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# Mariculture in Southern Central Region, Vietnam: Status and Orientation Toward Sustainable Development

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author PMT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PMT and HMS wrote the review and editing. Author HTA collected and analyzed the data of the study. Author PMT managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

The development of aquaculture, especially in mariculture, contributes to satisfy the increasing demand for aquatic food, but it also faces serious socio-economic and environmental issues. This is also consistent with aquaculture in the Southern Central Region (SCR), Vietnam. The paper conducted to evaluate the mariculture status and activities by questionnaire interviews of 255 mariculture stakeholders (cages/rafts owners) and their challenges by in-depth interviews of 16 aquaculture managing officers at eight provinces in SCR, 2018-2019. The results showed an assessment of the current status of mariculture, SWOT (strengths, weaknesses, opportunities, and threats) analysis, and orientation strategies of mariculture development. For a long time, the aquaculture area has not varied considerably, and mainly distributed in inland, coastal and off-coastal waters, almost it is not implemented in the open sea yet. Mariculture was also challenged by various concerned issues: various types of mariculture and species, small scale, outdated traditional technology, and labor force with fair practices in mariculture. Almost them are made the

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challenge for aquaculture expansion and implementation in open seas. Moreover, capital sources and credit access of stakeholders, and enterprise's investment are key factors to develop offshore mariculture. Based on the results of SWOT analysis, five strategies are proposed for sustainable development of mariculture in the SCR, as well as to meet the objectives of Vietnam's mariculture strategy. It is noted that when developing mariculture on an industrial scale to increase commercial products, the small- and medium-scale ones are vulnerable, so expansion and development of mariculture should be combined with the creation of job opportunities, reduction of poverty alleviation and economic growth and sustainability.

*Keywords: Mariculture; Southern Central Region; Vietnam; mariculture sustainable development.*

## 1. INTRODUCTION

The rapid population growth over the past half-century has pressured food security worldwide, especially in solving the demand for the protein of humans and raw materials for other economic sectors. This has created momentum for aquaculture to meet the demand for an increase in food fisheries [1]. According to FAO [2], the world fishery production reached 179 million tones, of which aquaculture accounted for 46% of the total fishery production in 2018 and is forecasted to have an increase of 53% by 2030, but aquaculture and fishery also cause several negative impacts on economics and natural resources. To minimize the conflicts on the land and resources uses with other economics and to reduce impacts on the environment, aquaculture does not only take place in inland and coastal waters but also expanding the offshore waters [3,4]. Aquaculture in inland and coastal waters has a limitation of spatial distribution, resources used conflicts, negative impacts ecosystems and degradation environment [3-7], whereas open/offshore mariculture (defined as the farming of marine organisms in offshore waters with less significant influence from coastal regions [8]) applies advanced technology to increase aquaculture production and to minimize the above limitations. However, open/offshore mariculture is still in the development and shaping stage, so it is necessary to develop standards for the open mariculture industry to ensure global sustainable development goals [8].

For Vietnam, marine food sources are not only needs of domestic consumption but also for export. The total of aquatic products reached 8497 thousand tonnes in 2020, of which aquaculture accounted for about 54% and fishing made about 46% [9]. In mariculture, farming reached 260 thousand hectares of surface areas and 7.5 million $m^3$ of cages with products of 600 thousand tones, in which marine fish culture had only 8.7 hectares of surface areas and 3.8 million $m^3$ of cages with products of 38 thousand tones, making only 0.44% of total aquatic production and 6.33% of aquaculture production. Farming regions for ponds and cage culture in the coastal and estuarine waters have a spatial restriction and faced serious issues of the environment, aquatic diseases, and over carrying capacity [10-13], the offshore waters in the continental shelf of Vietnam are not used for mariculture [14, 15]. The total potential area for mariculture is about 500,000 ha, of which the intertidal zones are 153,300 ha; coastal and around-island waters are covered 79,790 ha, and offshore waters are 167,000 hectares, the rest are other types of mariculture [16]. However, the potential for open/offshore mariculture in Vietnam, especially the Southern Central Region (SCR), has not been evaluated in detail.

The paper aims to present and analysis the situation of mariculture in SCR as well as their opportunities and challenges by conduction a socio-economic survey. Then, it orients to form and developing open/offshore mariculture, in the term of sustainable development.

## 2. METHODOLOGY

### 2.1 Study Area

SCR, covered from the northernmost point of Da Nang City to Binh Thuan Province (latitude: 10.57 °N - 16.21 °N and longitude 107.58 °E – 109.70 °E), are many satisfactory conditions for mariculture development. Climate is divided into two seasons, the dry season from January to August and the rainy season from September to December, having the period of minor flooding usually occurring in May or June. The average monthly surface sea temperature fluctuates 22.43–29.08 °C [17, 18]. The average monthly surface salinity ranges in 32.7–33.77 ‰ and the deep layer fluctuate around 34 ‰ [17, 18]. Salinity varies due to the influence of runoff from short and sloped rivers/streams [19], which have

flooding in the rainy season and no water in the dry season. The current velocity is about 20-30 cm/s in the north part and 30-40 cm/s in the south part in the northeast monsoon season and decreases to 10-15 cm/s in the north part and 25-30 cm/s in the south part in the southwest monsoon season [17, 18]. The frequency of natural disasters is relatively low. In addition, the infrastructure system (ports, boats) is relatively good, supporting the logistics of developing mariculture.

## 2.2 Classification of Mariculture Systems

FAO [20] provides standard criteria to classify mariculture based on location, hydrodynamics, environment, and accessibility to land during operation and management of the systems (Table 1). The offshore mariculture has occurred at the location far enough from the coast to reduce or un-impact from coastal waters, but close enough for land-based logistical support. These regions have greater depth with stronger natural force from ocean-hydrodynamics.

## 2.3 Socioeconomic Survey

The socio-economic survey was conducted in 8 coastal provinces and cities (Da Nang, Quang Nam, Quang Ngai, Binh Dinh, Phu Yen, Khanh Hoa, Ninh Thuan and Binh Thuan) by the approach of Rapid Rural Appraisal with a questionnaire and depth-interview. The questionnaire targets the status of cage mariculture and other related issues. A total of 255 questionnaires were interviewed by all of the 255 mariculture stakeholders from eight provinces (about 25 – 42 questionnaires for each) about the types of mariculture, aquatic species, human resources for mariculture, and other issues of environment, feed, breed and financial investigation. The stakeholders were owners of cages/rafts mariculture systems (each raft includes several cages). In addition, 16 in-depth questionnaires (two for each province) were conducted for local aquacultural managing officers by a small group meeting. This in-depth questionnaire targeted challenges and opportunities in management and orientation of mariculture development in the SCR.

## 2.4 Data Analysis

Interviewed results were input and analyzed by Excel and statistically processed on this software of Excel version 2019 for statistical description and graphing data.

**Table 1. General criteria for defining coastal, off-the-coast, and offshore mariculture**

| Parameters | Coastal mariculture | Off the coast mariculture | Open/offshore mariculture |
|---|---|---|---|
| Location/ hydrography | - usually sheltered In the coastal bay or estuaries<br>- <10 m depth at low tide<br>- within sight | - 500 m up to 2 km from the coast, somewhat sheltered<br>- 10–30 m depth at low tide<br>- often within sight | - >2 km generally from the coast, within continental shelf zones, possibly<br>- open sea/ocean<br>- >30 m depth |
| Environment | - Hs usually <1 m<br>- short-period winds<br>- localized coastal currents<br>- possibly strong tidal streams | - Hs <2–3 m<br>- localized coastal currents<br>- some tidal streams | - Hs 4 m or more, regularly 2–3 m<br>- oceanic swells<br>-variable wind periods<br>- less localized current effect |
| Access | - 100 % accessible landing possible at all times | - >90 % accessible on at least once a day landing usually possible | - usually >80 % accessible, landing may be possible, periodic (e.g. every 3–10 days) |
| Operation | - manual involvement, feeding, monitoring and more | - some automated operations, e.g. feeding, monitoring and more | - remote operations<br>- automated feeding, distance monitoring,<br>- systematic function |
| Exposure | - Sheltered (<45° exposed) | - partly exposed (e.g. >90° exposed) | - exposed (e.g. >180°) |

*Hs = significant wave height, a standard oceanographic term, approximately equal to the average of the highest one-third of the waves. Source: modified from [20]*

## 3. RESULTS AND DISCUSSION

### 3.1 Status of Mariculture

#### 3.1.1 Mariculture area

The aquaculture in SCR has sharply increased from 1997 to 2003 and a fluctuation around the average of 26.75 thousand hectares in 2003-2020 (Fig. 1). The changes of aquaculture mainly conducted in an expansion of coastal culture and mariculture, such as shrimp pond culture [21], lobster cages culture [22] and finfish culture [13]. The changes of mariculture have impacted by pollution, disease and natural disaster [22, 23]. Results of aquaculture in the SRC have 28.2 thousand hectares of aquaculture in 2020 [9]. Based on the criteria presented in Table 1, almost aquaculture activities in the SCR is distributed in inland and/or coastal waters, with only a small part of aquaculture located off the coastal waters. Officially, there is no open/offshore mariculture in the SCR, although some lobster and finfish cage culture were existed in the waters around islands of Cham island (Quang Nam province), Ly Son island (Quang Ngai Province).

#### 3.1.2 Species and farming methods

Figure 2 shows that cage/raft mariculture is practiced mainly on finfish (58.36% of the samples) and lobster (36.95%), the rest are bivalve, snail, and squid. Finfishes are mainly cobia (*Rachycentron canadum*), grouper (*Epinephelus spp*), barramundi (*Lates calcarifer)*, red drum (*Sciaenop ocellatus*), snubnose pompano (*Trachinotus blochii, T. falcatus*), greater amberjack (*Seriola dumerili; S. quinqueradiata*). Lobster includes Tropical spiny rock lobsters (*Panulirus ornatus*) and Scalloped spiny lobster (*Panulirus homarus*). The aquatic species cultured in the SCR might not change when comparing with the last decade [13, 16, 24], however, the ratio of finfish culture has an increase in the structure of mariculture when comparing with [16].

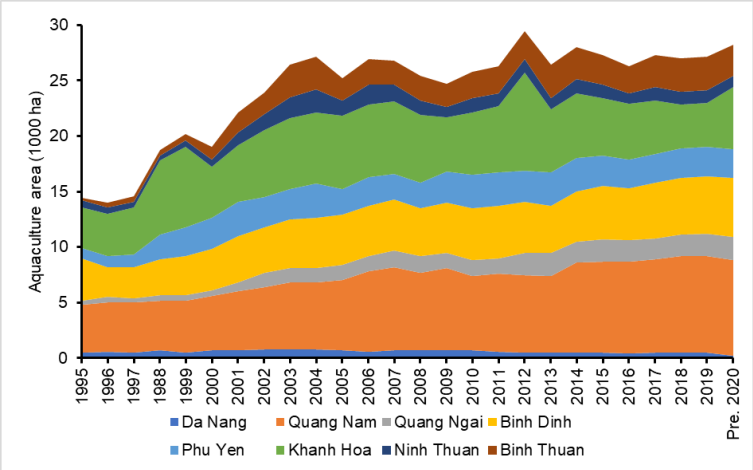


**Fig. 1. Development of farming area in South Central Coast [Data from 9]**

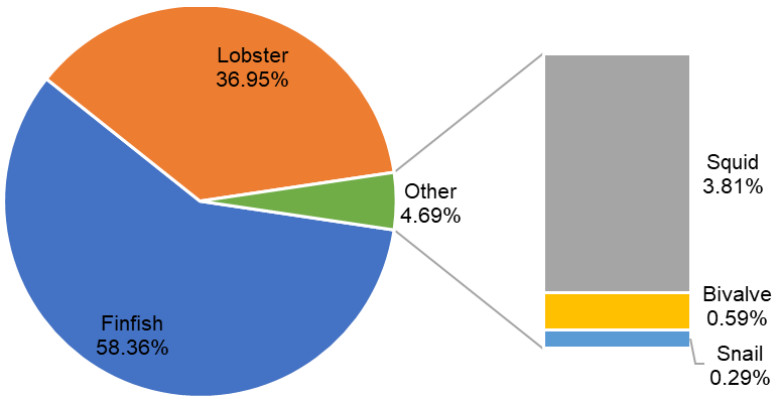


**Fig. 2. Species of mariculture in Southern Central Region of Viet Nam**

The types of mariculture in the SCR are very diverse and the marine species of culture are going to increase. The survey results indicate that the mariculture area was made in the types of cages/rafts on a small or medium scale. Each raft is formed from 1 to 230 cages, with an average of 21 cages per raft (n=255). Most of the cages are made of wood with plastic floats and each cage has a volume of 27-80 $m^3$, whereas the HDPE cages, which have the volume of range from 125 $m^3$ (square cage) to 2,400 $m^3$ (round cage), are only applied in Van Phong Bay, Khanh Hoa. The HDPE cages have been launched for finfish since 2003 [15], but in the SCR, HPDE practices have applied only Van Phong Bay with several improvements for hydrodynamic systems [13, 15]. In general, the survey results showed the marine cage/raft systems were made in the type of fixed rafts (less common and making 36.4% of total samples) and mooring systems (more common, making 63.6% of total samples). The mooring systems type could help prevent extreme weather, reduce the risks of marine fish farming and can be applied in deeper waters [15].

### 3.1.3 Labor force

Initially, the practical labor force in mariculture in the SCR can be assessed as relatively weak and poor practices. The survey result shows that the labor force for cage mariculture mainly used family labor, some rafts used outsourced workers. Laborers working at rafts range from 1 to 7 people, including 1-4 family laborers and/or hiding outsourced workers (up to 5 laborers). Each raft has more than 2 laborers per raft. Therefore, each laborer can work for 1-50 cages. However, 74.38% of laborers work with mariculture experience and do not officially train in mariculture, whereas only 25.21% of laborers have been trained in mariculture and 0.41% of laborers are trained in the field of economics. Generally, the technical workers accounted for a very low proportion of the labor force, making only 15.61% of laborers, including BSc. of 0.71%, technical college degree of 0.71%, technical diploma of 2.13 %, and technical workers of 12.06%. Thus, the labor force will become a challenge for mariculture development. That means the labor force is poor/fair practices and they are not really to meet the need of offshore and/or industrial mariculture. The quality labor force situation of offshore mariculture was the same pattern of the started shrimp/lobster development [16, 21-23, 25].

### 3.1.4 Other factors affecting marine farming

There are several factors affecting mariculture, but within the framework of this survey, the factors are:

- Breeds: Proactive breeding stock plays an important role in mariculture development. The survey results showed mariculture stakeholders mentioned artificially produced seed sources only encountered 74.02% of seed demand, in which 51.32% from domestic artificial seed and 22.70% from imports, mainly finfish seed, such as cobia, sea bass, snapper, and snubnose pompano. Wild seed sources accounted for 25.99% of seed demand, mainly lobster and other high economic finfish species. As a result, the seed demand not only affects the direction of mariculture development but also puts pressure on natural resources.

- Feed: The survey result showed that about 90% of stakeholders used trash fish (low-value fish, crustacean, mollusks, other bivalves) as main food sources for mariculture, only 9.41% of stakeholders used pelleted feed in cage mariculture of barramundi and pompano fish but the feeds were costly. Because the feed conversion ratio of trash fish can be range of 35-40 for industrial lobster culture, mariculture used trash fish can generate a local polluted point, especially in mariculture within regions being poor water exchange.

- Environmental pollution: the survey result indicated that mariculture stakeholders are aware that offshore mariculture is less affected by environmental pollution, whereas all stakeholders agreed that coastal mariculture in the bays and estuaries were faced with issues of pollution, over-carrying capacity, and spread disease.

- Supports: Mariculture investigation is requested large capital financial for mechanical construction (including cages, ships and infrastructure, those are accounting for approximately 50%), seed (14%), feeds (31%) and management (5%). However, the survey results indicated mariculture investigation was mainly from farmers' capital; and financial credits are low ratio. This may be the reason why the mariculture is small scale and it is difficult to expand the scale. However, mariculture stakeholders are also difficult to access financial sources due to lack of collateral (52.76% agreed), short-term loans (49.08% agreed) as well as lack of financial information

(22.70 % agreed). In addition, supports from local authorities for mariculture development is very limited, both in terms of technology and policy/regular.

### 3.2 Orientation Forward Mariculture Development

To develop orientations for mariculture development, the SWOT matrix is built based on data from in-depth interviews with local/provincial authorities and stakeholders of the medium-mariculture scale. Results of the SWOT analysis of mariculture in the SCR are shown in Table 2.

Table 2 provides the SWOT criteria from the interaction among mariculture development and natural resources, socio-economic conditions within (strengths and weakness), and outside (opportunities and challenge) studied regions of the SCR. The use of technical practices to increase the production of mariculture has interfered with the complex natural system, making the natural environment suitable for the development of mariculture effectively. The results of the current situation of mariculture and the SWOT analysis indicated existing problems in mariculture development in the SCR. Mariculture was implemented in small- and medium-scale, and mainly distributed in coastal bays and estuaries, but it was not in offshore/open waters, probably due to (1) open/offshore mariculture plans are un-proposed and unapproved; (2) detailed plan of coastal aquaculture is missing; (3) poor infrastructure, equipment, and techniques have not met the requirements of offshore mariculture; (4) inappropriate management policies may lead to mariculture facing many risks and challenges in terms of seed sources, environment and investment of financial sources; and (5) supporting and logistics systems and value chains (mariculture – harvesting – processing – distribution) for mariculture are poor. Seed sources have not encountered the demand for mariculture in both quantity and quality due to limitations or lack of research and practices of seed production technology. In addition, there is the contrast of environmental quality between the coastal and the open waters, the coastal environment is being degraded due to receiving waste from economic activities and is rick to over ecological capacity of the environment for mariculture, whereas environment in open/offshore waters has not been exploited yet. The coastal and marine environment is degraded not only due to mariculture waste but also from inappropriate farming practices, such as feeding with trash fish, a low feed conversion efficiency. Furthermore, the level of investment to develop mariculture for infrastructure (cages, net, ships, and other equipment), seed, and feeds are too large, and the capital turnover time is long, but farmers are lacking capital, and are hard to access national and international financial resources available. According to [13], the marine finfish culture also faced the issues of (1) poor quality and insufficient quantity of seed and bloodstock; (2) lack of private and/or public certification of production quality in small-scale aquaculture; (3) unplanning and spontaneously marine farming industry in off the coast and offshore mariculture; and (4) impacts from waste discharge from inland. In addition, all challenges of mariculture in the SCR might be the same issues in several countries [26-29]. These issues have limited the development and/or expansion of mariculture into open/offshore waters.

Based on the strengths and opportunities, mariculture can be developed by implementing the following strategies in the medium-term development with the long-term vision:

- Policy: Policies are going to complete gradually for sustainable mariculture development. It is important to implement the Fisheries Law revised in 2017 and current regulations, including realizing the policy on renting marine surface regions; creating favorable conditions for businesses, donors and stakeholders to access policies and manage tools for mariculture; encouraging them to contribute and support for value chain mariculture; perfecting insurance criteria and policies.

- Zoning for mariculture and marine spatial planning: Increasing area/space of mariculture; diversifying types and methods of mariculture; strengthening to investor modern cages systems and infrastructure to respond suitably for open/offshore features; diversifying high-value species for food demand of national and international markets.

- Supporting services: Building/improving information systems to support forecasting of weather and climate, analyzing the relationship of supply and demand for marine product markets; creating conditions to encourage stakeholders to participate in the digital transformation technologies of mariculture and

aquaculture industry; preparing sufficient capital and infrastructure to modernize mariculture industry; and creating new impetus for sustainable mariculture development.

**Table 2. SWOT for mariculture development in the Southern Central Region**

| **Strengths** | **Weakness** |
|---|---|
| • Perfecting step by step the plan and strategy of mariculture development in sustainability.<br>• Water space availability, offshore mariculture tends to increase.<br>• Good natural conditions<br>• Good environmental quality in open sea<br>• High biological and genetic diversity<br>• Supporting capability for research and development in mariculture, some farms have applied new technology for offshore mariculture.<br>• Available sources of raw materials for feeds<br>• Potential for seed supply<br>• Orientation support from the government and local authorities<br>• Available and cheap local labor<br>• High market demand of mariculture products for needs of local, domestic and exports<br>• Several units of research and training for supplying human resources for mariculture | • Fail aquaculture development due to unplanned expansion<br>• Limited and unclear enforcement of policies and laws/regulations in aquaculture and environmental management<br>• Negative impacts of using trash fish as feeds for mariculture leading to the deterioration of the environment in mariculture waters, and limitation to improve environmental carrying capacity of mariculture.<br>• High cost of quality feeds and supporting services<br>• Poor logistics systems and value chains for mariculture; thus, they have not encountered for needs of expanding mariculture yet.<br>• Limited research and development capability on mariculture practices and seed-producing techniques<br>• Limited techniques in harvesting, post-harvesting and processing products;<br>• Limited stakeholders' capacity and restricted access to finance<br>• Capacity of prevention and treatment of diseases<br>• Limited information system |
| **Opportunity** | **Challenge** |
| • National policy to encourage the expansion of mariculture<br>• Stable national politics and high economic growth.<br>• Develop planning and zoning for mariculture<br>• Improving product quality, especially focusing on high-economic species, promoting new aquatic products.<br>• Increased use of local ingredients in feeds<br>• Integrating global economy, expand product markets, especially promotion to develop of new species products.<br>• Strengthening training for the labor force in mariculture<br>• Increasing job opportunities and incomes, as well as improve living standards for local people<br>• Improving outcomes of research and development in mariculture<br>• Improving systems of information and support for mariculture development<br>• Opportunities for the investment of domestic | • Lack of detailed planning for mariculture.<br>• Unstable raw materials sources and feeds, and dependent on imported sources<br>• Price and market competition in seafood export from domestic and international markets<br>• International trade issues being diverse, complex and potentially concerns<br>• Pressure from increased demand for product diversity and quality of markets<br>• Pressure of waste from economic activities, aquaculture on marine environmental quality<br>• Conflict with other economic sectors to use marine space and resources<br>• Aquatic diseases and transformation complicated in the future<br>• Technical practices of workers having not yet responded to the development requirements of mariculture, and workers on the sea lacking practices and safety skills in mariculture. |

| | |
|---|---|
| and foreign enterprises.<br>• Promoting aquatic products | • Difficulties in research and transfer of new farming technology, or new species having not had a farming protocol.<br>• Management, recycling, and reuse of waste from mariculture |

- Training human resources: strengthen training capacity of human resources for mariculture in regional, national and international training units; improve qualifications practices of the marine farming labor force for needs of mariculture development.

- Science and technology: strengthen research and development of new technologies in mariculture protocol, seed production, and post-harvest such as aquatic food processing and extracting micronutrient, antibiotic and active components from mariculture products, second raw material from processing aquatic products. All results would increase the added value for mariculture.

These strategies support each other, especially the combination of two or more strategies that can create an optimal mariculture development strategy for each locality, each province, and the whole region. The expected result is how to achieve the goal of developing the mariculture industry with large-scale and sustainability. The mariculture industry would make high quality of products and goods supplying for national and export markets. However, the development of marine aquaculture in the SCR will be limited if it is without the framework of the general development of Vietnam's mariculture. In order to meet the increasing demand for marine food and to solve the problem of marine food safety and food security within countries and regions.

## 4. CONCLUSION

The article has analyzed and assessed the current status and development orientation of mariculture based on approaches of rapid rural appraisal with a questionnaire and depth-interview with farming stakeholders and managers. Mariculture in the SCR faces several issues in terms of mariculture zoning, farming types, and methods, technological practices, labor force, financial capital and environment. These issues have been summarized in SWOT. Therefore, improvement and development of mariculture is complex issues with various aspects: coordination of local authorizes and government; implementation of policies/strategies; and linkage with value chains of mariculture. In addition, mariculture sustainable development has to be built on a platform of good infrastructure, construction systems of farming, new/suitable technology, improving society, strengthening human resources, and improve farmers' access to credit. However, when mariculture development is on an industrial scale, the small- and medium-scales are vulnerable. Therefore, to achieve the goal of sustainable development, mariculture development needs to increase job opportunities for local people and reduce poverty alleviation.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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