



**Nexus interventions for small tropical islands:
case study Bonaire**
Food from the Oceans

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Food from the ocean holds promise for food provisioning without compromising other dimensions of the water-energy-food-ecosystem NEXUS. Fisheries, near-shore or offshore aquaculture and mariculture can provide valuable resources, produced without fresh water use and with limited use of fossil energy. The most important trade-offs are expected to be related to ecosystem impacts. Sustainable development of food from the ocean does not require technical innovation alone. A multi-faceted approach, consisting of technological development, strengthening human capital and an effective governance approach, is necessary.

	Current state	Desired state	Challenge	Nexus intervention
Fisheries	Limited, but unsustainable reef fisheries, pelagic fisheries is data insufficient (De Graaf et al, 2014/2017) Increasing demand by population and tourism growth	Sustainable fisheries contributing to provisioning of food, lesser imports (energy demand) better diet and	Over exploitation versus sustainable fisheries Stakeholder involvement – shared fact finding Monitoring	Introduction of FADs might lead to sustainable fisheries of the large pelagic fish, with lower demand for fuel, water and less ecosystem impact. Expansion of lionfish fisheries, could benefit the ecosystem but research is needed
Aquaculture	Not existing	Increased food supply, if possible through aquaculture	Sustainable business case	Explore innovative developments such as OTEC or algae parc to build a business case within aquaculture by reducing energy, water use.

Box 1. Summary factsheet Nexus Food from the Oceans.

INTRODUCTION: CURRENT STATE, TRENDS & DRIVERS OF CHANGE

Food provisioning is a known challenge for many small island states. This is due to limited availability of fertile land, a small number of people active in agriculture and often the dominance of other economic sectors, most notable tourism. Still, even though Bonaire is almost fully dependent on the import of food, food availability in quantitative terms is as of now not a real problem. However, food accessibility, quality in terms of vitamins and pesticide residues, actual food use and of long-term stability in availability are issues of concern (Judge et al. 2014).

Food from the ocean is important for Bonaire. In the Caribbean, the quantity of seafood consumed per capita per year is 24 kg per person per year (FAO 2012). This is significantly higher than in the Netherlands (17 kg). Fish is part of the diet and various fish products are available on the market and in restaurants, a mix of imported and local species is found. One can find fishes such as calamares (squid), salmou (salmon) and tilapia next to red snapper, barracuda fillet and grilled wahoo. Especially lionfish is wanted by restaurants. Tourists like to order lionfish as by doing so they feel they are helping to protect Bonaire's coral reef from this invasive species.

In comparison to alternative foods, total consumption of fish is limited by high fish prices. Due to low local production, almost all fish consumed locally must be imported. With a rapidly growing population size, expanding tourism and growing health-awareness, the demand for fish on Bonaire continues to grow. The main drivers for total fish consumption are:

- resident population size
- tourism stay-over visits
- health-motivated food preferences.



Figure 1. Population of Bonaire (in blue) & tourists arriving by air (in orange) CBS, 2017, with added in dark orange; ambition on tourist levels in 2025

Traditional fisheries play a visible and important role in the Dutch Caribbean islands food systems.

Fish serves various functions on multiple levels including food production, poverty alleviation, foreign-exchange savings and/or earnings, recreation and tourism (Agard et al., 2007). Actual employment in the fishery sector in Bonaire is low (de Graaf et al. 2014), most likely because of low profitability. Nearshore demersal fish stocks are very limited due to the narrow island shelf, and have long been overfished.

At present the fisheries of Bonaire can best be described as multi-species, multi-gear, small-scale and strongly traditional fisheries with no major recent innovations (Graaf et al. 2014, Debrot and de Graaf 2019). Aside from motorization instead of the use of sails and the use of nylon fishing lines instead of cotton cordage, practically the same techniques and technology are being used as a century ago. The fleet consists of about 84 small outboard driven vessels and 26 larger diesel vessels with cabin and lengths greater than 7 m. The total annual fish catch for Bonaire is around 103 tons (excluding small shoaling pelagics, which have not been recorded in the monitored catches). Of this about 12 tons is from handline fishing from shore, 30 tons from small fishing vessels and 60 tons from the larger trolling vessels (de Graaf et al. 2016; Tichelaar 2015). All fishing is currently marginal from a business point of view. The average Catch Per Unit of Effort (CPUE) for large vessels amounts to about 1,5 kg (= ± US\$ 15) per fisherman per hour. From this all fuel and boat costs must also be subtracted.

The total estimated annual landing of the Bonairian coastal fishery (in 2014) of has a value of ca. 0.7-1 million USD.

Attention has gone out to the development of aquaculture in Bonaire, since the 1950s.

Research was carried out on the potential of e.g. tilapia, spiny lobster, shrimp, and clams. In the 1980s a small laboratory was built to experiment with breeding and release of conch (*Lobatus gigas*), paving the way for establishment of the Marcultura foundation where research on the feasibility of aquaculture continued. Despite research efforts, there is no commercial aquaculture on Bonaire today. Attempts to set-up a fish farm in 2015 (the Elijah Fish Farm) failed, reportedly due to power failure and subsequent loss of stock. Previously, anecdotal stories tell that efforts to building a proper business case on aquaculture failed due to lack of market potential and mismatch of product offer and product demand, and marketing skills.

Desired future state

Sustainable use of ocean space for the production of food can benefit the provision of healthy food. It can stimulate the local economy and livelihoods, without compromising the other dimensions of the water-energy-food-ecosystem NEXUS. Growth of the fisheries and aquaculture sector for the wider Caribbean is foreseen by the Food and Agricultural Organisation of the United Nations (FAO, 2018)

KNOWLEDGE NEEDS & CHALLENGES

If Bonaire is to realise the same growth in fisheries and aquaculture as expected for the rest of the region (see Figure 2), many challenges need to be addressed. Products need to compete with commodity seafood prices and strong competition from third-world countries. To avoid negative trade-offs, this development must take into account the demand for water and energy and ensure that developments do not negatively impact on the ecosystem.

A key question is to what extent local initiatives can cater to a local food demand and compete in terms of food import prices. Answers to these questions also determine in part whether local initiatives might not best focus on niche markets (Bogaardt et al. 2015), instead of trying to compete with imports from foreign industrial agriculture. Based on the high local labour and utility prices and high cost of feeds importation, it is likely that niche markets can best be served with specialty products.

Fisheries

Practically nothing is known about the stock status of small, alternative pelagic species. Pilot studies are needed to provide basic information on stock status and resource availability (Couperus et al. 2015).

These should be accompanied by trials introducing new technology, such as FAD's and small gillnets for use in flying fish fisheries and as used in the eastern Caribbean. Pilot trials with special traps to target lionfish are recommended to investigate feasibility of developing a directed lionfish fishery. Stock assessments of deep water conch and snapper populations on the east side of the island could help assess resource availability and sustainable harvest levels for these less-fished demersal resources. Critical, also in the case of new and as yet untargeted stocks, is the introduction of effective management systems with which to control fishing and avoid overfishing. Successful examples from the Saba Bank and St. Eustatius can be used as guides to implementing fisheries monitoring and adaptive management (Debrot and de Graaf 2018, Brunel et al. 2018).

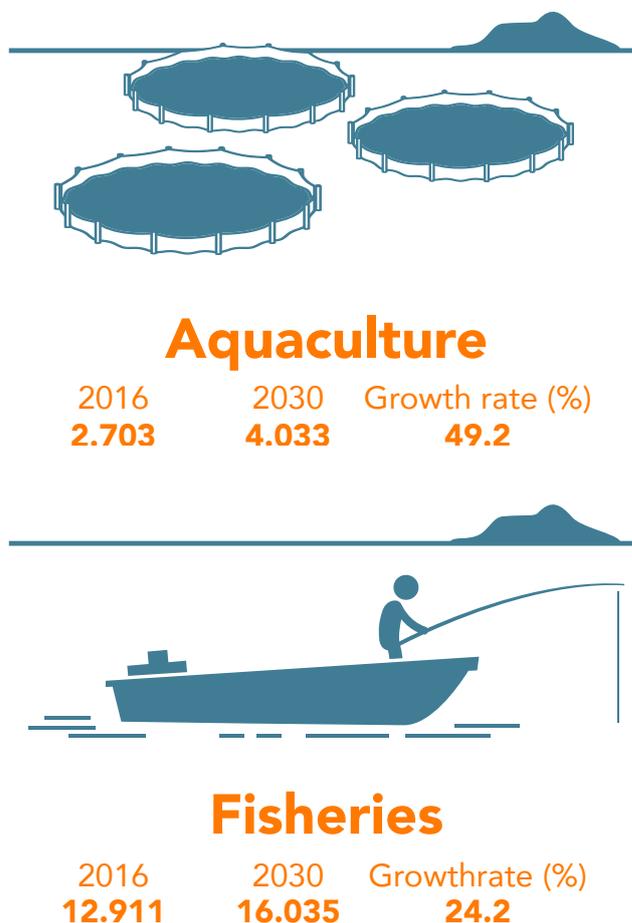


Figure 2. Projected growth rates of fisheries and aquaculture in the Latin America and Caribbean region (production in 1.000 tonnes) (based on FAO, 2018)

Aquaculture

All efforts so far have involved aquaculture on land. The species requiring fresh or brackish water are also problematic due to the low availability of natural fresh water and the high price of desalination. Aside from the protected Ramsar lagoon of Lac Bay, the island has no major areas of shallow sea that are sheltered from the waves. Offshore aquaculture would therefore have to withstand exposed conditions. Potential exists for saltwater aquaculture on land, especially on the low-lying southern part of the island, currently largely in use for low productivity solar salt production.

Currently, there is no infrastructure or value chain to cater to the demands of an aquaculture industry. There is no local food industry that can cheaply provide inexpensive protein feeds for e.g. carnivorous species for which there is also high price competition in the global market. Technical and managerial knowledge needed to successfully run an aquaculture facility is lacking. In order to export products to the regional or global market, additional investments are needed (e.g. cooling houses, logistics).

Mariculture - involving the production of plants (algae and or seaweeds) or herbivores is interesting to investigate, potentially showing more financial potential than mass culture of expensive protein-feed consuming fishes and crustaceans.

POSSIBLE NEXUS INTERVENTIONS

In this section several interventions (Box 2) are presented to improve the provision of food from the ocean in Bonaire, without comprising other NEXUS dimensions, or even to be beneficial to nexus dimensions such as the ecosystem. Note that each exercise comprise the assumption that fisheries and aquaculture should be compliant and be operated within the limits of sustainable fisheries and maximum sustainable yield principles. The main intervention is that several innovations are needed:

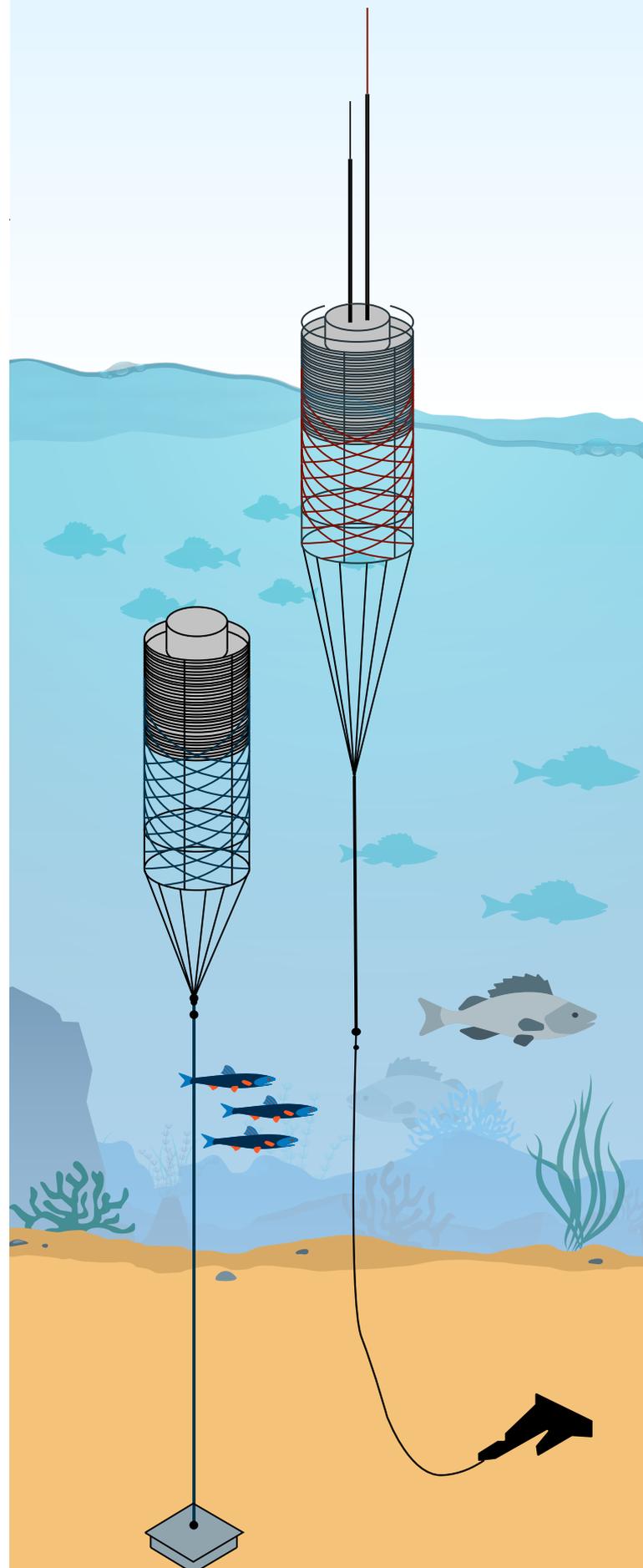
Development of fisheries to target under exploited small pelagic shoaling species represent a major opportunity for sustainable food production.

As part of the Dutch Kingdom, the Caribbean Netherlands, including Bonaire, have access to EEZ area of approximately 90,000 km² of Caribbean Sea which possess various as yet underutilized fish stocks. Almost all fishing is currently directed towards coastal pelagic species and coastal demersal stocks. Prominent among these species with untapped potential are the so-called "small pelagic species" such as various small tunas, shads, flying fishes, needle fishes, clupeids and even squid. It is a major goal of the kingdom parties represented in the formal EEZ Commission and of the 2010 EEZ management plan, to work towards transformation of the fisheries sector of the islands so as to both guarantee sustainability and simultaneously improve local food self-sufficiency for the islands. Assessing potential and developing a small pelagics fishery is highlighted as an important fisheries goal by Meesters et al. (2010) and by Debrot and de Graaf (2019). Couperus et al. (2015) provide an initial inventory of the species concerned and discuss the potential for a small pelagics fishery in the Dutch EEZ. Consumption of small pelagic fish, rather than top piscivores, is more efficient from a biological and an economical point of view.

Pelagic fisheries can be expanded by the the use of FADs. This technology has the ability to concentrate pelagic species to a smaller area close to shore, thereby greatly improving CPUE and lowering engine fuel consumption during fishing. The technology is simple and this type of fishing can be conducted profitably with the current fleet of small fishing vessels and during short fishing trips. Previous experiences with FADs on Bonaire failed due to design in combination with deployment possibilities (Fig. 3). Loss of FAD's mainly occurred due to high vessel traffic and strong currents.

A second type of technology that can be introduced to target small pelagic shoaling species of flying fish is the use of small floating gillnets deployed from drifting boats as commonly used in the Barbados and other islands of the eastern Caribbean (Sobers 2010). This simple-to-apply technology also can be deployed using the present fleet and will not require costly changes to the current fishing vessels.

Figure 3. Basic designs of floating and sumberged Fish Attracting Devices. Left FAD is planned on Bonaire



Expand lionfish fisheries

Lionfish is an invasive species in the Caribbean, inhabiting reefs and deeper waters. Recent research has also revealed that lionfish can tolerate brackish coastal zones, so mangrove and estuarine habitats may also be at risk of invasion. Adult lionfish have no predators, and they are primarily fish-eaters. A single lionfish residing on a coral reef can reduce recruitment of native reef fishes by 79 percent (Albins and Hixon, 2008) thereby potentially affecting the reefs species structure and function. Because lionfish feed on prey normally consumed by snappers, groupers, and other commercially important native species, their presence could negatively affect the commercial and recreational fisheries and dive tourism.

An invasive lionfish food fish market is practical, feasible, and should be promoted (2013 GCFI lionfish workshop). Alternative invasive lionfish end-uses, such as the curio and aquarium trade, are also viable markets. Regarding consumption and the risk for ciguatera poisoning, invasive lionfish ask for a general caution statement displayed within all establishments that serve this species (Johnston et al. 2015).

Explore the potential of aquaculture to contribute to food provisioning. To develop successful aquaculture will require much more in terms of technological development than to innovate the fisheries. Experiences in the Caribbean at large can inform the development of aquaculture in Bonaire. Caribbean aquaculture is characterised by a wide diversity of species and production methods. The geography of these islands are favourable for aquaculture, with long coasts, clear and relatively

unpolluted waters. Significant development has been limited to countries like Jamaica and Belize, but other countries like Guyana, Haiti, Suriname and Trinidad and Tobago have put more emphasis on aquaculture as an area for development. All of these are relatively poor countries with low labour costs and in this differ greatly from the situation on Bonaire. "The practices mainly involve the use of ponds to culture such species as penaeid shrimp (*Penaeus* spp.), tilapia (*Oreochromis* spp.), carp (*Ctenopharyngodon idellus*, *Hypophthalmichthys nobilis*, *Hypophthalmichthys molitrix*) and cachama (*Colossoma macropomum*). Also, there is long line culture for algae (*Eucheuma* spp. and *Gracilaria* spp.) in St. Lucia and the mangrove oyster (*Crassostrea rhizophorae*) in Jamaica (FAO, 2018).

Develop seaweed culture for high value markets.

There is no seaweed production business on Bonaire, but Bonaire has recently been hit by *Sargassum* outbreaks, with seaweeds that drift to the islands from elsewhere. This is a local problem; as *Sargassum* smothers the coastline, killing seagrass beds that don't have access to light anymore. *Sargassum* is used for several purposes including as fertilizer, but a problem is that that *Sargassum* is not available Bonaire on a regular basis, so one need to have an opportunistic business model and early warning systems that takes this into account. One must be able to deal with extreme variability in the accumulation of *Sargassum* onto beaches and harvests the *Sargassum* quickly before it decays but also carefully without damaging the beaches onto which it collects. Seaweed culture using longlines as in St. Lucia, as a basis for the production of seaweed products for a niche market (potency elixirs and health food products) could also be explored.

Box 2. Evaluation of possible interventions from a NEXUS perspective

Intervention	Water	Energy	Food	Ecosystem
Develop small pelagic fisheries	No fresh water use	More efficient use of energy for fishing compared to trawling	Provide fish product without using top predators in food web (higher overall efficiency)	Must be managed properly to avoid negative impact
Use of FADS	No fresh water use	Reduce energy use by fishermen	Enhance fisheries	Must be managed properly to avoid negative impact
Explore aquaculture	No fresh water use	Limited energy use during production	Potential source of fish products	Facility must be managed properly to avoid negative impact
Develop seaweed culture	No fresh water use	No energy use in production	Potentially for human food but could also be used for (fish) feed	Potential ecosystem benefits
Innovations (AlgaePark, OTEC)	No fresh water use	Energy could be provided via OTEC, nutrients delivered	Provides water and nutrients to culture fish or other edible species	Impact assessment needed on effluents and other operational aspects
Expand lion fish fisheries	No fresh water use	Limited energy use expected (air for divers, cages), but increase in risk for divers	Provides fish product targeting an impacting top predators in food web	Positive effect on ecosystem structure and function (reef fish) through decreasing an impacting invasive species

INTERLINKAGES WITH OTHER DEVELOPMENTS

The development of sustainable energy generation on Bonaire – for example using OTEC – can reduce the carbon footprint of the infrastructure needed in aquaculture. Building a sustainable business case around (offshore) aquaculture seems only suitable with large investments, and a solid and structural market demand. The development of AlgaeParc Bonaire is interesting in this context, as it is a potential source (water, nutrients, algae) of locally produced fish feed for aquaculture.

GOVERNANCE

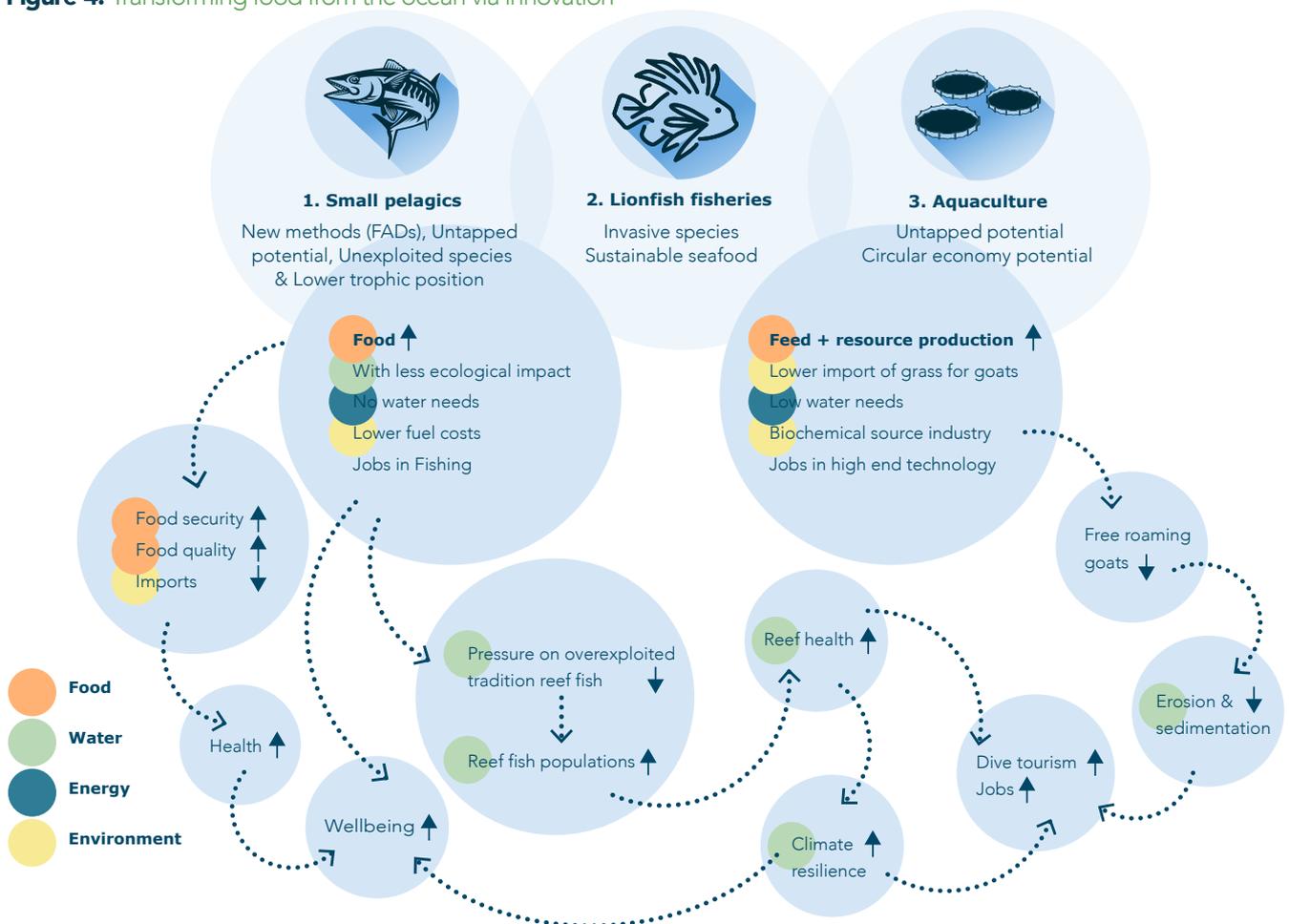
With proper management, simultaneously profitable and sustainable fisheries demersal fisheries are possible in the future. Reef fisheries exert many negative effects on the environment and hence that reef-associated fishing mortality needs to be drastically controlled (Debrot and de Graaf 2019). The benefits of proper management are currently witnessed in the case of the snapper and lobster fisheries of the Saba Bank and the conch fishery of St. Eustatius, all fisheries which have shown consistent improvement of profitability and population status, thanks to judicial management in recent years (Debrot and de Graaf 2018, Brunel et al. 2018). The key to this is to successfully limit total fishing mortality to sustainable levels based on adaptive management.

Controlling and limiting fishing effort for the demersal coastal fisheries of Bonaire, which are currently suffering from heavy overfishing, is a key challenge to improving sustainable catches in the long term.

Controlling fishing pressure is by far the main factor determining success or failure for sustainable management of Caribbean fisheries. Transforming coastal fisheries towards sustainability is a major challenge towards sustainable natural resource management as well as food self-sufficiency for these severely resource-limited island communities.

In the region, various initiatives to expand the aquaculture sector are underway. This includes investigations into the potential of aquaculture by Caribbean Regional Fisheries Mechanism, support programmes by FAO, and development of best management practices for marine cage culture operations (Price and Beck-Stimpert, 2014). According to Frank van Slobbe (OLB) Bonaire is not interested to be a trial-island for aquaculture. The island is only interested in already-proven ways of aquaculture with limited environmental risks. The focus can include culturing marine algae and seaweeds or selected herbivores and targeting niche markets. Pilot trials and research to test and adapt for suitability under uncommon local conditions and constraints will be essential.

Figure 4. Transforming food from the ocean via innovation



FUTURE PRIORITIES & RESEARCH NEEDED

- Innovation of the fisheries sector and developing an aquaculture sector in Bonaire
- Stimulating entrepreneurship
- Creating human capital / entrepreneurial skills
- Facilitating innovation (financially)
- A first step is sharing of knowledge and making use of experiences in the region

IMMEDIATE RESEARCH NEEDED

Fisheries

- General stock information of all fished species
- Pilot studies on resource availability and stock
- status of alternative pelagic fisheries resources
- Pilot trials with new technology for under-fished pelagic
- Pilot trials with lionfish traps (and learn from recent trap-studies done in the region)
- Stock assessment for deep water conch stocks and deep water snappers on the east side of Bonaire
- Introduction of management systems for new target fisheries to guarantee controlled fishery development and to avoid overfishing ahead of time

Aquaculture

- Pilot trials and research with selected algae and seaweeds of value with low need for freshwater and expensive additives (nutrients and anti-biotics)
- Investigate possible integration between primary producers with herbivorous species (fish and/or shellfish using Integrated Multi Trophic Aquaculture (IMTA))

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Colophon

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The KB program "Nexus Strategic policy case", included a Bonaire NEXUS case study. The case study was funded under KB-33-005-013, and administered under project number 4318300087. A letter report (number 1900369.ds) summarises the activities. In the study a set of 8 factsheets was drafted (and attached to the letter report). The set of factsheets can be found on : www.wur.eu/sustainablewatermanagement