Aquaculture 481 (2017) 245–254

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aquaculture

Causes and consequences of spatial links between sea cage aquaculture and coral reefs in Vietnam

N. Hedberg*, I. Stenson, N. Kautsky, M. Hellström, M. Tedengren

Department of Ecology, Environment and Plant Sciences, Stockholm University, SE-10691 Stockholm, Sweden

ARTICLE INFO

Keywords:
Sea cage aquaculture
Coral reef
Vietnam
Coral reef fish
Trashfish

ABSTRACT

A majority of the sea cage farms in South East Asia are located close to coral reefs. This causes a conflict between conservation and food production since sea cage aquaculture has a number of negative impacts on coral reefs. The aim of this investigation was to assess the drivers causing the sea cage farmers to place their farms close to reefs and to examine some potential farming effects in detail i.e. usage of coral reef fish for grow out farming and feed. For some 3500 Vietnamese fish and lobster farms, we measured; the distance to the closest coastal city (proxy for infrastructure access), satellite derived Chl *a* (proxy for water quality), wind fetch, and the adjacent coastal slope and elevation. We also performed 159 semi-structured interviews with fish and lobster cage farmers from three regions in Vietnam.

The interviews revealed that the choice of farming site is mainly determined by access to infrastructure, wind and wave shelter, and water quality. Although the farmers used coral reef services, e.g. coral reef derived seedlings, they were in general not aware of coral reef presence or did not find it important for selection of site. Both coral reefs and sea cage farms were found close to steep rocky coasts, which are favorable for corals, and provide sufficient depth for sea cages. Sea cages were always found on the leeward side of the coast where the wind fetch is low enough for the floating farms and their inhabitants. Most of the farms were located within 20 km from a coastal city confirming the importance of access to infrastructure. With few exceptions, sea cage farms were located in areas with good water quality, where also coral reefs are present. The study showed that several of the coral associated species groups farmed were dependent on wild caught seedlings and that 22% of the feed used at farms was "trashfish" of coral reef associated species.

We consider the spatial correlation between sea cage farms and coral reefs as circumstantial and suggest that shared environmental preferences explain the farm distribution pattern, rather than access to ecosystem services provided by the nearby reef itself. We found no evidence that it is necessary for sea cage farms to be located near coral reefs and strongly recommend that sea cages are moved further away from coral reefs, but to areas still providing clear water, shelter and access to infrastructure.

1. Introduction

South East Asian sea cage farms, raising finfish and lobsters are systematically found close to coral reefs and in Vietnam > 50% of sea cages are found within 1 km from a reef (Hedberg et al., 2015). The farms are not evenly distributed but cluster in areas comprising < 5% of the coastal zone and coincide with the presence of coral reefs, which raises concern for the well-being of the coral reef ecosystem. This paper aims to untangle the mechanisms underpinning the spatial overlap between coral reefs and cage farms in Vietnam, and to substantiate the suggestion by Hedberg et al. (2015) that sea cage practitioners place their farms close to coral reefs because of shared environmental preferences and/or easy access to coral services such as fish seeds originating from coral reefs.

Vietnam is the fourth largest aquaculture producer in the world both in volume and value and holds the third place as an exporter of fisheries products. The export value has risen by 12.6% annually between 2004 and 2014 (FAO, 2016). Sea-based aquaculture expanded rapidly during the first decade of the present millennia, but in the last years the increase in production has stopped and even decreased in some areas, due to diseases, and reduced demand. Both in terms of volume and value, land based fresh- and brackish-water culture systems are of larger significance, but expansion is limited by land availability (De Silva and Phillips, 2007; Hung and Tuan, 2009; FAO/FISHSTAT, 2016). Although FISHSTAT data from Vietnam do have gaps, this is, to the best of our knowledge, the best available information. Furthermore,

* Corresponding author.
E-mail address: nils.hedberg@su.se (N. Hedberg).

http://dx.doi.org/10.1016/j.aquaculture.2017.09.009
Received 15 December 2016; Received in revised form 26 July 2017; Accepted 8 September 2017
Available online 09 September 2017
0044-8486/

Vietnam is one of the countries most susceptible to elevated sea levels because the fertile low-lying coastal areas are also often very flat, a large part of Vietnam's population live here, and most of the aquaculture production is situated here (Dasgupta et al., 2008; GSO, 2015). With the country's fast growing population, there is a need for the growing aquaculture sector to expand into new areas, and for reasons mentioned above, floating sea cages, if managed properly, might be one possibility to meet the increasing demand for seafood.

In Vietnam today, aquaculture is proposed to provide a possible solution for decreasing pressure on depleted wild stocks and at the same time meeting the consumers demand for high valued species such as groupers (*Epinephelinae*), snappers (*Lutjanidae*) and spiny lobsters (*Panulirus*) (Pomeroy et al., 2006). Due to the lack of local hatcheries in Vietnam, the cage farmers experience problems regarding quality and quantity of seedlings for their farms, and therefore resort to buy fry from Taiwanese hatcheries or locally wild caught fingerlings (Hasan, 2012).

Large quantities of small/juvenile fish are also caught and sold as trashfish to be used as feed in different Vietnamese aquaculture systems (Edwards et al., 2004; Pomeroy et al., 2009). There is now around 3500 family owned small-scale cage farms along the Vietnamese coast (Hedberg et al., 2015) that mainly use trashfish as feed (Hasan, 2012). The trashfish is mostly caught in inshore waters at < 50 m depth, with some of the main species groups reported being coral reef associated fish such as rabbit fish (*Siganus* spp.), barracudas (*Shyraena* spp.), red big eye (*Priacanthus* sp.) and moon fish (*Mene* spp.) (Edwards et al., 2004; FAO, 2007).

Cage farms are point sources of dissolved nutrients, feces, feed fragments, chemicals, and diseases (Wu, 1995). The main environmental problems are thus associated with eutrophication which has proven to be harmful to coral reefs (Fabricius, 2011; Weber et al., 2012; Hedberg et al., 2015). The effects of cage farming on coral reefs are usually most severe within 0–500 m from cage farms, but may extend as far as 5 km from farms (Garren et al., 2008; Huang et al., 2011; Hedberg et al., 2015). The environmental effects of sea cage aquaculture on coral reefs depend on feeding practices, feed type, source of seeds, water circulation and the physical location of the farms (Wu, 1995). The sea cage farms in Vietnam are usually found along steep coasts, on the leeward side of islands and bays, stretching from Halong bay in the north-east to Phu Quoc in south-west, with a majority located in the south-central area (Hedberg et al., 2015).

The reasons underpinning farmers' choice for suitable sites for their farming activities close to coral reefs are not clear. The main aim of the present interview survey was thus to explore in more detail which factors determine where small-cage fish and lobster farmers position their sea cages, and to what extent the farmers are aware of the presence of coral reefs. Additionally the types of fish species farmed and composition of the trashfish for feed were investigated in order to understand the dependence of coral reef and associated fish species.

2. Methods

2.1. Interview sites

Three regions were chosen for this survey along the 3200 km long Vietnamese coast, fulfilling the criteria of harboring sea cage farms (based on Hedberg et al., 2015) and representing different climate zones (Kottek et al., 2006): 1) Cat Ba (Gulf of Tonkin), the humid subtropical zone with sea surface temperatures (SST) varying between17.8–31.8 °C, 2) Nha Trang in Central Vietnam (South China Sea) representing tropical wet and dry climate with SST between 23.7 and 31.0 °C, and 3) Phu Quoc in the south (Gulf of Thailand) representing tropical wet climate and SST between 26.6 and 32.0 °C (Fig. 1). The small-scale farms in these areas consist of simple rafts, which hold net cages and a platform with an accommodation facility. The socio-economic conditions vary among the practitioners with some farm owners having employees while others live on the farm alone or together with their families and invest all their financial and time resources in the farms. The farms are located at different distance from the local reefs: in Cat Ba (mean 1090 m), Phu Quoc (mean 863 m), and in Nha Trang (mean 108 m). The three regions also differ in numbers of farms: Cat Ba (280 farms), Nha Trang (190 farms), and Phu Quoc (35 farms) (Hedberg et al., 2015).

2.2. Interviews

The interview survey was part of a large-scale research collaboration between Stockholm University, Centre for Marinelife Conservation and Community Development (MCD) in Hanoi, the Institute of Oceanography (IO) in Nha Trang, and Institute of Marine Environment and Resources (IMER) in Haiphong Vietnam, and was approved by the Vietnamese authorities and collaborating institutions. The purpose of the survey was thoroughly explained to the participants prior to the interviews, and all the interviewees gave their consent to participate in the survey and for possible usage of pictures or recorded interviews. The identities of the interview subjects were kept anonymous in any subsequent analysis or report, which is crucial for the upkeep of trust (Valbo-Jørgensen and Poulsen, 2000). To avoid biased responses the interviewees were not financially compensated for their collaboration.

The semi-structured interviews, mainly focusing on quantitative data sampling, lasted for 20–30 min and were assisted by a Vietnamese–English speaking interpreter. The interviews were conducted in two parts, where the first and most extensive one (109 interviews, Appendix A) focused on general farming practices among the cage farmers and the second part focused on trashfish use (50 interviews, Appendix B). The first 109 interviews took place between September and November 2012 and were distributed as follows; Cat Ba n = 30, Nha Trang n = 50 and Phu Quoc n = 29 (Fig. 1).The second set of 50 interviews, 26 in Cat Ba and 24 in Nha Trang, were done with cage farmers (n = 20), fishermen (n = 15) and trashfish retailers (n = 15) evenly distributed between the 2 sites in November–January 2014/2015. The interviews were randomly distributed to cover all sites spatially and to include all farm sizes. If a chosen farm was unattended at the time of sampling or if the farmer(s) was too busy to participate in the study, convenience sampling (Denscombe, 2007) was used, meaning that the closest available farm was included instead. Each interview followed the protocol provided in Appendices A and B.

In order to investigate to what degree the farming practices were dependent of coral reef organisms as a resource, questions about farmed species, source of seedlings and species of trashfish were asked. Farmed species and trashfish were classified as coral associated or not, according to FishBase (Froese and Pauly, 2015).

The source of the fish- or lobster seedlings were classified as coral derived for all coral reef species that were not bred in a hatchery and hatchery bred species or wild caught non coral reef fish were classified as not being coral reef associated. The farmer awareness of adjacent coral reefs was investigated by asking: “Do you know if there is any coral reef nearby, and if so, where?” They either said “yes” or could point out the reef, then their answers fell into the category “aware of coral reef presence”, or they said “no” and then fell under the category “not aware of coral reef presence”. The farmers were also asked to state the reason to why they had chosen a specific site for their farms. Cage farmers, fishermen and trashfish retailers were asked what fish species that their trashfish consisted of. A list of previously reported trashfish (Edwards et al., 2004) was provided as a support. To roughly estimate the volume of individual species in the trashfish, photographs were taken and analyzed. For calculating trash fish usage, the cage farmers average trashfish use (from interviews) was multiplied with how frequently a specific species was reported (from interviews) and its average volume (from photographs).