Journal of Coastal Zone Management

Quiazon, J Coast Zone Manag 2015, 18:1
http://dx.doi.org/10.4172/2473-3350.1000396

Mini Review Open Access

Updates on Aquatic Parasites in Fisheries: Implications to Food Safety, Food Security and Environmental Protection

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Abstract

Cheap protein sources from fishery products come from both capture fishery and aquaculture industries. Despite the available technologies that help increase wild catch and aquaculture production, our food security is being threatened by several factors including parasitic infections. Zoonotic parasites infecting our fishery products are one of the several concerns for our food safety. Among these include the infections with the nematode *Anisakis* in marine fishes and cephalopods causing human anisakiasis and/or allergy-associated health risks, the nematode *Gnathostoma* causing gnathostomiasis, and food poisoning due to the myxozoan infection of the genus *Kudoa*. On the other hand, the increasing human population, dwindling fish catch from the wild, degradation of aquatic environment, and declining or slow growth of aquaculture sector due to parasitic diseases are all posing global threats to the security and sustainability of fish supplies. The wild fish populations are affected by the parasitic diseases that directly and indirectly affect fish reproduction, growth, and survival, whereas intensifications of aquaculture operations cause fish health problems associated to parasitic diseases resulting to decline in production. Despite these negative impacts of parasites, there are several parasite groups that are used as biological indicators for food chain structure, heavy metal contamination, environmental pollutions and fish stock assessment (i.e., nematodes *Anisakis*, *Hysterothylacium, Anguillicola*, *Spirophilometra*, *Raphidascaris,* and *Philometra*; acanthocephalans Pomphorhynchus**,** *Serrasentis*, **and** *Acanthocephalus*; cestodes *Bothriocephalus*, *Monobothrium*, and *Ligula*; monogenean *Pseudorhabdosynochus*; and digenean *Didymodiclinus*), as well as reducer of heavy metal accumulation in the body of their host fish (i.e., acanthocephalans *Pomphorhynchus* and *Acanthocephalus*). The use of these parasites for proper management of fishery resources can be of help in addressing food safety, fish security, and food sustainability, while at the same time managing our fishery resources. As we are addressing these global issues, these parasites that we are considering as threats can be of useful value to attain sustainable development.

Keywords: Aquatic parasites, Aquaculture, Wild fish catch, Biological indicators, Food safety, Food security, Environmental protection

Introduction

A non-mutual symbiotic relationship happening between two unrelated species is considered parasitism, wherein the parasites benefit at the expense of their hosts. Parasites can either be large enough to be seen by the naked eyes (e.g., macroparasites such as helminthic worms) or can be seen with the aide of microscope (e.g., microparasites such as ciliated parasites). Aquatic parasites do not purposely kill their host unlike the parasitoids. Host mortality, however, can occur due to complications of secondary infections.Aquatic parasites are generally smaller than their hosts, living in their host (and being transfered to other hosts) for certain period of time depending on their life stages. Fishes can be an intermediate host or final host of parasites, whereas other aquatic (e.g., cetaceans) or terresial animals (birds, dogs) can serve as final or definitive hosts. Parasites usually mature and reproduce in their final or definitive hosts, while intermediate hosts only serve as their temporary host during their pre-mature stages. Parasites can be host-specific infecting only specific parasitic group or non host-specific infecting wide host species.

Despite of the various negative contributions of these parasites to their hosts, they could be key players and of beneficial use in the management of aquatic environments or fishery resources. Extensive studies have been conducted on the use of marine fish parasites to assess the ecological conditions of marine ecosystems. Fish parasites have been explored as possible use in varieties of ways that could help scientists in solving certain issues such as issues on food chain structure [1], pollution [2-10], global climate change [11,12], anthropogenic impacts, environmental stresses and general ecosystem health [13], and fish stock assessment [14-22]. The complex integration of fish to its parasites and general ecosystem cannot be separated.

This paper presents a review of some aquatic parasites negatively contributing to our food safety and security. Also, the benefits on the use of these parasites as biological indicators for environmental protection and as heavy metal reducer in the body of their hosts are also presented. For parasites involved in human food safety, this paper will deal on three common parasitic groups (i.e., nematodes of the genera *Anisakis* and *Gnathostoma*; and myxozoans of the genus *Kudoa*), whereas for parasites that may affect in food security and sustainability, this paper deals on various groups of parasites (i.e., various parasites affecting aquaculture production and fish reproduction). Furthermore, for the different groups of parasites that have been reported as biological indicators for the management of our aquatic resources, this paper will focus on the following parasites: a) The nematodes (round worm) (of the genera *Hysterothylacium, Anisakis, Anguillicola*, and *Philometra*), acanthocephalans (Pomphorhynchus and *Acanthocephalus*)**,** and cestodes (tapeworm) (*Bothriocephalus*, *Monobothrium*, and *Ligula*) for

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Received January 05, 2015; **Accepted** January 26, 2015; **Published** February 05, 2015

Citation: Quiazon KMA (2015) Updates on Aquatic Parasites in Fisheries: Implications to Food Safety, Food Security and Environmental Protection. J Coast Zone Manag 18: 396. doi: 10.4172/2473-3350.1000396

heavy metal pollution in the aquatic environment; b) The monogenean (*Pseudorhabdosynochus*), digenean (*Didymodiclinus*), nematodes (*Spirophilometra*, *Philometra*, and *Raphidascaris*), and acanthocephalan (*Serrasentis*) for anthropogenic impacts/environmental stresses/ pollution; and c) The anisakid nematode (*Anisakis*) for fish stock assessment. The acanthocephalans (*Pomphorhynchus* and *Acanthocephalus*) reported to have beneficial effect to their host by reducing heavy metal from their respective host fishes is also presented. Finally, the future prospects of research works on aquatic parasite, either as negatively contributing to the fishery industry and food safety or positively using them for beneficial purposes, are discussed.

Parasitic threat to food safety

Human anisakiasis and allergies: Human anisakiasis, also referred as "herring-worm disease", has been widely associated in the consumption of raw (sushi and sashimi), partly cooked or even marinated fishery products that are infected by zoonotic worms of the genus *Anisakis*. Apart from this, allergy-associated health risks can be experienced by sensitized patients who have consumed even processed or cooked infected fishery products [23-27]. Marine mammals are known to be the final host of *Anisakis* worms, wherein euphausiids (krills) serve as their intermediate hosts, with cephalopods and various marine fishes serving as paratenic hosts, and humans are regarded as accidental hosts once infected paratenic hosts are consumed [28-29]. The site of infection in the host fish is an important risk determinant of human anisakiasis. The presence of larval anisakids in the body muscle of fish is more of human food safety concern than those infecting the non-edible parts (visceral organs and other non-consumable parts) [30]. The incidences of human anisakiasis due to *A. simplex* sensu stricto (s.s.) and *A. pegreffii* have been well documented from Japan [31-33] and Mediterranean [34-35], respectively. Moreover, though past studies have evaluated the migration of *A. simplex* complex and unidentified *Anisakis* larvae into the body muscle of both live and dead fish [36-42], these parasites were not clearly identified to sibling species level (i.e., if *A. simplex* s.s., *A. pegreffii* or *A. berlandii*). Until recently, a study showed that it was *A. simplex* s.s. that migrates from the body cavity to the body muscle, whereas the *A. pegreffi* usually stays in the body cavity [30]. Despite this, both species have been noted in the body cavity and body muscle of European hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), angler (*Lophius piscatorius*), Atlantic mackerel (*Scomber scomber*), and Atlantic horse mackerel (*Trachurus trachurus*) [43].

Gnathostomiasis: A disease due to infection by a nematode *Gnathostoma* spp. (gnathostomiasis) is an emerging infectious disease among travellers from Europe and other western countries to some tropical countries where this parasitic infection is predominant [44]. This zoonotic worm is known to infect Asian swamp eel (*Monopterus albus*) from Southeast Asia, where cats and dogs serve as an important reservoir (as final hosts) of infection. The ingested third stage (L3) larvae mature to adult worms in approximately 6 months only from their final hosts [45]. The infection with L3 larvae can be acquired by accidental consumption of infected raw or partly cooked food (such as fish, shrimp, crab, crayfish, frog or chicken) due to a country's dietary habits [46]. As larva cannot mature into the adult form in humans, the L3 larva can only wander within the body of the host, wherein clinical symptoms of gnathostomiasis then occur due to the inflammatory reaction provoked by the migrating larvae [46]. Gnathostomiasis is either cutaneous or visceral forms depending on the sites of larval migration and subsequent symptoms. Infection results in initial nonspecific symptoms followed by cutaneous and/or visceral larval migration, with the latter carrying high morbidity and mortality rates if there is central nervous system involvement [44,47]. In gnathostomiasis, encephalitis, myelitis, radiculitis, and subarachnoid haemorrhage formed the majority of clinical syndromes [48].

Kudoa poisoning: Myxozoan parasites of the genus *Kudoa* have been reported to cause food poisoning due to consumption of raw fish. Such infections in the muscle tissues can be a serious problem for fisheries and aquaculture of some marine fishes such as the olive flounder (*Paralichthys olivaceaus*) due to post-mortem myoliquefaction, thus making the fish unmarketable. Since 2003, outbreaks of an unidentified food-borne illness associated with the consumption of raw fish have increased in Japan. Those affected with this illness develop diarrhoea and emesis within 2-20 h after meal. No known causative agents such as bacteria, viruses, bacterial toxins, or toxic chemicals have been detected in the foods ingested; until recently that the etiological agents of this novel food-borne illness outbreak associated with consumption of raw olive flounder was discovered to be due to the spores of *Kudoa septempunctata* [49-52]. Apart from the olive flounder, diffuse outbreaks of food poisoning with unknown aetiologies leading to diarrhoea and vomiting within a short time have been also reported after ingesting tuna (*Thunnus* spp.) and amberjack (*Seriola dumerili*). The detection of *K. hexapunctata* spores detected in the somatic muscle of juvenile Pacific bluefin tuna (*Thunnus orientalis*) from Japanese waters also suggested to be likely the cause of the diarrhoea outbreak [53,54].

Parasitic threats to food security and sustainability

Aquaculture is now the fastest growing food-producing sector globally. Asia contributes more than 90% to the world's aquaculture production which is not even exempted from being plagued with disease problems resulting from its intensification and commercialization [55]. The intensification in the culture of different marine fish species and large-scale international movement of fingerlings or juveniles, as well as the rapid expansion and concentration of fish farms, have caused severe problems resulting from parasitic infections [56]. Parasitism poses a serious threat to hosts under certain circumstances [13]. There are numerous different diseases that have emerged as serious economic or ecological problems in aquaculture species. Diseases have emerged through pathogen exchange with wild populations, evolution from non-pathogenic micro-organisms, and anthropogenic transfer of stocks. Aquacultural practices frequently resulted in high population densities and other stress factors, thus increasing the risk of establishing and spreading the infections [57].

There have been different parasitic diseases that are causing problems to the aquaculture industry. Among these group of parasitic diseases reported include the parasitic copepods (often referred as sea lice) [58], cymothoid isopods [59], cestodes (tapeworm), sacromastigophora, ectoparasitic protozoans, coccidians, myxosporeans, myxozoans, microsporidians, monogeans, digeneans, metacercaria of trematodes, nematodes, ergasilids, lernaeids, and argulids in marine and freshwater aquaculture [60-63]. These parasitic infections are resulting from low to high mortalities, decrease growth rates, lower immunity, and prone to other disease-causing agents, which consequently resulting to low production and ultimately low to high economic loss. Other sublethal effects (a partial misnomer since many such effects lead indirectly to mortality) of parasites include muscle degeneration, liver dysfunction, interference with nutrition, cardiac disruption, nervous system involvement, castration or mechanical interference with spawning, weight loss, and gross distortion of the body [64]. Among the parasites that affect fish reproduction are the gonad-infecting *Philometra* spp.

and *Eustrongylides* spp. (nematodes) that infect mainly the gonads of marine fishes [65-68] and freshwater fish goby (*Glossogobius giuris*) [69], respectively. These gonad-infecting nematodes infect both the testes and ovaries of their hosts, wherein heavy infection may result to reduced fecundity or even total castration and further decline in the population of the host fish [69,70]. Furthermore, the most thoroughly documented example of endocrine disruption in wild fish is in roach (*Rutilus rutilus*), and it is conceivable that this disruption is not only due to chemical activity but also to cestode parasites such as *Ligula intestinalis* or species of the phylum Microspora. The *L. intestinalis* can elicit physiological changes which are attributed to chemicals with endocrine disrupting activity that suppress gonadal development in roach [10]. These effects on the gonads of marine fishes affect ecological balance of fish population in the wild, which consequently affects sustainability of fish catch.

Parasites as biological indicators for environmental protection

Biological monitoring refers to the use of living organisms to evaluate environmental conditions [71]. Fish parasites represent a major part of aquatic biodiversity, and consequently become affected either directly through the environment or indirectly through their respective hosts. Studies have demonstrated that fish parasites can serve as biological indicator organisms to illustrate the ecology of their infected hosts, including feeding, migration, and population structure [72].

Biological indicators of food chain structures: Food webs are networks of trophic relationships which map the location of energy flows in a community [1]. Parasites have been rarely incorporated into food web studies [73,74]. In real system, host–parasite interactions are ubiquitous [75,76] which are known to affect community structure [77-79], trophic relationships [80,81], and energy flow [82,83]. Parasites reflect the host's position in the food web and are indicative of changes in ecosystem structure and function. Thus, parasites can provide information on population structure, evolutionary hypotheses, environmental stressors, trophic interactions, biodiversity, and climatic condition [84]. An example of which is the study conducted on the impact of parasitism on the food web structure in New Zealand intertidal mudflat community, wherein result showed that when individual parasites were added to the food web, their effect on food web properties was generally minimal. However, a trematode species that affected several host species, because of its complex life cycle and low host specificity, produced food web properties similar to those in the web version including all parasite species [1].

Biological indicators for heavy metal contaminations: Heavy metal contaminations of both inland and marine aquatic environments are becoming complex wherein environmental problems do not only endanger aquatic animals but as well pose serious human health hazards. In assessing levels of biologically available pollutants, biological indicators are useful tools in addition to chemical water analyses, which primarily describe the total concentration of a particular pollutant [85]. The use of parasites as biological indicators for pollution deals with the question as to whether environmental contamination could affect the composition of parasitic communities in their final hosts [86-88]. The endohelminths (mainly acanthocephalans and cestodes) of fish are nowadays widely accepted as good indicators of environmental pollution by heavy metals in aquatic ecosystems [5,8,9,89,90].

Several studies have shown significantly higher quantity of heavy metal accumulation in tissues of endoparasites than their final hosts [8,9,91]. Among these is the higher concentration of lead and cadmium in *Monobothrium wageneri* and *Bothriocephalus scorpil* (cestodes) from the intestine of tench (*Tinca tinca*) and turbot (*Scophthalmus maximus*) than in the muscle, liver, and intestine of their fish host [3,4], and higher lead, cadmium, and cupper in *Hysterothylacium aduncum* (nematode) than its host sea bream (*Sparus auratus*) [91]. Also, there were reports on an elevated selenium concentration in the cestode *B. acheilognathi* in comparison to the tissues of its fish definitive host [92]. Futhermore, *Philometra ovata* (nematode) served as sensitive indicator species of heavy metal pollution in freshwater ecosystem [93]. Also, the *Pomphorhynchus laevis* (acanthocephalan) may serves as a very sensitive biological indicator for the presence of lead in aquatic ecosystem [2]. The endoparasite *L. intestinalis* (cestode) was found to be suitable to reflect the amount of heavy metals in sediments, providing more reliable information about the actual pollution of the reservoir [94].

A laboratory studies on eels experimentally infected with the swimbladder nematode *Anguillicola crassus* reveal that toxic chemicals such as polychlorinated biphenyls produce immunosuppressive effects which facilitate parasite infection [10]. Furthermore, the anisakid nematodes, a parasite group widely distributed in oceans that infects a wide range of host species, can accumulate essential and non-essential metals to levels far in excess of their host tissues. As a result, they could be used as biomarkers of trace-metal contamination in studying environmental impact [71].

Biological indicators for environmental pollutions (general ecosystem health) and global climate change: It has been known that parasite populations and communities are useful indicators of environmental stress, food web structure, and biodiversity [13]. Parasites can interact with environmental pollution in different ways. Parasites can interfere with established bioindication procedures owing to their effects on the physiology and behaviour of the host which may lead both to false-negative and false-positive indications of pollution. On the other hand, parasites can be used as effective biological indicators of environmental impact and as accumulation indicators because of the variety of ways in which they respond to anthropogenic pollution [9,10,95].

As parasites are integral part of the biosphere, host switching correlated with events of climate change is ubiquitous in evolutionary and ecological time. Global climate change produces ecological perturbations, which cause geographical and phonological shifts, alteration in the dynamics of parasite transmission and increasing the potential for host switching [11]. Most observed host-parasite associations can be explained by a historical interaction between ecological fitting, oscillation (episodes of increasing host range alternating with isolation on particular host) and taxon pulses (cyclical episodes of expansion and isolation in geographical range). The major episodes of environmental changes appear to be the main drivers for both the persistence and diversification of host-parasite systems, creating opportunities for host-switching during periods of geographical expansion and allowing for co-evolution and co-speciation during periods of geographical isolation [96]. The biological features of parasite species can potentially override local environmental conditions in driving parasite population dynamics [12].

The digenean *Didymodiclinus* sp., the nematode *Raphidascaris* sp., and the acanthocephalan *Serrasentis sagittifer* can be used for environmental assessments on the reef-associated grouper (*Epinephelus areolatus*) from Indonesian waters [97]. Similarly, the use of the grouper fish (*E. coioides*) parasites (i.e., dominant parasites include the monogenean *Pseudorhabdosynochus lantauensis*; the nematodes

Spirophilometra endangae, *Philometra* sp., and *Raphidascaris* sp.; and the digenean *Didymodiclinus* sp.) as an early warning system for environmental changes in Indonesian ecosystem has been reported [98]. Other study has demonstrated that parasites:a) may influence the metabolism of pollutants in infected hosts, b) interact with pollution in synergistic or antagonistic ways, and c) may induce physiological reactions in hosts which were thought to be pollutant-induced [10]. A healthy system is considered to be one that is rich in parasite species as there is increasing evidences that parasite-mediated effects could be significant as they shape host population dynamics, alter inter-specific competition, influence energy flow, and appear to be important drivers of biodiversity and production [99].

Biological indicators for fish stock assessments: One of the major goals from the last decade in the study of the parasite fauna of aquatic organisms has been, among the others, the assessment of fish stocks, their movement, and recruitment. Indeed, the use of parasites to discriminate fish host populations has been one of the most useful approaches in a multidisciplinary study of fish stock detection and characterization. Nowadays, the modern concept of "fish stock" integrates all the information gathered from a broad spectrum of techniques, ranging from morphology (morphometrics, meristic, otolith microchemistry) to biology (life-history characteristics, mark-recapture, parasites) and genetic structure (allozymes, microsatellites, DNA sequences) of fish host throughout their geographical range. In this "holistic approach" to the definition of fish stock [100], the use of parasites as "biological tags" has become a useful tool, mainly concerning species with a high commercial value in fisheries. The basic principle on the use of parasites as biological tag is that a fish becomes infected by a parasite species only when it is in the endemic area of that parasite. The endemic area of the parasite is the geographical region where the abiotic (temperature and salinity) and biotic (presence of suitable intermediate and definitive hosts) factors are suitable for the transmission and completion of its life-cycle. Thus, we can assume that when a fish population is found infected by a parasite species, it means that the fish has spent part of its life-history in the endemic area of the parasite, where fish behavior and feeding habits could result in different infection levels by that parasite species. As a consequence, when the parasite fauna of two populations of the same fish species sampled from two different geographical areas is different, it means that the life-history of those fish samples were different [17]. Parasites can provide ecological information on the origin, migration, nursery ground and life-history of the fish species [101]. Hence, a parasite can be used as suitable biological tag for fish stock identification when its geographical distribution and life-cycle are known, and when the parasite's residence time in the host is long enough compared to the life span of the fish host. In this sense, the parasite as biological marker reflects the geographic origin of the fish population on a spatial scale. Indeed, the genetic/molecular markers define the stock on the evolutionary temporal scale, while the parasite taxa characterize the stock on a spatial/geographical scale [17].

Anisakid parasites are an integral part of aquatic ecosystems as they play key roles in population dynamics and community structure and can provide important information about the general biodiversity of the ecosystem. Recent data on the possible use of anisakid nematodes have been presented as biological indicators of: a) the definition of fish stocks within a multidisciplinary approach, b) integrity and stability of trophic webs, and c) habitat disturbance [16]. Among the parasite species that have been used in fish stock definition is the larval anisakid nematodes of the genus *Anisakis* which represent one of the best biological tags [22]. The biogeographical aspects of *Anisakis* spp., in recent years, have allowed the fish stock identification of several demersal and pelagic species [15]. Such use of *Ansakis* spp. as biological indicator for host fish stocks identification have been used particularly for Atlantic horse mackerel [21,15,16], Jack mackerel (*Trachurus symmetricus murphyi*) [102], European hake (*Merluccius merluccius*) [14,15], swordfish (*Xiphias gladius*) [15,20], and herring (*Clupea harengus*) [18]. Other metazoan parasites, apart from *Anisakis*, have also been reported as possible use to distinguish fish stocks of rough scad (*Trachurus lathami*) [19] and herring [18].

Biological reducer of heavy metals in host fish: Despite the negative role of the parasites to their hosts, studies have also shown their beneficial sides. Parasites have the capability in reducing heavy metal accumulation in the body of their host fish [7]. In a study conducted on chub (*Leuciscus cephalus*) experimentally infected with the parasite *Pomphorhynchus laevis* (acanthocephalans), results revealed that rapid accumulation of the aqueous lead exposed to the fish by the intestinal acanthocephalans reached concentrations which were significantly greater than in the host muscle, liver, and intestine 1000 times higher than the exposure concentration [7]. This study supported the findings from previous study that heavy metals lead and cadmium are predominantly accumulated by the adult acanthocephalans (*Pomphorhynchus* and *Acanthocephalus*) inside the chub's and perch's (*Perca fluviatilis*) gut and not by the larvae inside the hemocoel of the crustaceans [6]. Moreover, experimental studies on the uptake and accumulation of metals by fish reveal that fish infected with acanthocephalans have lower metal levels than uninfected hosts (e.g., *Pomphorhynchus laevis* reduces lead levels in fish bile, thereby diminishing or impeding the hepatic intestinal cycling of lead, which may reduce the quantity of metals available for fish) [10].

Discussion and Future Perspective

Attainment of safe and sustainable fish supplies with this continuous changing world, which influences highly vulnerable complex ecosystem and interaction between parasites, host fishes, and humans, will always be the forefront of global efforts for scientific endeavours. We now understand that the different important roles of these parasites in the aquatic ecosystem as a whole cannot be underestimated. Though they are small enough in a very diverse ecosystem, they play key roles that could be either of benefit or harm to human or to their respective host fishes. Though proper food preparation can be of help in reducing food-related health problems, the custom, tradition and expansion of consumption of raw or partly cooked dishes worldwide enables us to seek measures to combat food-borne illness. As a result of food safety issues brought by parasites, we have to continuously develop, improve, establish and implement a strict protocol that would help us detect and diagnose fishery products before their distribution in the market. Molecular approaches such as diagnostic PCR assays may facilitate screening and monitoring for any parasitic infection on fishery products to be sold for public consumption.

Food security and sustainability are two main global issues that we have to currently address. Aquaculture industry is currently helping us address our fishery demands. Currently, due to the dwindling capture fishery catch, as a result of intense fishing pressure, environmental pollution, illegal fishing activities, more advanced fishing vessels and equipments, and increasing global fish demand, the aquaculture industry contributes more to food security. However, aquaculture has been facing different problems including parasitic diseases that greatly affect fish production. Currently, many researchers have been working to solve emerging disease threats to the aquaculture industry. As part of the management measures, prevention of any parasitic disease outbreaks should be carried out. This can be done through different strategies such as application of molecular tools which may greatly help improve the disease prevention or management in the wild and aquaculture facilities. Strategies dealing with trans-boundary diseases affecting aquaculture sector should also be considered strictly which includes the: a) compliance with international codes and development and implementation of regional guidelines and national aquatic animal health strategies; b) new diagnostics and therapeutic techniques and new information technology; c) new bio-security measures including risk analysis, epidemiology, surveillance, reporting and planning emergency response to epizootics; d) targeted research; and e) institutional strengthening and manpower development (education, training, extension, research, and diagnostic services) [55]. Also, the rate and extent of emergence can be reduced by the application of bio-security programmes designed to mitigate the risk factors for such disease emergence [57]. As the aquaculture industry continuous to expand, it is certain that more novel host-parasite relationships will be observed providing challenges for fish farmers and parasitologists [62]. Despite the current lack of information regarding the biology of many parasites affecting cultured marine fishes, it is nevertheless possible to develop methodologies to produce an integrated health management system specifically designed to the needs of the mariculture practiced, which include a sequence of prophylaxis, adequate nutrition, sanitation, immunization, and effective system of marketing for farmed fishes [56].

Sustainable fishery supply and quality of wild fish catch depend on a healthy and quality aquatic environment. The use of parasites as biological indicators for aquatic pollution or any environmental stress and as a reducer of heavy metal accumulation in the body of its host fish indicate that despite of their negative effects to food safety and in the aquaculture industry, these parasites have also beneficial sides. This also indicates that since we cannot totally eliminate them because of their natural existence and ecological function in the complex ecosystem, we just have to make use of them to benefit the fisheries industry, improve the aquatic environment, and improve food safety and quality. The recommendation for the design of future studies to evaluate anthropogenic impact on host-parasite interaction and increase the environmental monitoring program [95] is currently needed to protect our environment from continuous and permanent degradation. It has been suggested that an early warning or alert signal of high ecological relevance due to anthropogenic stress in a marine ecosystem can be determined by use of anisakid nematodes [71]. Thus, continuous gathering of parasitological data on these anisakid nematodes in our respective territorial waters, which could be easily accessible to every researchers and scientist in the field, should be part of the collective effort in the management of the marine environment. Since we cannot totally eliminate aquatic parasites as healthy ecosystems have healthy parasites [13], the greatest challenge for parasitologist is to convince everyone, from resource managers, scientists, researchers, academicians, students, and those in the policy making that parasites are a natural part of all ecosystems, and we just have to discover how we can make use of them for the benefit of our fishery industry and the environment.

Acknowledgement

The author would like to thank his family, friends and colleagues for their continuous support in his research undertakings.

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Citation: Quiazon KMA (2015) Updates on Aquatic Parasites in Fisheries: Implications to Food Safety, Food Security and Environmental Protection. J Coast Zone Manag 18: 396. doi: 10.4172/2473-3350.1000396