

**MOLECULAR DETECTION OF IRIDOVIRUS IN FISH COLLECTED AT
MAGSAYSAY FISH MARKET AND LANDING CENTER,
DAGUPAN CITY, PANGASINAN, PHILIPPINES**

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ABSTRACT

DUCUSIN, JEANNE LEIA T. Department of Biological Sciences, College of Arts and Sciences, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **JUNE 2019. MOLECULAR DETECTION OF IRIDOVIRUS IN FISH COLLECTED AT MAGSAYSAY FISH MARKET AND LANDING CENTER, DAGUPAN CITY, PANGASINAN, PHILIPPINES**

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The increase in aquaculture operations worldwide has delivered new opportunities for the occurrence of several novel diseases, which include viral diseases, that have caused serious complications for producers. Iridoviruses are a group of emerging viral pathogens causing infections in several marine finfish.

For this study, the fishes were collected at Magsaysay Fish Market and Landing Center, Dagupan City, Pangasinan, Philippines. The identification of fish was done through morphological means. The detection of the viral pathogen iridovirus was done through molecular means using E.Z.N.A.® Tissue DNA Extraction Kit for the extraction of the viral DNA, then was amplified with the use of PCR procedure using 1-F and 1-R as primers for the detection, then was observed through the use of gel electrophoresis and gel documentation. After sending the PCR product for sequencing, molecular analysis was done through the use of BLAST to verify the presence of said virus.

Three out of four species of fishes showed signs of infection that may or may not be caused by an iridovirus. Based on the molecular analysis, the results showed no presence of iridovirus in the collected fish species. This would then point out that the signs observed in the collected fish species may be symptoms of other diseases or may have been caused by other disease-causing microorganisms such as virus, bacteria and fungi.

LITERATURE CITED

- Abdullah, A., Ramli, R., Ridzuan, M. S. M., Murni, M., Hashim, S., Sudirwan, F., Abdullah, S. Z., Mansor, N. N., Amira, S., Saad, M. Z. & Amal, M. N. A. (2017). The presence of Vibrionaceae, Betanodavirus and Iridovirus in marine cage-cultured fish: Role of fish size, water physicochemical parameters and relationships among the pathogens. *Aquaculture Reports*, 7, 57-65.
- Andalecio, M. N. & Cruz, P. S. (2010). Integrating aquaculture in coastal river planning: The case of Dagupan City, Philippines. *Tropical Deltas and Coastal Zones*, 33.
- Aypa, S. M. (1995). Aquaculture in the Philippines. *Aquaculture Department, Southeast Asian Fisheries Development Center*, 137-147.
- Badali, H. & Nabili, M. (2012). Molecular tools in medical mycology; where we are. *Jundishapur Journal of Microbiology*, 6(1), 1-3.
- Bagarinao, T. U. (2008). The filter net [tangab] fishery in Iloilo Strait, Philippines: Food and livelihood for coastal communities in the midst of waste of non-target fishery resources. *Fish for the People*, 6(3), 42-47.
- Belton, B. & Thilsted, S. H. (2014). Fisheries in transition: Food and nutrition security implications for the global south. *Global Food Security*, 3(1), 59-66.
- Berry, F. H. & Smith-Vaniz, W. F. (1978). Carangidae. *Food and Agriculture Organization (FAO) Species Identification Sheets for Fishery Purposes*, 1.
- Bondad-Reantaso, M. G., Subasinghe, R. P., Arthur, J. R., Ogawa, K., Chinabut, S., Adlard, R., Tan, Z. & Shariff, M. (2005). Disease and health management in Asian aquaculture. *Veterinary Parasitology*, 132(3-4), 249-272.
- Brenes, R., Gray, M. J., Waltzek, T. B., Wilkes, R. P. & Miller, D. L. (2014a). Transmission of ranavirus between ectothermic vertebrate hosts. *Public Library of Science One*, 9(3), 1-6.
- Brenes, R., Miller, D. L., Waltzek, T. B., Wilkes, R. P., Tucker, J. L., Chaney, J. C., Hardman, R. H., Brand, M. D., Huether, R. R. & Gray, M. J. (2014b). Susceptibility of fish and turtles to three ranaviruses isolated from different ectothermic vertebrate classes. *Journal of Aquatic Animal Health*, 26(2), 118-126.
- Brunner, J. L., Storfer, A., Gray, M. J. & Hoverman, J. T. (2015). Ranavirus ecology and evolution: from epidemiology to extinction. *Ranaviruses*, 71-104.

- Caramantin-Soriano, H., Vega-Pérez, L. A. & Niquen, M. (2008). Growth parameters and mortality rate of the *Scomber japonicus peruanus* along the Peruvian coast, South Pacific. *Brazilian Journal Oceanography*, 56(3), 201-210.
- Cervigón, F., Cipriani, R., Fischer, W., Garibaldi, L., Hendrickx, M., Lemus, A. J., Márquez, R., Poutiers, J. M., Robaina, G. & Rodríguez, B. (1992). Field guide to the commercial marine and brackish-water resources of the northern coast of South America. *Food and Agriculture Organization (FAO) Species Identification Sheets for Fishery Purposes*, 513.
- Chao, C. B., Yang, S. C., Tsai, H. Y., Chen, C. Y., Lin, C. S. & Huang, H. T. (2002). A nested PCR for the detection of grouper iridovirus in Taiwan (TGIV) in cultured hybrid grouper, giant seaperch, and largemouth bass. *Journal of Aquatic Animal Health*, 14(2), 104-113.
- Chinchar, V. G. (2002). Ranaviruses (family Iridoviridae): Emerging cold-blooded killers. *Archives of Virology*, 147(3), 447-470.
- Chinchar, V. G., Hick, P., Ince, I. A., Jancovich, J. K., Marschang, R., Qin, Q., Subramaniam, K., Waltzek, T. B., Whittington, R., Williams, T. & Zhang, Q. Y. (2017). ICTV virus taxonomy profile: Iridoviridae. *Journal of General Virology*, 98(5), 890-891.
- Chou, H. Y., Hsu, C. C. & Peng, T. Y. (1998). Isolation and characterization of a pathogenic iridovirus from cultured grouper (*Epinephelus* sp.) in Taiwan. *Fish Pathology*, 33(4), 201-206.
- Collette, B. B. (1995). Scombridae. Atunes, bacoretas, bonitos, caballas, estominos, melva, etc. *Guide for the Identification of Species for the Purposes of Fishing*, 1521-1543.
- Collette, B. B. (2010). Reproduction and development in epipelagic fishes. *University of California Press, Berkeley*, 21-63.
- Collette, B. B. & Aadland, C. R. (1996). Revision of the frigate tunas (Scombridae, Auxis), with descriptions of two new subspecies from the eastern Pacific. *Fishery Bulletin*, 94(3), 423-441.
- Collette, B. B. & Nauen, C. E. (1983). Scombrids of the world: An annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. *Food and Agriculture Organization (FAO) Fish Synopsis*, 125(2), 137.
- Crane, M. & Hyatt, A. (2011). Viruses of fish: an overview of significant pathogens. *Viruses*, 3(11), 2025-2046.

- Daszak, P., Berger, L., Cunningham, A. A., Hyatt, A. D., Green, D. E. & Speare, R. (1999). Emerging infectious diseases and amphibian population declines. *Emerging Infectious Diseases*, 5(6), 735.
- De Silva, S. S., Nguyen, T. T., Abery, N. W. & Amarasinghe, U. S. (2006). An evaluation of the role and impacts of alien finfish in Asian inland aquaculture. *Aquaculture Research*, 37(1), 1-17.
- Do, J. W., Moon, C. H., Kim, H. J., Ko, M. S., Kim, S. B., Son, J. H., Kim, J. S., An, E. J., Kim, M. K., Lee, S. K. & Han, M. S. (2004). Complete genomic DNA sequence of rock bream iridovirus. *Virology*, 325(2), 351-363.
- Do, J. W., Cha, S. J., Kim, J. S., An, E. J., Park, M. S., Kim, J. W., Kim, Y. C., Park, M. A. & Park, J. W. (2005). Sequence variation in the gene encoding the major capsid protein of Korean fish iridoviruses. *Archives of Virology*, 150(2), 351-359.
- Dong, C. F., Xiong, X. P., Shuang, F., Weng, S. P., Zhang, J., Zhang, Y., Luo, Y. W. & He, J. G. (2011). Global landscape of structural proteins of infectious spleen and kidney necrosis virus. *Journal of Virology*, 85(6), 2869-2877.
- Duffus, A. L. J., Pauli, B. D., Wozney, K., Brunetti, C. R. & Berrill, M. (2008). Frog virus 3-like infections in aquatic amphibian communities. *Journal of Wildlife Diseases*, 44(1), 109-120.
- Earl, J. E. & Gray, M. J. (2014). Introduction of ranavirus to isolated wood frog populations could cause local extinction. *Ecological Health*, 11(4), 581-592.
- Estrada, J. E. (2010). Explanatory note: An act to provide for a five-year public markets program involving infrastructure improvement, microfinancing support, institutional advancement and consumer protection. Retrieved from <https://senate.gov.ph/lisdata/81756645!.pdf>.
- Figueiredo, J. D., dos Santos, A. P., Yamaguti, N., Bernardes, R. A. & Rossi-Wongtschowski, C. D. B. (2002). Fish from the exclusive economic zone of the southeast-south region of Brazil: Survey with half-water network. *São Paulo: Publisher of the University of São Paulo, Official State Press*, 242.
- Food and Agriculture Organization. (2014a). Fishery and aquaculture country profiles: The republic of the Philippines. *FAO Fisheries and Aquaculture Department, Rome*. Retrieved from <http://www.fao.org/fishery/facp/PHL/en>.
- Food and Agriculture Organization. (2014b). Fishery and aquaculture country profiles: National aquaculture sector overview of the Philippines. *FAO Fisheries and Aquaculture Department, Rome*. Retrieved from http://www.fao.org/fishery/countrysector/naso_philippines/en.

- Frimodt, C. (1995). Multilingual illustrated guide to the world's commercial warmwater fish. *Fishing News Books Limited Company*, 215.
- Garcia, Y. T., Mohan Dey, M. & Navarez, S. M. M. (2005). Demand for fish in the Philippines: A disaggregated analysis. *Aquaculture Economics & Management*, 9(1-2), 141-168.
- Gluyas-Millán, M. G. & Quiñonez-Velázquez, C. (1996). Evidence of different stocks of mackerel *Scomber japonicus*. *Marine Sciences*, 22, 77-395.
- Go, J., Lancaster, M., Deece, K., Dhungyel, O. & Whittington, R. (2006). The molecular epidemiology of iridovirus in Murray cod (*Maccullochella peelii peelii*) and dwarf gourami (*Colisa lalia*) from distant biogeographical regions suggests a link between trade in ornamental fish and emerging iridoviral diseases. *Molecular and Cellular Probes*, 20(3-4), 212-222.
- Go, J. & Whittington, R. (2006). Experimental transmission and virulence of a megalocytivirus (Family Iridoviridae) of dwarf gourami (*Colisa lalia*) from Asia in Murray cod (*Maccullochella peelii peelii*) in Australia. *Aquaculture*, 258(1-4), 140-149.
- Gomez, D. K., Baeck, G. W., Kim, J. H., Choresca Jr, C. H. & Park, S. C. (2008). Molecular detection of betanodavirus in wild marine fish populations in Korea. *Journal of Veterinary Diagnostic Investigation*, 20(1), 38-44.
- Guo, C. J., Wu, Y. Y., Yang, L. S., Yang, X. B., He, J., Mi, S., Jia, K. T., Weng, S. P., Yu, X. Q. & He, J. G. (2012). Infectious spleen and kidney necrosis virus (a fish iridovirus) enters mandarin fish fry cells via caveola-dependent endocytosis. *Journal of Virology*, 86(5), 2621-2631.
- Haenen, O., Fouz, B., Amaro, C., Isern, M. M., Mikkelsen, H., Zrnčić, S., Travers, A., Renault, T., Wardle, R. & Hellstrom, A. (2014). Vibriosis in aquaculture. 16th EAFP conference, Tampere, Finland, 4th September 2013: Workshop report. *Bulletin of the European Association of Fish Pathologists*, 34(4), 138.
- Hassanzadeh, Y., Bahador, N. & Baseri-Salehi, M. (2015). First time isolation of *Photobacterium damsela* subsp. *damsela* from *Caranx sexfasciatus* in Persian Gulf, Iran. *Iranian Journal of Microbiology*, 7(3), 178.
- He, J. G., Wang, S. P., Zeng, K., Huang, Z. J. & Chan, S. M. (2000). Systemic disease caused by an iridovirus-like agent in cultured mandarin fish, *Siniperca chuatsi* (Basilewsky), in China. *Journal of Fish Diseases*, 23(3), 219-222.
- Heemstra, P. C., 1995. Additions and corrections for the 1995 impression. *Smiths' sea fishes*, 5-15.

- Hernández, J. J. C. & Ortega, A. T. S. (2000). Synopsis of biological data on the chub mackerel (*Scomber japonicus* Houttuyn, 1782). *Food and Agriculture Organization (FAO) Fish Synopsis*, 157, 77.
- Hussain, S. M., Paperno, R. & Khatoun, Z. (2010). Length–weight relationships of fishes collected from the Korangi-Phitti Creek area (Indus delta, northern Arabian Sea). *Journal of Applied Ichthyology*, 26(3), 477-480.
- Hyatt, A. D., Gould, A. R., Zupanovic, Z., Cunningham, A. A., Hengstberger, S., Whittington, R. J., Kattenbelt, J. & Coupar, B. E. H. (2000). Comparative studies of piscine and amphibian iridoviruses. *Archives of Virology*, 145(2), 301-331.
- Jeong, J. B., Jun, L. J., Park, K. H., Kim, K. H., Chung, J. K., Komisar, J. L. & Do Jeong, H. (2006). Asymptomatic iridovirus infection in various marine fishes detected by a 2-step PCR method. *Aquaculture*, 255(1-4), 30-38.
- Jeong, J. B., Cho, H. J., Jun, L. J., Hong, S. H., Chung, J. K. & Do Jeong, H. (2008). Transmission of iridovirus from freshwater ornamental fish (pearl gourami) to marine fish (rock bream). *Diseases of Aquatic Organisms*, 82(1), 27-36.
- Jancovich, J. K., Steckler, N. K. & Waltzek, T. B. (2015). Ranavirus taxonomy and phylogeny. *Ranaviruses*, 59-70.
- Jiménez-Prado, P. & Béarez, P. (2004). Marine fishes of continental Ecuador. *Society for the Investigation and Monitoring of Ecuadorian Biodiversity / Nazca Institute of Marine Research / French Institute of Andean Studies*, 2, 393.
- Jithendran, K. P., Ezhil Praveena, P. & Bhuvaneshwari, T. (2017). Viral Nervous Necrosis: A Challenge to Finfish Aquaculture. *Basic and Clinical Virology*. Retrieved from https://www.researchgate.net/profile/Jithendran_KP2/publication/323393490_Viral_Nervous_Necrosis_A_Challenge_toFinfish_Aquaculture/links/5a93c7cd45851535bcd97a32/Viral-Nervous-Necrosis-A-Challenge-toFinfish-Aquaculture.pdf.
- Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A. & Grieve, C. (1993). Australian fisheries resources: Bureau of resource sciences, department of primary industries and energy. *Fisheries Research and Development Corporation, Canberra, Australia*, 422.
- Kim, J. H., Gomez, D. K., Choresca Jr, C. H. & Park, S. C. (2007). Detection of major bacterial and viral pathogens in trash fish used to feed cultured flounder in Korea. *Aquaculture*, 272(1-4), 105-110.
- Klinger, R. E., Francis-Floyd, R., Slaughter, J. & Watson, C. (1996). Iridovirus in gouramis. Retrieved from <https://aquarium-digest.com/2009/11/06/iridovirusin-gouramis/>.

- Kuiter, R. H. & Tonozuka, T. (2001). Pictorial guide to Indonesian reef fishes. *Zoonetics, Australia*, 1-302.
- Kumar, S., Stecher, G. & Tamura, K. (2016). MEGA7: Molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution*, 33(7), 1870-1874.
- Kurita, J., Nakajima, K., Hirono, I. & Aoki, T. (1998). Polymerase chain reaction (PCR) amplification of DNA of red sea bream iridovirus (RSIV). *Fish Pathology*, 33 (1), 17-23.
- Lopez, N. A. (2006). Sustainable development and trends in the Philippine aquaculture. *International Workshop on Innovative Technologies for Eco-friendly Fish Farm Management and Production of Safe Aquaculture Foods held in Denpasar, Bali (Indonesia)*, 4-8.
- Ma, H., Peng, C., Su, Y., Feng, J. & Guo, Z. (2016). Isolation of a Ranavirus-type grouper iridovirus in mainland China and comparison of its pathogenicity with that of a Megalocytivirus-type grouper iridovirus. *Aquaculture*, 463, 145-151.
- Mahardika, K., Yamamoto, A. & Miyazaki, T. (2004). Susceptibility of juvenile humpback grouper *Cromileptes altivelis* to grouper sleepy disease iridovirus (GSDIV). *Diseases of Aquatic Organisms*, 59(1), 1-9.
- Mao, J., Wang, J., Chinchar, G. D. & Chinchar, V. G. (1999). Molecular characterization of a ranavirus isolated from largemouth bass *Micropterus salmoides*. *Diseases of Aquatic Organisms*, 37(2), 107-114.
- Masuda, H. & Allen, G. R. (1993). Marine fish of the world - Greater Indo-Pacific region. *Tetra Verlag, Herrenteich, Melle*, 528.
- Miller, D. L., Pessier, A. P., Hick, P. & Whittington, R. J. (2015). Comparative pathology of ranaviruses and diagnostic techniques. *Springer Cham*, 171-208.
- Mishra, A., Nam, G.H., Gim, J. A., Lee, H. E., Jo, A. & Kim, H. S. (2018). Current challenges of streptococcus infection and effective molecular, cellular, and environmental control methods in aquaculture. *Molecules and Cells*, 41(6), 495.
- Miskiewicz, A. G. & Neira, F. J. (1998). Clupeidae: Herrings, sardines, shads, sprats, etc. *University of Western Australian Fishes*, 38-53.
- Mostarda, E., Campo, D., Castriota, L., Esposito, V., Scarabello, M. P. & Andaloro, F. (2007). Feeding habits of the bullet tuna *Auxis rochei* in the southern Tyrrhenian Sea. *Journal of the Marine Biological Association of the United Kingdom*, 87, 1007-1012.

- Munroe, T. A. & Priede, I. G. (2010). *Nematalosa nasus*. Retrieved from <https://www.iucnredlist.org/species/154774/115233646>.
- Murray, A. G. (2013). Epidemiology of the spread of viral diseases under aquaculture. *Current Opinion in Virology*, 3(1), 74-78.
- Muus, B. J. & Nielsen, J. G. (1999). Scandinavian fishing year book. *Hedehusene, Denmark*, 340.
- Nakajima, K., Inouye, K. & Sorimachi, M. (1998). Viral diseases in cultured marine fish in Japan. *Fish Pathology*, 33(4), 181-188.
- Nakajima, K. (2002). Diagnostic and preventive practices for iridovirus in marine fish. *Aquaculture Department, Southeast Asian Fisheries Development Center*, 75-79.
- Niiya, Y. (2001). Age, growth, maturation and life of bullet tuna *Auxis rochei* in the Pacific waters off Kochi prefecture. *Nippon Suisan Gakkaishi*, 67(3), 429-437.
- Nilsson, R. H., Abarenkov, K., Larsson, K. H. & Kõljalg, U. (2011). Molecular identification of fungi: Rationale, philosophical concerns, and the UNITE database. *Open Applied Informatics Journal*, 5, 81-86.
- Pomeroy, R. S. & Balboa, C. (2004). The financial feasibility of small-scale marine ornamental aquaculture in the Philippines. *Asian Fisheries Science*, 17, 365-376.
- Ramya, V. C., Benakappa, S., Anjanayappa, H. N., Jayaraj, E. G., Somashekara, S. R. & Mahesh, V. (2016). Reproductive biology of *Nematalosa nasus* (Bloch, 1795) off Mangalore coast, Karnataka. *Journal of Experimental Zoology, India*, 19(1), 313-319.
- Razak, A. A., Ransangan, J. & Sade, A. (2014). First report of Megalocytivirus (Iridoviridae) in grouper culture in Sabah, Malaysia. *International Journal of Current Microbiology and Applied Sciences*, 3(3), 896-909.
- Riede, K. (2004). Global register of migratory species: From global to regional scales. *Federal Agency for Nature Conservation*, 329.
- Risso, A. (1966). Ichthyology of Nice or natural history of the fishes of the Alpes maritimes department. *Asher, Amsterdam*, 11, 388.
- Sano, M., Minagawa, M. & Nakajima, K. (2002). Multiplication of red sea bream iridovirus (RSIV) in the experimentally infected grouper *Epinephelus malabaricus*. *Fish Pathology*, 37(4), 163-168.

- Schipp, M. (2012). Aquatic animal diseases significant to Australia: Identification field guide 4th edition. *Department of Agriculture, Fisheries and Forestry*, 3, 63-70.
- Shao, K. T. & Lim, P. L. (1991). Fishes of freshwater and estuary: Encyclopedia of field guide in Taiwan. *Recreation Press Corporation Limited Company, Taipei*, 31, 240.
- Shinmoto, H., Taniguchi, K., Ikawa, T., Kawai, K. & Oshima, S. I. (2009). Phenotypic diversity of infectious red sea bream iridovirus isolates from cultured fish in Japan. *Applied and Environmental Microbiology*, 75(11), 3535-3541.
- Shiraishi, T., Tanaka, H., Ohshimo, S., Ishida, H. & Morinaga, N. (2010). Age, growth and reproduction of two species of scad, *Decapterus macrosoma* and *D. macarellus* in the waters off southern Kyushu. *Japan Agricultural Research Quarterly (JARQ)*, 44(2), 197-206.
- Smith-Vaniz, W. F. (1984). Carangidae: relationships. *Ontogeny and Systematics of Fishes*, 1, 640-70.
- Smith-Vaniz, W. F. (1986). The Carangidae. *Fishes of the North-Eastern Atlantic and the Mediterranean*, 2, 638-661.
- Smith-Vaniz, W. F. (1995). Carangidae, Jureles, pampanos, cojinuas, zapateros, cocineros, casabes, macarelas, chicharros, jorobados, medregales, pez pilota. *Food and Agriculture Organization (FAO) Guide for the Identification of Species for the Purpose of Fisheries*, 4, 940-986.
- Smith-Vaniz, W. F. (1999). Carangidae: Jacks and scads (also trevallies, queenfishes, runners, amberjacks, pilotfishes, pampanos, etc.). *Species Identification Guide for Fisheries Purposes*, 4, 2659-2756.
- Smith-Vaniz, W. F., Williams, J. T., Pina Amargos, F., Curtis, M. & Brown, J. (2015). *Decapterus macarellus*. Retrieved from <https://www.iucnredlist.org/species/190117/115308983>.
- Spring, O. & Thines, M. (2010). Molecular techniques for classification and diagnosis of plant pathogenic Oomycota. *Molecular Identification of Fungi*, 35-50.
- Tendencia, E. A., Lavilla-Pitogo, C. R., Catap, E. S. & Lio-Po, G. D. (2004). Bacterial diseases: Diseases of cultured groupers. *Aquaculture Department, Southeast Asian Fisheries Development Center*, 19-28.
- Terceti, M. S., Ogut, H. & Osorio, C. R. (2016). *Photobacterium damsela* subsp. *damsela*, an emerging fish pathogen in the Black Sea: Evidences of a multiclonal origin. *Applied and Environmental Microbiology*, 82, 13.

- Tidwell, J. H. & Allan, G. L. (2001). Fish as food: Aquaculture's contribution: to ecological and economic impacts and contributions of fish farming and capture fisheries. *European Molecular Biology Organization Reports*, 2(11), 958-963.
- Torres, M. A., Ramos, F. & Sobrino, I. (2012). Length-weight relationships of 76 fish species from the Gulf of Cadiz (Southwest Spain). *Fisheries Research*, 127, 171-175.
- Wang, X. H., Qiu, Y. S., Zhu, G. P., Du, F. Y., Sun, D. R. & Huang, S. L. (2011). Length-weight relationships of 69 fish species in the Beibu Gulf, northern South China Sea. *Journal of Applied Ichthyology*, 27(3), 959-961.
- Wang, Y. Q., Lü, L., Weng, S. P., Huang, J. N., Chan, S. M. & He, J. G. (2007). Molecular epidemiology and phylogenetic analysis of a marine fish infectious spleen and kidney necrosis virus-like (ISKNV-like) virus. *Archives of Virology*, 152(4), 763-773.
- Watanabe, C. & Yatsu, A. (2006). Long-term changes in maturity at age of chub mackerel (*Scomber japonicus*) in relation to population declines in the waters off northern Japan. *Fisheries Research*, 78, 323-332.
- Whitehead, J. P. (1985). Fishes of the world (suborder Clupeoidei): An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies, and wolfherrings. *Food and Agriculture Organization (FAO) Species Catalogue*, 125(7), 1-303.
- Whitehead, P. J. P. & Wongratana, T. (1986). Clupeidae. *Smiths' Sea Fishes*, Springer-Verlag, Berlin, 199-204.
- Williams, T. (1996). The iridoviruses. *Advances in Virus Research*, 46, 345-412.
- Williams, T., Barbosa-Solomieu, V. & Chinchar, V. G. (2005). A decade of advances in iridovirus research. *Advances in Virus Research*, 65, 173-248.
- Work, M. T. (2003). Public markets & community-based food systems. Retrieved from https://s3.amazonaws.com/aws-website-ppsimagenas05y/pdf/kellogg_report.pdf.
- Yanong, R. P. (2010). Lymphocystis disease in fish. Retrieved from <http://edis.ifas.ufl.edu/fa181>.
- Yanong, R. P. & Waltzek, T. B. (2010). Megalocytivirus infections in fish, with emphasis on ornamental species. *University of Florida Institute of Food and Agricultural Sciences Extension*, 1-7.
- Yap, W. G. (1999). Rural aquaculture in the Philippines. *Regulatory Assistance Project (RAP) Publication*, 20, 7.

Yesaki, M. & Arce, F. (1994). A review of the Auxis fisheries of the Philippines and some aspects of the biology of frigate (*A. thazard*) and bullet (*A. rochei*) tunas in the Indo-Pacific region. *Food and Agriculture Organization (FAO) Fisheries Technical Paper*, 336(2), 409-439.