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Mitigating uncertainty and enhancing resilience to climate change in the fisheries sector in Taiwan: Policy implications for food security

Ching-Hsien Ho [a, b], Jyun-Long Chen [c], Yagi Nobuyuki [b], Huu-Sheng Lur [d], Hsueh-Jung Lu [a, e, *]

[a] Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, No. 2, Beining Rd., Jhongjheng District, Keelung City, 202, Taiwan, ROC
[b] Department of Global Agricultural Sciences, Tokyo University, Japan, 7-3-1 Yayoi, Bunkyo, Tokyo, 113-8657, Japan
[c] Marine Fisheries Division, Fisheries Research Institute, Council of Agriculture, 199 Hou-Ih Road, Keelung City, 20246, Taiwan, ROC
[d] Department of Agronomy, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, 10617, Taiwan, ROC
[e] Center of Excellence for the Oceans, National Taiwan Ocean University, No. 2, Beining Rd., Jhongjheng District, Keelung City, 202, Taiwan, ROC

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ABSTRACT

The human population is projected to grow to more than 9 billion by 2050. New farming and fishing techniques are continually being developed. However, food production remains restricted by the finiteness of natural resources and the rapid increase in the global population. In the future, food production may decline because of the aggravated effects of climate change. Food production will be unable to satisfy the demands of the global population, leading to a food security crisis. As the world population continues to increase, food shortages will become increasingly severe, particularly for regions located in "climate impact hot spots" in tropical and subtropical zones and for small-island countries such as Taiwan. In the present study, supply and demand are analysed to examine the risks and uncertainties associated with the impact of climate change on the domestic and imported seafood supply. First, we conduct a literature review to identify the climate risk for sea food security, and then, we analyse the domestic production of both the marine fishing catch and aquaculture. This study also examines the critical problems of the imported seafood supply and applies a comparative analysis of impact type and differences in the top 10 seafood import countries to organize adaptation strategies to climate change. Moreover, due to the type of climate impact and the differences between long-term climate impact and extreme climate impact, we collect and compile the existing climate adaptation strategies of fishery production, seafood importing, and the demand and supply of seafood in Taiwan. Finally, we perform a comparative analysis to seek any deficiencies in the existing climate adaptation strategies and offer new adaptation guidelines based on the existing climate adaptation strategies. The results show that Taiwan's major adaptation strategies have been precautionary mitigation measures. In terms of resilience management, only the buffer stock scheme plan and the stabilization funds method are selected for some specific species to mitigate the short-term fluctuation in both yield and price for imported domestic seafood. However, we will confront uncertainties stemming from global climate change in the future; the existing climate adaptation strategies of Taiwan are still not sufficient to respond to climate impacts. For example, the climate change early warning system is still very inadequate, the existing scientific knowledge is insufficient, and the current adaptation strategies are insufficient for resolving the fluctuations in the market mechanism of seafood. According to the principles of risk management, the adaptation strategies recommended in this study can be differentiated into two categories: precautionary mitigation measures can be used to adapt to domestic production and uncertainties; such

* Corresponding author. Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, No. 2, Beining Rd., Jhongjheng District, Keelung City, 202, Taiwan, ROC.
E-mail address: hjlu@ntou.edu.tw (H.-J. Lu).

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measures include avoidance, transfer, and reduction to prevent the frequency and consequences of climate change for building a resilient fisheries sector. Moreover, resilience management (e.g., risk retention) can be used to respond to uncertainties in supply for adjusting production and mitigating the risks of climate change.

1. Introduction

The global population will increase to more than 9 billion people by 2050, and most of the increase will be in less developed states, representing a 30% increase (UN-DESA, 2009; Rice and Garcia, 2011). A large-scale migration and relocation pattern is expected; reports have indicated that 70% of the human population will live in urban centres, and most will live in megacities of more than 20 million inhabitants in 2050 (UN-DESA, 2009; Rice and Garcia, 2011). Currently, half of the global population lives within 60 km of a coast, but several studies have predicted that, by 2020, the proportion living in coastal areas will increase to more than 60% (Kennish, 2002; UNEP, 2007; Rice and Garcia, 2011).

The World Food Summit indicates that food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary and food preferences for an active and healthy life (FAO, 2009, 2014). Currently, although farming techniques are continually being improved, agricultural production remains restricted by the limitations of natural resources and the excessively high growth rate of the global population. As Malthus (1789) noted in "An Essay on the Principle of Population," food production will eventually be unable to satisfy the requirements of the global population, which will lead to starvation. Numerous sources of uncertainty will affect food supplies; climate change (e.g., rainfall mode changes, floods, global warming, and sea level rise) is one source of uncertainty that will become more serious in the future.

According to a report by the Intergovernmental Panel on Climate Change (IPCC, 2007, 2014), climate change has occurred gradually (e.g., crop production vegetal period changes). The report identifies declines in food production resulting from changes in temperature and rainfall. In the future, the aggravated effects of climate change on agricultural production will lead to a continual decline in food production (Cline, 2007). If the existing allocation patterns of food do not improve, then the phenomenon of food shortages accompanied by population growth will become more severe (Rice and Garcia, 2011; OECD-FAO, 2014). As the uncertainty of agricultural production increases, a critical concern becomes how to satisfy the demand (e.g., heat calories and protein) for nutritive substances obtained from seafood (FAO, 2009; Rice and Garcia, 2011; OECD-FAO, 2014).

Fish are a major intake source of animal protein: even a small amount of intake can supply adequate nutrition (FAO, 2005, 2009). In the world's 127 developing countries, fish constitute 20% of the animal protein intake and as such are a major source of food (FAO, 2005). In accordance with the dietary needs of the global population, global seafood demand has increased sharply over the past 50 years. Although global production in the marine fishing industry became gradually saturated after the 1980s, aquaculture production continues to gradually increase (Fig. 1). This phenomenon shows the increasing importance and contribution of seafood to global food security; seafood has become a major source of nutritional needs such as heat calories, protein, vitamins, unsaturated fatty acids, and carbohydrates (OECD-FAO, 2014; FAO, 2014). According to forecasts by the Organization for Economic Co-operation and Development (OECD), to meet global food demands, in 2020, the demand for global seafood will increase by 18%. Developing nations are the main source of the increases in seafood demand, with their demand in 2020 projected to increase by 20%. By 2050, the global seafood demand will increase by approximately 50% (Rice and Garcia, 2011; OECD-FAO, 2014).

Accompanied by open markets of international trade, the decrease in export subsidies causes animal and plant quarantine measures to upgrade contributions to the trade liberalization of seafood. However, the comparative advantages of global seafood production have become more obvious when accompanied by trade liberalization and the operations of the World Trade Organization. Developing nations have gained increasingly prominent roles in the global food supply and demand system because of their low production and manpower costs. Since the 1990s, seafood imports have increased and gradually replaced domestic production to become a major supply source of seafood (FAO, 2009). Moreover, 40% of the total value and 33% of the total volume of the fish supply relies on international trade (Delgado et al., 2003), indicating an insufficient domestic production under trade liberalization and a growing reliability on imported seafood (FAO, 2009). However, although trade liberalization can increase product diversity, it ignores the uncertainty of production risks from developing nations. Increasingly, the globalized fish markets are exposed to market disruptions that may result from climate change. In the past 20 years, climate change has resulted in oceanic changes that have already led to changes in the fishery yield and value in various countries. This climate impact and seafood market trade liberalization produce more uncertainty and climatic risks (Rice and Garcia, 2011; OECD-FAO, 2014).

Because climate changes have already resulted in lower production in the marine fishing industry and aquaculture, the rate of fishing and aquaculture production has gradually decreased. However, climate and production changes have a powerful influence on the stability of seafood supply and demand, particularly in tropical districts, subtropical zones, and small-island countries (Cheung et al., 2009, 2010, 2013). In the future, more severe challenges will be encountered in ensuring the stability of the global seafood supply and demand. Under the continued influence of climate change, the yield and price of food will undergo high volatility (FAO, 2011; Chang et al., 2013). The major exporters of the world will face climate effects and risks, which may lead to an undersupply and a global food security crisis (OECD-FAO, 2014). Taiwan is located in a subtropical zone and encounters the same problems caused by climatic changes.

According to the influence path of climatic change, the influence of climatic change on fisheries can be differentiated between the environment, the ecosystem, society and the economy (Fig. 2) (FAO, 2009; IPCC, 2014). Several studies have noted the impacts of climate change on Taiwan's fisheries, which include ocean warming, ocean acidification, an increasing debris flow, rainfall pattern changes, and sea level rise; Fig. 2 illustrates the impact routes (Lu et al., 2012; Chang et al., 2013; Lan et al., 2014; Lu and Lee, 2014; Ho et al., 2016). The environmental changes will cause alterations in marine physics and chemistry, the aquaculture area and fitness, the marine ecosystem, the fish composition, and the catch composition (Chang et al., 2013; Lan et al., 2014; Lu and Lee, 2014;