TRADITIONAL INGREDIENT OR SUSTAINABLE SUPERFOOD?

AWARENESS AND CONSUMPTION OF DUCKWEED IN LAOS AND THAILAND

MSc Thesis
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Awareness and Consumption of Duckweed in Laos and Thailand

MSc Thesis Report

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ABSTRACT

On a planet where the available natural resources are declining, but the population and its consumption of the said resources are growing, humanity faces an urgent necessity to explore more sustainable and healthy food options. Duckweed, an aquatic, almost worldwide native plant features both sustainability and health qualities and is already consumed by some people in Thailand, Myanmar and Laos. The goal of this thesis is to understand, what drives or hinders awareness and consumption of duckweed in these countries by 1) assessing the way and extent of duckweed awareness and consumption, 2) evaluating the influence of a selection of seven aspects (recognition as food, food insecurity, access, status concerns, safety concerns, health and sustainability considerations, taste) on duckweed consumption, and 3) looking into possible future developments of duckweed as human food. The methods used therefore are a set of 38 direct, in-depth, semi-structured interviews next to informal conversations and participant observation conducted in Laos and Thailand. The overall goal is to get a first understanding of current duckweed consumption to inform potential future upscaling initiatives in Southeast Asia and to other areas worldwide in order to improve global human and planetary health.

The main findings of this fieldwork are that 1) duckweed awareness and consumption are closely linked to Lao/Isaan culture, to one's area of residence and to one's age, with the highest awareness and consumption found among older Lao and Isaan people living in rural areas, 2) the aspects with the highest (encouraging or constraining) influence on duckweed consumption are awareness of duckweed as human food, financial and physical access to duckweed, availability and taste of duckweed; the ones with the lowest influence are health and sustainability considerations in overall food choices, recognition of duckweed as food and a situation of food insecurity 3) while some Lao interviewees fear duckweed to disappear due to climate change and a declining popularity among younger generations, several private and public initiatives rise in Thailand to counter this risk by tackling awareness, access, quality and popularity issues currently related to duckweed. All in all, the potential seen in duckweed to feed the world in a healthy and sustainable way seems legitimate, but constrained by some individual and contextual aspects which need to be considered to increase duckweed consumption in Southeast Asia and worldwide.

TABLE OF CONTENTS

CHAPTER 1. PROBLEM DESCRIPTION

1.1 CONTEXT

At the end of 2022, we officially hit the count of 8 billion humans on this planet (Victor, 2022). A smooth reminder that humanity faces, on the one hand, a growing population and limited planetary resources to provide for its survival (Roser et al., 2013). As illustrated with Earth Overshoot Day[1] moving towards an earlier date each year, it is only a matter of time before the nine planetary boundaries[2] have been reached by earthly human existence and its activities (Global Footprint Network, 2022; Steffen et al., 2015).

On the other hand, this overexploitation issue comes alongside a human health challenge. Both matters are interlinked through environmental determinants of health. Next to these, current diets also count for a substantial health factor with the so-called "double burden of malnutrition" (Willett et al., 2019; World Health Organization, 2021). This issue refers to the "coexistence of overnutrition (overweight and obesity) alongside undernutrition (stunting and wasting), at all levels of the population—country, city, community, household, and individual" (The Lancet, 2020). Considered that "the consumption of 'unhealthy' food items had outpaced the consumption of 'healthy' foods in most regions of the world" (Fanzo & Davis, 2019, p. 498), one can see why 86% of diets worldwide are considered not recommendable by the World Health Organization (WHO) (Fanzo & Davis, 2019) .In the face of this plague, humanity needs to find healthier ways to feed themselves, under various contextual conditions.

Together, the environmental and health issues form a pressing situation which is largely and increasingly impacted by – and impacts – food systems (Fanzo & Davis, 2019). These are understood as "the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal (loss or waste) of food products that originate from agriculture (incl. livestock), forestry, fisheries, and food industries, and the broader economic, societal, and natural environments in which they are embedded" at various geographical levels (Ritchie & Roser, 2020; von Braun et al., 2021). Therefore, tackling worldwide production and consumption of food seems like a crucial lever to adjust humanity's way of life to our planet's biocapacity, as well as to tackle the above-mentioned health challenge (Ritchie & Roser, 2020).

This translates into a need for solutions to eat healthier and more sustainably. There is a tendency in the literature to place a lot of responsibility on governments as the only instances able to bring about impactful and sustainable change (Fanzo & Davis, 2019; Springmann et al., 2018). Yet, Bai et al. (2016) indicated that "in the Anthropocene, where different sectors and societies are increasingly connected, learning from practices and sharing them in other contexts has the potential to enable an expedited large-scale transformation towards more desirable futures." (Bai et al., 2016, p. 360). Based on this statement, investigating the possibility to upscale existing solutions seems promising in this quest, before taking it to governmental level. And this is the approach characterizing the present paper.

[1] "Earth Overshoot Day marks the date when humanity has used all the biological resources that Earth regenerates during the entire year." (Global Footprint Network, 2022).

[2] Nine planetary boundaries according to Steffen et al. (2015): Climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biochemical flows, freshwater use, land-system change, biosphere integrity.

1.2 Duckweed

Among many arising efforts worldwide to come up with foods and diets fitting health and sustainability criteria, one of the most praised solutions in Europe lately is known under the name of “duckweed”, or “water lentils” (Mes et al., 2022). Duckweed (*Lemnoideae*) is a subfamily of tiny, vibrant green flowering plants growing on still water surface (Bhanthumnavin & Mcgarry, 1971). Five genera and thirty-eight different species of the climate resilient plant grow all over the globe, except for desert or permafrost regions (Chen et al., 2022; Mes et al., 2022). While seasonal variations have been observed in the yield of this edible plant, it grows all year-round – and in an exponential way (Iqbal, 1999). It is, in fact, the fastest growing flowering plant on earth and can double in volume in up to less than thirty hours (Sree et al., 2015). This is also how duckweed beds can quickly cover entire ponds (see figure 1) and impact life below water (Sengupta et al., 2010). Only to add to the uniqueness of this crop, it also holds the record for being the smallest flowering plant on earth, as some species are “as tiny as the eye of a needle” (Nosowitz, 2021; Park et al., 2021).

Figure 1. Duckweed exponentially growing on a canal in the Netherlands.

From an environmental point of view, duckweed gets its Western fame from several characteristics. First, it is one of the lowest water crops and it even cleans the water it grows on with its eutrophic water purification properties (Chen et al., 2018). However, as much as it would be desirable to, for instance, use wastewater streams to circularly grow duckweed on, the plant’s cleaning capacity is not combinable with its potential as human food. This is because the plant takes up chemicals present in the water it grows on, including heavy metals making it unsuitable for human consumption (Nosowitz, 2021). Yet duckweed further impresses with its remarkably low land use. Its cultivation in outdoor basins allows the production of up to ten times more proteins per hectare than a comparable plant-based source such as soybean, let alone animal sources making an even less efficient use of land and further natural resources (Universiteit van Nederland, 2020). Duckweed can even be grown in multi-layer vertical farming systems (possible in urban settings) or hydroponic systems without any “precious arable land” required (Michail, 2021, p.2). All in all, considering its incredibly low impact on the environment, cultivating and replacing current foods with duckweed in diets worldwide could

considerably cut the over thirty percent share of all greenhouse gas emissions (GHGE) coming from food systems (Crippa et al., 2021).

But what foods can the tiny aquatic plant adequately replace? What mainly makes a name for duckweed among researchers and early producers is its astounding nutritional profile (see figure 2). Not only does the plant have a higher protein content than most plant-based sources with around forty percent on dry weight, but the bioavailability of all nine essential amino acids makes it one of the few complete plant-based protein sources on earth (Mes et al., 2022; Xu et al., 2021). Next to proteins, duckweed provides its consumers with a relevant to considerably high content of key micronutrients. These include calcium, iron, zinc, antioxidants, vitamins A, C, E, K and B12 – the presence of the latter making duckweed one of the only natural plant-based sources of this vitamin (Appenroth et al., 2018; Michail, 2021). With this unique nutritional composition duckweed outcompetes kale or spinach in terms of nutrient density and reaches what some would call “superfood” levels close to spirulina (Appenroth et al., 2018).

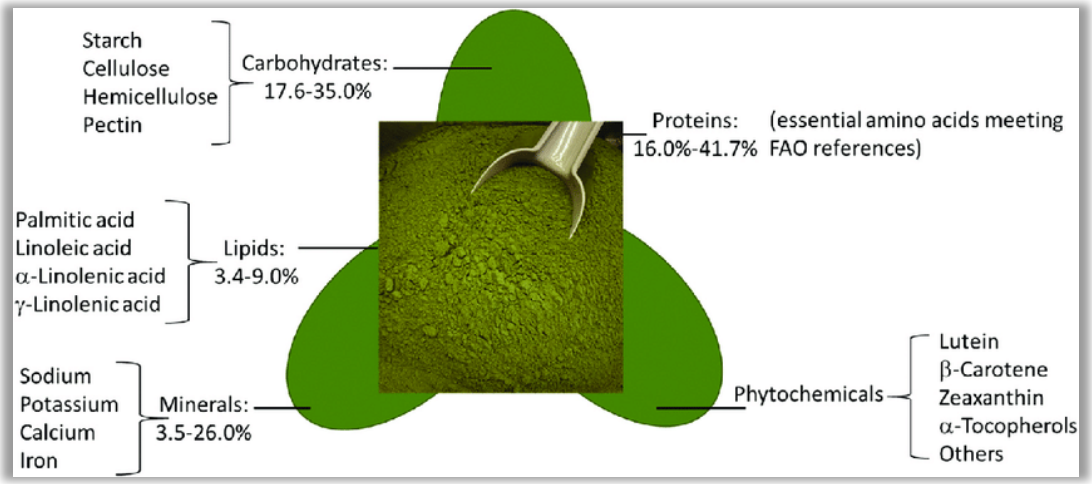

Figure 2. Approximate nutrient compositions of duckweed (on dry weight basis) (Xu et al., 2021).

1.3 Duckweed use

Its outstanding performance on both sustainability and nutrition criteria has brought duckweed to be considered for the National Aeronautics and Space Administration (NASA) space expeditions as a highly resource efficient crop (Demmig-Adams, 2020; Mes et al., 2022). But how can its potential best be leveraged down on earth? While it is currently mainly used as a base ingredient for animal feed, duckweed can serve as human food in three main forms: as a fresh product, as a dried product, or as a protein powder (Xu et al., 2021).

1.3.1 Fresh product

Fresh duckweed has a vibrant green color and can be referred to as a vegetable. In Laos, Myanmar and Northern Thailand it is either directly foraged from ponds or bought on local markets (Iqbal, 1999; Xu et al., 2021). It is then eaten unaltered, boiled for a few minutes, or it can also be frozen for later consumption – similarly to spinach for instance (Universiteit van Nederland, 2020). Despite a reported slightly bitter taste, the plant then offers a wide range of meal insertion options, going from eaten on its own as a side dish, to mixed into smoothies, soups, salads, or noodles (Iqbal, 1999; Permaculture Institute of Thailand, 2019). Compared to other vegetables, duckweed offers a balanced composition

with a high content of essential micronutrients and a relevant protein content of 3%, but also the advantages of a year-round and low-cost cultivation in terms of time, water, land, financial, technological and human resources (Demmig-Adams, 2020; Mes et al., 2022)

1.3.2 Dried product

After solar, oven or freeze-drying, duckweed turns dark green and mainly becomes an ingredient sold to companies to replace wheat flour in their industrialized food products like e.g., baked goods (Xu et al., 2021). However, the market for this protein ingredient is not as big as for competing crops like soybean or wheat, where the protein is recycled from the by-product of an existing production line (I. van der Meer, personal communication, October 31, 2022). Nevertheless, compared to the fresh product, dried duckweed offers an extended shelf life and a considerably higher protein concentration, while maintaining most of its minerals and vitamins content depending on the drying method (Xu et al., 2021).

1.3.2 Protein powder

Recently, several American companies have been looking into the extraction of the valuable protein present in duckweed to develop a high-end protein powder (Plantible Foods, 2018; Sustainable Planet, 2022). This food supplement is often referred to as “superfood”, while its content in natural B12 vitamin makes it particularly interesting for vegan consumers (Xu et al., 2021).

These different forms of duckweed mainly distinguish from one another in terms of costs and nutritional profile. While the high-end protein powder presents the most condensed availability of nutrients, it is also the most complex to produce. Some drying techniques are also relatively costly in terms of technology, although the disadvantage of more accessible methods is either a loss of nutrients or time. In this regard, fresh duckweed seems to offer the most interesting effort-to-nutrient ratio and is, therefore, the form of interest for this study.

1.4 Food security

When looking at the food security pillars – availability, access, utilisation and stability[3], fresh duckweed also seems to score interestingly on all four of them. While the plant is readily available in nature worldwide, it is also accessible physically and financially (affordable) for anyone being able to move to the nearest collection point and forage it for free. When it comes to utilisation, duckweed seems to be prepared just like any other vegetable and could be inserted in pretty much any dish, while offering a great bioavailability of its nutrients (Xu et al., 2021). However, the safety component of utilisation might not be as straightforward for this plant on which pathogenic organisms easily stick to, and which absorbs heavy metals or any chemical potentially present in the growth water(Iqbal, 1999; Xu et al., 2021). Lastly, these three first elements offered by duckweed can be estimated stable over time as the plant’s supply cannot be interrupted by any conflict or economic crisis, since any duckweed carpet rapidly and naturally grows back on any pond and, therefore, assures an almost constant yield. Moreover, it is considered “climate resilient”, namely through its remarkably low dependence on natural resources to grow (Mes et al., 2022).

[3] The four pillars presented in the definition of food security of the FAO (FAO, 2006).

1.5 Research in Low- and Middle-Income Countries

Duckweed's potential to "relieve food shortage stress globally in future due to many advantageous features" (Xu et al., 2021, p. 12) is especially relevant for Low- and Middle-Income Countries (LMICs) where these issues are mostly present. LMICs indeed "deal with the highest prevalence of diet-related deaths and DALYs[4]"(p. 498), but also of protein, vitamin, and mineral deficiencies (Fanzo & Davis, 2019). As the same authors state, "healthy, nutritious foods are increasingly more expensive than energy-dense, nutrient-poor foods, putting them out of reach for lower income populations" (Fanzo & Davis, 2019, p. 500) which makes the affordability of this nutritious food an even stronger argument for looking into the plant's consumption in LMICs.

Another reason for this focus is "the great differentials in the causation of the Anthropocene [between OECD Member countries[5], BRICS[6] and the rest] and the inequities in sharing its benefits" (Bai et al., 2016, p. 356). In this regard, research targeted to contribute to the wellbeing in LMICs helps levelling out these inequalities, instead of deepening them further.

1.6 Duckweed consumption in Southeast Asia

While several American duckweed exploring start-ups emerge, the plant is only starting to be explored on the old continent, as the European Food Safety Authority (EFSA) just approved the protein concentrate (dried powder extracted) from duckweed (mixture of *Lemna gibba* and *Lemna minor*) as safe novel (human) food in February 2023 (EFSA Panel on Nutrition et al., 2023). However, the food is already part of some people's everyday life in Southeast Asia. The literature mentions a consumption of *Wolffia globosa* (Appenroth et al., 2018) and *Wolffia arrhiza* (Bhanthumnavin & Mcgarry, 1971; Xu et al., 2021) – two of the thirty-eight species in the duckweed family (*Lemnaceae*), in Laos, Myanmar and Thailand (Bhanthumnavin & Mcgarry, 1971). The fresh vegetable however is reported to have a low status and some articles point at a bad taste, which prevent it from being a widespread crop in the area and beyond (Iqbal, 1999; van den Berg et al., 2015).

1.7 Aim

While we just discussed the plant's assets, there seem to be barriers to the full exploitation of its potential for the health and environmental improvements presented above. The present paper investigates duckweed consumption and the reasons behind the observed consumption ways and extent in the cradle area, as well as possible future developments of these consumption patterns. The findings should inform future aims of upscaling duckweed production and improve societal uptake by integrating the preferences and obstacles observed in this study.

1.8 Societal relevance

The global context depicted above provides strong incentives to investigate alternative ways to feed humankind, after academic research has too long been focusing on ringing the alarm instead of aiming to come up with solutions (Bai et al., 2016). In Laos for instance, an upscaled duckweed production and

[4] DALYs : Disabiliy-adjusted life years
[5] OECD: Organisation for Economic Co-operation and Development; Member countries are considered High Income Countries (HICs)
[6] BRICS: Brazil, India, China, South Africa; which are the five countries said to have emerging economies

consumption might be fit to tackle not only the 20% of food insecure people and the overall serious national challenge of malnutrition (World Food Programme, 2022). This development, I assume, could also positively impact other local issues like "vulnerability to climate change, […] declining land availability, volatile prices, low agricultural productivity, difficult access to markets and lack of diversified livelihood options" (World Food Programme, 2022). However, in a country like Laos where women are overrepresented in the informal employment sector, the formalization of duckweed production could see unformal tasks currently carried out by women taken over by men once formalised and increase gender inequality (OECD & International Labour Organization, 2019).

In Thailand, one in three person is moderately or severely food insecure, and almost one in ten is undernourished (FAO, 2022). As these numbers are growing, a food security crisis erupted in the summer of 2022 (The Nation, 2022). This happens as food gets more expensive with the recent inflation and droughts increasingly threaten rural farmer's sustenance (The Nation, 2022). Despite being a net exporting nation, rural households struggle to access this food abundance (Isvilanonda & Bunyasiri, 2009). In the light of the food and nutrition insecurity in the region, this paper finds purpose in investigating a promising and sustainable solution element to this plague. After all, ''overcoming micronutrient malnutrition is a precondition for ensuring development'' and improving life conditions for all on this planet (FAO et al., 2012, p. 23). This is especially true for women who are more at risk to suffer from the double-burden of malnutrition than men, and this inequality is even projected to increase in the coming years (Hasan et al., 2022; Traissac et al., 2016)

1.9 Report structure

After depicting the general context and describing duckweed and its potential, this paper is structured as follows. It will expose the research questions of the present empirical study looking at how awareness and consumption are for duckweed currently and why, and how they could be in the future, the initial knowledge gap on which the research questions are based, the scientific relevance of the latter, as well as an explanation of the conceptual framework and methods used to conduct this research. Then come the presentation of the findings, followed by a discussion reflecting on the present research and the ones to come on this topic, before ending the present report with some concluding words.

CHAPTER 2. RESEARCH QUESTIONS AND GOALS

2.1 KNOWLEDGE GAP

By making an entry into dietary patterns worldwide, duckweed seems to have a potential to make these healthier. However, Fanzo and Davis (2021) remind us that healthy diets should be "affordable, accessible, and culturally acceptable" (p. 10). While duckweed is said to grow easily everywhere and not to require much infrastructure or processing that could justify a high price, I guess it is this last aspect about culture that seems to be the current hurdle to its wider uptake among locals in Southeast Asia.

The same authors further specify that "food is also integral to people's values, traditions, cultures, religions, and the everyday structures that comprise societies. The choice of food helps define a person's identity, habits, and aspirations. People make food choices based on their beliefs and values, preferences and desires, and relationship to the origins of food" (Fanzo & Davis, 2021). However, when looking at the existing literature on duckweed, so much is being explored about the plant's nutritional profile and further technical features, while so few is being said about how it is perceived by the people who are supposed to benefit from these characteristics. In fact, to this date, there seems not to be a single study about awareness and consumption of fresh duckweed in Southeast Asia. While studies have been done with local consumers to launch duckweed-based protein powders in the United States, the only study focusing on future potential consumers' opinion of the fresh product has been conducted in the Netherlands by de Beukelaar and colleagues (2019), and incidentally by Mes and colleagues (2022), where the fresh food product is yet to be approved for consumption by the European Food Safety Authority (EFSA).

In Southeast Asia, when reporting the current consumption of duckweed there, Iqbal (1999) only adds the mentions of a reputation as "poor man's food" and a declining popularity. Van den Berg and colleagues further stipulate that "this may be because of the high content of oxalic acid in some species of duckweed affecting its taste, and the difficulty in separating worms, snails, protozoa, and bacteria from this aquatic plant" (van den Berg et al., 2015, p. 36). These assumptions are so far the only trace of an interest in social acceptance of duckweed in the area.

The present study aims at filling the hereby identified gap on the popularity of the aquatic plant among its consumers and non-consumers in Laos and Thailand, the reasons behind their awareness or ignorance and consumption or abstention choice and the product-, individual- and environment-related criteria that are determining for duckweed awareness and consumption. We need to know more about the individual and social factors of food choice pointed out above by Fanzo and Davis (2021) in the case of duckweed consumption in Laos and Thailand.

2.2 RESEARCH QUESTION

Bai et al. (2016) state that "how to initiate and upscale purposeful changes that deliver sustainability outcomes […] remain[s] as [an] important research question[s]." (p. 357). While duckweed consumption as a "purposeful change" has already been initiated long time ago in Southeast Asia, it is about upscaling it there, but also about initiating (and upscaling) it in other parts of the world as well to bring about those "sustainability outcomes".

Based on Bai et al.'s statement, the present research will aim at understanding:

What influences human duckweed awareness and consumption in Laos and Thailand?

through the following subquestions:

- How and to what extent is duckweed known and consumed in Laos and Thailand?
- To what extent do a selection of seven aspects known to influence food awareness and consumption constitute drivers or barriers in the case of duckweed in Laos and Thailand?
- What are possible future developments of duckweed in Laos and Thailand?

2.3 Scientific relevance

By trying to bring response elements to the above-stated questions, the present study aims to contribute to the social-scientific research base on duckweed. This research should provide a deeper understanding of how duckweed is perceived by current and potential consumers and how these perceptions could evolve based on society-based changes to the product and/or its environment. Future research could draw upon the findings of this empirical insight to enrich the general knowledge on the potential of this fascinating plant as nutritious and sustainable human food. However, one should be careful about the use of the later presented results as these are context and product specific. Further, they base solely on qualitative data, which prevents its generalisation to any higher observation unit than that of the individual. The aim of this research is no other but to "start somewhere" to better understand the meaning of duckweed for current consumers and non-consumers and to identify the circumstances under which an awareness and consumption increase of duckweed would be possible. And for this, it made sense to begin there where the consumption is already observable.

CHAPTER 3. CONCEPTUAL FRAMEWORK

The above proposed potential of duckweed consumption to tackle both nutrition and environmental challenges is an incentive to look more into the extent, drivers, barriers, and other particularities of its current consumption in Southeast Asia.

When looking at the development of food industries, Gokirmakli and Bayram (2017) identified several determining factors for the uptake and impact of technological innovations. While global warming, world population growth and urbanisation are listed as global drivers, consumer preferences are defined as a crucial societal criterion (Gokirmakli & Bayram, 2017). This is confirmed by Jairath et al. (2021) and Sharma et al. (2015) as they all emphasize the essentiality of consumer acceptability for the uptake of cultured meat. Now what exactly determines whether individuals know and consume a food product or not?

To investigate this question, we shall first define what awareness and consumption exactly mean. The term “food awareness” is nowadays often seen to be used to indicate either an understanding of how one’s food intake and health are related – sometimes also called “nutrition awareness” (Eze et al., 2017), or a mindfulness of one’s eating practice and habits (Abundance Wholesome Foods, 2021). Yet this is not what I refer to here. In our case, awareness of duckweed simply means knowing of the existence of duckweed as human food. Someone would be “unaware of duckweed”, if they had never heard about the aquatic plant being consumed by some as human food. Yet, individuals who own such knowledge of duckweed have the possibility to take the next step: consumption. Only in exceptional cases we could imagine someone eating duckweed without knowing beforehand what it is. Rather than only referring to the actual intake, processing and physiological use of food with the term ‘food consumption’, we here include an idea of food choice happening at the moment of purchase or collection, and/or right before intake (Rozin, 2007), as well as the preparation and pairing of the food. In short, while awareness refers to a state of consciousness, consumption describes a behaviour.

3.1 IDENTIFICATION OF ASPECTS EXPECTED TO INFLUENCE DUCKWEED AWARENESS AND CONSUMPTION

Several authors elaborate on various contextual and personal aspects boosting or preventing the awareness and consumption of certain food products. Looking at the case of duckweed as human food in Laos and Thailand, I identified a set of seven aspects to investigate in this specific case (see figure 3) and formulated expectations regarding their possible influence on duckweed awareness and consumption. The selection was made looking at product and/or context similarities with the case of duckweed in Southeast Asia to estimate the level of relevance of each aspect. Through the subsequent data collection, the aim is to investigate how and to what extent each of the aspects influence duckweed awareness and consumption.

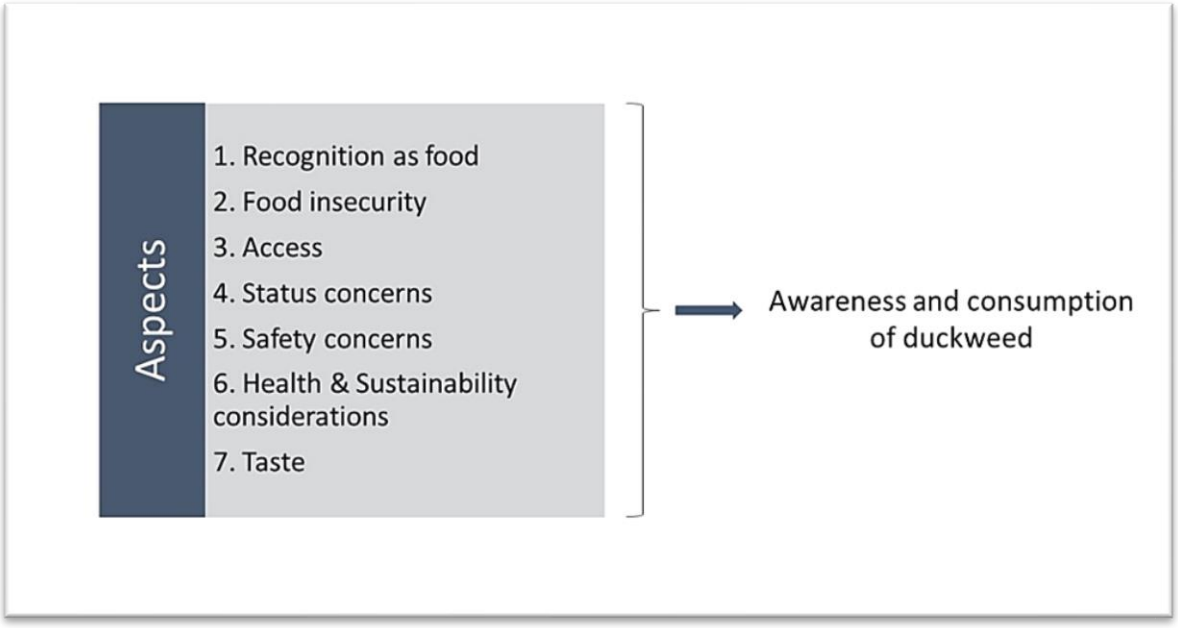

Figure 3. Graphic representation of the conceptual framework.

3.1.1 Aspect 1: Recognition as food

According to Rozin's reflection on the reasons behind food consumer's choices (2007), a first decision takes place when people identify items as edible or inedible. This fundamental distinction, as he calls it, is a categorization that is often "transmitted by parents and others, as a form of cultural wisdom" (Rozin, 2007, p. 5). An example of a product for which the fundamental distinction is set and passed on differently in France or in the United Kingdom is horse meat: while this meat is integral of the first country's eating culture, horse is perceived differently from other livestock species and would never be served on a British table (Fiddes, 1994). Similarly, I imagine that in different subnational cultures in Laos and Thailand, duckweed is varyingly regarded as human food or not. This distinction is expected to primarily impact the willingness of people to eat duckweed.

3.1.2 Aspect 2: Food insecurity

In a study on wild meat consumption in Madagascar, results showed a consumption increase in food insecure households compared to other households, despite both groups expressing a general dislike of this type of meat (Reuter et al., 2016). As this pattern is observable in other African countries too (Lindsey et al., 2013), I wonder about its applicability to duckweed consumption in Southeast Asia. As both commodities are readily available in nature, either hunted or foraged, is duckweed also a source of food security for more vulnerable Southeast Asian households? At least it seems like the potential is there, as duckweed seems to score well on all four food security pillars.

3.1.3 Aspect 3: Access

Access is an aspect that refers both to the financial and physical ability to attain, in our case, duckweed (FAO, 2006). While higher-income households spend a smaller portion of their income on food than lower-income households, they still buy significantly more, not in terms of quantity but of costs (Kinsey, 1997). On the other side of the income spectrum, price remains a "driving force in food demand" of lower-income households (Kinsey, 1997, p. 1463). This price elasticity might likewise affect duckweed

consumption, within financially struggling households depending on the plant's price on the market. However, keeping in mind that duckweed can be foraged for free from ponds out in nature, a distinction should be made between these two types of access in order to separately understand the impact of income on the consumption of each kind of duckweed in various consumers. This distinction between bought and foraged duckweed is just as relevant when looking at the physical access to this food. Considering that one is brought to the consumer while the other one needs to be collected out in the wild, I imagine that this latter kind is not accessible for older or physically less fit people. In this sense, duckweed foraged for free might be financially more, but physically less accessible and vice versa for the market version.

3.1.4 Aspect 4: Status concerns

Foods often put their consumers in a socioeconomic category (Vartanian et al., 2007). For instance, food is known to be "gendered" with leafy greens being associated with women and spicy meats with men (Zhu et al., 2015). However, meat has also been shown to be associated with a higher socioeconomic status which, in some cases, leads to (perceived) status change-motivated meat consumption (Chan & Zlatevska, 2019). Based on the socioeconomic stereotypes associated with duckweed consumption, we might observe a social pressure influencing duckweed eaters or non-eaters to avoid the food, when possible, to not fall under the "poor man" status indicated by Iqbal (1999).

3.1.5 Aspect 5: Safety concerns

The safety of their food is a primordial aspect to consumers worldwide, and most Western consumers even expect "absolute food safety" from all food products they purchase (Wilcock et al., 2004). Therefore, I assume the importance of the safety offered by duckweed to its current consumers in Southeast Asia. Yet, this safety aspect could be even more crucial for the upscaling of duckweed consumption when introducing the food to people who have never heard of it before (Mohorčich & Reese, 2019). According to Mancini & Antonioli (2020), the natural aspect of this untransformed plant might help with its popularity. At the same time, this "naturalness" could bring uncertainties regarding the hygiene and safety of the plant, as (micro)organisms could remain on the food depending on the growing environment and washing procedure (Gijzen & Khondker, 1997). Through this research, I aim to understand the level of food safety expectations and awareness about duckweed among current consumers and non-consumers in Laos and Thailand.

3.1.6 Aspect 6: Health & sustainability considerations

People make more or less conscious food choices regarding the health and environmental impacts of their diets. When it comes to health considerations, "knowledge of the relationship between diet and health seems to increase the consumption of micronutrients" (Kinsey, 1997, p. 1462). As a micronutrient-rich food, duckweed might be more popular among consumers who know about these nutritious features of the aquatic plant and at the same time pay attention to their health. This assumption also applies to other health-related characteristics of duckweed like its high and complete protein content. Furthermore, Vermeir and colleagues (2020) state that sustainable eating habits are currently trending in high-income countries - but what about LMICs? How important is it to Lao and Thai people to eat sustainably, and (to what extent) is that an argument for duckweed consumption to them?

3.1.7 Aspect 7: Taste

As previously mentioned, Iqbal (1999), and later, van den Berg and colleagues (2015) reported an unpleasant taste of duckweed and attributed its origin to the presence of a certain chemical in the plant. However, neither of the publications mention a confirmation of this assumption by a consumer's opinion. Interestingly, most participants tasting duckweed in Mes and colleagues' experiment (2022) mentioned a rather neutral taste, similar to spinach. While this difference in taste perception might be strictly subjective, the discrepancy could be caused by the difference in species (*Wolffia arrhiza* in Iqbal's paper, *Lemna minor* in Mes and colleagues' research). In Thailand and Laos, Xu and colleagues (2021) report *Wolffia globosa* to be the generally consumed species.

Also, I am aware that this question is only relevant for our target group: people who have heard of and/or eaten duckweed before. For these, their own or other people's reported (dis)appreciation of the taste of duckweed might have a decisive impact on their consumption of that food.

3.2 Application of the conceptual framework

The conceptual framework offers a structure to the understanding process of what drives or refrains current DAC in Laos and Thailand, while I expect to find other elements that might be more relevant than the seven aspects that I selected. Furthermore, some of the seven or newly discovered aspects may be interlinked. For instance Based on Kinsley's (1997) statement that "higher-income consumers demand […] safer, healthier and more exotic foods" (p. 1463), we may expect income to be linked positively with safety concerns (the higher the income the higher the safety concerns), nutritional value perception (the higher the income the more important that food products be healthy) and maybe even fundamental distinction, if we consider that Kinsley's 'exotic foods' might comprehend an unknown food product that wealthier consumers might be more willing to try than their poorer counterparts. Yet, the contrary is also possible, thinking that the lack of money to spend on food or even the food insecure state of certain poorer households might push them to widen the limits of the category of what they consider edible.

Similarly, the relationship between income and food security is well-established in the literature and, therefore, we might observe the same pattern of higher vulnerability to food insecurity among poorer households (FAO et al., 2022). Talking about poorer households, we can imagine that higher-income consumers would not want to be associated with duckweed considering its reputation of "poor man's food" reported by Iqbal (1999). Moreover, I expect further interconnection patterns to emerge from my interviewee's statements.

All in all, discovering the extent and the way in which the seven aspects are relevant or not will enable me to answer my second subquestion. Similarly, the new variables mentioned by my interviewees will complete my answer to the main research question. Based on my findings, I hope to come up with a better understanding of DAC and relevant factors of influence for future studies on DAC.

CHAPTER 4. METHODOLOGY

4.1 STUDY DESIGN

The research question and the first two subquestions are informed by an assessment of individual and cultural circumstances or preferences that are conducive or not to duckweed awareness and consumption (DAC). This assessment has been done by collecting qualitative data through direct interviews from a relatively diverse sample of interviewees in Laos and Thailand, as well as through participant observation of duckweed-related activities and contextual elements. The shared narratives and observed content have then been thematically analysed to discover what aspects of the individual or their environment influence more or less, positively or negatively people's position towards and consumption of duckweed.

The last subquestion can be considered to follow a speculative method, which is "aimed at envisioning or crafting futures or conditions which may not yet currently exist, to provoke new ways of thinking and to bring particular ideas or issues into focus" (Ross, 2017, p. 215). The content gained from this method can then further be used as part of a technology assessment which aims to support an innovation by collecting social-scientific data among different stakeholders to inform its development. The relevance of this type of society-led research for the further development of duckweed as a staple human food has namely been noted by Xu and colleagues (2021). In our case, I conducted a narrative analysis to synthetize the received inputs into different narratives that currently draw different future developments of a same food.

4.2 DATA COLLECTION

The data for the thematical and narrative analyses has mainly been collected through direct interviews and a couple of information conversations shared with a total of 51 locals – hereafter referred to as "interviewees" – in Laos and Thailand.

In Laos, the sampling process was determined by local authorities and a set of 11 interviewees was picked for me after I indicated the wish to speak to people who eat duckweed and others who (usually) don't with, if possible, some sociodemographic diversity within the sample. In Thailand, the selection process of the 27 interviewees was, at first, guided by the network of my contact person in Thailand. As I interacted with my first interviewees, I then ethnographically followed duckweed to identify where and from whom I could get additional relevant information regarding that research object. This led me to conduct not only semi-structured interviews based on the interview guide I used in both Laos and Thailand (see appendix 1), but also to have more spontaneous interactions with locals. When possible, I grabbed the opportunity to interact with several other people in a less structured way whenever I would be accompanied by a potential translator, or my interlocutor would have sufficient English skills. Through these discussions I collected precious additional or background information which brought some depth to my data. These interactions could be considered part of a participant observation which I conducted while roaming through my fieldwork and also included non-interactional forms of observation of my environment.

With my planned interviewees, I conducted in-depth, semi-structured interviews of approximately 60 minutes each. In both countries, a local contact accompanied me during these to translate the content

in both directions (English to local language for the interviewee and from local language to English back to me). The audio part of the interactions was recorded on my smartphone and then transcribed.

Overall, I gathered answers from representatives of various demographic, economic and social categories. I namely interacted with female and male duckweed consumers and non-consumers of different ages, with different cultural backgrounds, occupying professional positions (for the active ones) as diverse as diplomats, farmers, or taxi drivers.

4.3 Methods of analysis

To proceed with the analysis of the collected data, all interview records have first been transcribed into a text following the scheme of a dialogue. This has been done following an intelligent transcription style to have an authentic trace of the interaction that has only been cleaned for readability.

These transcripts then served as a base for the thematical analysis of the collected content. This involved the coding of text elements based on which (sub)question(s) and which variable(s) in the conceptual framework are addressed in the given section. This classification allowed for the gathering of all elements referring to the same question in order to confront them with each other and to formulate a complete and robust answer. Using the coding software Atlas.ti, this method of analysis provided me with an overview of all the results relevant to my research question and subquestions. The rest of the elements providing other useful insights have been kept to be addressed in the discussion part.

CHAPTER 5: RESULTS

With the goal to get a better understanding of duckweed awareness and consumption where it is already known to be consumed as human food (Bhanthumnavin & Mcgarry, 1971; Mes et al., 2022; Xu et al., 2021), I left for fieldwork to two different countries – expecting that these would constitute my two distinct case studies. In the course of my data collection, I noticed my terrain in fact brought similar results on both sides of the Mekong River. I, therefore, grouped my Lao and Thai findings in the coming results sections, while pointing out regional differences where applicable. Following the structure established with my research questions, I will start with describing duckweed awareness and consumption (DAC) patterns, then present what aspects turned out to be more or less influent on those patterns, and lastly showcase three visions that draw different possible developments of duckweed in the near future.

5.1 AWARENESS AND CONSUMPTION OF DUCKWEED

The awareness and consumption of duckweed (DAC) as a human food seems to have spread from Laos – the alleged birthplace of duckweed consumption in Southeast Asia – to Thailand, Myanmar, and according to some interviewees, even to Cambodia and Vietnam following the migration of Lao people. This origin and dissemination pattern of the food was identified and shared by about half of the interviewees from both Lao and Thai sides, among which a Thai scientist and entrepreneur producing and selling his own duckweed grown in a monitored environment, and a Thai government worker in charge of a project to map and support duckweed production nationwide.

In all explored regions of Laos and Thailand, all my interviewees seemed to agree that there would be only one consumed duckweed species – which the above-mentioned Thai scientist and entrepreneur confirmed to be *Wolffia globosa.* This and the following sections about DAC and various aspects influencing it more or less are about *Wolffia globosa* in its "traditional" form, meaning either collected directly from ponds in nature or bought from local markets.

5.1.1 A LAO FOOD…

The close connection of duckweed consumption to Lao settlements was reflected in different examples of cultural duckweed presence throughout Thailand. First, the Isaan region in the Northeast of the country (see figure 4) – where duckweed consumption is said to be born and mostly happening to this day in Thailand – has also an ethnical majority of Lao descendants (Hesse-Swain, 1968). Besides Isaan sharing over half of its borders with Laos, this ethnical distribution is mainly a consequence of the 1959-1975 civil war in Laos pushing numerous Lao refugees to find shelter on the other side of the Mekong – especially communist dissidents since the Pathet Lao took over the country in 1975 and a communist government rules the country up to this day (New World Encyclopedia, 2023). In Isaan, duckweed seems widely known as a source of food and is a full-fledged part of Isaan cuisine (Greenhouse et al., 2012).

Secondly, the West of the country (Kanchanaburi, Ratchaburi and Nakhon Pathom provinces – see red dots on figure 4) hosts several duckweed farms or "pond collectors". I visited two farms and one individual collector, who all started their activity due to the duckweed demand set by Lao/Isaan settlers in the area. In these three provinces where duckweed is not part of the original food culture, people only know it in the specific villages where Lao/Isaan people settled and introduced duckweed. The two

farms I visited during my fieldwork both offer the possibility for visitors coming from further away to learn about and taste duckweed in respectively the café area at the farm or the community center of the village. One of the farms called their brand of duckweed food products “Phum” – literally duckweed in Thai – with the hope to increase awareness around their key ingredient. As a result of this duckweed production and presentation initiative, duckweed awareness slowly starts to detach itself from a strictly Lao/Isaan environment as visitors spread the word after getting in touch with the food at the farm. However, Phum owner reveals that many visitors enjoy the duckweed-featuring products they consume at the café area of her farm, but only rarely buy the fresh product to prepare it at home, preventing consumption from growing alongside awareness outside of Lao/Isaan communities.

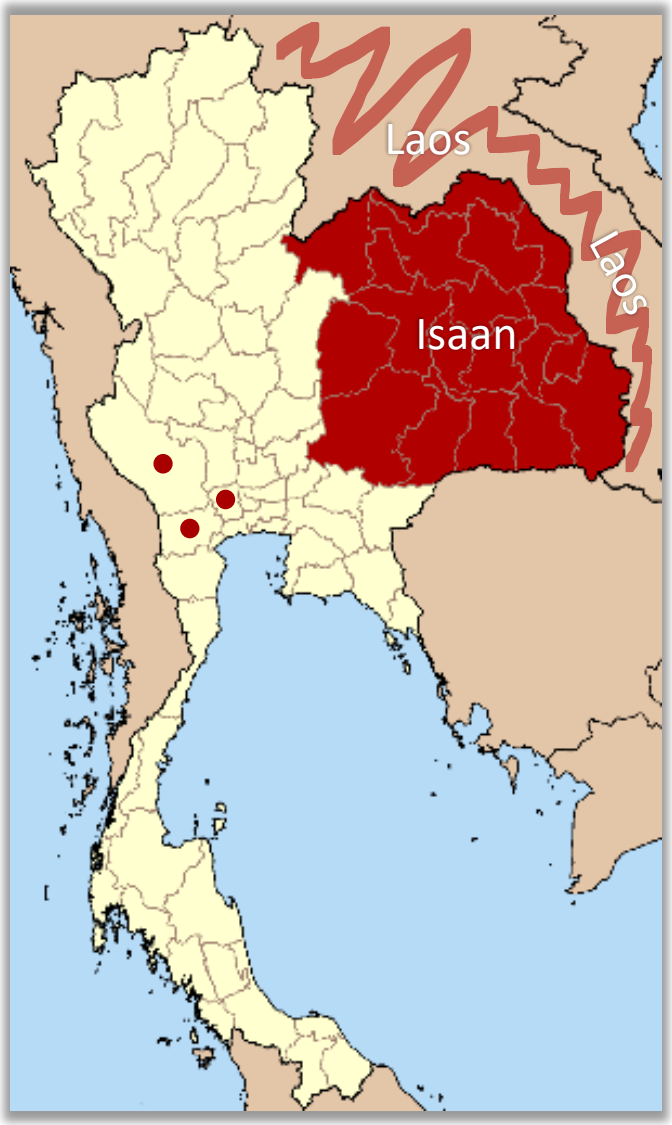

Figure 4. In red, all locations known to have an established duckweed consumption: Isaan completely coloured, Laos hatched, and three provinces where further Lao/Isaan descendants have settled and introduced duckweed (Kanchanaburi, Ratchaburi and Nakhon Pathom) marked with a dot.

In the rest of Thailand, no duckweed cultivation or collection is known to take place, but some sporadic consumption happens in places like Chiang Mai or Bangkok where, again, Lao or Isaan people have set foot. Regarding awareness, the food seems known to a limited extent and is often directly associated with Isaan. For instance, among the Bangkok respondents, only one older Isaan woman who moved to

Bangkok when she was young knew about duckweed and began cooking it after her Isaan husband asked for it. Overall, duckweed awareness is estimated by a duckweed business owner to reach around 2% of Bangkok's population, and an even lower prevalence of duckweed consumption. Numbers were not found for other regions of Thailand, but I would not be aware of any parameter that would change this percentage drastically from what it is in the capital city.

5.1.2 … OR PARTLY

Duckweed is said to be born as a food in Laos, and virtually all my Lao respondents considered it as part of the traditional Lao diet. However, it doesn't seem to appear in every citizen's basic recipes. While a few respondents had never heard of duckweed, others who did were pretty sure about the food only being consumed in certain regions. Yet, it is unclear where exactly duckweed is consumed in Laos, as some interviewees reported it is more popular in the South, and others attribute it to the North of the country. Some respondents seemed to link its consumption to where it would grow, as its availability is also reported by all respondents who answered this question to vary regionally. Yet, again, without a clear idea among participants where exactly in the country the aquatic plant could be found. Overall, awareness seems not to reach the entirety of the Lao population, but mostly the people who have lived in or have some connection to an area where it is consumed.

While not every Lao person knows about duckweed, even fewer have ever eaten it, or even still regularly do. A substantial part of the respondents only had duckweed on their childhood plate as their parents served it to them in their rural home, and then never had it again as they moved out – often to the city. In some households where only one of the parents grew up eating duckweed, it often doesn't make it onto the menu of the newly founded family, and with that, also not to their children's food baggage. Overall, it seems like growing up with duckweed or not is crucial in duckweed consumption, as people are rarely introduced to it later in life. This rare passing on of duckweed to the next generation leads to a decreasing awareness and a much lower consumption among younger people.

Based on the demographics observed among the respondents and their assumptions about general consumption patterns of duckweed, the people who still regularly eat it appear to often be older and to live in a rural area where a pond with duckweed is accessible nearby, as its collection then often constitutes a family habit. Twelve out of seventeen Lao people I interacted with remember going to collect duckweed at the pond with their parents, who would teach them the specific collection technique. These participants all grew up in a rural area of Laos. Older people who consume duckweed in urban environments like Vientiane or Bangkok report a more occasional consumption, often whenever they would find it on a market or when relatives would bring it as they visit from rural areas.

Overall, Duckweed Awareness and Consumption (DAC) seems to be bound to specific areas in Laos and Thailand where it is part of the local diet of Lao/Isaan people. There, the consumption is reported to be relatively infrequent and declining with clear differences between age groups, and between the city and the countryside. DAC prevalence patterns imply a highest probability among older rural people with at least some connection to Isaan in Thailand or an area of duckweed availability in Laos, and the lowest among younger city dwellers without such connection to Laos/Isaan. While some representatives of this last urban group have stopped eating duckweed but still know it, this portion of society is said to soon forget about duckweed completely as generations get replaced by the next ones.

5.1.3 Preparation

I will here answer the "how" of duckweed consumption by addressing cleaning and cooking methods observed during participant observation and reported by interviewees. While access to duckweed may seem like an important point of "how" people get to eat that food, it will be discussed in the next session as one of the aspects influencing DAC, answering the "why" of duckweed consumption.

Throughout Laos and Isaan, duckweed is traditionally prepared in soups, various curries, omelets (see figure 5) and spicy (papaya) salads. Interestingly enough, duckweed is seen as a vegetable in those traditional dishes and, therefore, often paired, when possible, with another source of protein like pork, chicken or fish. Most people assess these menus to be quite accessible as they are prepared "just like any other Lao or Isaan food". Both cuisines have a lot in common, as some ingredients like fermented fish sauce, chili, lemongrass, and "Lao herbs" seem to form a constant base which provides Lao and Isaan cuisine with their signature flavors. However, this traditional cuisine is becoming less and less popular among younger locals and limits the consumption of duckweed and other "traditional" ingredients in that age group. Among older, rural non-consumers, the traditional Lao or Isaan cooking style is how duckweed would often instinctively be cooked, if they were offered the chance. However, most younger city-dwellers who never had it before admit not to know how to cook duckweed if they were to ever get it, as they also do not cook often in general.

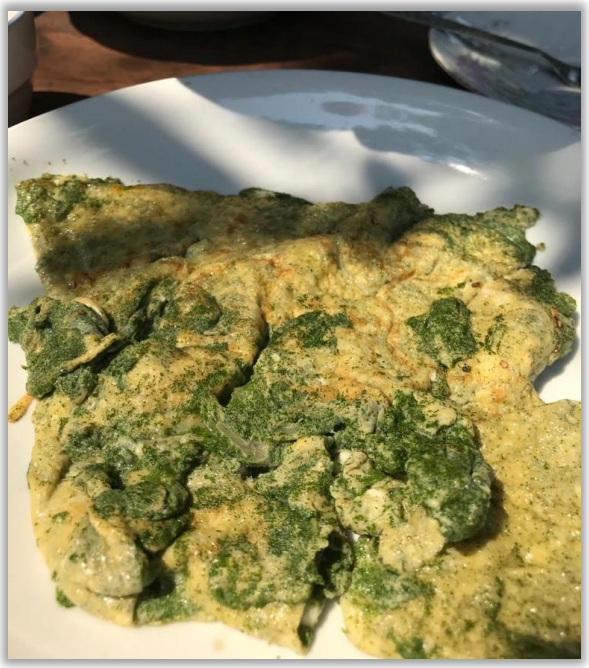

Figure 5. A typical Isaan omelet prepared and offered by one interviewee: eggs, onion, fermented fish sauce, and duckweed.

The cleaning of the collected or bought duckweed requires a specific cloth with the right tightness to drain the dirty water out, without losing any of the cleaned product. This same piece of fabric is also regularly used to make homemade coconut milk out of the fresh fruit. As regards technique, the respondents agree on washing the duckweed several times in clean (tap) water before boiling it to get rid of any remaining bacteria. However, three (out of three) interviewed Biology professors warn against relying on this cleaning method, as it doesn't eliminate heavier toxins that get absorbed by duckweed if present in the water it grew on. Yet among the interviewees besides the three Biology professors, only Biology and Medicine students seem to be aware of that risk. None of the respondents reported to ever eat duckweed raw, because of its categorization as a vegetable – which, based on the

sayings of the interviewees and my observations on site, are always prepared at high temperature in Southeast Asian cuisine: either boiled or fried.

5.2 Influences on awareness & consumption

Earlier on, I presented seven aspects which, according to available literature, were expected to each explain part of the duckweed awareness and consumption (DAC) described above: 1) the recognition of duckweed as food, 2) food insecurity leading to duckweed consumption, 3) physical and financial access to duckweed, 4) status concerns around the reputation of duckweed, 5) safety concerns around the cleanliness of duckweed, 6) health and sustainability considerations in choosing duckweed (over another food), and 7) the rating of the taste of duckweed.

A Thai government worker I interviewed had a very clear selection of reasons why duckweed is disappearing from Thai plates: urbanisation disconnecting people from "rural foods", the insufficient level of cleanliness keeping some from eating it, and lastly the increasing difficulty to find it in nature. While his statement proved to be matching the findings from my data to some extent, other additional aspects cannot be overlooked to paint a more accurate picture of the drivers behind the DAC depicted above. The following sections indicate on the basis of my interviews and participant observation, which aspects contributed more or less to that DAC, and in what way.

5.2.1 A changing food scene…

The statement of a Lao interviewee sets the scene: "overall food consumption in Laos is changing". Another older respondent further shared that, for instance, thirty years ago, people would mainly find their food, including duckweed, directly in nature and would also more often live in rural areas where this was possible. Nowadays, people are shifting towards more convenient and faster foods, with foreign foods trending particularly. This is especially true for Vientiane where the offer of such food has arrived after the opening of the country to foreign companies, while fast food franchises haven't made it yet to rural areas and other cities than Vientiane. This observation is based on sayings of interviewees, my own observations of urban vs. rural streets during fieldwork, as well as the statement of Roman and Russell about recent Western influences on the food offer of Southeast Asian cities (2009).

Furthermore, this shift in Lao foreign trade is said to have changed the whole food scene after several episodes of national food shortage. Another older Lao citizen shared how under closed Lao regime "there was not enough food for everyone in the country, so people would eat duckweed. But now, there is more import, so availability of food has increased." While imports now allow a sufficient availability of food in most regions of the country, some residents still are food insecure. This is the reason why an interviewee mentioned to cook duckweed alongside "a main source of protein like meat or fish – when possible", as these products are more expensive than other foods. For people in this unfortunate situation, several Lao interviewees seemed to see duckweed collection as a helping factor for food security. As one of them said, "in case of lacking money, duckweed is an option, because then people can go and find food in nature for themselves and their households", while another interviewee shared his own experience of duckweed foraging as a kid as a meal option when his family was lacking money to buy food.

In Thailand however, when asked about this food insecurity relieving potential of duckweed, most answered with a hypothetical formulation, showing that the possibility of ever becoming food insecure seems far away from them. In fact, a majority of both rural and urban Thai respondents rather emphasized the fertility of their soil and abundance of food in all rural areas year-round. Some, therefore, did not see the necessity to eat duckweed on top of the broad food options they already have. As one Chanthaburi province resident shared, "where I live, we have many other food options year-round, so I don't need to try this [duckweed]". And in the city, where other food doesn't grow, duckweed won't grow either, making it more difficult to access natural duckweed ponds in case of food insecurity. When in such situation, an interviewee shared that many rely on getting their food from the temple nearby if needed as part of a Buddhist tradition.

While the opening to international trade in Laos seems to have alleviated food insecurity to some extent, it also allowed a food trend of foreign, "modern" foods to enter the country that was already well present outside of its borders (Roman & Russell, 2009). In Thailand, it has been changing food consumption habits all over the country, but particularly among younger generations and in urban environments. In both rural Laos and Thailand, the shift has been slower than for instance in Bangkok. With over 10 billion inhabitants, the megacity unsurprisingly offers an extremely varied food scene. According to Roman & Russel, the important place given to food in overall Southeast Asian culture is one of the reasons for the curiosity for, and therefore, success of this wide offer of foreign foods (2009).

With many ready-to-eat options, this food scene further fits the bustling lifestyle of most Bangkokians. An interviewee namely reported that "in Bangkok, people often live alone and therefore barely cook. Especially students often live in small rooms, where cooking is just too inconvenient" compared to buying highly convenient and ready-to-eat foods. These products are found in supermarkets, but also at abundant food stands in (quite literally) every corner of the city and on the streets between them.

5.2.2 …WITH DUCKWEED IN THE LAST ROW

Especially the younger Bangkokians I interviewed nearly all confirm this rather occasional cooking frequency for convenience reasons and admit that they would especially refrain from preparing a food like duckweed which requires multiple washing steps. Also, the coconut milk cloth required in this process is commonly found in rural households, but barely in urban apartments, as no one in the city bothers making their own coconut milk (with that cloth) when a fresh pack can be bought in no time and for little money in the 7-eleven[7] downstairs. Finally, some of the younger respondents also admit not to trust their rarely used cooking skills and that they wouldn't really know how to prepare fresh duckweed. This lack of experience comes as an additional barrier to duckweed consumption at home besides the inconvenience and missing tools to prepare it.

Next, duckweed is put in a category which is on a slippery slope among younger citizens, urban or rural: vegetables. There seems to be some generalized reluctance from younger people towards eating vegetables or anything that resembles it. The reason therefore is that they expect an unpleasant taste out of it and prefer other trendier foods, as reported by many parent respondents struggling to get their kids to eat their greens. Admittedly based on an image coming straight from the USA, meat is now for instance gaining a higher status over vegetables, which was not the case when the adult respondents were kids, as shared by a Bangkok resident. And in this regard, duckweed is in a

[7] Widespread supermarket franchise in Thailand.

particularly difficult position with its vibrant green colour. Indeed, not only kids, but a substantial number of urban interviewees mentioned the "very green" colour as a "suspicious", "off-putting" appearance that would keep some people from trying duckweed. "When you see it fresh on the market, it is like a very, very green bag – and then you don't know, you're not sure" shared an interviewee, while another described her experience at the restaurant: "they put it fresh, in front of you, and I thought, 'Is this a real green [colour]? Did they put some colorant in it?' Suspicious, I would never eat it." Besides the colour constituting a barrier in itself, an interviewee selling duckweed herself said "some are worried about a bitter taste based on the green colour". Another added, "I think it is not inviting to eat for many people because its green colour reminds them of 'vegetable taste'". "But it works quite well if you don't think about the color", as a Thai government worker shared.

For all the above reasons, fresh duckweed appears to be less and less attractive in Laos and Thailand. Besides new generations investing less time in the preparation of their food than their parents as a result of moving to larger cities, the foods trends[8] these young professionals encounter there do not exactly fit duckweed's characteristics. Western (American and European), Japanese, and Korean food seem to be particularly trending, as reported by many, especially younger respondents, and observed by myself with the abundance of restaurants, shops and advertisements displaying these nationalities on Bangkok streets.

A university professor explains that these foreign foods "look so clean, structured, and fancy compared to traditional Thai food". As duckweed cannot claim any of the public's favourite food origins, it seems even strongly stuck to labels such as "traditional" or "local", which are largely used by all respondents on both sides of the Mekong when referring to it. This leads to a perception of duckweed as old-fashioned among younger, urban citizens.

5.2.3 Taste above all

Besides duckweed's unattractive appearance to a new generation of consumers, duckweed may also, quite literally, not fit their taste. The food itself was described by a vast majority of respondents to be tasteless and to take up the flavor of whatever other ingredients it is mixed with.

This property was especially appreciated from parents who struggled to get their kids to eat their vegetables, but also from a majority of the respondents who, before trying it for the first time, feared a bitter or unpleasant vegetable taste based on the "very green" colour of the food. They liked the fact of getting all the nutritional benefits from eating a vegetable without having to bear with the taste, that is decreasingly popular among urban and younger generations. Despite describing the food as tasteless, some interviewed regular consumers expressed a favourable opinion towards its taste, "especially when prepared with fish" or "in omelets and green curries, I love it!".

However, over half of the respondents who had tried duckweed in traditional meals (curry, soup, papaya salad, etc.) reported not to like the taste of it – mostly younger tasters. This might be related to the palette of flavors in which duckweed is often featured. Indeed, traditional Lao/Isaan cuisine is widely unpopular among younger people as they seem to dislike any bitter or very strong, fishy flavors - and one of the staple ingredients in this traditional cuisine is fermented fish sauce, or *padaek*. The

[8] The term "trend" is used hereafter to describe a current fashion putting certain foods in the spotlight, and not to speculate around tendencies announcing which foods will be popular in the future.

same issue arises around chili, which is central in a multitude of dishes in many cuisines throughout Southeast Asia – including the meals where duckweed is usually featured. Its appreciation, or resistance to spice in Lao and Thai society is said to (regrettably) decrease over time, as shared by several respondents of various ages.

This societal taste evolution could be crucial for duckweed uptake, as taste was reported by many respondents to be the most important criteria for food. Not only for themselves, but they claimed this centrality of tasty food to be distinctive of Southeast Asian (food) culture. Therefore, the neutrality was often seen as a lack of exciting sensory content, while many look for nice flavors in their food instead of just texture or other less relevant benefits to them.

A minority also complained about the "green taste" of the food, referring to a note of vegetable, while most of the rest were neutral about its "non-existing taste". Further noted was the interesting texture that some compared to *ebiko* (Japanese shrimp eggs) or described as "a little bit crispy". This slight similarity to the famous Japanese topping was described in a positive way, which aligns with the Japanese food trend presented above: "I think that's good for the new generation, they are used to that kind of small balls on sushi for instance". Yet as set forth earlier, this positive note for the texture given by some is no match to compensate a lower appreciation of the taste of duckweed by a majority of younger tasters, as taste is and remains paramount in Southeastern food choices.

5.2.4 Where is duckweed?

Now if someone would try to pair duckweed with ingredients that are to their liking, they would still first have to access the traditional food somewhere to prepare it in that way: either on a local market, (newly) online, or out from a pond in nature (see figure 6). In Lao's countryside, contrarily to expectations created from the literature, duckweed is not quite so invasive as to cover literally every pond, even where people (like fish farmers using the said pond for their pisciculture) don't want it. First, the spatial frequency of ponds themselves is declining as a result of climate change shortening the rainy season and leaving ponds dried out for longer each year. Then, a duckweed entrepreneur as well as several older respondents shared that the probability of having duckweed on a pond is also declining together with water quality due to increasing intensive agriculture or industrial activity. Interestingly, an interviewee further mentioned the expansion of urban areas as a reason for duckweed decline, as some buildings are now constructed where duckweed holding ponds used to be.

Figure 6. A pond in Nakhon Pathom province from the surface of which an individual collector comes to harvest the duckweed almost daily.

The fact that, according to these interviewees, duckweed was more easily found in nature thirty or forty years ago than today, is especially an issue on Lao and Isaan grounds. There, many respondents who grew up in the countryside remembered collecting duckweed directly from ponds with their parents as kids. Even though the targeted ponds were sometimes at a several hour walking distance (as there were no motorbikes, let alone cars at that time) from their village and the collection required a certain technique and knowledge. Indeed, a majority of these respondents emphasized the difficulty of the collection task, as well as the knowledge required for the pond localization, and the need for a special net to collect the aquatic plant. All these represent additional unexpected hurdles for people to get access to duckweed. Most non-consumer interviewees shared that they wouldn't know how to collect the plant nor where to find it in its natural environment. The washing process mentioned earlier is where another layer of skills and specific tools complicate the consumption process and take duckweed a step further away from new consumer's plate. With that, the only aspect of utilisation as one of the four food security pillar that stills presents steady results is the bioavailability of duckweed's macro- and micronutrients presented by Xu and colleagues (2021).

On Thai ground, I observed and heard from two farmers that most rural duckweed consumers seem to get their own duckweed from their household-owned ponds for private consumption mostly, while a few also sell it on the local market. As a result, duckweed is hard to access in nature for someone who happens not to have an individual pond. These farmers as well as a university professor who accompanied me to this rural area of Thailand told me that, in the past, the ponds used to be common to the whole village community. Yet this is not the case anymore since the land got divided into private properties. But the less lucky ones without a private pond for their use can still get duckweed from neighbors or at the local market of a village in which duckweed is commonly consumed.

Those markets would sometimes be far away from one's village: "one to two hours from home traveling by foot – which is common in rural areas. Not everyone has a motorbike". Therefore, some have relatives send them some duckweed from other parts of Laos or Isaan where it is (more) available, or some grab the opportunity to get it with every trip they make to a region with more duckweed than theirs. Only few expressed the proximity to duckweed ponds from their village, while still emphasizing the difficulty of the collection task.

When it comes to financial access, duckweed is sold on Lao markets for 20.000 Lao Kip (LAK) per kg, 10.000 LAK per plate or 5.000 LAK for a bowl (1 portion), based on my own observations and prices being reported to me by respondents. On the other side of the Mekong, an individual collector sells it for 20 Thai Baht (THB)/kg directly to neighbours and a middleman who then sells it for double the price on the local market. For reference, a woman selling chickens at the market makes about 20.000 THB a month, while a student that just graduated from university makes 15.000 THB a month.

These market prices are generally considered cheap, as all my interviewees who knew about those agreed on the affordability of duckweed. Yet, no one mentioned this financial accessibility to be an incentive for their duckweed consumption. I further noticed that a majority of the respondents are not really aware of the price of duckweed because they've never or rarely seen it on the market. Some guessed it must be cheap because of its natural origin, while others assumed it to be expensive because of its rareness and "because getting duckweed from natural ponds is difficult to access and collect" as expressed by an interviewee, and agreed on by many of those who know about the collection task.

When it comes to urban environments, this quote from a Vientiane resident turns out to be representative for the situation of many of my Lao and Thai urban interviewees: "I don't know how to get duckweed because I was born in the city and live in the city." Another added that "in Bangkok, if you go to the market, like a fresh market, you can see any kind of vegetable, but not duckweed. I don't think you can see it easily. So then, people don't think about eating it, you know, it's not common". Also, a respondent specified that "it's not available in supermarkets because duckweed is traditional, local food". And this was expressed as the reason why some Vientiane and Bangkok residents share that they would simply not know where to find duckweed in the city.

In Laos, approximately half of the interviewees who ate it as a kid outside of Vientiane would nowadays get if from a handful of markets who offer it throughout the city. As my translator and I visited one of those markets, only one from over 200 sellers there would have it in her supply (see figure 7). She shared with my translator that she would sell it less than other of her fresh food products, as "it is not part of people's usual food choices here in Vientiane". Among the Bangkok interviewees, only one woman with Isaan origins knew at which exact market specified in Isaan food to find duckweed.

Figure 7. The only duckweed seller found on a Vientiane market with over 200 stands occasionally sells her duckweed collected by relatives on ponds outside the capital for 10.000 LAK per plate.

Although Thai people could order their duckweed online from one of the duckweed farms/collectors in the Western Thai provinces mentioned above, none of my respondents ever placed such order. Indeed, partially due to the covid-19 pandemic, this other way to access duckweed has recently emerged. Besides selling directly at the farm, both interviewed farm owners and the individual collector sell their harvest on Facebook and Shopee (the Thai equivalent of Amazon in Western countries). Around them, the online offer is supposed to be quite larger, as one of the farmers mentioned a growing competition among online sellers. Both visited farms sell their "particularly clean" duckweed at 150 THB/kg online, as well as directly at the farm. This is said by them to be equivalent to the price of any other organic vegetables, but three to five times more than a 'regular' vegetable or duckweed on the local market. To this price are added 100 THB for cold chain delivery. The Thai duckweed collector mentioned earlier shared that his son would also sell some of his (the father's) harvest online to people in Chiang Mai for 70-80 THB/kg.

While the individual collector's online offer is substantially cheaper, it is still much more expensive than other vegetables and, therefore, by no means an incentive to replace those with duckweed in someone's diet. Especially since, according to the farmers and two university professors, organic seems not to be a criterion for many and, therefore, the price (of both organic food and duckweed) seems not justified considering the abundancy of cheaper food options that Thai people have. On top of that, the same sources shared that the COVID-19 pandemic cut 10% of overall household expenses (in Thailand, and probably also in Laos), which had a dramatic impact on the income of online duckweed sellers.

Nevertheless, both farms we visited refer to Facebook and Shopee as successful selling platforms with customers all over the country. Isaan people would namely constitute a substantial duckweed demand during the colder months of the year when their local duckweed won't grow. The same reason is given by the farmers to explain their online customers from Chiang Mai, in the North of Thailand.

All in all, fresh duckweed seems less affordable online, but quite cheap for a vast majority if found on a market. The better question is whether it can be found there, since physical access seems overall to be bigger of an issue than financial access.

5.2.5 And availability?

While financial and physical access were listed as factors in my conceptual framework, another pillar of the FAO food security definition results to be a substantial driver of the overall low DAC identified above: availability. While assumption vary among respondents as to exactly when and where the plant can be found on selected ponds, there seems to be a consensus around the regional and seasonal restrictions of its availability.

Indeed, in Laos some pretend it is rather found in the South and others say it comes from the North. In Thailand too, some say it only exists in the places where it is actually consumed like Isaan or Nakhon Pathom, Kanchanaburi or Ratchaburi provinces, others guess it must grow anywhere where the climate is warm enough and the water clean enough. When it comes to the seasonality of the crop, the cacophony resembles the one for its regionality. Some agree to say duckweed grows anytime but in the rainy season, and some say it grows specifically in the rainy season between May and September October, or until the rain stops. This, at least, goes in the same direction as the ones claiming you can get it all year round except for April-May, which are the driest months of the year – right before the rain comes back. Others then claim it grows in May-June and then in October-November, and a last group won't mention specific months but remembers to have it only once a year, or two or three times a year as a child.

All in all, aside from where and when exactly duckweed can be found, duckweed seems characterized by a regional and seasonal growth only on selected ponds. This restriction, coupled with rare appearances on market stalls and high online prices makes it a less robust food security factor.

5.2.6 Safe or not?

The safety aspect of duckweed generated contrasting answers: while some expressed pure disgust for the plant, others perceived it as one of the cleanest products for highly varying reasons. Based only on the statements that my interviewees made about their own safety concerns (excluding the many assumptions that were made about other people's concerns), about half of the respondents expressed concerns regarding the safety of duckweed, while one third felt confident about its cleanliness, and the remaining few were undecided. Among the concerned ones, all of them pointed at the natural provenance as a source of concern, as duckweed would then be vulnerable to all kinds of contaminants in nature.

Based on the sayings of a university professor, duckweed, as an aquatic plant, seems to raise even more concern among those who know where duckweed grows. This is because natural, or even tap water is generally not considered very clean in Southeast Asia, he shared. This was reflected by the sayings of a few respondents who gave more background information during the interviews, and the fact that I was told to be careful with consuming not only water itself in Laos and Thailand, but also anything that was made from (ice cubes) or washed with (fruit, vegetables) that water. A handful of interviewees also mentioned concerns around the increasing amount of chemicals present in natural waters. While the negative association with water could also come from the ability of another duckweed species to treat wastewaters by absorbing bacteria, heavy metals or any other contaminant present in the water (Nosowitz, 2021), two interviewed university professors estimated that only a minority would know of this characteristic. One of them added that besides the quality of natural waters declining over time (in Thailand, but not only), the other evolution at work is that "people grow up and become more skeptical of the cleanliness or overall quality of what they eat". This developed concern about anything growing in or on natural water is namely the reason why one of the visited farms switched from collecting their duckweed from a natural pond nearby to transferring it first into smaller basins they built for a better, cleaner image (see figure 8).

Figure 8. The basins to which the duckweed collected from a natural pond nearby gets transferred before being sold to visitors or prepared into duckweed products – either sold as products from the Phum brand or offered at the café area of the farm visited in Kanchanaburi province.

What all respondents seem to agree on is that duckweed needs to be washed and cooked like many other foods in the vegetable category, as eating it raw is considered dangerous. This is because of the presence of parasites and the prevalence of foodborne diseases, which was explained to me by locals to be higher in tropical regions like Southeast Asia than in other areas – hence the higher prudence among consumers. Therefore, the rule seems to be as one respondent stated it: "if I want to eat something leafy, it should be cooked very thoroughly".

While some respondents expressed a basic concern deriving from the fact that duckweed comes directly from nature, this exact point of direct association with nature seemed to be the source of trust regarding the safety of this food for others. These usually saw added chemicals as the main source of unsafety in food, and perceived natural ponds as clean growing environments for duckweed. One interviewee thought that "most Lao people eat duckweed because it is safe, it comes from

[uncontaminated] nature", "but if people grow it on a farm, they may use chemicals" nuanced another one. Some older participants in rural areas further explained that duckweed is perceived as an indicator for clean water as it only grows on certain contaminant-free ponds. Other respondents there mentioned the good health and fitness status of their elderly after consuming duckweed for years as a proof in itself for duckweed's safety.

With some exceptions, the differentiation between concerned and non- or less concerned respondents seems to follow an urban-rural and generational divide pattern. Younger people living in cities generally expressed the least favourable opinion towards the cleanliness of duckweed, while elderly in rural areas seem to be worry-free about any risks linked to contaminated duckweed consumption. Again, this might be linked to the fact that people outside of cities (used to) look for their own food in nature and accept anything they would find to be (part of) their next meal, and still tend to get a lot of fruit directly from trees nearby. In fact, a Thai interviewee shared that "Lao/Isaan elderly eat pretty much anything if it's cooked or fermented, so duckweed definitely fits their standards". This habit of collecting many vegetables – including duckweed, but also catching frogs, snails, etc. is however declining among younger generations who become more conscious and selective of what they eat or not. This phenomenon is said to be amplified as many move to the city and "lose the connection to nature". The above-mentioned degrading quality of grounds and waters due to increasing intensive agriculture and industrial activity is also reported to gradually limit this quest for natural food resources.

5.2.7 Health ok, but sustainabili-what?

After having displayed the aspects like status concerns, access, taste and safety concerns that seem to have the most influence on DAC, the assets of duckweed which initially motivated this whole thesis seem to be of less relevance to the Thai and Lao public. The level of concern for one's health or environment as a result from eating duckweed, or food in general, seems overall lower in Laos than in Thailand. In the latter country, it would tend to be higher in urban than rural environments, and health seems overall to play a slightly bigger role than sustainability.

Globally, Lao people seem not too aware about the health or sustainability impact of duckweed consumption. When asked about the health benefits of eating duckweed, some assumed that because of its green colour, it must be somewhat healthy. Or because their ancestors ate it: "my mother is 104 years old because she mainly eats duckweed", shared a Lao interviewee. A Biology student specified that it was for the chlorophyll content of the tiny green balls, that she considered it healthy. Overall, Lao interviewees either said to have no clue about the health benefits or issues of duckweed, or expressed a positive idea of the plant in terms of healthiness because of its natural source – as if anything that nature gave them was fundamentally good. In terms of sustainability however, none of the respondents mentioned any possible impact of duckweed consumption on nature, but rather the other way around. Duckweed is expected by some to disappear as a result of increasing pollution and degrading water quality: "duckweed becomes difficult to find, especially in industrial areas. I don't know if we will [be able to] eat duckweed or not in the future", feared a Lao woman.

Several older Lao respondents shared to have been raised to eat whatever was put on their plate, as this was basically whatever their parents could find for this meal. According to a university professor, this lack of choice around food led to a diminution of other considerations in the food choices they make as grown-ups, therefore excluding health and sustainability as relevant criteria. Others who don't mention this restriction in their childhood were also rather unaware of the nutritional profile or

sustainability impact of their food in general. When asked about the criteria defining everyday food choices, taste is always mentioned first: “here, people always go for food they like [the taste of]” shared a Vientiane resident. Price and nutrition then usually share the second place, while sustainability is not mentioned at all in the ranking.

On the other side of the Mekong, concerns vary among classes and regions. For instance, the owner of the Phum brand in Kanchanaburi (rural area) mentions that the customers expressing interest in the health benefits of her products are the upper middle class and the well-educated. Yet overall, people are generally unaware of duckweed’s health benefits, let alone the medical virtue claimed by some older interviewees. The first question of curious visitors is always about the taste of the green food, and then only about its benefits and shelf life. A university professor and duckweed entrepreneur estimated that probably one in ten Thai people eat the food they eat primarily for its nutritional properties, but the rest will mostly care about the taste of their meal. Among the 10%, one would rather find older or people struggling with some health issues, since the younger and fitter people could “afford not to care (yet) about their health too much”, according to an older Thai interviewee.

When it comes to sustainability concerns, a government worker explained that the concept of considering planetary boundaries in their food choices, and sometimes even paying more for it, doesn’t make sense to a vast majority of Thai people. On the one hand, because their land is so fertile, she says, that they cannot imagine any issue with growing an abundance of food on it: “we have plenty of vegetables and other food choices, so we don’t need to worry about sustainability”. On the other hand, because of their income which doesn’t allow them to pay the premium price of any food products advancing sustainability claims. An interviewee talked about a huge income and education gap in terms of sustainability sensitivity, as the vast majority of Thai people haven’t heard about sustainability. And most of those who have, cannot afford it.

Things look slightly different in the capital city, where quite some interviewees were able to identify a variety of health benefits from the food. This might however be linked with the nature of the sample, with a majority of them being university students or professors or other highly educated people. Among the mentioned benefits were the high content in a complete protein, various vitamins (A, B12, E), iron and fibers. However, sustainability outcomes seemed harder to identify for the urban interviewees, except for some academicians who are directly involved with the plant and mentioned the reduced land and water use, as well as the high CO_2 fixation capacity compared to other vegetable sources of proteins like soybeans or peas. For the rest, a Bangkok interviewee probably summarized in one sentence the majority of the answers I collected: “I still consider the benefits [food has] for my personal health more than for nature”. While sustainability timidly starts to become a public topic here and there among the most educated, it is assessed by a university professor to only have very limited concrete impact on Bangkokian, let alone Thai, lifestyles. Some see it as a criterion for tomorrow, but certainly not in today’s food scene.

For the health aspect, another university professor mentioned that especially Bangkokians are increasingly concerned about their health, especially NCDs, and rely on foods to help them with this concern as they don’t have time to invest much more time in it. “Many people nowadays just work work work, and don’t have time to care about their health, so they eat ready foods that can help them with that”, shares a university student. However, this “healthy lifestyle” trend also means that a great

variety of other food products already saturate this segment of the market and make it difficult for duckweed to make its entry there as the competition is high, as shared by a Nutrition professor.

Another challenge is the overall relatively low level of education of Bangkokians about the content of their foods, which prevents them from making the healthiest food choices. A clear communication about the nutritional benefits of duckweed would probably help its image and popularity, as it would at least fit in the "healthy lifestyle" trend, despite not being a trendy food in terms of origin and convenience. Yet this communication would only reach an educated, urban public, as lambda Thai and Lao people seem to show relatively low health concerns, and virtually inexistent sustainability concerns.

5.2.8 DUCKWEED IS FOOD… FOR NOW

On a positive note for duckweed consumption, none of the respondents in either of both visited countries denied duckweed to be human food. Some emphasized that their ancestors had been eating it for a long time already, sometimes even taking it as medicine. Only one interviewee from India explained that there, duckweed is also present but solely used as animal feed, which leads to a totally different perception of the plant. However, all of my interviewees had already heard of duckweed, and one of them noted that people who don't know it could first wonder whether it is a plant, food or even an animal when first seeing it. This supposition was confirmed, as most of the random people I talked with on Bangkok streets hadn't heard about duckweed and often instantly asked what it was.

Also, Medicine students met on a Bangkok campus expressed some concerns about humans eating duckweed when being shown a picture of the plant growing on a pond. With a declining awareness of duckweed as younger generations replace the older ones without necessarily inheriting knowledge of this food, some declare that the food is bound to disappear from Southeast Asian plates in the near future. For now, we could conclude that the recognition as food seems indeed to play a role, but mainly outside of Thai or Lao borders (like in India). Within the two Southeastern countries, people either know duckweed as human food, or not at all.

5.2.9 IMPACT ON CONSUMPTION MORE THAN AWARENESS

Looking back at the presented results, the investigated aspects, including the ones that were discovered along the way and added to the initially selected seven, all seem to bring more clues to understand duckweed consumption than awareness. Considering the initial presentation of those aspects, such observation makes sense as I realize that most of the literature mobilized to motivate my aspect selection actually addresses influences on food consumption rather than awareness. In fact, it looks like all aspects (except maybe for access) presume awareness, as it constitutes a logical first step for consumption. In the end, it seems sensible to relocate awareness from the explained to the explanatory side of the framework, as it influences consumption alongside the other identified relevant aspects.

5.3: Possible futures for duckweed

After getting a clearer understanding of what drives DAC today, we will now have a look into what it will be made of tomorrow. While my third subquestion about possible futures for duckweed was not formulated as such before starting fieldwork, I happened to collect several expressions of hopes, concerns or even more concrete visions for different forms of development of duckweed as human food, which were sometimes very contrasting from each other. Considering the richness of content shared about this topic, I decided to group it under an additional subquestion about the future development of duckweed, which seems also relevant for a research project like this one investigating an assumed potential that still awaits to be unleashed. The three sections below will expose people's expectations about the development of the food in the near future, followed by the experiences and goals of one of the first firms producing and selling monitored duckweed, as well as public initiatives launched by the Thai government.

5.3.1 Concerns over duckweed disappearance

In Laos as well as in Isaan, older people are worried about younger generations losing their connection to the food heritage of their ethnic group. This happens as they often move to cities to make a better living than in their rural hometown. There, as mentioned above, they often don't find the products they would find at their local market back home and easily get attracted by foreign, convenient food which better fits the urban lifestyle. "[Duckweed] is considered one of the ancient menus or diet and the new generation doesn't realise what it is", shared a duckweed farmer. An interviewed Ethnobotany student namely mentioned that duckweed isn't the only plant or food with interesting health benefits that is known only in certain rural areas and barely in urban settings anymore, as this knowledge fails to be passed onto the next generations. Concerns around this loss of knowledge about Southeast Asian food plants over time have been shared before by Wester and Chuensanguansat (1994).

While Isaan/Lao elderly seem to hold tight onto this culture of theirs, a majority of younger interviewees did not express much interest in duckweed nor concern for its future development. The few who expressed a concern, were rather worried about the overall food production of tomorrow, without being specifically concerned about duckweed, as is it not part of their current diet: "I don't know about duckweed, but in general there is a decrease in the quality of the natural resources producing our food, like polluted rivers and lands" shared a Bangkok student.

Besides a gradual disinterest in duckweed over time, the decreasing availability of duckweed due to environmental degradation is the other reason behind the concern of many Lao/Isaan elderly of duckweed disappearing from their plates and ponds. Together, these two factors lead to an unexploited and endangered potential of duckweed. These are the reasons behind several initiatives which all have in common to try and restore the rightful value of duckweed, and which will be presented below.

5.3.2 flo Wolffia

The depletion of safe natural food sources coupled to the rising concern among consumers worldwide around the quality of their food are the very reason behind the birth of the first of these projects – as indicated the founder of the start up Advanced Green Farms (AGF). From an idea to produce an ultra-clean duckweed was born flo Wolffia: this high-end *Wolffia globosa* produced and marketed by AGF in Thailand (see figure 9). Since 2019, their product is industrially grown in indoor controlled water basins

and enhanced in protein, vitamin B12, iron, calcium and zinc. With this close production monitoring, AGF is here betting on the insertion of flo Wolffia on a premium market to get rid of the unpopular "traditional food" label stuck to duckweed. This image upgrade seems efficient as flo Wolffia is already making its name in Bangkok as the "green caviar". Several discussions with the founder, as well as an interview with the managing director of AGF gave me a complete insight into their product, current strategy, and ambitions, which are presented below.

Figure 9. flo Wolffia is boxed in a transparent packaging featuring nutritional and health claims aiming at generating trust from new consumers.

5.3.2.1 Access

flo Wolffia is a fresh, ready-to-eat product which can be ordered online (only) in two different box sizes for ten times the average Thai market price. It can also be found on the menu of a growing number of restaurants throughout the city, around fifty to this day, and counting. While these selling points represent the only chance for people in Bangkok to actually see flo Wolffia – or duckweed at all, for that matter – its availability at those places is often not advertised at all and therefore unknown to most visitors or passers-by.

Yet, those restaurants are a strategic choice in terms of reputation transfer from the place of consumption to the product (flo Wolffia), and the start up plans to increase the number of partnerships. While they also plan a supermarket launch soon, the issue with that type of selling point is the impossibility to communicate directly with each consumer to make sure no misinformation develops about their product. AGF want to hold the strings of information stream around flo Wolffia for as long as possible to first convince a maximum of consumers with the right arguments. This is the reason why, so far, their duckweed is only available online where consumers can be reached directly through the contact details they leave behind during the order.

5.3.2.2 Marketing strategy

Through their direct communication with consumers, AGF want their public to know 1) what duckweed is 2) why it is good for them 3) how to eat it. To first increase awareness of the plant itself, AGF intend to get people to be more in touch with their duckweed by namely recreating a pond on a fishbowl at any event they show up to. And in the future, they intend to open part of their high-tech farm for people to come and touch their product, besides having a café area where visitors could directly taste products made from the duckweed growing there. They especially believe in kids being able to play around and get familiar with it, as they represent the next wave of AGF customers and overall duckweed consumers.

Another attempt at boosting flo Wolffia's uptake was recently made by mixing it into a coconut ice cream (see figure 10) and selling it at a university fair in Bangkok. The experiment was a huge success, partly thanks to the already high popularity of coconut ice cream among Thai people. A key factor seems therefore to pair it with already adopted foods to create a positive association for people to then start ordering fresh flo Wolffia. Until the students reached at the fair turn into actual customers, most of regular flo Wolffia consumers so far are a niche of upper-middle class people with often an interest in nutrition and/or sustainability.

Figure 10. The coconut-duckweed "coflonut" ice cream topped with flo Wolffia successfully sold at a university fair contributed to a popularity boost of AGF's duckweed among the Bangkok student community.

Yet, the number of flo Wolffia consumers is expected to grow with upcoming TV apparitions and the government's support as part of Thailand's future food program. There even seems to already be a certain excitement around flo Wolffia itself, especially among students after the hit with the coconut-duckweed ice cream at the university fair that made the food go viral on the internet. While the hype seems to come in waves for now, AGF's managing director is confident about the stabilisation of their

product's success, until flo Wolffia becomes a synonym for duckweed in the capital city. While AGF founder estimated duckweed awareness to be at 2% (200.00 people) among Bangkok inhabitants before the arrival of flo Wolffia, he estimates to have now reached another 1% (100.000) with his product.

The second point of AGF's marketing plan is the showcasing of the benefits of their flagship product. The first aspect advertised by AGF's managing director is its convenience, as it fits the needs of a busy "sandwich generation". flo Wolffia can easily cover their own nutritional needs, but also those of elderly and youngsters who might have issues getting all their nutrients in from other vegetables, respectively for chewing difficulties and general dislike of green food.

Besides the convenience, AGF's monitored duckweed is also sold with food quality, sustainability and health arguments. Especially for this last reason, the company argues that their price of 1000 THB/kg is not expensive considering the nutrition acquired per THB (compared to supplements). They say to price their product like any other trendy superfood (kale, açai, etc.) as it fulfils the same needs. However, AGF aims at lowering the price to that of an organic vegetable (200-300 THB/kg) to make their product affordable for a wider public. This should be possible when all their duckweed growing ponds are built, and marketing expenses can be reduced once their product is better known. Only then, would flo Wolffia also have a chance at contributing to nutrition security. Besides health benefits, AGF's product claims zero waste, minimal land use, circular water use, solar electricity and other sustainability arguments – to which, however, their public isn't quite receptive (yet).

Last but not least, according to AGF founder, flo Wolffia aims to be a synonym of highest food safety and quality (FSQ) level. This is namely the reason why flo Wolffia now gains customers from the Isaan region, where some decide to switch to cleaner duckweed than the one they can sometimes barely find in their natural ponds. This last characteristic seems to hold the ability of flo Wolffia to unlock the potential of worldwide expansion of duckweed consumption.

Talking about consumption, the third point of communication AGF are banking on is the familiarity of the public with various ways to introduce flo Wolffia in their daily life. With its neutral taste, flo Wolffia consumers in the capital city explained that they would simply top any of their meals with about two spoonsful of the "green caviar", straight from the box without intermediate cooking or washing step (as this is not necessary). While most still associate it with savory dishes only, AGF claim their product to be so versatile that it could fit just any type of food, savory or sweet. Except for one traditional Isaan restaurant, the places which partnered up with AGF to offer duckweed on their menu tend to feature it in a modern way such as a sushi or salad topping, a burger patty ingredient or açai bowls. As if to continue along the foreign food trend, a popular recipe AGF recommend to their consumers is to mix flo Wolffia with some olive oil, salt, and pepper to create a bread spread similar to pesto.

According to many respondents, not knowing about this versatility or how to consume the food at all is the main factor holding them and probably other people back from consuming it. AGF's founder estimated that 90% of the few Bangkokians who have heard of duckweed don't know how to cook it, and named this general unfamiliarity as one of the reasons behind the rather slow introduction of flo Wolffia in the capital's food landscape. Therefore, AGF plans on further presenting flo Wolffia to the public and controlling the discourse over its benefits and versatility as a discreet, but powerful ingredient.

5.3.2.3 Competition

While AGF aims to reach a strong position on the duckweed market, this ambition is not aimed against competitors there. AGF's managing director clarifies that they don't compete directly with duckweed farmers outside Bangkok, since they work with different quality standards. Quite the contrary, they can benefit from each other by simultaneously increasing overall duckweed awareness and demand. While AGF are currently the trend-setters for high quality duckweed in Thailand, they expect some soon-to-come competition to eventually catch up. Yet they are not too worried (yet) about those since AGF first went through years of research to come up with an optimized product: the best strain in the best growing conditions and water mix, using the best fertilizer mix, etc. Their only worry is if duckweed production reaches such extent that less informed consumers are not able to tell the difference in safety standards between producers and start eating less clean duckweed raw – leading to undesirable public health issues.

For now, besides a handful of specific Isaan markets in Bangkok where duckweed can be found for 40 THB/kg, Advanced Green Farm (AGF) have a virtual monopoly over the city in terms of monitored duckweed offer. But an expansion of duckweed consumption, and therefore production, coupled with correct information about the food and its adequate preparation would represent a positive development in AGF's eye. Their mid-term ambition is to have everyone know about duckweed in Thailand and to launch their product in other forms (frozen, dry powder) to fit different needs. On the longer term, they aim to make their product more accessible both physically and financially for a worldwide reach of duckweed for a healthier planet and people.

5.3.2.4 Perception from potential consumers

I presented flo Wolffia to my interviewees and asked them what they think of this food product, and whether they would consider buying it. The gained insights inform us on the potential of monitored duckweed to boost duckweed awareness and consumption, or if other improvements, for instance to the production chain, to the packaging or to the taste, would be more efficient to lead to an upscaled consumption. Keeping in mind that a social desirability bias might lead to a discrepancy between what consumers say their consumption intentions are and what they would actually buy if the product was available to them, this is what I collected from my interviewees.

First, all our respondents across all contexts and age groups are willing to try it as they say it looks clean, safe and healthy when seeing the picture of a flo Wolffia box. Many particularly appreciate the modern packaging, adding that it would really help to make the product attractive, especially among younger generations. The transparency of the box was both mentioned as a positive point so the consumer could see what is inside and it could help build trust, as well as a negative point as the "very green" colour could be off-putting for some potential consumers. Only a slight majority of participants though are willing to pay the premium price for these benefits. These justified the price by the difficulty to access duckweed – by collecting it directly from ponds or to find it on markets, at least during certain months throughout the year.

Talking about access, especially older people seemed disappointed to hear that you could only order the product online as they did not feel comfortable with that type of purchase modality. Some added that they would not trust online shopping and preferred to see and touch what they would then be able to consciously buy or not. Others were worried about the decline in freshness of the product if it was for instance delivered to their door when absent. The worry of not having the possibility to directly

store the box in the fridge seems legitimate, considering that temperatures in Bangkok for instance reach 30-35 degrees Celsius all year round.

On the contrary, especially Vientiane and Bangkok residents liked the convenience of online shopping as it allowed them to save the time that a trip to the supermarket would take them.

5.3.2.5 Perception from consumers

Besides asking my interviewees about their opinion on flo Wolffia, I also collected feedbacks from three regular users. These flo Wolffia consumers praise the convenience of the product which can be topped on basically any food. They also appreciate its taste neutrality and tiny size which allow them to dissimulate the food in any dish, when necessary, for instance to make kids eat their vegetables without even noticing to avoid any resistance. One consumer eats it on such a regular basis that she regretted the impossibility to subscribe for a monthly delivery.

Besides the convenience, some consumers are convinced by the safety standards reached by the product. According to AGF founder, some Isaan consumers used to always eat the natural duckweed they have there, but switched to flo Wolffia once they heard about the difference in cleanliness levels between both sources. The only negative remarks concerned the price of flo Wolffia itself, or of the shipping costs that inevitably come with it as a product that is so far exclusively sold online.

Overall, when asked what could be improved in or around the product, many respondents suggested advertisements on various media to increase the reach of flo Wolffia. This should be efficient as the product fits the characteristics of several ongoing food trends in Bangkok like convenience and healthy (with other superfoods like spirulina, kale, açai being a hit), and to a minor but increasing extent, sustainability. AGF founder is confident that this last aspect will become of increasing importance in the coming years in Southeast Asia, which will make his environmentally friendly product shine in the light of this coming trend. With this, flo Wolffia is expected to soon become the standard for duckweed in the Thai capital city and beyond.

5.3.3 Thai Government Initiatives

In Thailand, we saw that duckweed consumption is to a large extent confined to the Isaan region and people. Yet in this community, it seems not always to be taken up in the diets of the next generations and is therefore at risk of disappearing in the long run. In order to counter this fate and loosen this strict link to Isaan cuisine, the Thai government recently started to invest public money in various projects from subventions for duckweed farmers to research and development of (functional) duckweed products. Conducting interviews with five people involved in diverse ways in those projects allowed to gather the following information.

5.3.3.1 Public Initiatives

Besides supporting flo Wolffia with appearances on national news, the Thai Government has two main ongoing projects to promote duckweed. Once as an alternative protein source, which changes its vegetable status in traditional cuisine where it is cooked with other source of protein and will require a mindset shift for its uptake. And once as a “value crop” among others (potato, sweet potato, sugar cane, oil palm, fern, banana) to help boost the economy of the country. This official support gives the food some much-needed media coverage.

The aim of the second project is to pass on knowledge to farmers for them to take up the cultivation of duckweed and improve their income. This transmission happens at monthly local “festivals” where farmers are shown how to grow, but also prepare and cook the plant, in order for them to further sell it to their future customers. In parallel, both farms visited in the West of the country host workshops to train future duckweed farmers and sell starter cultures to them.

In the meantime, flo Wolffia is expected to build a positive duckweed image for those future duckweed producers. Duckweed is seen as a “value crop” because of its low resource and maintenance, and high selling price compared to rice – which most farmers still grow nowadays in Thailand. Apart from the production side, the government interacts with potential consumers by implementing projects for schools to have their own duckweed pond and familiarize the students with this food, as they then have it on their school lunch menu.

The government-supported project includes a nutrition security aspect. Indeed, a government worker reported a concerning number of students in rural areas to be too thin or short as a result of poor nutrition. It seems like people there might always have access to food, but not to the right nutrients from it. The cultivation and inclusion of duckweed in their lunches is seen as a remedy for this issue.

At the same time, the students are encouraged to start their own for-profit duckweed cultivation at home. This mission and additional income should incentivize them to then start an established business out of it and, therefore, to stay in their home village instead of leaving for Bangkok, and with that help sustaining the development of their local community. The project is being implemented not only in areas where duckweed is already part of the local food plate, but in all regions of the country with a suitable climate for duckweed growth.

The Thai government is aware of the unattractiveness of traditional food, especially for the younger generations. Therefore, they experiment with fusion cuisine, featuring duckweed in popular Western or Japanese foods such as avocado toast or sushi. One of the visited farms also followed the idea by selling “modern products” featuring duckweed such as cookies or milkshakes. Additionally, they created a menu for their café area (see figure 11) showing different ways to cook the green vegetable for people to get familiar with it. Yet, so far, there is a bigger enthusiasm from the supply side and the Government, than from the consumer’s side.

Figure 11. The café area opened at one of the visited duckweed farms thanks to the support of governmental funds. The menu features among others a “Wolffia latte”, a “Wolffia lemonade” and a “Wolffia curry”.

Two other government funded initiatives indirectly supporting duckweed in specific locations are “community centers” and “community enterprise”. The first are the result of a governmental policy to promote local communities with unique products from each village/district by building an area where those could be sold and create a revenue stream out of visitors. In the villages hosting duckweed farms in the West of the country, duckweed products like crackers are sold at an affordable price. The second are entrepreneurial projects undertaken by students and recent graduates with the financial support of the government. There, the students focus namely on improving farmer income and artificially increase the price of duckweed on local markets from 10 THB to 20-30 THB to create more revenue, while keeping it relatively low to guarantee the affordability of this food.

5.3.3.2 Research

Besides these projects, the Thai government supports several ongoing research and food product development projects which suggest an expansion of duckweed availability in different forms in the coming years: drinks, deserts, pastries, spreads, salad dressings, jellies, etc. The main challenges for the development of such products are food safety regulations and consumer acceptance (taste, appearance, ‘user friendliness’, shelf life). While the absence of a distinctive duckweed taste is a major advantage for the development of future duckweed-based food products, (compared to algae which comes with a strong “sea smell” for instance), the green colour has shown before to be uninviting for potential consumers. This is namely the reason why a startup experimenting with a green duckweed drink chose an opaque over a transparent bottle. Besides making them appealing, high-tech product developers expressed the importance of keeping their production costs to a minimum by limiting high levels of processing and technology, with the aim to market affordable products for a majority of consumers.

With this, we see that, despite a large portion of Southeast Asians being unaware of the very existence of duckweed, some Thai actors at least recognize and work on activating its potential as a valuable human food, while protecting it from going extinct or falling into oblivion. Instead, duckweed now shows promising chances to improve livelihoods locally, and health of future consumers globally.

5.3.4 Conclusion

The duckweed products that are currently being developed by the dedicated research are still to be commercialized to assess their impact on duckweed awareness and consumption. Yet, the public initiatives funded by the Thai government seem to already have influenced part of the duckweed consumption observed during my fieldwork, namely with the support to the two visited duckweed farms as well as the community centers.

While these public Thai projects to boost duckweed production and consumption are still in their early steps, Advanced Green Farm's monitored duckweed in the form of flo Wolffia is another way to save duckweed from its risk of disappearing through an improved status and access. In Laos, however, there is no known industrial scale production of duckweed to this date, nor any other public or private initiative to counter the reported declining duckweed awareness and consumption. Hopefully, the projects initiated in the neighbouring country will prove successful and have an impact across national borders – to reach Laos and beyond.

CHAPTER 6: DISCUSSION

After exposing my results, I will now screen them in the light of the hypotheses formulated earlier based on available literature. This will then allow us to discuss the suitability of my framework and assess the scientific relevance of my findings. Switching to a broader angle, I will end this chapter with a reflection on my initial problem statement and the overall strengths and weaknesses of my research.

6.1: LITERATURE VS. MY FINDINGS

The literature on which the conceptual framework builds allowed me to formulate some expectations, namely regarding the impact the seven selected aspects would have on duckweed awareness and consumption. Looking back at them one by one with my results in mind, we see that in (the observed) reality, some aspects were influential in the expected way, and others less, or in a different way.

6.1.1 RECOGNITION AS FOOD

Except for one Indian interviewee who was currently working in Thailand, all of my respondents who had heard about duckweed were introduced to it as food, as no one talked about the plant as anything else than human food. To some extent, this general belief around duckweed meets Rozin's point that people get introduced to foods "as a form of cultural wisdom" (2007, p. 5), and in this case, duckweed would be part of Lao/Isaan wisdom that gets (less and less) passed on to further generations. This aligns with the sayings of some of my interviewees who expected most people outside of Lao or Isaan culture not to know it, or only a few who would somehow have knowledge about this other culture than theirs.

Among people who are aware of, and therefore able to categorize duckweed in the food or non-food category, Fiddes' divide exemplified through horse meat in France vs. UK (1994), can here be observed between Laos/Thailand and other countries like India for instance, thanks to one respondent who shared how duckweed was also present there but would never possibly be eaten by humans, as it is solely used as fish feed there. While this example of Fiddes' divide only bases on the sayings of one single interviewee, it can – to a certain extent – be backed up by literature: Koeleman's article is about "duckweed for balanced fish diets in India" (2020), but still mentions at one point a human consumption by a minority of Northeastern Indians. It would therefore take some additional research to draw conclusions about the status of duckweed in that country, but so far it looks like Fiddes' divide is observable in those different uses of duckweed reported from India.

6.1.2 FOOD INSECURITY

Although I didn't find anyone who (still) eats duckweed as a means to relieve their food insecurity, several respondents assumed that the food found in nature could well be useful in this sense for people who are still food insecure. Yet, we don't have enough information from people in such situation to conclude on this potential incentive for duckweed consumption, as initially assumed from Reuter et al.'s finding for wild meat in Madagascar (2016) and other African countries (Lindsey et al., 2013).

Yet, a decreasing and lower availability, stability and utilisation of duckweed than expected already informs us on the limited ability of the aquatic plant to counter food insecurity, as food insecure people could not all rely on duckweed (anymore) for their daily nutritional intake - at least not all year round.

6.1.3 Access

Many respondents who know about duckweed collection pictured it as a rather difficult activity or mentioned that markets with duckweed would sometimes be located far away from their home. Also, the online access newly available in Thailand is only an option for those with internet connection and usage skills. Therefore, physical access does seem to play a role as generally indicated by Bakker et al. (2021), both for the collected as well as the market bought duckweed.

Financial access however seemed to play less of a role, as the price of duckweed or its free access in nature seemed to be neither a hurdle nor an incentive for people to get it. As it seems that other aspects like physical access, taste or availability have more influence on duckweed consumption than its price, I did not observe the expected price elasticity presented by Kinsey (1997) among my interviewees.

6.1.4 Status concerns

The status associated with duckweed seems indeed to be of importance as demonstrated with other foods by Zhu et al. (2015) and Chan & Zlatevska (2019). In our case, duckweed seems to have a rather low status especially among younger urban citizens. However, the socioeconomic reasons advanced by Iqbal (1999) for this unpopularity are not verified by the answers collected from my respondents. Iqbal stated duckweed to be associated with precarity pushing poor people to consume “dirty” foods like duckweed, which would give it the reputation of “poor man’s food” (1999). Yet the sayings of my interviewees rather revealed a stigmatization of the food as old-fashioned for a younger public, as it doesn’t exactly fit the standards of the foreign, convenient foods which seem to be currently popular, especially in urban areas.

The difference in reputation of the same food between Iqbal’s and my findings might derive from several points. First of all, there are twenty-four years separating both publications, and it seems like Iqbal bases on findings published by Bhanthumnavin and McCarry in 1971, pushing the initial source another twenty-eight years back. Unfortunately, Bhanthumnavin and McCarry do not mention the source of their statements about duckweed consumption and status fifty-two years ago. They mention having observed the harvesting activity of locals in over a hundred ponds and one could deduct that such statements about the food’s reputation were collected during interactions with the said locals. Yet this will remain an assumption, as there is no trace of such form of more or less structured interviews in their methods.

Besides a fifty-year evolution of social and cultural norms around foods, possible sources of the results discrepancy might come from a difference in the observed target group, in the chosen angle to approach the topic or in the methods used to get to those findings.

6.1.5 Safety concerns

As expected, based on Wilcock et al.’s statement (2004), Lao and Thai consumers do indeed show some safety concerns towards duckweed, as all of my interviewees clarified that it needs to be cooked before consumption in order to get rid of contaminating microorganisms. Yet, the trust in this form of heat treatment of food seems relatively high, especially in rural areas. Some interviewees expressed that, especially for older people, boiling or fermenting is perceived as enough treatment to eat a wide range of animals or plants found in nature. Based on this statement, the safety barrier raised by Iqbal (1999)

would be less of an issue than he stated. However, one should be careful about what someone says about someone else's behaviour, or in this case, eating habits, especially when both come from two distinct groups differentiated by social markers that already seem relevant for other aspects around this topic (like age, here). Sticking to the sayings of my interviewees about their own perception of duckweed, I can however confirm that none of them commented the consumption of duckweed, or any "traditional" food for the matter, to be risky. Yet that perception might change if the fact that boiling duckweed is not sufficient to get rid of possible contaminants such as heavy metals gets more widely known (Nosowitz, 2021).

Finally, both theories about how the natural origin of duckweed could be perceived positively (Mancini & Antonioli, 2020) or negatively (Gijzen & Khondker, 1997) found some resonance among different respondents. This diversity of perceptions within a same cohort supports the possibility of having a source for the above-mentioned results discrepancy (about duckweed's reputation) in the fact that specific people were interviewed then and now, and not others.

6.1.6 Health & sustainability considerations

In terms of health considerations, it seems like only a minority, which doesn't coincide with the most typical duckweed eating interviewees (older Lao/Isaan people living in rural areas), take health considerations into account in their food choices. Therefore, Kinsey's statement that health considerations increase the intake of micronutrients (1997) cannot be verified with my interviewees. In fact, Kinsey's statement could be specified with the sayings of Phum brand owner that upper middle class and well-educated people show that kind of knowledge and interest in dietetics. While it would be too much to assume that duckweed eaters in Laos and Thailand don't know about this diet-health link, it seems like if they do, it would not be the first reason for their consumption of the plant.

The same conclusion can be drawn for sustainability concerns which seem to guide duckweed consumption and, it seems, overall food choices, to a very minimal amount among my respondents. This contrasts with the trend of environmentally sustainable food consumption identified by Vermeir and colleagues in high-income countries (2020), showing its in- or lower validity for (at least a part of) Southeast Asian people.

Overall, the nutritional and environmental benefits that motivated this whole thesis only seem to be of minimal interest to a majority in Southeast Asia. In that regard, a substantial educational effort would be needed for the informed and sensitive niche to become a majority, and such more popular concerns to then push for generalized duckweed consumption.

6.1.7 Taste

Regarding expectations related to the taste of duckweed, the neutrality reported by Mes and colleague's experiment (2022) was the most common answer collected from my interviewees as well (which all consumed *Wolffia globosa*). Some, however, still agreed with Iqbal's (1999) and van den Berg and colleague's (2015) unpleasant description of the plant's taste. This shows that taste remains a highly personal evaluation, while it would be possible with some large-scale research to detect generally more or less popular flavor directions among a specific target group.

Furthermore, my personal assumption that taste was relevant was largely confirmed by the many mentions of the primacy of taste on food choices in Southeast Asia, as if this attention brought to the

deliciousness of their food was part of the regional identity there. However, observing a similarly high importance given to the appearance of food – or in our case, the reluctance generated by the "very green" colour of duckweed among a younger, mostly urban public – was much more of a surprise and not expected on the base of any literature mentioning such phenomenon.

6.1.8 Unexpected aspects

Besides looking into financial and physical access, it looks like I overall failed to foresee the importance of other dimensions of food security like utilisation, availability and stability in the case of duckweed consumption. Indeed, many seemed to be constrained in their duckweed consumption by, on the one hand, a lack of knowledge, skills or appropriate tools to collect or prepare duckweed. And on the other hand, by its inconsistent and decreasing availability throughout the year and the visited countries.

This growing instability is the reason why many older people especially are not optimistic regarding the future consumption of the plant. After some additional literature search on this topic, I found that Bhanthumnavin and McCarry (1971) mention excessive or insufficient rainfall as constraining parameters for the growth of duckweed as wastewater treating plant. This point seems to be transferable to duckweed as human food, as I expect the lack or excess of water to be constraining for any duckweed species (including *Wolffia globosa*), or even for a majority of aquatic plants.

Yet the main explanation for the unexpectedly low availability seems to be specifically linked to *Wolffia globosa*. Indeed, according to Advanced Green Farm (AGF)'s founder who spent years researching this exact duckweed species to grow it in the best possible way, *Wolffia globosa* is a way less robust species than others from other genera like for instance *Lemna* or *Spirodela* found in the same Southeast Asian environment. This means that *Wolffia globosa* will often not be able to grow where *Lemna* or *Spirodela* species will, as it needs way stricter water and environmental conditions to appear on a pond, and sometimes only survives with the help of other *Lemna* species, as shared by AGF founder. Therefore, another source besides climate change for the discrepancy between my findings and the expectations formulated earlier based on the literature might come from the fact that the image of an all-available duckweed found in several articles does not apply to all species – or at least not to the more fragile *Wolffia globosa*.

Lastly, repositioning the lack of awareness as an explanatory factor for duckweed consumption allows to understand a further portion of the state of duckweed consumption in Laos and Thailand. Indeed, a study about functional food consumption shows that the factor having by far the highest impact on it is increased awareness and knowledge (Vella et al., 2014). Distinguishing awareness from knowledge, we understand that, while having heard (awareness) of a food obviously seems like a necessary first step, additional knowledge about a new, unknown food increases the chances of actual consumption - working with confidence and trust mechanisms (Vella et al., 2014).

6.2: Suitability of conceptual framework

This research focuses on seven aspects which were expected to have influence on duckweed awareness and consumption (DAC). As exposed above, the realities observed in different contexts sometimes confirmed or refuted those assumptions to various degrees, while also bringing other relevant aspects to light. While being overall fairly informative of duckweed consumption, I realized in the course of my analysis that I was mainly getting findings regarding this part of the dependent variable DAC, and barely

about the other part: awareness. Of the seven observed aspects, it seems like only access and, to a lower extent, the status concerns (in the sense that they would make a less popular collected type of duckweed less advertised and communicated about to a wider public) could have an influence on awareness. It therefore seems like awareness is just another aspect that enables or limits consumption, and therefore should be moved to the independent variables of my framework. This realization makes sense as the finality of this work is to look into how, where, why, and by whom duckweed is eaten in order to expand its consumption, and not just to get it known. Awareness is a first step, but not enough for duckweed to have an impact on human and planetary health – it takes actual consumption. And to inform the expansion of duckweed (production and) consumption, my third subquestion helps to understand what individuals seem to be valuing or missing in duckweed or in the more or less direct context of consumption for the food product to ideally meet their needs and interests.

Based on this, I am satisfied with finding out more about consumption than awareness through the seven selected aspects and the additional ones discovered along the way. For another research project with the specific aim of understanding more about the awareness of duckweed or any other specific unpopular food, one could imagine an adaptation of the framework to include key concepts like socialization. This specific and other possibly mobilized concepts would give insights into how individuals, as members of a particular society, get passed on – by different instances and in different situations – and interiorize knowledge about, for instance, specific foods and not others (Parke et al., 2008; Rozin, 2007). For now, I would consider awareness as an eighth aspect allowing or limiting duckweed consumption and would assess this independent variable to play a substantial role in duckweed consumption as a necessary first step.

6.3: Reflection on the problem statement

This research was born from an interest in duckweed sparked by its assumed potential to feed the world in a highly nutritious and environmentally sustainable way. While being at first disappointed that this excitement for duckweed's exceptional nutritional profile and environmental impact seemed not really to be shared by Thai and Lao locals, I now understand that the potential of duckweed to relieve food insecurity at all is limited by various aspects.

Indeed, duckweed seems to be of a weaker contribution than expected to the four pillars of food security. While for now financial access seems not to be a major issue, I largely underestimated the difficulty to physically access duckweed, in nature by means of rather tedious effort, or in the rare markets where it seasonally available. My initial imagination that foraging duckweed for free on natural ponds would be a joyful task comparable to berry picking was rather far off the reality I witnessed once on site. Access seems also (increasingly) constrained by a lower availability than expected, and the fact that the amount of duckweed found in nature is even currently decreasing shows a lack of stability to contribute to food security. Lastly, the collected data has shown utilisation to be a majorly underestimated hurdle to the consumption of duckweed.

Besides, these four unsteady food security pillars, the rather low popularity of duckweed can further be explained by the most relevant of the aspects discussed above, namely status concerns, taste and awareness. However, identifying those hurdles does not dim duckweed's potential to contribute to human and planetary health. On the contrary, this reality check allows us to plan and take targeted action to lift these obstacles currently limiting the further development of duckweed. But understanding that duckweed is at risk of disappearing from Thai and Lao plates and nature, we need

not only efforts to increase duckweed consumption, but also availability. Moreover, an additional challenge lies in limiting the additional costs generated with these conservation and upscaling efforts, or at least limiting their repercussion on the price offered to end consumers. Keeping the food affordable is necessary to safeguard the food security pillar of financial access.

Although the health and sustainability arguments for duckweed seemed not to be as convincing to the ears of Thai and Lao locals than they were to me, these aspects are expected to find more resonance among Western consumers (Vermeir et al., 2020). While this public also expect impeccable quality and safety of their food (Wilcock et al., 2004), a closely monitored product like flo Wolffia might be ideally, or at least better suited to such consumer requirements than the duckweed that the population of higher-income countries (HICs) might find there on their natural ponds. Furthermore, higher-income households tendentially spend more on food than lower-income households (Kinsey, 1997). Therefore, we could expect the price of flo Wolffia that many respondents assessed to be high, to represent less of a hurdle in the purchase process of this product. This affordability coupled to the safety, health and environmental arguments of a duckweed product like flo Wolffia are all elements building expectations for a successful uptake of duckweed as human food in HICs.

Yet for now, only duckweed protein powder has recently been approved as a safe human novel food by the European Food Safety Authority (EFSA Panel on Nutrition et al., 2023). We can therefore imagine that duckweed will first make its name into the old continent with an introduction under this dry form, which might also suit European consumer preferences. According to Santeramo et al. (2018), novel foods and functional foods constitute two of the three current food trends in Europe – two categories in which the extracted duckweed powder fits. From there, we could imagine a positive image of duckweed potentially built by the derived protein powder to pave the way for a later successful uptake of a fresh duckweed product.

While this identified potential in Europe and HICs represents a positive base for a global expansion of duckweed, the biggest need for nutritious, affordable and environmentally friendly foods remains in Low- and Middle-Income Countries (LMICs), as those overall suffer most from diet-related health issues, and environmental and health consequences of climate change (Fanzo & Davis, 2019). Furthermore, for the sake of reducing global inequalities that were amplified by the Anthropocene, LMICs are the countries which should benefit most from future research (in various domains). In this sense, besides efforts to reach HICs in a worldwide duckweed consumption goal, the focus on lifting the barriers limiting duckweed consumption where it is already consumed and in other LMICs should not be lost.

6.4: Scientific relevance of findings

The exposed findings and their discussion seem to bring substantial response elements to my research questions about the facets and extent of human duckweed consumption in Laos and Thailand, its more or less influencing aspects and possible future developments. Besides offering sufficient material to answer my research questions, my results can be used to develop hypotheses on the consumption facets and extent of other food products. These could be similar to duckweed for instance in terms of cultural attachment, low awareness or popularity, or natural (aquatic) origin. While some of the seven researched aspects are more specific to a certain type of foods (e.g., status concerns, recognition as food), others could also bring wider indications about what elements influence general food choices in

Laos and Thailand (e.g., health and sustainability considerations, access) – for instance to base the hypotheses of further research on.

Furthermore, my data and analysis constitute, to my knowledge, the first contribution to Social Scientific research about duckweed consumption. Admittedly, there seems to be some contradiction as in my findings only *Wolffia globosa* consumption was reported by my interviewees – which is aligned with Appenroth and colleagues (2017), while Bhanthumnavin & Mcgarry (1971) or Xu and colleagues (2021) for instance only mention *Wolffia arrhiza* in their article. Of course, despite one of my sources being a Plant Biology Professor and founder of his own duckweed growing company, I can only base my findings on what is reported to me, as I don't have the means and skills to identify by myself the duckweed species I observed during my fieldwork. But whether it is indeed *Wolffia globosa*, or in fact *Wolffia arrhiza* – or a mix of both – that my research is about, it seems like my findings – except maybe for taste (in case both species feature different sensory profiles) – are applicable to any comestible and available duckweed species in Thailand and Laos.

Last but not least, the formulation of hypotheses based on existing literature prior to data collection allows to contribute to the relativisation or reinforcement of the mobilized existing findings. Where my findings would not align with those in the selected literature, I conclude that my research enriched the latter by unveiling contextual variations. Also, it should be noted that, I selected a specific set of literature to compose a conceptual framework and this selection was based on estimated similarity to the case of duckweed in Laos and Thailand. Yet I am aware of the multitude of existing articles offering similar levels of relevance for my topic and presenting different, sometimes diametrically opposite findings. While it seems impossible for me to screen my results through all the relevant existing literature and draw comparative conclusions, I invite future researchers on the topic to use the material from my research and review it in the light of a different set of literature. Another set of articles could also be found to screen and review my unexpected findings for which I did not formulate upfront hypotheses. All in all, I hope for the present report to serve as a base for future research on this or other nutritious, potentially underrated plants in order to better understand and utilize them.

6.5 Strengths and weaknesses

6.5.1 Reach

If we reconsider the aim of this research to understand more about duckweed consumption only, it looks like my data collection and analysis allowed for a richness of exploratory understandings in the Southeast Asian context. Of course, the immensity and diversity of this region cannot be covered through this single research project and my findings would immensely benefit from further investigations on the same or related topics, in order to then further inform the potential upscaling of duckweed consumption to other regions as well.

6.5.2 Methods

Besides the participant observation, what my data collection provided me with are subjective opinions, which were inevitably covered in an additional layer of subjectivity through the translation process. This leads to results with a validity that is closely attached to the area of research and the specific interviewees which were part of the sample.

Nevertheless, I tried to gather answers from a diversity of actors like female and male consumers and non-consumers, students, professors, government and NGO workers, diplomats, farmers, businessmen, diverse business employees, restaurant owners, waiters and cleaners, taxi drivers and passers-by. Yet, I am conscious to have probably shared more contents from highly educated and specialized people, as they provided a larger number of relevant details than other participants. The aim of this detailed content is however to contribute to the richness and usability of this thesis' findings rather than to reflect a distorted image of the observed reality.

Moreover, the aim of this study was never to generate high-scale quantitative and generalisable data. With the significant knowledge gap identified earlier in mind, the idea driving this research is to "start somewhere" with practical and context-specific insights – which is inevitably the nature of all social-scientific data (Flyvberg, 2001). As Eysenck (1976) said, it is not necessarily about proving hypotheses right or wrong, but rather about learning something about duckweed awareness and consumption (DAC). As for any other discipline, case studies like these are essential to build up the social scientific knowledge base about duckweed (Flyvbjerg, 2006). The multiplication of, and confrontation with similar case studies could allow to assess the degree of typicality of the present one, as well as build expertise on the topic through experience (Flyvbjerg, 2006; Giddens, 1984). Besides quantity, the proximity with the study subjects and the learning process it involves speak for the quality of case study research (Flyvbjerg, 2006).

Last but not least, the conceptual framework developed for this research is suitable for qualitative as well as quantitative data, which would provide a type of results particularly useful to duckweed business developers or governments, for instance. Therefore, a study using the same set of aspects to research DAC, but this time using a large-scale survey collecting quantitative data, might be worth a shot. Similarly, the outline of this research could be used to explore the consumer awareness and consumption of other unpopular but high-potential foods for human and planetary health in other contexts.

Overall, despite the unexpected change of awareness going from a dependent to an independent variable, I consider my methods to have provided me with a substantial first understanding of what drives or hinders duckweed consumption in Southeast Asia and the variations of those aspects among urban or rural areas, and across different generations and cultures, in order to inform a wider uptake of this food.

6.5.3 Conceptual framework

Besides the reallocation of awareness from an explained to an explanatory variable, my conceptual framework could have better fitted the observed reality by formulating hypothesis based on available literature about unexpected aspects like availability or utilisation. Yet the impossibility to predict what the most relevant aspects will be is the very reason motivating this research, and in fact the purpose of research in general. Nevertheless, one way the model deriving from my conceptual framework could have been improved before the data collection phase, is by building it in a way where all four aspects of food security (including access) are investigated separately in an attempt to assess the potential of duckweed to contribute to food security (see figure 12). This food security score, coupled with the food security situation in Laos and Thailand would constitute one of the six aspects informing duckweed consumption in Laos and Thailand.

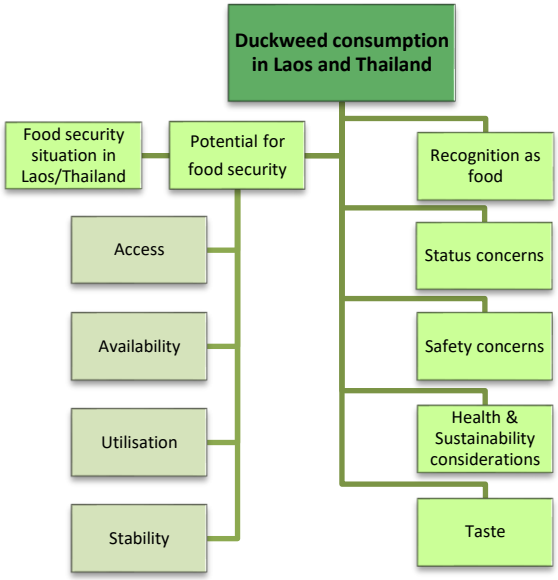

Figure 12. Possible model to investigate duckweed consumption in Laos and Thailand with a focus on the potential of duckweed to contribute to food security.

In fact, since it represents a major reason behind my interest in duckweed, assessing the potential of this plant to contribute to food security could have been one of my subquestions – if not my main research question. Yet considering my current research questions, the possibility to draw conclusions about each of the seven aspects, and to discover additional ones, proves not the perfection, but the functionality of my conceptual framework.

CHAPTER 7: CONCLUSION

Going back to my research questions, I conclude with the following findings. Duckweed awareness and consumption (DAC) are closely linked to a Lao food heritage and seem affected by both an urban-rural and generational divide, showing the highest DAC among older Lao and Isaan people living in rural areas, and the lowest DAC among younger people in urban areas without any link to Lao or Isaan culture. The aspects that seem to play a major role in duckweed consumption for both groups are awareness, access, availability and taste (see figure 13). Awareness seems to score the highest, especially for the younger of both groups, as it comes as a prerequisite for the rest of the aspects to be influential (except for access and availability).

In contrast, health and sustainability considerations, recognition as food and food insecurity seemed the least relevant, with recognition as food seeming slightly more relevant for the younger than the older group, and vice versa for food insecurity. The aspects showing the most difference between both groups are the concerns around status, and to a lower extent, those around safety and the utilisation of duckweed. Indeed, it seems like in the older, rural, Lao or Isaan group, duckweed is just a vegetable like any other that their community traditionally eats. Yet for the second group, the general image of the same food seems to be that of a suspiciously green, rather inconvenient, and dull, tasteless food which doesn't exactly benefit the popularity, and at the same time, consumption of duckweed among this target group. Safety and utilisation also raise less questions among the first group who is overall more used to preparing duckweed and foods from nature overall, than representatives from the second group.

Duckweed consumption by: **ASPECTS**	**older, rural Lao/Isaan people**	**younger, urban people without Lao/Isaan cultural background**
1) Recognition as food	-	+
2) Food insecurity	+	-
3) Access	++	++
4) Status concerns (trendiness)	-	++
5) Safety concerns	+	++
6) Health & sustainability considerations	+	+
7) Taste	++	++
Awareness	++	+++
Availability	++	++
Utilisation	+	++

Figure 13. Estimation of the degree of influence of each of the seven aspects, including three additional aspects discovered along the way (in italics), considered relevant to explain duckweed consumption for the most and least likely sociodemographic groups to consume duckweed in Laos and Thailand. Legend: [-] inexistent or minimal influence, [+] low influence, [++] moderate influence, [+++] high influence.

In the future, duckweed consumption may disappear, as feared by consumers in Laos. However, this decline may be countered by private and public initiatives in Thailand. For instance, one private company there addresses most of the main current hurdles to duckweed consumption – namely availability, physical access, and status concerns by cultivating and selling a clean, convenient, and modernly packaged duckweed. Yet the price of their product could well compromise the so far rather secure financial access to duckweed. Thai governmental projects target more status concerns among

(potential) consumers with public communication efforts, while including a focus on incentivizing production as well, as they see a double potential in duckweed as an alternative source of protein and a “cash crop” for their nation.

All in all, the main research question can be answered as follows: influencing human duckweed consumption in Laos and Thailand are mainly the awareness, availability, access, status, and taste of this food, with the last two aspects being the most relevant to people who are less familiar with duckweed. Besides those findings bringing answers to my research question and three subquestions, most of the investigated aspects also seem to inform overall Southeast Asian food choices, for instance showing the importance placed on taste and less on health or sustainability arguments. As phrased beautifully by Roman and Russell, “Southeast Asians are income-limited but all gourmets” (2009, p. 4).

These findings now set the base for deeper and further research to be done, businesses to be started and consumers to be reached. As the potential initially identified in duckweed is untouched, we now better understand how to best set the scene for it to be unleashed: by firstly tackling awareness, availability, access, and status issues around duckweed for it to improve overall human and planetary health.

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APPENDIX

APPENDIX 1: INTERVIEW GUIDE FOR CONSUMERS/NON-CONSUMERS

INFORMATION

My name is Miriam Burnand, and I am a Swiss student at Wageningen University in the Netherlands. This interview is part of my master's thesis data collection on the acceptance and consumption of duckweed in Laos and Thailand. This plant grows all over the world, but it is only eaten in Southeast Asia so far. Therefore, my aim is to understand to what extent it is consumed in Laos and Thailand, how, and why - or why not. My overarching research question is:

WHAT ASPECTS INFLUENCE HUMAN DUCKWEED ACCEPTANCE AND CONSUMPTION IN LAOS AND THAILAND?

With your consent, the present interview will be recorded for transcription and analysis purposes only. All content will be anonymized and used solely for the purpose of my MSc thesis research.

GENERAL QUESTIONS

- What is your life occupation?
- Where do you live?
- Is that also the place you grew up? If not, where do you come from?

RESEARCH QUESTIONS

"TRADITIONAL DUCKWEED"

- Do you know what duckweed is?

Answer = NO → show picture below

  - *If they recognize it: continue interview.*
  - *If they don't recognize it → description*
    - It is a type of tiny plant that grows on water a bit everywhere on earth, and it can be eaten raw as a salad or in smoothies for instance, or cooked together with rice and fish or meat of any kind. You can find it at the market or collect it yourself directly from ponds in nature.
    - Based on this description, would you be willing to eat that? Why? And would you go for the market or pond option?
      - End of interview -

Answer = YES → show picture below

- Are we both talking about this?

Clarify which species they are referring to and continue interview

- Have you ever eaten duckweed?

YES	*NO*
• What can you **tell me** about your duckweed consumption? • **How often** do you eat duckweed? • Do you eat it on special **occasions**, or anytime? • Is your duckweed consumption **seasonal**? Is it based on the availability of duckweed itself or **other foods** that duckweed can replace when they are unavailable? • How do you **prepare** it? As part of what **meal**? How do you **combine** it with other foods? • Do you think the preparation process is rather **easy or complex**? • Do you consider duckweed part of the "**Lao/Thai diet**"? Or only in certain **regions**? • When you eat it, **why** do you go for duckweed (instead of something else)? What are the **advantages** of eating duckweed? • (What do you look for (good taste, healthy benefits, decoration on your plate, mainly something to fill up your stomach, …) when eating duckweed?) RECOGNITION AS FOOD • Do you think **everyone** considers duckweed as "human food"? • Do you know **people who don't?** Do you know why? ACCESS • **Where** do you get it? (market/nature/other) Do you **always** get it this way? Would you **consider other ways** to get it? • Is this **access easy** for you? **How far** is it for you to go there from your home? • **How much** does it cost at the local market? Do you consider this price **expensive**? TASTE • How would you describe the **taste** of duckweed? Do you personally **like** it? Do you think it is **generally liked** in Laos/Thailand? SAFETY CONCERNS • Do you think eating duckweed is rather **safe** or not? Why?	• Why not? ACCESS • Have you ever been in a situation where you **could have** bought / collected (from ponds) / directly eaten duckweed? • Would you **know where to get** duckweed if you wanted? • **If yes, where** would be the easiest access point for you? And **how far** is that from your home? • Knowing that you can get it at the **market** for 20.000 LAK/kg **/** 50 THB/kg, what do you think about this **price**? • Would you prefer to order it **online** for 40.000-60.000 LAK/kg **/** 100-150 THB/kg? RECOGNITION AS FOOD • Do you **consider** duckweed as "human food" (or rather animal feed, or just a plant)? SAFETY CONCERNS • Do you consider duckweed **safe** to eat for humans? • Do you consider duckweed **clean**? HEALTH & ENVIRONMENTAL CONSIDERATIONS • What impact do you think eating duckweed has on your **health**? Why? • **How important** do you consider this health aspect of food? • What do you think of the impact on **nature** of eating duckweed? Why? • **How important** do you consider this nature aspect of food? TASTE • What have you **heard** about the taste of duckweed? STATUS CONCERNS • Do you **know people who eat** duckweed? • In your village/town, **who eats** duckweed and **who doesn't**? And **why**? Do you think this is the same in **Laos/Thailand in general**? • What do you **think of people eating** duckweed? FOOD SECURITY

• Do you think it is naturally rather **clean** or dirty? FOOD SECURITY • Has your consumption of duckweed ever been motivated by a **lack of money** to buy (other) food? • Have you ever been in a situation **without enough food** to feed yourself or your household? HEALTH & ENVIRONMENTAL CONSIDERATIONS • What impact do you think eating duckweed has on your **health**? Why? • **How important** do you consider this health aspect of food? • What do you think of the impact on **nature** of eating duckweed? Why? • **How important** do you consider this nature aspect of food? STATUS CONCERNS • Do you think **everyone eats** duckweed? • In your village/town, **who eats** duckweed and **who doesn't**? And **why**? Do you think that is the same in **Laos/Thailand in general**? • For **what reasons** do you think some people **don't eat** duckweed? WHAT TO IMPROVE • If you could **change some aspects** of duckweed (taste, appearance, hygiene, price, etc.) what would these be? • Do you think these changes would **bring more people** to eat duckweed? Or **what else** would be needed?	• Have you ever been in a situation **without enough food** to feed yourself or your household? • If you ever **were to be** in such a situation (again), would you **consider collecting** duckweed from ponds to eat it? And **why**? OTHERS • Would you **know how to prepare** duckweed if you wanted to eat it? • Are there **conditions** under which you would **consider eating** duckweed? • What should **change** in duckweed for you to be **willing** to consume it?

FLO WOLFFIA

In Bangkok (Thailand), a young business is growing duckweed on indoor basins under strict quality and hygienic **control**. The product is **enhanced** with various vitamins and minerals, and is sold as a **ready-to-eat** product. [show picture]

- What do you think about this product?
- Would you consider consuming it?
- Would you be willing to buy it for **75.000 LAK** / **189 THB** per 200g? **Why**?

- **How** would you like to **get** it? Is ordering **online** an option for you? **Why**?

Is there **anything else** you would like to mention?

Thank you so much for your time – I truly appreciate your help for my research on duckweed awareness and consumption. Maybe your answers will soon contribute to an upscaled duckweed consumption worldwide, and hopefully a healthier planet and healthier people on it!

Picture of fresh duckweed shown to interviewees: