Mitigating the Impacts of Salinity Intrusion due to Climate Change on the Tra Catfish Farming in Coastal Provinces of the Mekong Delta, Viet Nam

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The present state of our knowledge of the earth's climate change and tectonic plate movements suggests that sea level rise would greatly affect the Mekong Delta. Farming of the tra catfish (*Pangasianodon hypophthalmus*) is intensively done in Viet Nam, particularly along the Mekong River branches, and especially in Tien and Hau Rivers, and their associated tributaries. The contribution of the tra catfish farming industry to the economy and food security of Viet Nam is crucial as this sub-sector is one of the biggest employers in the country's Mekong Delta region. Against such a backdrop, a review was undertaken to determine the impact of sea level rise caused by climate change on tra catfish farming, assess the capabilities of tra catfish farmers in dealing with potential changes in the climate, and propose adaptation strategies useful to farmers and policy makers. Tra catfish farmers may have gained knowledge on climate change from mass communications media but they still have low perceptions on the gradual impacts of climate change, such as sea level rise. Their experience related to climate change has been shaped mainly by extreme climatic events. Nonetheless, representatives from the Tra Catfish Farmers, companies and key informants in Soc Trang Province pointed out that saltwater intrusion would continue to be one of their highest concerns in the future, and added that, changes in the farming techniques for tra catfish would be one of the most important adaptation measures to cope with climate change and saline water intrusion.

When the plausible impact of salinity intrusion induced by three climate change scenarios and associated sea level rise levels (SLR) of +30, +50 and +75 cm on the tra catfish farming sub-sector were simulated in a study, the initial results indicated that more areas in the coastal provinces of Viet Nam would be affected by salinity intrusion. Moreover, those areas that are already affected would experience longer periods of higher salinity levels, and as a consequence of the rising salinity levels due to SLR+75 cm, the window appropriate for the culture of tra catfish in the coastal areas would be greatly reduced. Facing the risk of salinity intrusion induced by sea level rise on the tra catfish farming industry in the Mekong Delta, a framework was proposed for decisions on the plausible autonomous and planned adaptation(s). The proposed suitable adaptive measures of tra catfish farmers under the autonomous adaptation category could include: (i) changing pond culture practice(s) (spontaneous adaptation), and (ii) stocking a salinity-tolerant pangasius if available (spontaneous adaptation). In the planned adaptation category, the appropriate solutions could include: (i) developing a salinity-tolerant strain of pangasius through the intervention of government/public agencies or private companies (active adaptation), and (ii) shifting to farming other salinity-tolerant species (spontaneous adaptation). Nonetheless, the latter adaptations may be chosen by only few farmers as it would require investments in terms of new know-how and networks, and in restructuring the culture ponds.

Nowadays, the striped catfish (*Pangasianodon hypophthalmus* Sauvage, 1878), commonly referred to as tra catfish (**Figure 1**), is the most important aquatic species being farmed in Viet Nam from the social and economic points of view. In 2015, the tra catfish farming sub-sector of Viet Nam produced 1.11 million tonnes (t) of fish in a pond area of 5623 ha. Such production had gradually increased not only in terms of quantity by up to 1.58 million t but also in terms of culture areas of up to 6675 ha in 2019 (VASEP, 2020), as shown in **Table 1**. Most of the tra catfish produced in Viet Nam is exported to 132 countries and territories (**Figure 2**), earning for the country's coffers of about USD 2.261 billion in 2018 (VASEP, 2020).

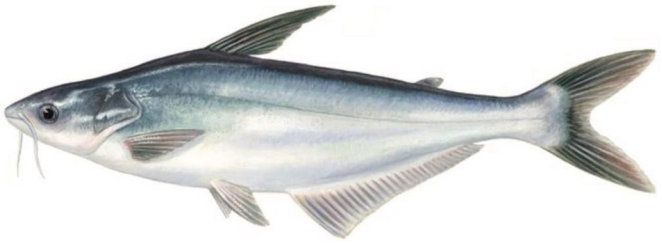

Figure 1. Striped catfish (*Pangasianodon hypophthalmus* Sauvage, 1878) also known as tra catfish in Viet Nam
Source: *https://tepbac.com/species/full/32/ca-tra.htm*)

Table 1. Annual increases of tra catfish production and culture area in the Mekong River Delta in Viet Nam

Countries surveyed	2015	2016	2017	2018	2019
Culture area (ha)	5,623	5,893	6,078	6,418	6,675
Production (million tonnes)	1.11	1.19	1.25	1.42	1.58

Source: *http://vasep.com.vn/san-pham-xuat-khau/ca-tra/tong-quan-nganh-ca-tra*

Recently, the Mekong Delta Region of Viet Nam (**Figure 3**) suffers the impacts of climate change through sea level rise, which is expected at 1.0 cm/year until 2100 (Grinsted *et al.*, 2009) and reduced river flow.

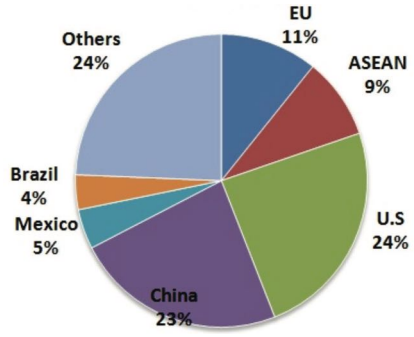

Figure 2. Countries of destination of tra catfish export from Viet Nam in 2018 (value)
Source: *http://vasep.com.vn/san-pham-xuat-khau/ca-tra/tong-quan-nganh-ca-tra)*

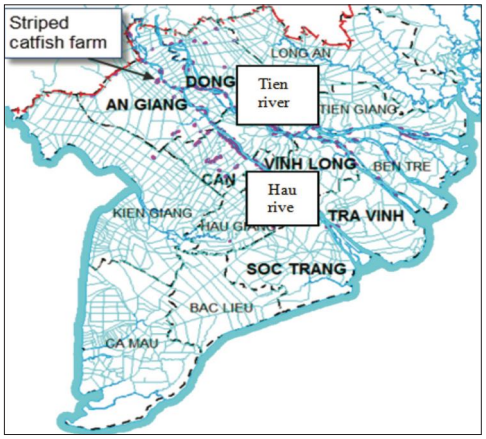

Figure 3. Mekong River Delta in Viet Nam showing Tien and Hau Rivers

The potential expansion of catfish farms in Viet Nam (**Figure 4**) is dependent on tidal regime and salt water intrusion would negatively affect the tra catfish culture industry (Department of Aquaculture, 2008) considering that water salinity higher than 4 ‰ is not suitable for tra catfish culture (Department of Aquaculture, 2008; De Silva and Phuong, 2011). In the Mekong River Delta of Viet Nam, the water used for tra catfish culture comes from Tien and Hau Rivers and their canal systems. Phan *et al*. (2009) reported that reduced production in catfish farms had been noted in areas located downstream, which was attributed to diurnal changes in salinity, albeit small. As a consequence of climate change, the production areas for the tra catfish culture in the Mekong Delta might have to be altered for some parts of the presently used areas may become no longer suitable for the culture of tra catfish.

Figure 4. Tra catfish farms in the Mekong River Delta of Viet Nam

Although temperature increase may also affect the culture of tra catfish, it is not much of a concern because tra catfish has a large temperature comfort zone (Department of Aquaculture, 2008). So that only the two main factors, *i.e.* water level rise and salinity intrusion induced by sea level rise, are critical and hence, while temperature increase due to global climate change will not have strong impact on tra catfish farming. Increased seawater intrusion in coastal areas or increased flooding in upstream regions caused by sea level rise and exacerbated by reduced river flow in the dry season or increased water discharge during the rainy season, would altogether increase salinity and water level significantly, affecting the farmed catfish from salinity stress as well as from risks related to flooding when water levels are higher than the pond dyke, or pond dyke could be destroyed. Therefore, farm location and the extent to which tra catfish can adapt to brackish water or the extent to which a pond can undergo flooding are the factors that affect the decision-making process of tra catfish aquafarmers. The most appropriate adaptive measures could be difficult to choose and therefore will have to be accompanied by relevant socio-economic changes within the aquafarming community as well as for those servicing this aquafarming sub-sector. Nonetheless, the results of several studies on the impact of salinity intrusion caused by climate change on tra catfish farming in the coastal provinces of the Mekong Delta and the adaptation strategies adopted by the tra catfish farmers are summarized in this article.

Salinity intrusion

Anh *et al*. (2014) simulated the salinity intrusion in the two branches of the Mekong River (Tien and Hau Rivers) based on the climate change and sea level rise scenarios of Viet Nam (Ministry of Natural Resources and Environment (MONRE), 2009) with the expected sea level rise of 30 cm in 2050, 46 cm in 2070, and 75 cm in 2100 using the MIKE 11 model, which was developed by the Danish Hydraulic Institute (DHI, 2003). The model makes use of data on water level, rainfall, and salinity from 24 hydro-meteorological stations (*i.e.* Kratie, Phnom Penh, Tonle Sap, Tan Chau, Chau Doc, Long Xuyen, Ha Tien, Rach Gia, Ca Mau, Ganh Hao, Bac Lieu, Soc Trang, Can Tho, Tra Vinh, My Tho, Vinh Long, Cao Lanh, Sa Dec, My Thuan, Ben Tre, Tan An, Moc Hoa, and Tan Son Nhat), and considered the boundaries for 68 downstream-end data of tidal water level and salinity, and seven upstream discharge boundaries with updated data on water discharge.

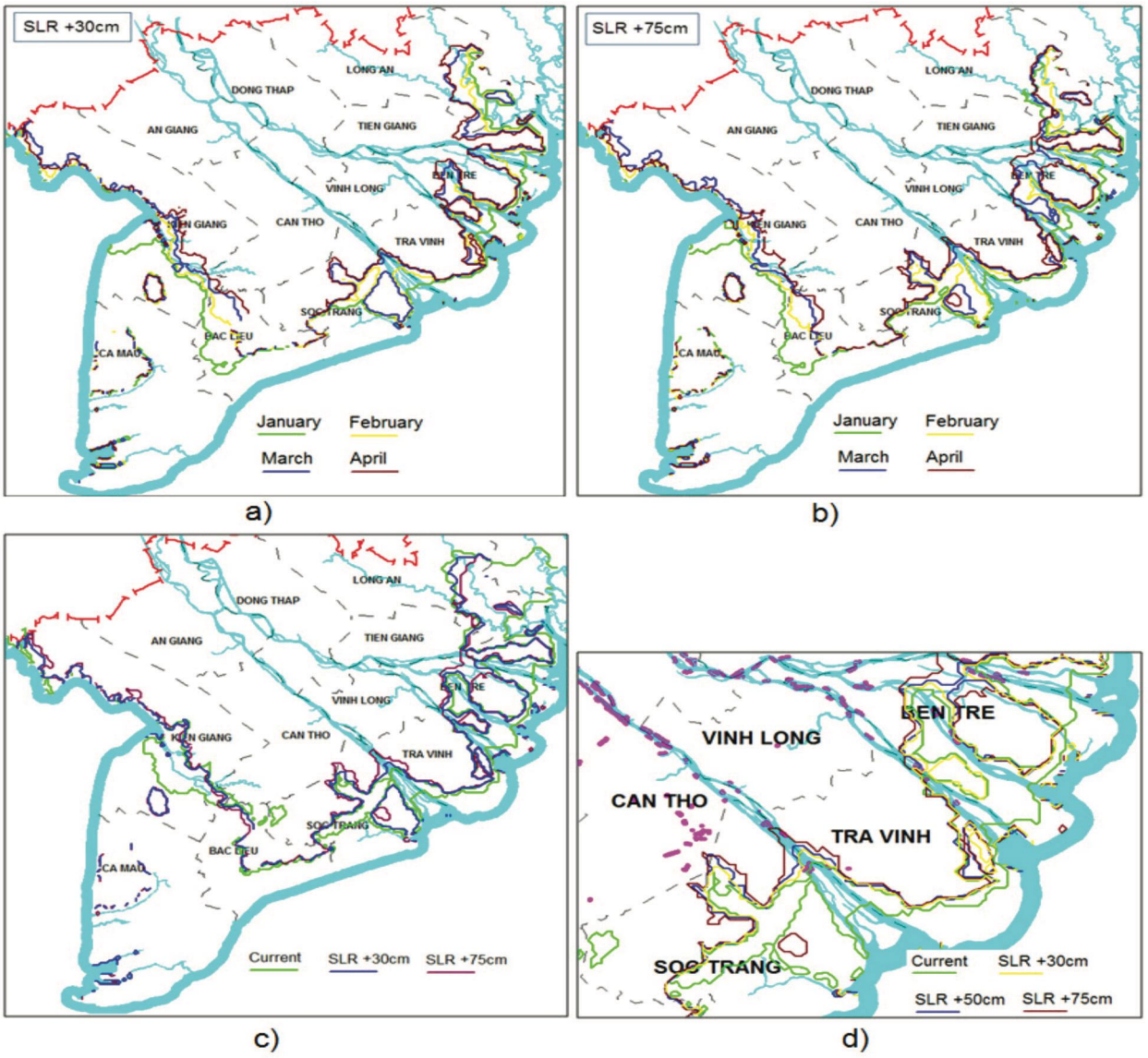

Figure 5. Coastal areas in the Mekong River Region of Viet Nam affected by salinity intrusion (4 ‰) from January to April for (a) SLR+30 scenario (a), and (b) SLR+75 scenario; in April for two scenarios and the baseline (c), and (d) effect of salinity intrusion on the striped catfish farms located in Ben Tre, Tra Vinh, and Soc Trang Provinces.

Source: *Anh* et al. *(2014)*

The input data for the model comprised the boundaries, as well as databases on hydrological and meteorological conditions. The hydraulic data included the hydrology of the Mekong River downstream from Kratie boundary, including the land levels above sea and the hydraulic elements of the river and canal systems. The model also included the irrigation and water control sluice systems.

As shown in **Figure 5**, salinity levels rose from January to April, where the saline front of 4 ‰ shifts inward 29 km and 32 km in Hau River during the end of March and April, respectively. For the SLR +50 cm scenario, the saline front of 4 ‰ in Hau River reaches 10 km inland from the sea in January then extends up to 24 km in February, 35 km in March, and 38 km in April. For the SLR +30 cm scenario, the central part of Soc Trang and the coast lines of Ben Tre will be affected by the intrusion of salinity concentration of 4 ‰ (Anh *et al*., 2014).

When the salinity map is overlaid on the map of the striped catfish farm locations as of 2009 for Ben Tre, Tra Vinh and Soc Trang Provinces, it was known that the effect of salinity intrusion on the farms is local. Tra Vinh, which is located in the southwestern area, is projected to suffer while the conditions for farms in the northeast would not significantly change. In Ben Tre, most farms have already dealt with the 4 ‰ salinity level phenomenon but the periods subjected to this salinity might become longer and farms located further upstream (*i.e.* to the west) might have to deal with such pattern too. In Soc Trang, all farms have already dealt with these prolonged periods (Anh *et al*., 2014).

Climate change concerns of striped catfish producers in the Mekong Delta, Viet Nam

Anh *et al*. (2015) investigated the perceptions on and adaptations to impacts of climate change on 235 tra catfish farmers in the Mekong Delta, Viet Nam including 30 farmers from Tra Vinh and Soc Trang coastal provinces. The semi-structured household survey was applied to collect data, and using the Chi-Square test, the correlation or association between variables was determined and the logit regression model was employed to examine the factors that influence the farmer's perceptions and adaptation. Results of this study showed that less than half of the respondents were concerned about climate change and sought suitable adaptation measures to alleviate its impacts. Improving information on climate change and introducing early warning systems could enhance the adaptive capacity of the catfish (pangasius) farmers, and in particular, help those farmers who are not concerned yet. Although most of the farmers rely strongly on technical support from government agencies, those in the coastal provinces seem not to express any interest to be trained by these institutions (**Table 2**). From the start, farmers from the coastal provinces had been confronted with seasonally high and gradually increasing salinity levels, but they had established and applied some forms of autonomous measures, such as delaying the cropping period, decreasing the stocking rates, or stocking larger fish that could tolerate higher salinity levels. These apparently contrasting results have urged the relevant agencies to assess the effectiveness of some adaptation measures, such as breeding salinity-tolerant pangasius (Anh *et al*., 2015).

In 2020, under the project of the Ministry of Education and Training of Viet Nam, a study was conducted to determine the impacts of climate change on the tra catfish farming in Soc Trang Province. The survey method made use of face-to-face interview using a semi-structured questionnaire of 97 aquafarmers who were members of individual fish nursing-growing households, fish farm managers of companies and key informants in Soc Trang Province. The results indicated that most of the aquafarmers were aware of the effects of saltwater intrusion and extreme weather to tra catfish culture and considered it difficult to overcome saltwater intrusion. In addition, the largest portion of the farmers indicated that abnormalities in the weather and climate extremes have occurred to some extent and saltwater intrusion was the most problematic situation. They expressed the concern that in the future, saltwater intrusion would still be the highest concern for tra catfish farming. Nevertheless, some groups considered that changing the techniques for nursing – growing tra catfish could be a possible and most important adaptation measure to cope with climate change and saline intrusion (Boi *et al*., 2020).

Adaptation to salinity intrusion

Using the decision tree framework, Anh *et al*. (2016) analyzed the possible options for the sustainability of pangasius farming in the Mekong Delta Region of Viet Nam, which could be adapted to minimize the impacts of projected climate change. After summarizing the risks of the impacts, the farmers' autonomous and planned public adaptations were analyzed using primary and secondary data.

Changing pangasius farming practice

Tra catfish farmers in the coastal areas have been encouraged to extend the nursing period of fish fingerlings, thus reducing the grow-out period in ponds during the months of high salinity intrusion (Anh *et al*., 2015). This period will result in slightly higher cost for transport, as juveniles will be heavier and perhaps at an increased risk (De Silva & Phuong, 2011).

In the Mekong Delta Region of Viet Nam, tra catfish farmers started to experiment on the use of recirculating aquaculture systems (RAS) for the nursery and grow-out phases, which could also be regarded as an autonomous adaptation. Although the results seem promising, the full costs and benefits are not yet known (Nhut *et al*., 2013). In the RAS, water intake is very restricted except for the last weeks of the grow-out period. Thus, RAS simultaneously reduces water pollution and contributes an added benefit for the mitigation of environmental impacts of the pangasius farming sub-sector (Bosma *et al*., 2011), a bone of contention of many environmental lobby groups (De Silva *et al*., 2010), and ultimately also contribute to the mitigation of the impacts of climate change too.

Table 2. Tra catfish farmers' agreement (%) on sources of support to adaptation of climate change, and the types of support

Areas surveyed	Source of support				Type of support		
	Government Institutions	Local Government Units	Private Sector	Friends/ Family Members	Technical	Financial	Capacity Building
All six provinces surveyed for the study	10.20	4.70	6.00	17.00	53.20	20.90	19.60
Upstream provinces	14.30	9.20	5.10	22.40	53.10	24.50	39.80
Mid-stream provinces	8.40	1.90	8.40	15.90	52.30	21.50	6.50
Downstream provinces	3.30	0.00	0.00	3.30	56.70	6.70	0.00

Source: *Anh* et al. *(2015)*

Shifting to another species

Another option in dealing with saltwater intrusion for tra catfish farmers in the coastal provinces is to also opt for the culture of other aquatic species (Anh *et al*., 2014). However, this option would require the development of new adaptive capacity by aquafarmers, and probably even changes in the farm infrastructure, in particular that of pond construction. A pond with water depth of 3.0 to 4.0 m is preferred for pangasius grow-out but such deep ponds are unsuitable for most of the other commonly farmed salinity tolerant species, such as the Asian sea bass or shrimps. Besides, pond restructuring would be necessary especially for ponds that are located directly next to rivers or main canals, and this is likely to be very costly as lowering the water level will increase, for example, the pressure on the dykes, while for other ponds, lowering pond depth may be realized by using lower water levels. Nonetheless, the technical and economic aspects of the feasibility of shifting to another species need further and thorough study (Anh *et al*., 2016).

Breeding salinity-tolerant pangasius

Many aquafarmers, who have been confronted with the risk from salinity intrusion prefer to continue producing pangasius rather than shifting to another species because they believe that only by farming catfish, can revenues be maintained at high level, enabling them to recover their investments (Anh *et al*., 2015). In this connection, De Silva and Soto (2009) suggested the development of a salinity tolerant strain of catfish as such a tolerant strain will require minimal changes in the farming techniques and in the related infrastructures, and would not require the development of new market chains (De Silva and Phuong, 2011.

According to Trong (personal communications), the generic cost of a salinity-tolerant catfish breeding program, starting with 150 individuals of wild broodstock of various origins in the Mekong River, is about US$ 120,000 (**Table 3**). However, due to the generation interval the actual cost in the long run, could be fourfold, *i.e.* US$ 480,000. The cost per kg of pangasius produced in the coastal provinces, estimated at 10 % of the total 1.2 million tonnes, would be US$ 0.004 kg^{-1}. This is slightly more than 0.4 % of the present production cost (US$ 1.1 kg^{-1}) and this appears to be a feasible investment. Whether or not such a program can successfully breed a salinity-tolerant pangasius, however, remains to be seen. The relatively long time frame (four years) of such a program and the large amount involved would require the continuous and persistent involvement of the public and private sectors (Anh *et al*., 2016). However, a most recent study by Boi *et al*. (2020) revealed that the farmers applied their own autonomous adaptation measures because the salinity tolerant fish breeding program is still at an experiment stage.

Conclusion and Recommendations

It is a fact that some of the expected impacts of climate change in Viet Nam are unavoidable, the most threatening of which, especially for the Mekong Delta Region, is sea level rise. In the projections of water level and salinity intrusion induced by three different sea level rise scenarios that had been simulated, results showed that the pangasius aquafarms in the coastal region are threatened by more frequent and higher levels of salinity concentration. The analysis of the perceptions of the tra catfish aquafarmers revealed that the impacts they experienced are due to extreme climatic events, although they failed to perceive the gradual climate changes, such as sea level rise. However, almost all tra catfish aquafarmers considered salinity intrusion as the most threatening. Through a decision-making framework, the appropriate adaptation and/or mitigation measures were assessed, and some autonomous adaptations identified by the pangasius aquafarmers include shifting to other salinity tolerant species or stocking a salinity tolerant pangasius. Nevertheless, the aquafarmers prefer to continue farming pangasius to recover their investments. It should be noted however that the development of a salinity tolerant strain of pangasius requires a strategic planned

Table 3. Generic cost (US$) of a salinity-tolerant catfish breeding program in Viet Nam (respecting the principles of an effective population size as established by Ponzoni *et al*. (2011))

	Year 1	Year 2	Year 3	Year 4
Fixed cost of infrastructure (rental of a 1.5 ha farm with 1.1 ha of ponds)*	7,200	7,200	7,200	7,200
Salary	4,700	6,400	6,000	4,250
Materials: broodstock and feeds	4,000	6,800	16,100	16,000
Accessories, disposable tools	480	2,850	950	950
Electricity, gasoline, diesel	320	1,700	320	320
Equipment	1,400	250	12,700	0
Maintenance cost	700	2,100	1,600	1,400
Total	**18,800**	**27,300**	**44,870**	**20,120**

***Cost of land:** about US$ 30,000 and infrastructure: US$ 23,0000; interest rate of 8% and depreciation of infrastructures over 20 years, accounted for (Exchange rate: 21,000 VND to 1.00 US$)*
***Source of primary data:** Dr. Trinh Quoc Trong, Director of National Breeding Centre for Southern Freshwater Aquaculture, Viet Nam (personal communication)*
***Source:** Anh* et al. *(2016)*

intervention of the government and private sectors to maintain and improve the tra catfish farming industry of the country and the associated livelihoods of the tra catfish aquafarmers.

References

Anh, L.N., Vinh, D.H., Bosma, R., Verreth, J.A.J., Leemans, R., & De Silva, S.S. (2014). Simulated impacts of climate change on current farming locations of striped catfish (*Pangasianodon hypophthalmus*, Sauvage) in the Mekong Delta, Vietnam. Ambio doi: 10.1007/s13280-014-0519-6

Anh, L.N., Minh, H.T., Verreth, J.A.J., Leemans, R., Bosma, R.H, & De Silva, S.S. (2015). Exploring the climate change concerns of striped catfish producers in the Mekong Delta, Vietnam. *SpringerPlus (2015) 4*:46. DOI 10.1186/s40064-015-0822-0

Anh, L. N., Verreth, J.A.J., Leemans, R., Bosma, R. & De Silva, S.S. (2016). A decision tree analysis to support potential climate change adaptations of striped catfish (Pangasianodon *hypophthalmus, Sauvage*) farming in the Mekong Delta, Vietnam. *Tropicultura, 2016*, NS, 105–115

Boi, N.V.Q., Anh, L. N., Luong, N. T. (2020). Effects of saltwater intrusion and extreme weather on striped catfish (*Pangasius hypopthalmus*) nursing –growing in Soc Trang. *Journal of Fisheries science and Technology, Vol. 4/2020* (in Vietnamese)

Bosma, R.H., Pham, T.A., & Potting, J. (2011). Life Cycle Assessment of Intensive Striped Catfish Farming in the Mekong Delta for screening hotspots as input to environmental policy and research agenda. *Intern. Journal of Life Cycle Assessment 16*(9): 903–915

Department of Aquaculture. (2008). Tra catfish culturing and marketing development plan to 2010 and strategy to 2020 (In Vietnamese)

De Silva, S. S. & Phuong, T. N. (2011). Striped catfish farming in the Mekong Delta: a tumultuous path to a global success. *Reviews in Aquaculture*, 3, 45–73

De Silva, S. S., Ingram, B.A., Phuong, T.N., Tam, M.B., Gooley, G.J. & Turchini, G.M. (2010). Estimation of nitrogen and phosphorus in effluent from the striped catfish farming sector in the Mekong Delta, Vietnam. *AMBIO* (2010) 39: 504–514

DHI. (2003). MIKE 11 – A modelling system for Rivers and Channels. Reference Manual

Grinsted, A., Moore, J. & Jevrejeva, S. (2009). Reconstructing sea level from paleo and projected temperatures 200 to 2100 ad. *Climate Dynamics* 10 DOI: 1007/s00382-008-0507-2

MONRE (Ministry of Natural Resources and Environment). (2009). Climate change, sea level rise scenarios for Vietnam. Publisher Ha Noi

Nhut, N., Hao, N.V., Bosma,R. Eding, Ep., Verreth, J. & Verdegem, M. (2013). Waste production from pangasius (*Pangasianodon hypophthalmus*) raised in ponds, flow-through and recirculating aquaculture systems. Presented at: Asian-Pacific Aquaculture 2013, Abstract - 401. Ho Chi Minh City, Vietnam

Phan, L.T., Tam, M.B., Thuy, T.T.N., Gooley, G.J., Ingram, B.A., Hao, V.N., Phuong, T.N., & De Silva, S.S. (2009). Current status of farming practices of striped catfish, *Pangasianodon hypophthalmus*, in the Mekong Delta, Vietnam. *Aquaculture*, *296*: 227–236

Ponzoni, R.W., Nguyen, H.N., Khaw, H.L., Hamzah, A., Abu Bakar, K.R., & Yee, H.Y. (2011). Genetic improvement of Nile tilapia (*Oreochromis niloticus*) with special reference to the work conducted by the WorldFish Center with the GIFT strain. *Reviews in Aquaculture 3*: 27–41

VASEP. (2020). *Overview of striped catfish farming*. Vietnam Association of Seafood Exporters & Producers (VASEP), Ha Noi, Vietnam (in Vietnamese) http://vasep.com.vn/san-pham-xuat-khau/ca-tra/tong-quan-nganh-ca-tra

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