, educational opportunities in the aquatic health faculty are not incorporated into the general veterinary curriculum. In fact, often only a few students, who have entered with a strong aquatic animal background from previous university study, even know that these programmes exist and so are able to participate in extra-curricular activities associated with aquatic animal health research and clinics. Current economic conditions have resulted in the closure and/or contraction of several aquatic animal health programmes at US veterinary schools in the last year.

In Europe, the picture varies across the continent. Some 87 veterinary training institutions (schools, faculties, universities) have been surveyed by the European Federation of Veterinarians. These institutions are unevenly scattered across the continent. Twenty-two countries (71%) have one or two institutions. Six (19%) have from three to six. Only three nations are remarkable for their high number of veterinary schools: the United Kingdom (UK) has seven, Spain has 11 and Italy boasts 13. A total of 74 institutions of the 87 (85%) publish their student courses on the worldwide web and 43 of these (57%) provide training in aquaculture.

In recent times, global discussions on the future of veterinary medicine, at high academic and government levels, have recognised the importance of aquatic animal medicine. In 2001, US veterinarians debated preparing veterinary students for non-traditional careers (10). Fish health issues were placed at the forefront of the Australian Veterinary Association plenary address in 2006, which examined changing demographics from rural to urban centres and future challenges for veterinary medicine in Australia and abroad (27).

Curricular requirements for aquatic animal medicine in veterinary education

The American College of Zoological Medicine and the University of California, Davis, have respectively developed recommendations on the future of the veterinary curriculum and advancing public health education in veterinary medicine. These recommendations can be directly modified with specific examples from aquatic animal medicine to help create a foundation for incorporating aquatic animal health into veterinary curricula (8, 24).

Foundation veterinary science

There are major structural and functional differences between mammals and fish. Many of these differences result from adapting to specific habitats, whether they are terrestrial or aquatic. Seventy percent of the surface of the earth is covered by water, of which 97% is seawater. Most water temperatures are temperate or cold, with bands of tropical areas. Roughly 58% of fish species are marine animals and most reside at less than 200 m depth, in shore, while 13% of these marine fish species are pelagic. The remainder of species are either freshwater (41%) or anadromous (i.e. swim upriver from the sea to spawn) (1%).

Fish are largely ectothermic, with no thermo-regulation, except for tuna and lamnid sharks. Fish have evolved to meet the demands of an aquatic environment by developing unique shapes, locomotive capabilities and buoyancy adaptations to meet the challenges caused by water density. This includes anatomical differences, with the development of a specialised organ called the swim bladder, to act as a buoyancy compensation device in many species of teleost fish. Most fish do not have lungs but rely on exchanging oxygen from their environment while exhaling carbon dioxide and ammonia through the gills. The solubility of gas in water, pH and ionic strength all play crucial roles in fish physiology for respiration and osmo-regulation. Recognising and appreciating these key anatomic and physiological differences between fish and mammals is a key component of veterinary education in the fish health sciences as they fundamentally determine the approach to fish medicine.

If students are to develop a basic understanding of aquatic animal medicine, fish must be included in the basic science courses of the veterinary curriculum. Less zoology and more cell biology have been incorporated into undergraduate life sciences curricula in the USA and abroad during the past three decades. With this evolution of scientific education, many veterinary students are ill-prepared to truly grasp and understand the diversity of animal taxa that may present as patients. There are crucial differences between aquatic and terrestrial animal species, as mentioned previously. Some of the foundation and basic knowledge needed for aquatic animal medicine includes:

– ichthyology
– fish anatomy
– fish physiology
– fish husbandry
– environmental quality (water quality, sound, light intensity/wave length requirements and air quality for aquatic systems and habitats)
– fish behaviour
– fish nutrition
– fish reproduction
– fish genetics.

These topics offer ideal subject matter for teaching comparative veterinary courses in general anatomy, biochemistry, physiology, histology and pathology.

Clinical science and training

Clinical science and training in aquatic animal species are essential. These include incorporating some case studies from aquatic animal medicine into general parasitology, immunology, pharmacology and microbiology lectures. It is important to grasp the critical differences that may be required to get accurate results for fish, such as:

– incubating pathogens at lower temperatures

– providing media that contain special agars, such as seawater

– creating haematologic and chemistry baselines for healthy animals

– requiring special fish cell lines for virus culture.

Veterinarians must perform a timely and thorough necropsy to interpret the pathology for aquatic patients, noting histopathologic differences, such as the absence of a defined adrenal gland or distinct pancreas, or identifying an epigonal organ or rectal gland. Interpreting diagnostics is another challenge when dealing with aquatic patients, and all veterinary students should be exposed to clinical chemistry, histopathology and haematology for common finfish. For companion animals or display fish, veterinarians are required to perform anaesthesia, advanced diagnostics and/or surgery on live patients, and then decide on treatment regimes, based on their diagnostic findings. These clinical skills must be taught to provide the best outcome for a variety of clients and fish patients. Pharmacology and pharmacokinetics, which are sometimes altered by the environment and health status of the individual, are poorly understood for a wide variety of aquatic animal species, leaving veterinarians with only a few treatment options and even fewer research-based efficacious dosages, especially for food fish (7, 23).

Population medicine

Aquatic animal health offers substantial examples in the disciplines of epidemiology, preventive medicine, risk analysis and biosecurity. Some of the greatest opportunities in fish medicine require a basic understanding and application of these disciplines when designing comprehensive fish health management programmes for specific industries. Not all aquatic animal practitioners readily apply these principles, yet the confined fish populations of aquaculture offer an ideal data set for population medicine.

Some of the challenges specific to fish include:

– practical considerations, such as holding-pen design or water source management

– population sampling, to establish feeding guidelines on shrimp farms or screen brood fish for specific pathogens

– the movement and mixing of populations, combining age classes of the same species

– adapting fish from a hatchery to open net or sea pens

– polyculture or housing multiple species and/or taxa

– understanding that stocking density and environmental quality are interdependent

– striving to balance fast and efficient growth with decreased aggression and reproductive behaviours

– modifying and maintaining adequate life support, husbandry practices and waste removal

– understanding the clustering response of fish in confined systems, as compared with the behaviour of terrestrial animals, especially during times of infectious disease outbreaks (6).

It is important to note that many concepts of pharmacology and immunobiology at the school level have been developed in fish research, but still await field implementation through education.

Public health

As more is understood about aquatic animal pathogens, so it becomes more important for veterinarians to take the lead on matters of public health. Zoonotic pathogens have been isolated from a number of aquatic animals, such as food, bait, marine ornamental and tropical fish (13). These include a variety of bacterial, fungal and parasitic pathogens that may be either a primary pathogen for aquatic species, or noted as an incidental finding. Newly emerging pathogens isolated from fish may also have the potential to cause zoonotic infections, such as *Exophiala* sp. isolated from a variety of temperate and coldwater marine fish (17). Recent research, involving the microbiological testing of water samples from fish tanks, suggests that hobby aquariums may be a reservoir for *Salmonella* (12). However, fish may simply serve as vectors for transporting mammalian pathogens when given contaminated feed, or when kept in poor environmental conditions harbouring large numbers of these pathogens, such as in the practice of raising fish under poultry or swine units, which is common in developing countries (14). The role of veterinarians in food safety is well documented, and the need for vigilance towards seafood safety is increasing as human populations grow. Several pathogens that have been isolated from seafood, or occur due to faecal contamination in seafood processing, can cause human illness (5).

Eco-system health and conservation medicine

Aquatic animal health also effectively illustrates the concepts of conservation medicine and eco-system health for veterinary students. In 1997, a consortium of Canadian veterinary schools stressed the need for eco-system-based medicine, using several examples from aquatic animal health (21). Water is essential for all animals, and fish are a true indicator species for monitoring the health of the environment, given the great diversity of fish species, which have adapted to nearly every niche on earth, from deserts to the Antarctic. These concepts build on foundational science, clinical teachings and population medicine to expand aquatic animal health knowledge by, for example:

– identifying pathogens traditionally considered terrestrial pathogens, such as *Listeria* in snails and leopard frogs (3)

– understanding the epidemiological threats and economic consequences that iridoviruses may pose for the ornamental fish trade and wild populations (26)

– detecting antibiotics and antibiotic-resistant pathogens in streams and groundwater (9)

– identifying new disease outbreaks, such as mycobacteriosis in wild striped sea bass (*Morone saxatilis*) from Chesapeake Bay (20).

Veterinary welfare

In this changing society, aquatic animal welfare and ethics must be included in veterinary education. As fish are increasingly used as display animals in zoos and public aquariums, questions involving euthanasia, captivity and animal use will be more frequently challenged and debated in the USA and Europe (11). Fish are regularly included in animal welfare and laboratory animal guidelines and manuals in the UK and other European countries. The Canadian Council on Animal Care has been in the forefront of providing care and husbandry guidelines for fish used in research (4).

Assessment of current approaches and future directions

The Aquaculture and Seafood Advisory Committee of the American Veterinary Medical Association conducted a survey of North American veterinary schools to identify aquatic medicine-related curricular requirements (1). Although the data suggested that most US veterinary schools had a relatively high number of credit hours that were relevant to aquatic animal medicine (an average of 146.7), the degree, nature and specific details of their relevance were not identified (1). In addition, after a more in-depth examination of lecture materials for these classes, it was unclear whether these data were consistent from university to university.

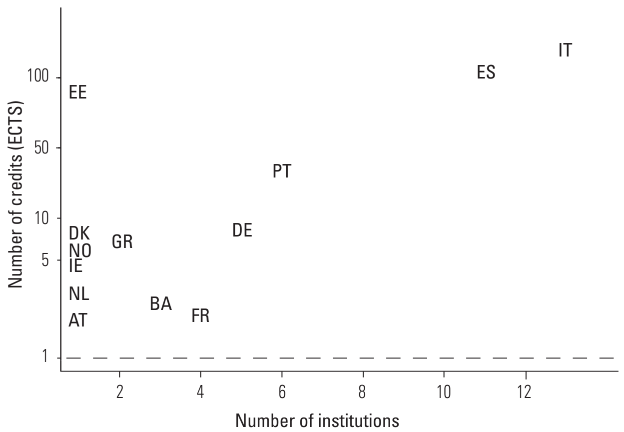
In an informal survey of 12 US and 6 Canadian schools, it was clear that the quantity and quality of aquatic animal medicine teaching varied greatly from institution to institution. Most schools surveyed included a relatively small number of credit hours for aquatic animal medicine in the core curriculum, but some offered well over 150 credit hours of potential elective courses in this field.

In Europe, 58% of veterinary institutions provide aquaculture training in 19 countries. This training effort has been assessed in 13 countries, for a total of 426 credits in the European credit transfer system, corresponding to a mean of 32.7 credits for each country, or 490 h in front of students, and the mean is 8.5 credits at the institutional level (Figure 1). Main topics include:

– animal health and regulations (17 countries)

– comprehensive overviews of aquaculture (13 countries)

– fish and shellfish product hygiene (4 to 5 countries).



ECTS: European credit transfer system
AT: Austria
BA: Bosnia-Herzegovina
DE: Germany
DK: Denmark
EE: Estonia
ES: Spain
FR: France
GR: Greece
IE: Ireland
IT: Italy
NL: Netherlands
NO: Norway
PT: Portugal

Fig. 1
Illustrative breakdown, by number of educational credits and veterinary schools, of the training efforts dedicated to aquaculture and fish health in European veterinary institutions

Training is provided through theoretical courses associated with clinical work, including visits to and audits of fish farms (10 countries). Only two countries start teaching aquatic animal health courses in the first year; all others begin instruction at the second level (i.e. in the third to fifth years), just before students begin professional/clinical coursework. A more comprehensive training in fish diseases is offered through additional doctorate or Doctor of Veterinary Medicine (PhD or DVM/VMD) degrees (10 countries) and by specialised Masters (MSc) programmes (9 countries).

Conclusion

Aquatic animals are the most abundant and species-rich vertebrates inhabiting the earth. The importance of aquatic animals in the USA and Europe as key indicators of the health of aquatic environments (eco-system health), as primary sources of high-quality protein for food, and as prominent laboratory animals for research, has historically been overlooked by the veterinary community. There has been a slow but steady increase in the acceptance of fish as companion animals needing care by small-animal practices (22), accompanied by an increased involvement of aquatic animal veterinarians in the economies of developing countries (25). This, plus the understanding that fish health is a key component of the concept of eco-system health during infectious disease outbreaks of fish (18), marks a significant change over the past 40 years. With a growing understanding of the importance for aquatic animal health, as reflected in aquatic animal health and food hygiene regulations, an even greater investment in the aquatic animal health sciences is needed at both the generalised and specialised levels, as follows:

a) Disease control regulations covering domestic fish and ornamental species can best be fulfilled through the involvement of local veterinary practitioners in developing a disease prevention network. Such local services should be built upon basic aquatic animal biology and foundation clinical sciences in fish health; which must both be represented in the core veterinary curriculum. A solid understanding of fish and their environmental requirements cannot be taught solely in weekend courses. Although fish are considered a lower vertebrate poikilotherm, assumptions on their diagnosis and treatment cannot be made empirically or without reference to basic ichthyology, including fish pathogens, and diagnosis and treatment options for these animals;

b) There is clearly a demand for specialists in aquatic animal pathobiology. These practitioners need a comprehensive knowledge and understanding of the codes of practice governing the fishing and aquaculture industries, as well as the economics and market organisation of farmed fish species.

A thorough understanding of fish health is also necessary for veterinarians who wish to incorporate fish medicine into their practices, if they are to provide appropriate veterinary care and instil confidence in clients.

At present, only a few US veterinary schools offer post-graduate education in aquatic animal medicine, and most continuing education courses provide only superficial or basic knowledge. There is no unique specialisation available in the USA for veterinarians who identify fish and/or shellfish as their primary professional activity.

To prepare veterinarians for the challenge of aquatic animal care, fish health must be represented at all levels of the curriculum as core, elective and independent training opportunities. Multiple and progressive levels of continuing education need to be readily available. Various teaching styles and programmes can be developed to accommodate these needs, and may take the form of internships, residencies, fellowships and PhD programmes.

In North America, special programmes must be developed to help augment the few programmes available to recent graduates, perhaps using current models, such as the MSc programmes offered at the University of Stirling Institute for Aquaculture (Scotland) and the Norwegian School of Veterinary Science. Masters programmes such as these seek to create highly competent fish health professionals by combining immersion courses in the biological and clinical sciences specific to aquatic animals with advanced training in a variety of disciplines, such as histopathology. Moreover, such programmes both conduct and foster research projects designed to strengthen the foundational practical and academic components completed earlier in the course. Each year, these programmes can provide training to a greater number of graduates than more labour- and cost-intensive residencies and internships. Few residency programmes in aquatic animal medicine are available in the USA and, even in total, such programmes may accommodate only one student (annually to once every three years, depending on the programme and available resources) at fewer than three institutions. A growing body of specialised professionals, trained through a variety of immersive programmes, would provide a far broader foundation for more effective and multi-dimensional educational opportunities, research initiatives and professional development. In Europe, the lack of funding for residencies and immersion programmes is also a serious deficiency in the objective of training a reasonable number of high-level specialists who can play a leading role in the professional development of aquatic animal medicine throughout the world.

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Les fondamentaux de l'enseignement vétérinaire dans le domaine de la santé des poissons : une perspective mondiale

E.S. Weber III, G. Blanc & R.P. Hedrick

Résumé

Les poissons forment la plus grande classe de vertébrés, avec plus de 25 000 espèces et sous-espèces répertoriées. Les poissons ont évolué au fil d'adaptations anatomiques et physiologiques exceptionnelles, si on les compare à celles des vertébrés terrestres, pour survivre dans une grande variété d'environnements aquatiques. L'intérêt des civilisations orientales et occidentales pour les animaux aquatiques est attesté depuis plus de 2 000 ans. Plus récemment, on assiste à une augmentation du nombre d'animaux aquatiques utilisés comme animaux de compagnie, mais aussi pour l'alimentation ou pour un usage au laboratoire ; ils sont également abondamment utilisés dans des programmes de repeuplement et de conservation. De ce fait, la question de la santé et du bien-être des animaux aquatiques fait l'objet d'une préoccupation croissante. Des considérations d'ordre moral et éthique imposent d'optimiser les pratiques d'élevage et d'améliorer la santé des animaux aquatiques. Comme c'est le cas avec les autres espèces de vertébrés, ce sont les vétérinaires qui sont le mieux placés pour relever les défis posés par la santé des animaux aquatiques aux plans clinique, scientifique et juridique. Afin d'atteindre cet objectif, il est important, d'une part, que les systèmes d'enseignement vétérinaire intègrent la santé des animaux aquatiques dans les programmes de formation initiale et, d'autre part, qu'ils proposent des possibilités de formation postdoctorale et participent à l'offre de formations tout au long de la vie afin de renforcer les compétences et l'expertise dans le domaine de la santé des animaux aquatiques.

Mots-clés
Animal aquatique – Programme d'enseignement – Santé – Santé des animaux aquatiques – Santé des poissons – Vertébré.

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Enseñanza veterinaria básica en materia de salud y enfermedades de los peces desde una perspectiva mundial

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Resumen
Los peces, con un número de especies y subespecies cifrado en más de 25.000, configuran la clase de vertebrados más numerosa. La evolución los ha dotado de una serie de adaptaciones anatómicas y fisiológicas singulares (inexistentes en los vertebrados terrestres) que les permiten vivir en muy diversos medios acuáticos. Ya hace más de 2.000 años que el hombre, tanto en Oriente como en Occidente, empezó a interesarse por la salud de los animales acuáticos. De un tiempo a esta parte viene aumentando el número de estos animales utilizados como mascotas o animales de compañía, fuente de alimento o animales de laboratorio, como también en programas de repoblación y protección ambiental. Asimismo, ha aumentado en consecuencia la preocupación por su salud y bienestar. Por razones morales y éticas, es imperativo optimizar los métodos y nuevos procedimientos de cría aplicados a la sanidad de los animales acuáticos. Como ocurre con otras especies de vertebrados, los veterinarios están en posición idónea para abordar estas cuestiones desde el triple punto de vista clínico, científico y jurídico. Para ello es fundamental integrar el tema en los planes de estudios universitarios, ofrecer oportunidades de formación de postgrado avanzada y apoyar la oferta de continuas posibilidades de especialización profesional de todos los niveles en materia de sanidad de los animales acuáticos.

Palabras clave
Animal acuático – Pez – Plan de estudios – Sanidad de los animales acuáticos – Sanidad de los peces – Vertebrado.

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