LEIBNIZ CENTRE
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ZMT

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POLICY BRIEF 2017/1

Estimating sustainable levels of scallop bottom aquaculture in Sechura Bay (Northern Peru)

SUMMARY

The Peruvian bay scallop *Argopecten purpuratus* is the economically most important cultivated bivalve species along the South American Pacific coast. A major cultivation spot is Sechura Bay, North of Peru, where scallops are grown in shallow-water bottom cultures. This activity is very important for the socio-economic development of the region: in 2013, about 5000 artisanal fishers work in the scallop production chain, with an annual export value of US$158 mill. However, the intense scallop cultivation can lead to changes in the species composition of the bottom community. Overstocking, combined with adverse environmental conditions, may cause poor scallop growth and mass mortalities with severe impacts on the entire ecosystem and the scallop production chain.

The 2013 German-Peruvian research project SASCA (Sustainability Analysis of Scallop Culture in Sechura Bay, Peru) aims at determining the bay's carrying capacity – the maximum amount of cultivated scallops that the system can support without experiencing unacceptable changes. We therefore

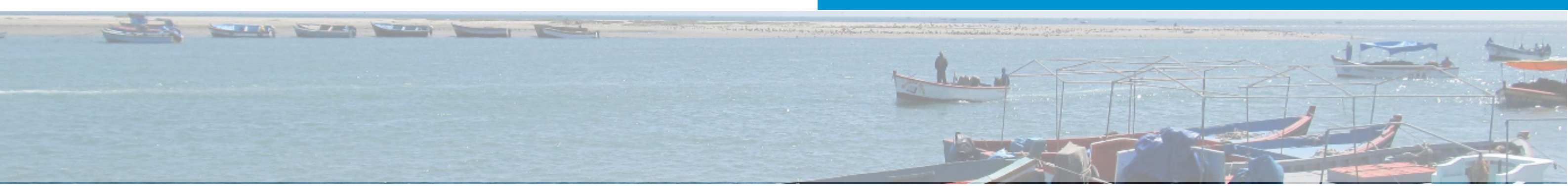
- investigated the impact of scallop culture on the species composition of near-bottom communities,
- determined the oxygen demand and optimum scallop grow-out densities,
- constructed a food web model for the bay that evaluates the impact of scallop culture under current and hypothetical scenarios of culture expansion, as well as the ecological carrying capacity, and
- analysed the value chain of the scallop production in Sechura through a socio-economic survey.

KEY RESULTS

- Scallop aquaculture induced a shift in ecological community structure and sediment composition.
- Current culture levels do not yet exceed the bay's carrying capacity but may do so, if culture was to be expanded beyond 10% of 2013 production levels.
- The risk for scallop mass mortalities increases with higher water temperatures, e.g. during the summer.
- Seed availability, mainly from natural banks, represents a bottle-neck for scallop mariculture.
- Despite its profitability, a further expansion may substantially decrease the farmers' individual benefit.

KEY RECOMMENDATIONS

- A constant environmental monitoring of the cultivation is required to detect changes in the community composition driven by environmental and/or farming activities.
- Production levels should not be expanded by more than 10% of 2013 levels to avoid exceeding the bay's carrying capacity and risking biodiversity.
- Scallop stocking densities should be decreased mainly during summer to avoid mass mortalities; if feasible, scallops should be harvested before summer.
- Scallop spat provision should be enhanced through collector bags for wild and hatcheries for laboratory seed.
- A culture expansion may decrease farmer incomes and requires therefore a prior cost-benefit analysis.



THE CONTEXT

Sechura Bay lies at the edge of the Northern Peruvian upwelling system in a transition zone between warm tropical and cold upwelling waters (see Figure 1). Here, sea surface temperatures are higher than in the south of the country and food conditions are favorable for culturing the Peruvian bay scallop (*Argopecten purpuratus*), a native species that is targeted by artisanal diving fishermen since the 1950's. Under conditions of El Niño warming and heavy rainfall, scallop mass mortalities may occur, disrupting ecosystem functioning and inflicting great economic losses. Despite these constraints, Sechura Bay has developed into the major production center for this scallop species in Latin America. By now, more than 150 small-scale scallop farmer cooperatives are operating bottom cultures in assigned areas in the bay. About 80% of all revenues from scallop exports of Peru originate from this bay (US$158 Million in 2013).

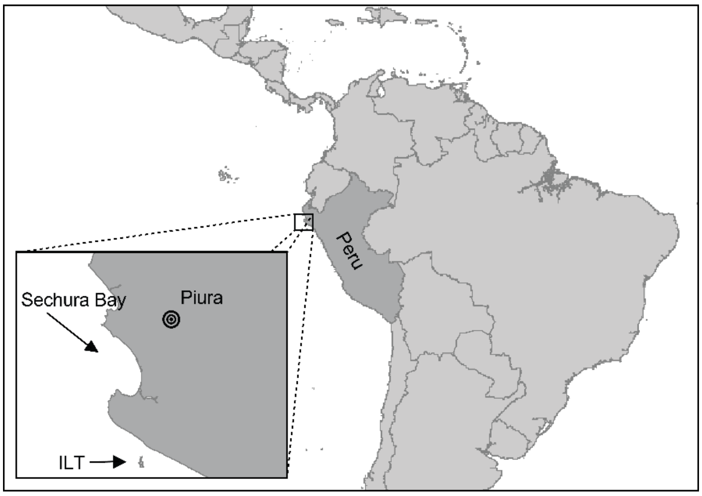


Figure 1: Sechura Bay, Peru, and Isla Lobos de Tierra (ILT)

For the mariculture, small scallop individuals are obtained frequently from natural scallop banks at a nearby island (Lobo de Tierra ILT, Figure 1), which are then placed on the sea bottom for grow-out. Divers hand-collect the scallops when grown to market size.

Filter feeding bivalves have a positive impact on surrounding communities by removing suspended solids, nutrients, silt, bacteria, and viruses from the water column, a process which in turn improves pelagic and benthic ecosystem conditions. However, the introduction of large scallop biomass into the bay can also have severe ecological consequences (see Figure 2), as they modify the environment for other species and potentially change biodiversity and overall ecosystem functioning. Too high stocking densities may cause small-scale oxygen depletion, reduced scallop growth performance, and may even lead to scallop mass mortalities and detrimental consequences also for other organisms. Moreover, scallops filter their food (phytoplankton - small algae) from the water column, altering flows of organic matter and energy in their environment. As an example, this process removes the food source for zooplankton and other filter-feeding bivalves in the system that may (on the long run) be out-competed. The introduction of scallops may also change the species composition of the near-bottom community by providing settling substrate for hard-bottom fauna in an originally soft-bottom habitat. Scallop's excretions may cause organic enrichment and changes in sediment composition.

The continuously increasing levels of scallop production in Sechura over the past decade created concern about the long-term sustainability of the activity. This was the reason for initiating the SASCA project. It aims at understanding the biology of the cultured scallop species, and to assess its effect on the ecosystem for the identification of long-term sustainable levels of production.

The following research questions were addressed:
1. How does intense scallop bottom culture change the structure of the food web within the bay's system?
2. Is the bay's sand-bottom community changing to a hard-bottom like community in areas of high coverage of scallop shells?
3. What is the bay's biological (long-term) carrying capacity for scallop production?
4. How can scallop culture be made adaptive to environmental variability (e.g. ENSO - El Niño Southern Oscillation)?

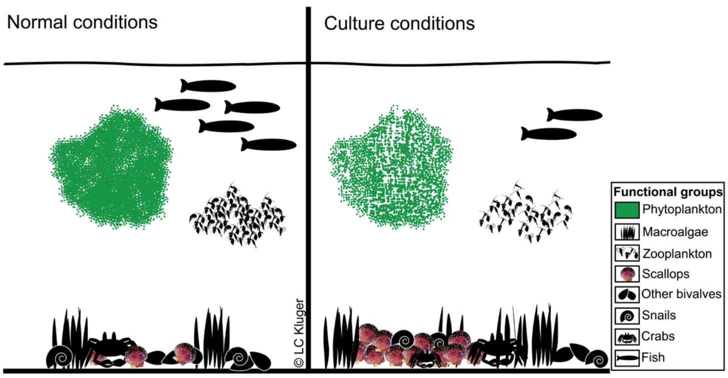


Figure 2. Scallops interact with other organisms in the ecosystem. Introducing large amounts of scallop biomass (i.e. under culture) can cause phytoplankton (small algae) depletion which in turn impacts other organisms that also feed on phytoplankton (e.g. zooplankton, bivalves, small pelagic fishes).

RESEARCH RESULTS

We conducted ecological studies within the bay during summer (January-April) and winter (July-September). These studies investigated a) the impact of scallop culture on the species composition of the near-bottom communities, b) the oxygen demands and c) optimum growth conditions of scallops. In addition, we used a food web model to evaluate the impact of scallop culture and estimate the carrying capacity. Data from a socio-economic survey provided insights into the relationships of social actors in the scallop production chain.

Scallops modify oxygen concentrations

Scallops are filter feeders that obtain their food (phytoplankton - small algae) from the water column. The rate at which food is taken up and oxygen respired depends for most bivalves on individual body sizes and the temperatures of the surrounding waters. Our results show that the smaller an individual scallop is, the higher are these rates per gram of body weight. With higher water temperatures, scallops increasingly require more oxygen and food. Thus, during periods of high temperatures – usually the summer months – the elevated metabolic rates of the cultured scallops increase the risk for oxygen depletion in near-bottom waters. Under such conditions scallops, as well as other organisms, may die, with possible negative effects for the ecosystem and involved scallop farmers. During summer, natural food concentration may also be reduced due to a weakening of coastal upwelling processes, while scallops require more food at elevated temperatures. In this period, scallop seed are particularly vulnerable due to the higher needs.

Scallops impact species living on the seafloor

The introduction of large scallop quantities into the bay system may change the composition of the near-bottom community by providing settling substrate for hard-bottom associated fauna in an originally soft-bottom habitat. In areas with scallop mariculture, we found a higher number of species. For example, some sea snail species, which represent natural predators of the scallops, were increasingly abundant in culture areas. At the same time, other bivalve species were less often present. These changes are important since the species composition of an ecosystem determines its functioning. Particularly the loss of species may make the system more vulnerable to external disturbances such as future El Niño events.

Scallops impact species living in the sea bottom

As filter feeders, scallop retain suspended particles from the water column but also excrete components that are not used, which may cause organic enrichment and changes in sediment composition. Deposit feeders (feeding on small parts of (dead) organisms that have sunken to the seafloor) and species preferring fine sand, silt and clay dominated the communities in culture areas, whereas motile and carnivorous species (feeding on other (living) organisms) favoring coarse sand controlled non-culture sites. In addition, scallop aquaculture altered sediment composition towards smaller grain sizes, likely a result of altered small-scale currents.

The bay's ecological carrying capacity is not yet reached

The bay's ecological carrying capacity is the maximum amount of cultivated scallops that the ecosystem can support without experiencing unacceptable changes. We constructed a food web model of the bay that represented all biological species and their feeding connections. The model simulated the ecological effects of mariculture expansion and defined the carrying capacity as the point at which species composition of the food web was still maintained (i.e. no other species lost). The results suggest that aquaculture should not be expanded more than 10% above 2013 levels to avoid a loss in biodiversity and ecosystem services.

Socio-economic evaluation

One of our studies focused on the value chain of the scallop production in Sechura Bay, identifying all involved stakeholders (Figure 3). Mariculture in Sechura currently involves 5000 artisanal fishermen organized in scallop farmer cooperatives, who represent the core of scallop production. About 20000 additional personnel works in related businesses, e.g. scallop processing,

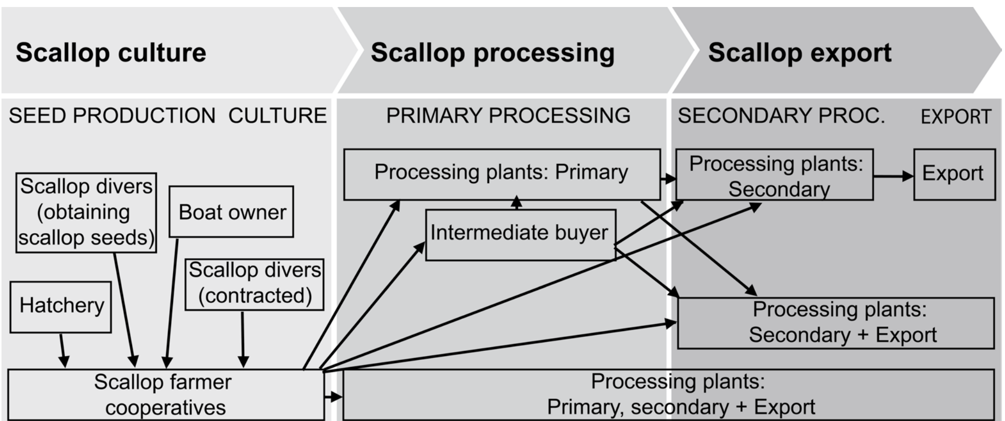
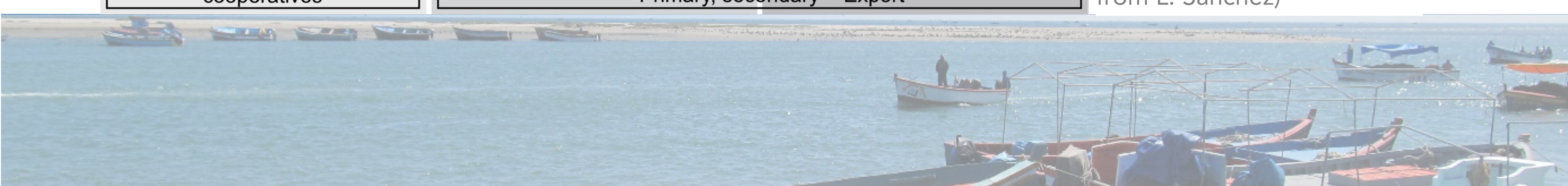


Figure 3. Results of the value chain analysis of the scallop mariculture production in Sechura. All actors for the different steps of the production chain (scallop culture, processing, and export) are shown. (Figure modified from L. Sanchez)



transport or supplying materials. The highest percentage benefit per kg scallop product was found for scallop producers (i.e. small-scale scallop farmer cooperatives). However, considering the number of involved persons in each production step, the highest overall economic benefit lays with the exporters. Interviews further revealed that seed (spat) is the largest cost factor for scallop mariculture. 80% of spat originates from natural banks within the bay or the island Isla Lobos de Tierra (ILT, see Figure 1).

Scallop mariculture and ENSO

The warm phase of the climate phenomena ENSO (El Niño Southern Oscillation) causes heavy rainfalls and elevated sea surface temperatures of up to 5°C above average for this part of the country. Decreasing salinities (as induced by increasing freshwater input through rainfall) and the high temperatures represent a risk for scallop mariculture in Sechura Bay. During the last very strong El Niño 1997/98, scallop mass mortalities occurred. Since then, mariculture activities have greatly expanded, indicating the potential threat of a future El Niño event to the entire system of Sechura.

POLICY RECOMMENDATIONS

Adapt scallop grow-out densities and harvest timing. The summer season represents a potential bottleneck for scallop production due to increased temperatures, leading to enhanced metabolic rates of the scallops and a decrease in available oxygen on the seafloor. Scallop farmer cooperatives should reduce scallop grow-out densities during this period (less than 30 scallops/m^2). Whenever feasible, scallop harvest should be done before the summer in order to avoid (scallop) mass mortalities.

Adopt a regular monitoring scheme. Scallop mariculture alters species composition of the biological near-bottom communities and thus function. This fact requires a constant ecological and environmental monitoring of the scallop cultivation activities to follow future changes in species composition, for example under changing environmental conditions. Both scallop farmers and local authorities should be involved in the development and implementation of adequate monitoring strategies for (bi-)annual observations of near-bottom species composition as well as oxygen and phytoplankton concentrations.

Limit expansion of scallop cultivation. Current culture levels do not yet exceed the bay's ecological carrying capacity. However, changes are already visible on the community level and need to be further monitored (see above) to avoid a loss in biodiversity and ecosystem functioning, if cultivation levels were to be increased. Scallop farmers should not expand production on the bay level by more than 10% of 2013 levels to avoid exceeding the bay's carrying capacity.

Enhance the availability of scallop spat. The sustainability of the scallop business depends on the successful management of natural scallop banks, which until today represent the major source of scallop spat used for mariculture. Scallop farmers could enhance spat production through the use of seed collector bags. Since environmental variability causes highly fluctuating spat abundance, the enhanced production in hatcheries is recommendable. For this, political and financial support for the construction of (at least four) more hatcheries in the region would be required.

Expansion of cultivation may risk individual income. At present, scallop culture is very profitable in Sechura Bay, due to relatively low production costs. A further expansion may nevertheless decrease the income of individual farmer cooperatives critically and should therefore be considered carefully by planning authorities. Future cost-benefit research should be directed towards this aspect.

Design strategies for mitigating ENSO impacts. ENSO events are expected to affect scallop mariculture negatively in this region of Peru. Hence, adaptive strategies for scallop farmers and all other stakeholders depending on the activities should be drafted in a collaborative way. Scallop farmers, for example, should postpone scallop grow-out in the face of an El Niño event and could seek alternative income sources in the fisheries sector.

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ABOUT THIS POLICY BRIEF

This Policy Brief is part of a series aiming to inform policy-makers on the key results of the ZMT research projects and provide recommendations to policy-makers based on research results. The series of ZMT Policy Briefs can be found at www.leibniz-zmt.de/policy_briefs.html. This publication was commissioned, supervised and produced by ZMT. DOI: 10.21244/zmt.2017.002

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