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CHANGES IN FOUR SOCIETAL DRIVERS AND THEIR POTENTIAL TO REDUCE SWEDISH NUTRIENT INPUTS INTO THE SEA

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PREFACE

This report, that was commissioned and financed by the Swedish Agency for Marine and Water Management (SwAM), aims to assess the potential to reduce Swedish nutrient inputs to the sea by influencing underlying societal phenomena or drivers. Four phenomena are investigated: protein intake, unnecessary food waste, phosphorus additives in food and horse keeping. For each phenomenon, potential load reductions are presented and discussed.

Three of the four abovementioned phenomena are directly related to food, and keeping horses may interfere with food production because it represents an alternative use of agricultural land. This emphasis of food and land use in the present study can be justified by existing source apportionments of the waterborne input of nitrogen and phosphorus to Swedish marine waters. Agriculture is by far the largest anthropogenic source of both nitrogen and phosphorus. Moreover, emissions from both municipal and on-site sewage systems are primarily due to the phosphorus and nitrogen content of human faeces and urine.

Assessing potential changes in the pressure on the environment due to societal changes is an insurmountable task, unless a number of simplifying assumptions are made. In contrast, our analysis goes deeper into society than conventional source apportionments. For example, the role of protein consumption in nutrient loads to the sea is investigated by assessing substance flows along the entire product chain from the production of animal feed and food in agriculture to the input and output from sewage systems and retention in freshwater systems.

It is important to note that the potential reductions of nutrient loads presented in this report should be regarded as estimates of maximum reductions, given a number of constraints on the systems under consideration. The actual load reduction may be lower if the potential is not fully utilized due to goal conflicts or competing interests. In addition, it has to be taken into account that some changes in the input of nutrients to the sea may appear with substantial time lags or be strongly modified due to complex interactions in the current socio-economic systems. Nevertheless, we hope that this report may clarify which of the investigated societal phenomena can play a major role and which are of minor importance for the input of nutrients to the sea.

As a help to the reader, a list of technical terms and definitions is given in Appendix 1. Moreover, some important reading instructions are given at the end of Chapter 1.

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ARE VALLIN, ANDERS GRIMVALL, EVA-LOTTA SUNDBLAD AND FARUK DJODJIC

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SUMMARY

Large parts of the Baltic Sea and the Kattegat and Skagerrak suffer from eutrophication. Historically, this is due to due to an excessive input of nitrogen and phosphorus to the sea. In the present report, we focus on some of the root causes of this input and how changes in society can reduce the eutrophication pressure on marine environments. Four societal phenomena were selected for a closer analysis. Three of these phenomena - protein consumption, unnecessary food waste, and phosphorus additives in food - are related to the impact of food consumption on the sea. Horse keeping was also considered to be a relevant case study, as the number of horses in Sweden is growing rapidly

Assessing how changes in societal phenomena can influence the physical flow of nutrients into the sea is a complex task. The number of factors that can modify the final result is very large, and one type of changes in society is normally accompanied by a set of other changes. For example, changes in the consumption of food will inevitably have implications for land use. Moreover, many of the actors that influence the flow of substances and products through society operate on a market where the current activities are continuously modified or substituted by others.

In this report we tried to handle the complexity of the problems addressed by making simplifying assumptions. For example, we assumed that changes in food consumption will be identical or similar for Swedish produced and imported products and that agricultural land not any longer needed for food production will obtain a leaching coefficient corresponding to a theoretically derived background level. Keeping in mind that the load reductions presented here are maximum load reductions based on a number of assumptions our study allowed the following conclusions:

- A lower intake of protein-rich food products (25% less protein) could imply that, each year, about 200 tonnes less phosphorus and nearly 9.000 tonnes less nitrogen would reach the sea. Dietary changes can reduce the land area needed to ensure an adequate food supply but also lower the households' burden on municipal and on-site sewage systems. Replacing some animal protein with legumes can help to reduce the input of nutrients into the sea, but it is more important to reduce the total intake of protein-rich food.

- If phosphorus compounds added to various food products are substituted or eliminated, the annual input of phosphorus to the sea could be reduced by about 60 tonnes per year. This amount is of the same order of magnitude as the effect of the already implemented ban of phosphate in dishwasher detergents.

- Reducing the amount of unnecessary food waste is both desirable and feasible, and smaller amounts of waste imply that less land is needed for food production. However, the load reductions of 6 tonnes of phosphorus and 450 tonnes of nitrogen are relatively small compared to the effect of dietary changes.

- Horse keeping is a growing sector and source of nutrient emissions. Moreover, paddocks can locally cause relatively large emissions of nutrients. However, horse keeping cannot be regarded as a major driver of eutrophication because the leaching of nutrients from this form of land use is lower than the average for all agricultural land in Sweden.

The potential load reductions are substantial compared to the remaining Swedish reduction targets in the Baltic Sea Action Plan. Altogether, the results of the present study suggest an increased emphasis on what and how much protein-rich food consumers eat and on the use of phosphorus additives in the food industry.

SAMMANFATTNING

För att minska övergödningen i Östersjön och Västerhavet ska Sverige reducera belastningen av näringsämnen på haven enligt det svenska miljökvalitetsmålet *Ingen övergödning* och internationella överenskommelser, framför allt Baltic Sea Action Plan. I en tidigare rapport från Havsmiljöinstitutet[1] identifierades 17 samhällsfenomen av relevans för övergödningen. Fyra av dessa analyseras vidare här med utgångspunkt från befintliga data. De är:

- *Konsumtion av animaliskt och vegetabiliskt protein.* Konsumtionen av proteinrika livsmedel har ökat och det ger upphov till utsläpp av näringsämnen både under produktion och efter konsumtion. Kväve och fosfor läcker från jordbruket och hamnar även i avloppsvattnet från hushållen så att de bidrar till utsläpp från enskilda avlopp och reningsverk.

- *Matsvinn.* Ätbar mat som slängs i onödan orsakar onödiga emissioner i produktionen.

- *Tillsats av fosfor i livsmedel.* Fosfor tillsätts som bland annat stabiliseringsmedel och smaksättare och hamnar i avloppsvattnet.

- *Hästhållning.* Antalet hästar ökar och detta medför emissioner vid foderproduktion, samt vid beten och hagar där hästarna vistas.

Syftet med rapporten är att kvantifiera potentialen för att belastningar på havsmiljön reduceras om dessa fenomen förändras. Slutsatserna bygger på beräkningar och antaganden och det har varit nödvändigt att göra många förenklingar vilket gör att resultaten inte ska tolkas som en förutsägelse (prediktion) av framtiden. Avsikten är istället att nå fram till riktvärden att förhålla sig till i vidare diskussion om de reella förändringar som kan ske i samhället. Denna kunskap är värdefull för att kunna identifiera och värdera nyttan av nya åtgärdsområden för havsmiljöförvaltningen.

De tre första fenomenen avser påverkan från livsmedel på emissioner av näringsämnen. Emissioner uppstår vid livsmedlens produktion men även vid avloppsreningsverk, eftersom mängderna kväve och fosfor som tillförs avloppssystemen är direkt kopplat till konsumtionen av livsmedel.

Konsumtion av animaliskt och vegetabiliskt protein. Proteinrika livsmedel innehåller alltid betydande mängder kväve och i allmänhet också avsevärda mängder fosfor. I Sverige konsumeras i genomsnitt 174 gram (g) rått benfritt kött per dag (data från år 2009). Griskött är vanligast (79 g) men även nötkött, kyckling och lamm

[1] Sundblad et al. (2015)

konsumeras i betydande mängder (50, 40 respektive 5 g). Dessutom äts i genomsnitt 39 g fisk, 28 g ägg och 840 g mejerivaror och 15 g baljväxter. Mejerivaror inkluderar mjölk och ost och är här utryckt i mjölkenheter. Med baljväxter avses inslag i en diet som förutom bönor, ärtor och linser även innehåller baljväxter i förädlad form såsom tofu.

Genom att undersöka hur emissionerna av näringsämnen förändras från nuvarande genomsnittliga kost till alternativa dieter är det möjligt att värdera nyttan för havsmiljön av att människor ändrar diet. Tre alternativa dieter med olika proteinprodukter används i analyserna och dieterna benämns: *Rekommenderad diet* (i linje med bland annat Livsmedelsverkets kostråd), *Klimatsmart diet* (byte från rött kött till kyckling) samt *Mer Baljväxter*.

I analysen av hur en minskad konsumtion av protein påverkar emissionerna användes två olika metoder. Först gjordes en sammanställning av data om emissioner av kväve och fosfor från befintliga Livscykelanalyser (LCA) av svenska livsmedel. Denna sammanställning visar att kött från nöt och lamm skapar större emissioner än fläsk och i sin tur kyckling, om man räknar utsläppen per kg protein från dessa livsmedel. Baljväxter, kyckling, mejeriprodukter och ägg har liknande utsläppsnivåer. Viktiga faktorer i beräkningarna är bland annat effektiviteten i omvandling från foder till protein och hur mycket kraftfoder (till exempel spannmål och raps) som djuren äter utöver foder från vallar (hö och ensilage) och naturbeten. Eftersom LCA-studierna är utformade för att visa på skillnader mellan produktionssystem och underliggande data är hämtade från ett fåtal gårdar använde vi inte dessa för att räkna på belastningar från svensk produktion som helhet. För detta syfte utgick vi istället ifrån hur jordbruksmarken används. Närmare bestämt tog vi hänsyn till hur stora landarealer som krävs för att producera foder till djur och livsmedel som kan konsumeras direkt av människan, samt hur läckaget från jordbruksmarken varierar med markanvändningen. Kalkylen avsåg den andel av den svenska konsumtionen som produceras i Sverige.

När vi beräknade läckageförändringen som följer av de tre dieterna tog vi även hänsyn till var i Sverige en förändrad konsumtion av olika köttslag kan få genomslag, d v s var jordbruksmarkens markanvändning förändras och vilket läckage som kan följa av detta. Foderproduktionen för vart och ett av de animaliska livsmedlen antogs ske i samma produktionsområde som djuren föds upp. För den friställda marken, det vill säga den mark som inte längre behövs för livsmedelsproduktion om proteinintaget minskas eller på annat sätt förändras, antogs läckaget på sikt bli detsamma som för en gräsmark som inte plöjs, sås eller gödslas.

Beräkningar av de olika dieternas emissioner utfördes för två nivåer av det sammanlagda intaget av protein genom de produkter som ingick i kalkylen. Den nuvarande proteintaget via dessa produkter är 80 g per person och dag och vi räknade på såväl detta intag som en minskning till 60 g. Om man även tar hänsyn till konsumtion av spannmålsprodukter och annan mindre proteinrik mat så får en genomsnittlig svensk idag i sig totalt ca 108 g protein per dag. Detta kan jämföras att världshälsoorganisationen WHO rekommenderar att en person som väger 70 kg bör konsumera 58 g för att tillgodose kroppens grundläggande behov.

Förändrade dieter innebär även att det avloppsvatten som kommer till kommunala reningsverk och enskilda avlopp får en ändrad sammansättning. För att beräkna hur dieterna påverkar utsläppen från avloppssystemen användes officiell statistik avseende reningsgrader vid kommunala reningsverk[2] samt tillgängliga schablonvärden för enskilda avlopp[3]. Emissioner från såväl svenska som importerade produkter inkluderades i beräkningarna.

Nedanstående tabell visar att kväve- och fosforbelastningen på havet kan reduceras avsevärt till följd av dietförändringar. Det finns även skillnader mellan de tre alternativa dieterna. Den viktigaste orsaken till att de alternativa dieterna ger mindre kväve- och fosfor belastning än nuvarande diet är dock att det totala proteinintaget från de studerade livsmedelstyperna dragits ner från 80 till 60 g per person och dag.

Beräknade förändringar av kväve- och fosforbelastningen på havet, om nuvarande diet ersätts med alternativa dieter som alla minskar det sammanlagda intaget av protein via animaliska livsmedel och baljväxter från 80 till 60 g per person och dag.

	MINSKNING AV KVÄVE- OCH FOSFORBELASTNINGEN PÅ HAVET F(TON/ÅR)					
	REKOMMENDERAD DIET		KLIMATSMART DIET		MER BALJVÄXTER	
	TOTAL N	TOTAL P	TOTAL N	TOTAL P	TOTAL N	TOTAL P
JORDBRUKETS MARKANVÄNDNING	3714	64	3947	71	5148	72
ENSKILDA AVLOPP	324	67	324	68	324	67
KOMMUNALA RENINGSVERK	3350	56	3350	58	3350	57
TOTAL	7387	187	7621	196	8822	196

Matsvinnets inverkan på belastningen av havet studerades med hjälp av data över mängden onödigt matavfall från hushållen och hur detta avfall fördelar sig mellan olika huvudtyper av livsmedel. Kalkyler gjordes såväl baserat på emissioner i jordbruket som efter konsumtion. Vi antog att med ett reducerat svinn för svenskproducerade proteinrika livsmedel kan emissionerna från motsvarande jordbruksproduktion undvikas. Vidare antog vi att matsvinnet minskar med 50 procent, vilket är enligt med genomförandet av FNs hållbarhetsmål (Sustainable Development Goals). Med dessa utgångspunkter beräknades att de årliga emissionerna av näringsämnen i jordbruket skulle kunna minska med 470 ton kväve och 6 ton fosfor. Efter att även retentionen i sjöar och vattendrag beaktats uppskattades belastningen på havet kunna minska med ca 300 ton kväve och 4 ton fosfor per år. Emissioner uppstår även på grund av att hushållen häller ut flytande mat i vasken. Efter en reduktion till hälften av emissionerna, och med beaktande av retentionen, blir resultatet att kvävebelastning kan reduceras med 50 ton och fosforbelastningen med 2 ton per år.

[2] Statistics Sweden (2014)
[3] Olshammar et al. (2015)

Fosforhaltiga tillsatser i livsmedel utnyttjas av livsmedelsindustrin för att stabilisera produkterna eller påverka deras smak. Vår utgångspunkt är att dessa tillsatser inte behövs för människors hälsa och därmed är potentialen för belastningsminskningar lika stor som dagens belastning från sådana tillsatser. Belastningen på havet uppstår när fosfor från maten hamnar i avloppsvatten och reningsverken inte renar allt ingående fosfor. En uppskattning baserad på den totala användningen av fosfortillsatser i den svenska livsmedelsindustrin indikerade att 28 ton fosfor når haven via enskilda avlopp och att 32 ton fosfor når haven efter att ha passerat kommunala reningsverk. Beräkningar gjordes även för ett urval produkter där tillsatsen av fosfor är känd: coladrycker, smältost, importerad kyckling och charkuterier. Den samlade konsumtionen av enbart dessa produkter uppskattades leda till att den årliga belastningen av fosfor på havet ökar med omkring 15 ton.

Hästhållning. Sverige har för närvarande ca 360.000 hästar och antalet ökar. En genomsnittlig häst antas väga ca 420 kg, och behöva ca 1,5 kg grovfoder (torrvara) per 100 kg samt 0,3 kg spannmål per 100 kg häst och dag. Emissioner av kväve och fosfor sker från betesmarker samt åkermark som används för produktion av foder. Genom att bedöma hur mycket mark som krävs för att producera tillräckligt med foder för att föda alla Sveriges hästar samt vilka läckagekoefficienter som gäller för denna mark beräknades de sammanlagda emissionerna av fosfor och kväve från hästhållningens foderproduktion (se nedanstående tabell). Läckaget beräknades även från delar av rasthagarna som kan anses vara högriskområden för fosforläckage, det vill säga de områden där hästar utfodras och vistas stora delar av dygnet. Emissionerna av fosfor från sådana områden uppgår till drygt ca 11,5 ton per år (exkl. retention).

Emissioner av fosfor och kväve (ton per år) från foderproduktion samt hästhagar.

	TOTAL-P	TOTAL-N
FODER: HÖ, ENSILAGE INKL BETE	28	800
FODER: SPANNMÅL	22	940
HÄSTHAGAR	11.5	Uppgift saknas
TOTAL	61	>1.740

På grund av brist på data är det svårt att kvantifiera de belastningsminskningar som skulle kunna uppstå vid förändrad hästhållning. Två saker är dock värda att påpeka: Räknat per ytenhet är det genomsnittliga läckaget från hästhållningen mindre än för jordbruksmark i allmänhet. Lokalt kan utsläpp från intensivt betade marker och rasthagar vara stort vilket kan påverka vattendrag, sjöar och grundvatten. Vi gör antagandet att förbättringar kan nås genom åtgärder i rasthagar.

Total reduktionspotential. Tabellen nedan sammanfattar potentialen att minska kväve- och fosforbelastningen på haven runt Sverige (med hänsyn till retention) genom att påverka olika samhällsfenomen.

Uppskattad potential (ton/år) att minska belastningen av fosfor och kväve på havet, uppdelad på bidrag från jordbruket respektive reducerad mängd avfall i avloppssystemen.

SAMHÄLLS-FENOMEN	POTENTIELL REDUKTION AV BELASTNING PÅ HAVEN					
	N TON/ÅR			P TON/ÅR		
	JORDBRUKS-PRODUKTION	AVLOPPS-RENINGSVERK	TOTAL	JORDBRUKS-PRODUKTION	AVLOPPS-RENINGSVERK	TOTAL
PROTEININTAG	5148	3674	8822	72	124	196
MATSVINN	300	50	350	4	2	6
TILLSATT FOSFOR	–	–	–	–	60	60
HÄSTHÅLLNING	n.a*	–	n.a*	5	–	5
TOTAL	5348	3724	9172	81	186	267

*inte tillgänglig uppgift

För att ge perspektiv på dessa beräknade belastningsminskningar, som avser alla bassänger kring Sveriges kuster, kan de jämföras med de minskningar från 2010 som behövs i Egentliga Östersjön. Enligt Sveriges åtagande i Helcom samarbetet (Baltic Sea Action Plan, BSAP) ska belastningen minska med 2.916 ton kväve och 400 ton fosfor till 2021. Om vattenmyndigheternas åtgärdsprogram genomförs finns ett kvarvarande minskningsbehov av 1866 ton kväve och 194 ton fosfor. Men programmen är bara föreslagna och ännu inte beslutade. De därefter återstående minskningskraven kan delvis avräknas mot åtgärdsöverskott I andra bassänger. Det innebär att kvävebetinget kan nås 2021, medan det då fortfarande återstår ca 80-100 ton fosfor att reducera. Denna rapports beräknade potentialer av minskat proteinintag är betydligt större än Sveriges återstående åtagande år 2010.

Av de fyra analyserade samhällsfenomenen har reduktionen av proteinintaget en större potential att reducera belastningen på havet än vad den tillsatta fosforn i maten har. Hästhållning och matsvinn har betydligt mindre potential.

Eftersom de samhällsfenomen som analyserats är komplexa har det varit nödvändigt att göra ett ganska stort antal förenklande antaganden för att beräkna belastningar och potentialer. Vi har exempelvis antagit att Sveriges självförsörjningsgrad och arealen öppen mark ska vara oförändrad. Vidare har vi antagit att reningsgraden i avloppssystemen kommer att vara oförändrad.

Utan tvekan skulle stora ändringar i hushållens dieter påverka Sveriges produktion av djurfoder och människoföda. Men det är knappast möjligt att förutsäga hur och var markanvändningen skulle förändras. Vi har därför inte spekulerat i marknadstrender eller ekonomiska konsekvenser för lantbrukare utan använt teoretiskt uträknade läckage koefficienter för att räkna ut möjliga näringsemissioner. Här finns också förenklingar som att läckagekoefficienten hålls oförändrad. En annan osäkerhetsfaktor är att förändringar i jordbruksmark inte kan förväntas leda till omedelbara ändringar i läckage utan kan dra ut på tiden.

Effekterna för dietförändringar analyserades för tre alternativa dieter. Dieten Mer Baljväxter visade störst potential även om skillnaderna är ganska små. Skillnaderna kan eventuellt vara ännu mindre beroende på att läckagekoefficienterna är mer osäkra för baljväxter än för andra grödor.

Stor osäkerhet finns även i data som gäller tillsatt fosfor, matsvinn samt hästhållning. Men det är ändå tydligt att slutsatsen kvarstår att tillsatt fosfor i livsmedelsindustrin innebär ett betydande tillskott till avloppen. Det är av samma omfattning som de tidigare emissionerna från maskindiskmedel.

Myndigheternas åtgärdsprogram för mindre övergödning fokuserar på så kallade end-of-pipe-lösningar. Vi vill hävda att det finns möjligheter att arbeta med alternativ. Istället för att ytterligare reglera hur lantbrukare ska undvika emissioner av näringsämnen skulle belastningen på havet kunna minskas genom att på olika sätt påverka vilken mat som efterfrågas av konsumenterna. Såväl konsumenter som producenter, upphandlare, detaljhandlare och opinionsbildare i media kan bidra. Då det finns en tydlig trend att öka proteinintaget finns en risk för att näringsämnesbelastningen på haven ökar om inte åtgärder vidtas.

I vår tidigare rapport har vi framhållit köttkonsumtionens roll för både klimatet och övergödningen av havet. I denna rapport, påvisas att det snarare är den totalt sett höga konsumtionen av proteinrika livsmedel som bör minska. Att byta kött mot grönsaker innebär oftast en reducerad belastning på haven, men ett högt intag av vegetabiliskt protein, såsom bönor, är inte nödvändigtvis bättre än att konsumera kött från betande djur eller kyckling

1 INTRODUCTION

1.1 BACKGROUND

Large parts of the marine waters surrounding Sweden have long suffered from eutrophication. Due to massive investments in improved sewage systems and improved agricultural practices the total input of nutrients into Swedish marine waters is now decreasing[4]. However, the current input of nitrogen (N) and phosphorus (P) to the sea is still too large. Together with internal loading of phosphorus from sediments it causes extensive, undesirable algae blooms and widespread oxygen depletion of bottom waters. This calls for additional measures so as to achieve the national Swedish environmental objective *Zero Eutrophication* and to comply with EU directives and international conventions about inland and marine waters.

Which measures can most efficiently reduce the eutrophication effects is the subject of a continuing debate. Existing and planned programmes of measures emphasize the need for further regulations of agricultural practices and further improvement of sewage systems. Some scientists advocate that it would be more cost-effective to address the internal loading of phosphorus from sediments, for example by oxygenating stagnant deep waters. Here, we focus on a third aspect – the potential to reduce Swedish nutrient inputs to the sea by influencing underlying the societal phenomena or drivers of the flow of nutrients.

In a recently published report, the Swedish Institute for the Marine Environment (SIME) listed seventeen activities or behaviours of individuals, organisations and institutions that were considered to influence the input of nutrients into the sea from land-based sources[5]. For each phenomenon, possible measures or policy instruments were listed. But no attempt was made to quantify their effects. In the present report, we perform a more comprehensive analysis of four of the phenomena: listed: intake of protein, unnecessary food waste, phosphorus additives in food, and horse keeping.

The nutrient reduction scheme of the HELCOM Baltic Sea Action Plan (BSAP) stipulates how large the input reductions that are required to effectively address the eutrophication of the Baltic Sea, including the Kattegat. The current Swedish targets imply that that the yearly input from both land and air must be reduced by 9.240 tonnes N and 530 tonnes P by 2021[6]. In 2010, the remaining reduction targets for the Baltic Proper were about 2.916 tonnes of N and 400 tonnes of P to be reached 2021. If the currently proposed but not decided programme of measures will be implemented, there is still a remaining demand of 1.866 tonnes of N and

[4] Ejhed et al. (2014)
[5] Sundblad et al. (2015)
[6] HELCOM (2007,2013)

194 tonnes of P. This can partly be handled by deducting over-achievements from Sweden in other parts of the Baltic Sea that have an inflow into Baltic proper. However, there would still be a reduction target of approximately 100 tonnes of P, while the N target by 2021[7]. Targets for the period after 2021 are not specified, but the Swedish environmental objective *Zero Eutrophication* is not likely to be achieved by then.

The cited targets include both airborne and water-borne inputs, but water-borne inputs dominate strongly over airborne inputs, especially for phosphorus. Therefore, this report will focus on the water-borne flow of nutrients from Swedish land-based activities. The input along this pathway has four major sources: agriculture land, municipal and on-site sewage systems, and industry. Compilations based on data from 2011 resulted in the following estimates of their respective contribution to the net load to the sea[8]:

- Agriculture: 960 tonnes of P and 34 800 tonnes of N;
- Municipal sewage systems: 270 tonnes of P and 15.500 tonnes of N;
- On-site sewage systems: 190 tonnes of P and 1.700 tonnes of N;
- Industry: 280 tonnes of P and 4.400 tonnes of N.

In this type of conventional source apportionments, emissions from agriculture and sewage systems are presented as separate sources although they have common factor, i.e. food. Almost all nutrient emissions in agriculture are either directly associated with the production of food, or indirectly via production of animal feed or animal keeping. Moreover, nutrient emissions from both municipal and on-site sewage systems are primarily caused by the phosphorus and nitrogen content of human faeces and urine. From a societal perspective, it thus appears logical to regard the human demand for food as the key driver of the anthropogenic nutrient flows causing undesirable eutrophication of the Baltic Sea. This justifies that three of the selected societal phenomena (protein intake, unnecessary food waste and phosphorus additives in food) were directly related to food. Horse keeping was selected because it is a growing activity in Sweden, and represents an alternative use of agricultural land.

From a methodological point of view, it is a huge challenge to assess how changes in societal phenomena can influence the physical flow of nutrients into the sea. The number of factors that can modify the final result is very large, and one type of changes in society is normally accompanied by a set of other changes. For example, changes in the consumption of food will inevitably have implications for land use. Moreover, many of the actors that influence the flow of substances and products through society operate on a market where the current activities are continuously modified or substituted by others.

[7] Swedish Agency for Marine and Water Management (2015)
[8] Ejhed et al. (2014)

In this report we try to handle the complexity of the problems addressed by making several simplifying assumptions. Some factors will be held constant, and factors or processes that are considered to be of minor importance will simply be ignored or omitted. This may be regarded as a weakness. On the other hand, it can be an even larger simplification not to consider societal phenomena in search of the root causes of marine eutrophication.

1.2 OBJECTIVES

The objective of this report is to assess the potential to reduce Swedish nutrient inputs to the sea by influencing underlying societal phenomena or drivers. The four phenomena that were examined are named and defined as follows:

A. *Intake of protein*
The human consumption of animal and plant protein has increased over recent decades. Nutrient emissions occur both when this type of food is produced and after consumption, when human faeces and urine is handled in the sewage systems. Production of animal feed and animal keeping contribute to the total nutrient emissions from the intake of animal protein.

B. *Unnecessary food waste*
Not all food that is brought to households is eaten although it could have been consumed. Unnecessary food waste implies unnecessary production emissions.

C. *Phosphorus additives in food*
The use of phosphorus additives to stabilize or preserve food products or to enhance flavour is increasing. This type of additives implies an increased phosphorus burden on domestic sewage systems.

D. *Horse keeping*
The number of horses in Sweden is increasing rapidly. Nutrient emissions occur both during production of animal feed and from grazed lands and paddocks.

The potential reductions of nutrient loads presented in this report should be regarded as estimates of maximum reductions of the input of nutrients to the sea. The actual load reduction can be lower if the potential is not fully utilized due to goal conflicts or competing interests. In addition, it has to be taken into account that some changes in the input of nutrients into the sea may appear with substantial time lags or be strongly modified due to complex interactions in the current socio-economic systems. Nevertheless, we hope that this report can clarify which of the investigated societal phenomena that could play a major role and which are of minor importance for the input of nutrients into the sea.

1.3 HOW TO READ THE REPORT

Chapters 2 to 5 are devoted to calculations of potential load reductions due to changes in the underlying societal phenomena. Each of these chapters deals with one of the selected phenomena and contains descriptions of input data, calculation methods (including system boundaries and simplifying assumptions) and presentations of the outcomes of the calculations in tables and bullet points. Chapter 6 is devoted to a wider discussion of what conclusions that can be drawn from the results of the calculations in Chapters 2 to 5. This discussion includes assessments of strengths and weaknesses of the calculations performed.

2 INTAKE OF PROTEIN

During the past decades, the average diet in Sweden has changed significantly. The consumption of meat, fish, eggs and cheese has increased, and the per capita intake of animal protein is now about 55 percent higher than in 1970[9]. Moreover, it is generally accepted that the present total intake of animal and plant protein (108 grammes/person/day) is considerably higher than that required from a nutritional point of view[10,11]. Considering that the agriculture and food sectors play a major role in the pressure on marine ecosystems, the environmental consequences of dietary trends need to be thoroughly analysed.

Research on societal drivers behind the ongoing climate change has drawn attention to relationships between the emissions of greenhouse gases and the production and consumption of meat, especially beef[12]. It is generally assumed to be climate-smart to switch to diets in which the direct consumption of plant protein plays a bigger role, because only a certain fraction of the energy in the animal feed is transferred to the final food products, and cows, goats and sheep also cause methane emissions. Here, we examine whether dietary changes might also be an option to achieve a lower input of phosphorus and nitrogen to the sea.

First, we present three diet scenarios in which the total intake of high-quality protein is lowered but the protein sources differ. Then we describe how we compute potential emission reductions and present the results of these calculations in tables and bullet points. Two methods are used for the calculations. The first is based on relatively simple amendments to already published life-cycle assessments (LCA) of protein-rich foods. The second is based on the assumption that changes in demand for certain food products will result in land use changes and those different crops have different leaching coefficients.

2.1 DIET SCENARIOS AND SELF SUFFICIENCY

The current average diet (year 2009) in Sweden includes a daily consumption of 174 grammes (g) meat, counted as raw bone-free meat[13]. Pork accounts for the largest amount (79 g), followed by beef, chicken and lamb (50, 40 and 5 g, respectively). In addition, the average diet includes 39 g fish, 28 g egg, 840 g dairy products and 15 g beans. Dairy products here include milk, fermented milk products, and cheese, and cheese is converted to milk using a conversion factor of

[9] Swedish Board of Agriculture (2011)
[10] The recommended daily intake according to WHO (2007) is 0.83 g per kg body weight.
[11] Westhoek et al. (2011)
[12] SOU 2005:51, Larsson (2015)
[13] Swedish Board of Agriculture statistical database, National Food Agency (2012), Hallström (2014)

10[14]. Beans stand for a broad range of products (beans, peas, lentils, tofu) which are summarized as legumes in Tables 1 and 2.

To illustrate how dietary changes may influence emissions of phosphorus and nitrogen to the environment, we consider three alternative diets that will be named *Recommended*, *Climate-smart* and *High legume*, respectively. The first is called *Recommended* because it adheres to national and international dietary guidelines proposing a lower consumption of processed meat (primarily based on pork), red meat in general, and saturated fat. The *Climate-smart* diet is similar to the *Recommended* one, but more specifically focused on replacing beef for chicken, and beef is produced only as a by-product of milk. The *High legume* diet stands for a more extensive dietary change in which a considerable part of the meat is replaced by protein-rich legumes. Moreover, it should be noted that we only consider changes in the amount and sources of high-quality protein, i.e. protein that is needed to ensure an adequate intake of all essential amino acids[15]. The consumption of cereals, which is an important source of complementary amino acids with approximately 25 g protein/day and capita, is assumed to be unchanged.

All three alternative diets include a daily milk consumption of 500 g and provide a total of 60 g high-quality protein. This is considerably less than in the current Swedish diet, which includes a daily intake of 840 g milk and provides 80 g high-quality protein. Further details of the four diets are shown in Tables 1 and 2. The first table shows amounts of protein-rich food products and the second shows amounts of high-quality proteins. The protein content of the food products was acquired from the Food Database at the National Food Agency and is shown in Table 25, Appendix 2.

Table 1 Amount of food products (g per capita per day) providing high-quality proteins in the current Swedish diet and three alternative diets.

PRODUCT	CURRENT DIET	RECOMMENDED	CLIMATE-SMART	HIGH LEGUME
BEEF (RAW, BONE-FREE)	50	30	13	13
PORK (RAW, BONE-FREE)	79	30	0	0
CHICKEN (RAW, BONE-FREE)	40	66	107	0
LAMB (RAW, BONE-FREE)	5	2	0	0
DAIRY PRODUCTS (MILK EQUIVALENTS*)	840	500	500	500
FISH (SALMON, RAW, BONE-FREE)	39	39	39	39
EGG (RAW)	28	28	28	28
LEGUMES (DRY SUBSTANCE)	14.5	14.5	14.5	132

* All milk products, including cheese, are expressed as milk.

[14] Berlin (2002)
[15] Legumes contain most, but not all, essential amino acids. Cereals can provide complementary amino acids so that the total protein intake will be adequate.

Table 2 Daily intake of protein (g per capita per day) through food products providing high-quality proteins in the current Swedish diet and three alternative diets.

PRODUCT	CURRENT DIET	RECOMMENDED	CLIMATE-SMART	HIGH LEGUME
BEEF	11	7	3	3
PORK	15	6	0	0
CHICKEN	10	16	26	0
LAMB	1	0.4	0	0
DAIRY PRODUCTS	29	18	18	18
FISH	7	7	7	7
EGG	3	3	3	3
LEGUMES	3	3	3	29
TOTAL	80	60	60	60

The Swedish self-sufficiency of the protein-rich food products was assumed to be the same in the current and *Recommended* diets (Table 3), i.e. the lower consumption of certain food products in the *Recommended* diet was assumed to influence the consumption of imported and Swedish-produced food to the same extent. In the *Climate-smart* and *High legume* diets, we assumed a higher self-sufficiency of beef, legumes and chicken. The complete self-sufficiency of beef in those two diets can be attributed to our assumption that beef was then assumed to be exclusively a by-product of Swedish milk production. When emissions from the *High legume* diet were assessed, we assumed that all legumes required to replace animal protein sources will be produced in Sweden, and this resulted in a self-sufficiency of 94 percent (Table 3).

Table 3 Sweden's self-sufficiency (in percent) of selected protein-rich food products in the current diet together with our assumptions regarding the self-sufficiency in the three alternative diets. Data for the current diet were procured from the Swedish Board of Agriculture[16].

PRODUCT	DIET			
	CURRENT DIET	RECOMMENDED	CLIMATE-SMART	HIGH LEGUME
BEEF	58	58	100	100
PORK	76	76	n.a.*	n.a.*
CHICKEN	71	71	76	n.a.*
LAMB	39	39	n.a.*	n.a.*
DAIRY PRODUCTS	100	100	100	100
EGG	87	87	87	87
LEGUMES	50	50	50	94

*Not applicable

[16] Swedish Board of Agriculture (2011a-c, 2012b-d)

2.2 METHODS TO ASSESS EMISSIONS

Emissions of phosphorus and nitrogen during the production of food were assessed using two different approaches: Life Cycle Assessments (LCAs) and Land Use Assessments (LUAs). LCAs were used to identify the most crucial phases of existing product chains and to compare nutrient emissions caused by different products or production systems. LUAs were used to assess possible reduction in food-related emissions caused by dietary changes that are assumed to drive large-scale changes in land use. Emissions of nutrients from municipal sewage systems and on-site sewage systems were also calculated for the diets.

2.2.1 Life cycle assessments

Table 4 summarizes emissions to air and water reported in Swedish LCA studies. All quantities are expressed as grammes (g) of nitrogen or phosphorus per kilogramme (kg) product and include all emissions occurring at the farm stage of the food product's life cycle. Moreover, they refer primarily to Swedish emissions, but include emissions from imported animal feed to the extent that such import is common practice. For example, some soy beans are imported to the pork and chicken production. Ammonia (NH_3-N) emissions represent losses to air from manure, whereas emissions of nitrogen oxides (NO_x-N) are due to the use of tractors or other agricultural machinery. Emissions to water are calculated losses from the root zone and are expressed as nitrate (NO_3-N) or total nitrogen. Phosphorus emissions to water are expressed as phosphate phosphorus (PO_4-P) or total phosphorus.

Table 4 Food-related emissions of nutrients to air and water expressed as g of nitrogen or phosphorus per kg product. For meat, emissions are given per kg carcass weight[17], and for dairy products emissions are given per litre energy-corrected milk (ECM).

PRODUCT	NUTRIENT EMISSIONS PER AMOUNT OF PRODUCT						LITERATURE SOURCE
	AMMONIA (NH_3-N)	NITROGEN OXIDES (NO_X-N)	NITRATE (NO_3-N)	TOTAL NITROGEN	PHOSPHATE (PO_4-P)	TOTAL PHOSPHORUS	
BEEF (SUCKLER, ORGANIC)	25.0	5.0	72.3			0.087	Cederberg and Nilsson, 2004
BEEF (MILK BY-PRODUCT)	16.5	15.7	111.9			0.093	Cederberg and Darelius, 2000
PORK	6.9	6.4	56.4			0.044	Ahlmén, 2002
CHICKEN	7.0	2.7	23.1			0.036	Ahlmén, 2002
LAMB	18.2		86.9			0.220	Wallman et al., 2011
DAIRY PRODUCTS	1.4	1.3	3.8			0.010	Cederberg et al., 2007
EGG	2.7	3.9	17.1		0.041		Sonesson et al., 2008
LEGUMES (SOUTHERN SWEDEN)	0.2	0.7		22.1		0.018	SIK Animal feed database, Flysjö et al., 2008
LEGUMES (WESTERN SWEDEN)	0.2	0.5		15.8		0.019	SIK Animal feed database, Flysjö et al., 2008
LEGUMES (EASTERN SWEDEN)	0.2	0.5		12.5		0.021	SIK Animal feed database, Flysjö et al., 2008

The LCA studies cited indicate that there are substantial differences in nutrient emissions between the meat products studied. Some of these differences can be explained by the fact that chicken more efficiently than pigs, sheep and cows can convert the nitrogen in the animal feed into meat protein. However, before drawing far-reaching conclusions, one should take into account that each of the LCA studies refer to a specific production system that is not necessarily representative for the current average production in Sweden. Nor do the cited LCA studies include any estimates of the retention of nitrogen and phosphorus along the pathway from farm to sea. This calls for complementary methods in order to assess emissions and load reductions for the whole of Sweden.

Closer examination of the emission estimates in Table 4 shows that the reported nitrogen emissions directly to water (expressed as NO_3-N or total nitrogen) are considerably larger than emissions to air (expressed as NH_3-N or NO_x-N). In addition, a substantial fraction of the ammonium emitted to air from Swedish agriculture will be deposited on land and subject to a considerable retention before

[17] Carcass weight (also called dressed weight) refers to the weight of an animal after removing all the internal organs and oftentimes the head as well as less desirable portions of the tail and legs.

it reaches aquatic environments. For phosphorus, airborne pathways play an even smaller role in the input to the sea[18]. Consequently, it can be justified to focus on water-borne pathways in a study that primarily aims to distinguish between large and small potentials for reducing the input of nutrients to the sea. This motivates the land use assessment methodology described in the following section.

2.2.2 Land use assessments

Here we assume that dietary changes cause changes in land use, which in turn cause changes in production emissions. If, for example, the consumption of meat is reduced, the area needed to produce animal feed will be smaller, and the leaching of nutrients will be lower, provided that the alternative crop or land use has lower leaching coefficients. Calculations of the total change in production emissions ($\Delta\, ProdEm_{diet}$) from Swedish agriculture when an alternative diet is substituted for the current one were carried out using the formula

I) $$\Delta\, ProdEm_{diet} = \sum (\Delta\, \mathrm{Area}_{crop,region} * Leach_{crop,region})$$

where

$Area_{crop,\, region}$ = *change in area demand per crop and production region*

$Leach_{crop,\, region}$ = *area-specific leaching/emission coefficient by crop and production region*

and the sum was taken over all combinations of food products in the diets under consideration, and crops and agricultural production regions involved in the production of each food product. Emission changes in countries other than Sweden were outside the scope of the present study.

The estimated area demand per unit of beef, pork, lamb, chicken and milk in Sweden was derived from a publication by Cederberg and co-workers[19], and the area demand for legumes was derived from hectare yields published by the Swedish Board of Agriculture. In the assessment of emissions, we assumed that land no longer used to produce animal feed is converted to a land use for which the leaching coefficients are identical to the background values published in the latest available Pollution Load Compilation (PLC) for HELCOM[20]. We do not specify exactly how that land is used. However, the leaching coefficients cited were derived for a grassland that is neither ploughed nor fertilized, but kept as a monoculture. For the sake of simplicity, it will thus be called permanent grassland.

Leaching of phosphorus and nitrogen from agricultural land varies substantially between different agricultural production regions[21] in Sweden. The type of production is also unevenly distributed. Therefore, we used data regarding the number of animals and area of agricultural land in different production regions in

[18] Ejhed et al. (2014)
[19] Cederberg et al. (2009)
[20] Johnsson et al. (2008)
[21] In official statistics Sweden is divided into 18 production regions.

order to select a typical region for each product[22]. For beef and dairy products, we selected production region 7 (essentially the counties of Kronoberg and Jönköping), for pork and chicken region 2 (essentially the counties of Blekinge and Kalmar and the eastern part of Skåne), and for lamb region 3 (Öland and Gotland). The legumes were assumed to be cultivated in production region 2, 3 and 7 in proportion to the land area freed due to changes in demand for the current crops.

Tables 5 and 6 summarize the area-specific leaching coefficients used in our calculations. More specifically, we used leaching coefficients for different crops and soil types and then computed average leaching coefficients for the regions and products selected. Production of animal feed and animal keeping was assumed to take place in the same region. Concentrate feed for cattle was modelled as a mix of autumn wheat, rye and barley. Legumes for human consumption were assumed to have an average leaching coefficient equivalent to the average for all crops[23]. This assumption will be commented in the discussion (Chapter 6).

Table 5 Phosphorus leaching coefficients (kilogrammes P/hectare/year) for typical Swedish production regions in 2005. Source: Johnsson et al., 2008.

PRODUCTION REGION	2 (BLEKINGE, KALMAR)	3 (ÖLAND, GOTLAND)	7 (KRONOBERG, JÖNKÖPING)
LEY	0.22	0.07	0.28
PERMANENT GRASSLAND	0.10	0.05	0.12
CEREALS	0.29	0.11	0.41
LEGUMES	0.26	0.09	0.31

Table 6 Nitrogen leaching coefficients ((kilogrammes N/hectare/year) for typical Swedish agricultural production regions in 2005. Source: (Johnsson et al., 2008).

PRODUCTION REGION (COUNTIES)	2 (BLEKINGE, KALMAR)	3 (ÖLAND, GOTLAND)	7 (KRONOBERG, JÖNKÖPING)
LEY	14	9	13
PERMANENT GRASSLAND	5	4.4	6
CEREALS	33	29	32
LEGUMES	27	18	18

When assessing emissions related to the *Recommended* diet, we assumed that areas no longer needed for the production of pork, beef and milk (or animal feed for such production) are primarily used for the production of chicken feed and secondly replaced by permanent grassland. The *Climate-smart* diet implies further conversion of areas not needed for beef and pork production into permanent grassland or the production of chicken feed. The *High legumes* diet also implies that areas used for

[22] Data on animals and agricultural area in the 18 agricultural production regions in Sweden were obtained from Statistics Sweden (SCB). Personal communication with Rolf Selander and Ylva Olsson, respectively.
[23] Leaching coefficient for legumes has not been published because of the small area presently used for such products.

production of chicken feed are converted into cropland for legumes or, secondly, to permanent grassland.

2.2.3 Assessment of emissions from sewage treatment

Nutrients discharged from sewage systems originate almost exclusively from the food consumed. Phosphorus entering the human body via food contributes to several processes in the body, but is not, to any great extent, accumulated in adults. Therefore, we assumed that, for this element, the inflow into treatment plants equalled the intake via food. For nitrogen, the inflow into treatment plants was assumed to be 15 percent lower, because substantial amounts can be released from the human body via perspiration[24].

The amount of nitrogen in food is directly related to the protein content (about 160 g N per kg protein according to the Food Database at the National Food Agency). In contrast, the amount of phosphorus can vary strongly among food products with similar protein content (Figure 1). Milk, in particular, has a relatively high phosphorus content.

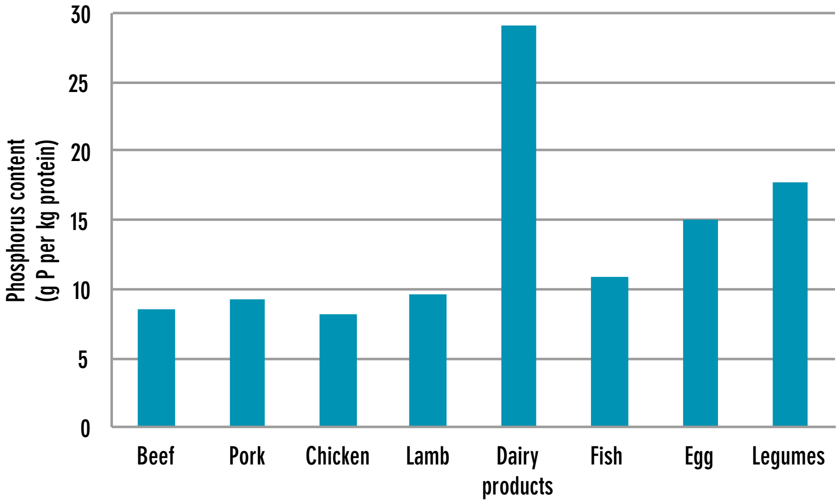

Figure 1 Phosphorus content of protein-rich food products.

On average, municipal sewage systems are far better than on-site systems at removing nutrients. Table 7 shows the removal efficiency we assumed for the two types of treatment systems. Data on municipal plants was obtained from the Swedish Environmental Protection Agency. For on-site systems, average removal efficiencies and the number of person equivalents connected to such systems, were derived using methods and data published by SMED[25].

[24] Pellett (1990)
[25] Olshammar et al. (2015)

Table 7 Average removal efficiency of phosphorus and nitrogen for different types of sewage treatment systems in Sweden.

CATEGORY	AVERAGE REMOVAL EFFICIENCY (PERCENT)		PERSONS INVOLVED (PERSON-YEAR EQUIVALENTS[26])	SOURCE
	NITROGEN	PHOSPHORUS		
ON-SITE SEWAGE SYSTEMS	39	20	787 119	Olshammar et al. (2015)
MUNICIPAL SEWAGE SYSTEMS	60	95	9 006 053	SCB (2014)

The impact of dietary changes on the total nutrient emissions from Swedish sewage systems was assessed by computing differences in emissions between the current and three alternative diets. More specifically, such changes in sewage emissions (ΔSEm_{diet}) were computed using the formula

II) $$\Delta SEm_{diet} = \sum \Delta Cons_{product} * Conc_{product} * PEq_{system} * (100\text{-}REff_{system})/100$$

where the sum was taken over all food products and sewage systems,

$\Delta Cons_{product}$ = *change in per capita consumption of the product per person*
$Conc_{product}$ = *nutrient concentration (N or P) in the product*
PEq_{system} = *number of person equivalents connected to the sewage system (on-site system or municipal sewage treatment plant)*
$REff_{system}$ = *nutrient removal efficiency (%) in the sewage system*

and the sum was taken over all products included in the investigated diet and the two types of sewage systems. In particular, it may be noted that, for each type of sewage system, the output is proportional to the input.

2.3 CALCULATED EMISSIONS FROM VARIOUS DIETS

2.3.1 Calculations based on Life Cycle Assessments

The idea of reducing nutrient emissions by changing diets originates from scientific reports claiming that that some food products have less environmental impact than others. In general, the evidence comes from LCAs in which emissions per amount of product are estimated. Here, we compute emissions per amount of protein in the food consumed (protein-normalized emissions).

Figures 2 and 3 illustrate that nutrient emissions per kg protein can vary strongly between products. Especially high emissions are attributed to beef and lamb, whereas legumes seem to cause lower emissions than all the animal products investigated. The high emissions of phosphorus and nitrogen from lamb may be attributed to the fact that a large land area was needed for each unit of meat in the production systems analysed. In addition, the utilized leaching coefficient for

[26] We used person-year equivalents because the number of full-time users of the systems is smaller than the number of persons formally connected.

phosphorus was high in comparison with coefficients used in other studies[27].

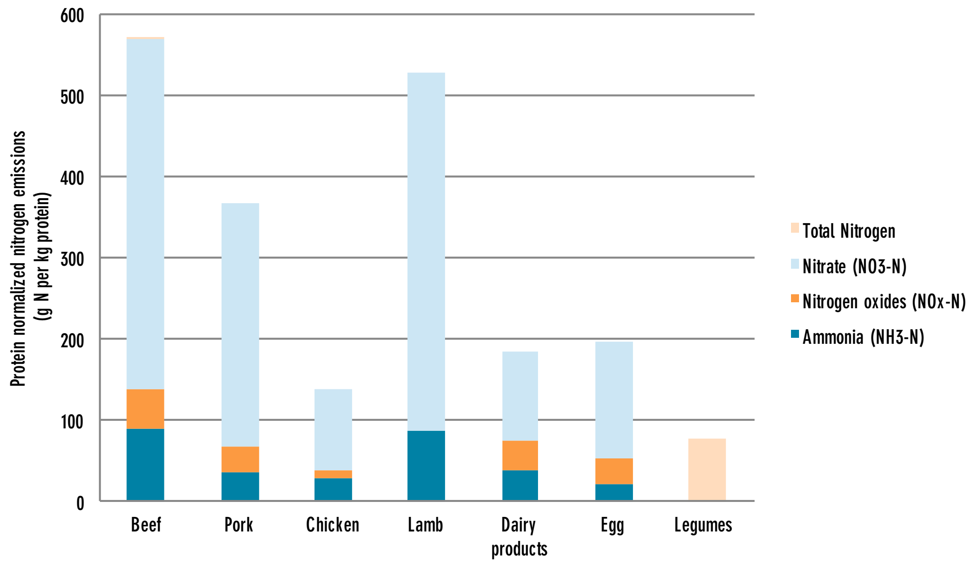

Figure 2 LCA-based estimates of nitrogen emissions per kg protein in selected food products. The emission estimates refer to losses to air and water where animal feed and food are produced and do not take into account the fate of the substances emitted outside the farm.

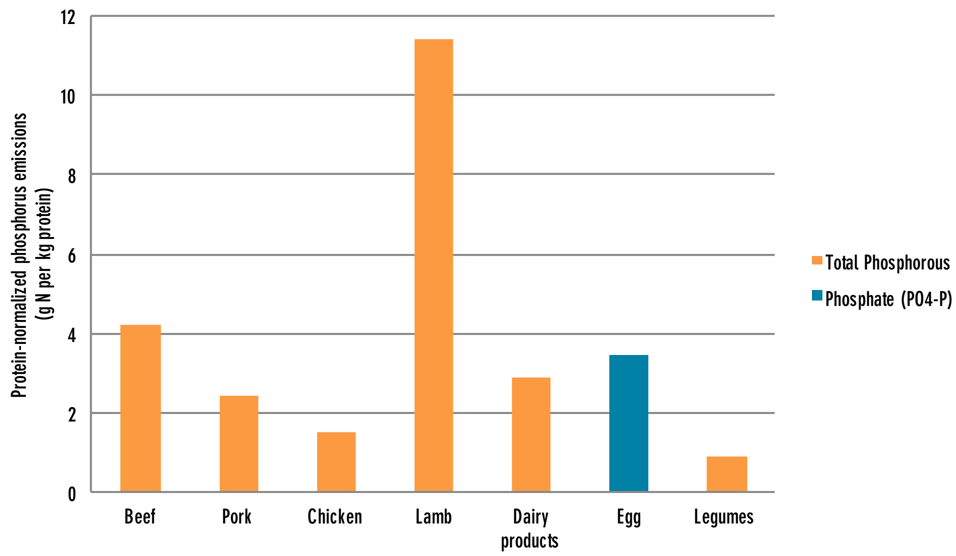

Figure 3 LCA-based estimates of phosphorus emissions per kg protein in selected food products. The emission estimates refer to losses to air and water where animal feed and food are produced and do not take into account the fate of the substances emitted outside the farm.

By combining the emission data in Figures 2 and 3 with the self-sufficiency data in Chapter 2.2, emissions from Swedish food products and diets were quantified. The

[27] In the lamb meat study, the leaching coefficient for P was 0.52 kilogrammes per hectare and year (kg/ha/yr), compared to levels around 0.3 in other studies.

graphs in Figures 4 and 5 show the calculated per capita emissions for the current diet and the three alternative diets (*Recommended*, *Climate-smart* and *High legume*).

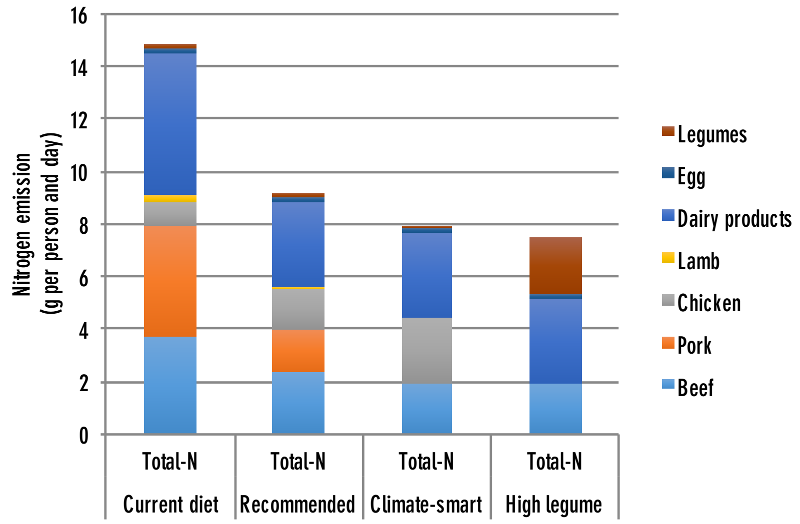

Figure 4 Nitrogen emissions attributed to the current and three alternative diets. The alternative diets have a lower total intake of high-quality protein (60 g/person/day) than the current diet (80 g/person/day).

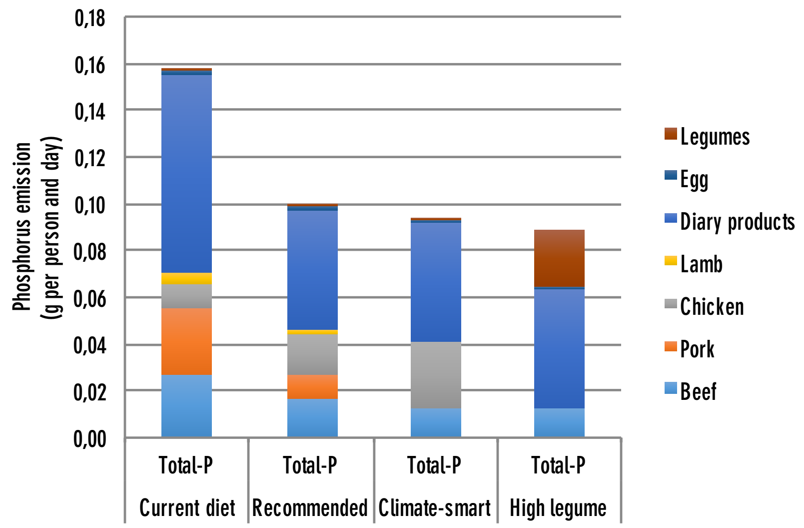

Figure 5 Phosphorus emissions attributed to the current and three alternative diets. The alternative diets have a lower total intake of high-quality protein (60 g/person/day) than the current diet (80 g/person/day).

Considering that the calculated emissions differ so much between the current and alternative diets, it would be tempting to conclude that the nutrient emissions from Swedish food production could be approximately halved if the current production were to be adapted to a different diet. However, two circumstances are worth mentioning. First, the land area freed will continue to leach. Second, a lower intake of high-quality proteins would probably imply a higher intake of other food products. The next section that follows presents the results of the land use assessments, which more specifically address the lower demand for agricultural land for food production.

2.3.2 Calculations based on Land Use Assessments

Figure 6 summarizes our estimates of the land area needed for the Swedish-produced parts of the current and alternative diets. As can be seen, all three scenarios of alternative diets imply a substantially lower demand for regularly ploughed land (crop land or ley). However, the differences between the three alternatives are comparatively small.

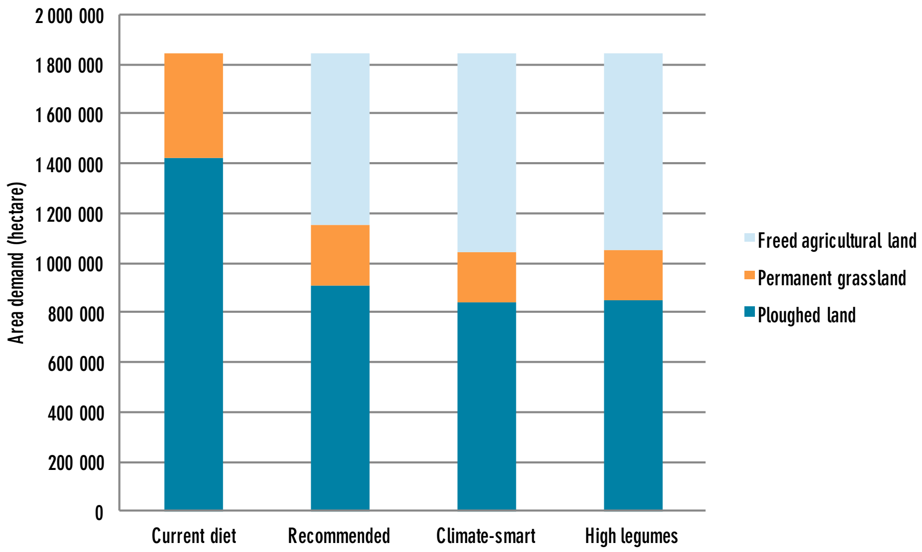

Figure 6 Land area demand for the Swedish-produced parts of the current and alternative diets. The regularly ploughed area consists of crop land and ley. The area freed under the alternative diets is neither ploughed nor fertilized.

Closer examination of the area demand for the different diets showed that a reduced beef and milk production (as in the *Recommended* diet) implies a lower demand for ley and permanent grasslands. A reduced production of pork and chicken (as in *High Legume* diet) implies a lower demand for crop land, but this change in land use is partly counteracted by a higher production of legumes (see Figure 7).

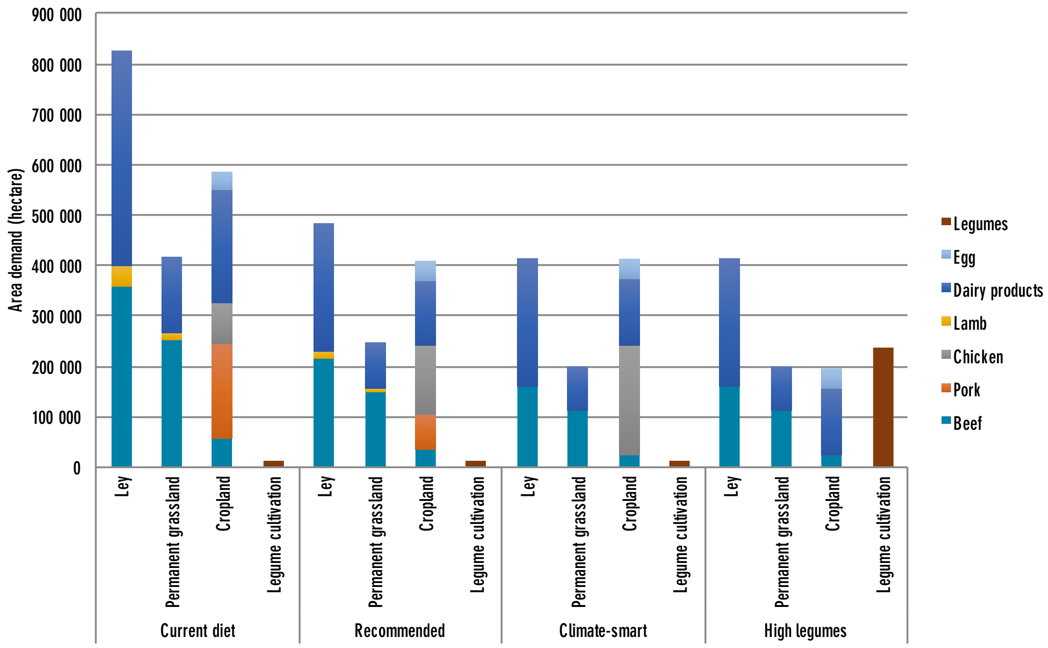

Figure 7 Demand for agricultural land induced by the current and alternative diets.

How large the emission reductions would be that could be achieved if the current Swedish production of protein-rich food is modified to fit alternative diets depends strongly on the assumptions made regarding emissions from land no longer used for food or animal feed production. Table 8 shows how large reductions that could be achieved in the whole of Sweden, if the freed agricultural land is assumed to have the same leaching coefficient as permanent grassland, and the selected production areas are representative of the entire Swedish production.

Table 8 Estimated emission reductions (tonnes/year) in Sweden if the current diet is replaced by alternative diets and land no longer used for food or animal feed production is assumed to have the same leaching coefficient as permanent grassland.

	EMISSION REDUCTIONS		
	RECOMMENDED DIET	CLIMATE-SMART DIET	HIGH LEGUME DIET
TOTAL-N	5800	6300	8100
TOTAL-P	97	108	110

As can be seen, all three of the alternative diets have a considerable potential to induce lower emissions during animal keeping and production of animal feed. There are also differences between the alternative diets. However, these differences should not be exaggerated.

2.3.3 Emissions from sewage systems

Emissions from sewage systems were computed for the entire consumption of protein-rich food, regardless of the self-sufficiency of the products investigated. Table 9 provides an overview of the potential emission reductions that could be achieved by replacing the current diet with each of the alternative diets. The reduction of nitrogen emissions was the same for all three alternative diets, because they contain the same amount of protein and the nitrogen content is proportional to the protein content. The reduction of phosphorus emissions varied slightly between the three diets, because some protein-rich food products have an elevated phosphorus content.

Table 9 Estimated reductions in emissions (tonnes/year) from sewage systems due to dietary changes.

	REDUCTIONS OF SEWAGE EMISSIONS COMPARED WITH CURRENT DIET					
	RECOMMENDED DIET		CLIMATE-SMART DIET		HIGH LEGUME DIET	
	TOTAL N	TOTAL P	TOTAL N	TOTAL P	TOTAL N	TOTAL P
ON-SITE SEWAGE SYSTEMS	530	94	530	96	530	94
MUNICIPAL WASTEWATER TREATMENT PLANTS	4000	67	4000	69	4000	68

As already noted, the formula used to compute emission reductions implies that, for each type of sewage system, changes in the output are proportional to changes in the output. This was deemed to be a reasonable assumption as long as the composition of the inflow is not changed too dramatically.

2.4 POTENTIAL NET LOAD REDUCTION

The Pollution Load Compilations for HELCOM assessments[28] take into account that the net input of nutrients to the sea can be substantially smaller than the sum of all emissions measured at their respective sources. As can be seen in Figures 9 and 10 (Appendix 3) the retention of nutrients is particularly large for emissions occurring upstream of the major lakes in Sweden. In the present study, we used estimates of the gross and net loads of phosphorus and nitrogen[29] to derive average retention coefficients for each of the emissions (Appendix 2, Table 26). The net reduction of the input of nutrients to the sea is summarized in Table 10.

[28] Swedish Environmental Protection Agency (2008)
[29] The relative difference between gross and net loads as reported in Swedish Environmental Protection Agency (2008) is used as the average retention.

Table 10 Estimated changes in net loads of phosphorus and nitrogen (tonnes/year) for alternative diets compared to the current diet.

	NET REDUCTION OF NUTRIENT INPUTS TO THE SEA					
	RECOMMENDED DIET		CLIMATE-SMART DIET		HIGH LEGUME DIET	
	TOTAL N	TOTAL P	TOTAL N	TOTAL P	TOTAL N	TOTAL P
AGRICULTURAL PRODUCTION	3714	64	3947	71	5148	72
ON-SITE SEWAGE SYSTEMS	324	67	324	68	324	67
MUNICIPAL SEWAGE SYSTEMS	3350	56	3350	58	3350	57
TOTAL	7387	187	7621	196	8822	196

Detailed analysis of the spatial variation in nutrient retention was outside the scope of the present study. However, a few facts are worth mentioning. In particular, it might be noted that the current production of chicken and pork is concentrated to areas where the retention is relatively low. In production region 2 (Eastern Skåne and the counties of Blekinge and Kalmar), which was considered representative of such production, the retention is usually less than 10 percent for phosphorus and in the range of 21–40 percent for nitrogen (Figure 9 and Figure 10 in Appendix 3). In production region 7 (the counties of Jönköping and Kronoberg), which was used as a model for beef production, the nitrogen and phosphorus retention vary substantially from low (0–10 percent) to high (60–80 percent).

2.5 SUMMARY IN BULLET POINTS

In this section, the results of the calculations performed are summarized in bullet points with brief explanations and comments. A wider discussion of what conclusions that can be drawn will follow in Chapter 6.

- *Dietary changes can substantially influence the input of nutrients to the sea along two major pathways: (i) leaching of nutrients from agricultural land to inland and coastal waters, and (ii) input of sewage from households to on-site and municipal sewage treatment systems.*

The present study showed that both pathways play a substantial role. However, the time until the input into the sea has changed can vary strongly with the pathway. Emissions from sewage systems respond immediately to changes in the input from households, whereas changes in the leaching of nutrients from agricultural land can occur with time lags ranging from years to decades after the land use has changed.

- *Relatively moderate decreases in the consumption of protein-rich food (meat, dairy products, eggs etc.) can have large effects on the total nutrient emissions during production of food and animal feed.*

Our compilation of already published LCA analyses indicated that the nutrient emissions caused by the Swedish production of protein-rich food could be radically reduced (by 50 and 40 percent for nitrogen and phosphorus, respectively) if the consumption of high-quality proteins is reduced by 25 percent. LUA analyses confirmed the crucial role of the amount of high-quality proteins in our diet.

- *Dietary changes can directly reduce the phosphorus and nitrogen burden on wastewater treatment systems, and thereby also the emissions from such systems.*

The nitrogen burden is almost proportional to the overall protein intake. The phosphorus burden is also positively correlated to the protein intake, but the phosphorus-to-protein ration as higher for dairies than meat.

- *Substituting legumes for animal protein can have a substantial impact on nutrient emissions but lowering the overall protein intake is more important.*

The *High legume* diet produced the lowest nitrogen and phosphorus emissions among the three investigated alternative diets. However, reducing the total daily intake of high-quality protein from 80 to 60 g had a greater influence on the emissions from food and animal feed production. If emissions from sewage treatment systems are also taken into account, our calculations indicate that reducing the total intake of proteins is more important than substituting legumes for meat.

- *There are substantial differences in nutrient emissions among the investigated animal products.*

The differences in nutrient emissions depend largely on two factors: how efficiently animals transform animal feed to protein and the requirement for ploughed land for animal feed production. Chickens can, more efficiently than pigs, transform animal feed into protein for human consumption, and pigs are more efficient than cows and sheep. On the other hand, cows and sheep get a large share of their feed from grazed land.

3. UNNECESSARY FOOD WASTE

Unnecessary food waste is defined as food thrown away that could be eaten if it had been handled correctly. An example is food that is thrown away only because the “consume before” date has passed irrespective of the quality of the food. The total amount of food that is thrown away in Sweden (approximately 1.100.000 tonnes/year) comes from the food industry, restaurants, retailers, caterings and households. The food waste from households thrown as garbage is estimated to be 720.000 tonnes per the year in 2014, of which 30 percent is considered unnecessary[30]. The major fraction (60 percent) of this unnecessary food waste consists of carbohydrate-rich products, such as vegetables, pasta, potatoes and bread[31]. Meat and fish contribute about 10 percent. In addition, nearly 250.000 tonnes solid and fluid waste is poured into the sink yearly[32]. In this section, we analyse the potential to reduce the input of nutrients into the sea by reducing the amount of unnecessary waste from protein-rich food.

3.1 SCENARIO REGARDING UNNECESSARY FOOD WASTE

Changes in nutrient inputs into the sea were assessed for a scenario presuming a 50 percent reduction from the 2015 levels of unnecessary food waste. This scenario is in line with the Sustainable Development Goals to be reached by 2030. Our analysis focused on waste generated in households. Moreover, it was restricted to protein-rich foods (meat, eggs, dairy products and legumes) produced in Sweden.

3.2 METHODS TO ASSESS EMISSION CHANGES

3.2.1 Land use assessments

Changes in emissions of production due to lower amounts of unnecessary food waste were calculated using the previously described land use assessment technique (see section 2.3.2). This technique is based on the assumption that changes in food consumption drive changes in land use, which in turn cause changes in emissions. More specifically, we assumed that fifty percent of the land presently used to produce food that ends up as waste will be converted so that the leaching coefficient equals that of permanent grassland.

The current amount of unnecessary solid food waste thrown as garbage was assumed to be 220.000 tonnes per year, or 67 g per capita per day[33]. To this amount, we added food poured into the sink. Since the composition of the abovementioned 250.000 tonnes was unknown, we used data from a study in which the amount of dairy products poured into the sink was estimated to 15 g per capita per day expressed as milk[34]. Furthermore, we gathered data on the composition of unnecessary food waste from a study of such waste in a Swedish residential area

[30] National Food Agency, Sweden (2016)
[31] Andersson (2012)
[32] 26 kg per year and capita
[33] National Food Agency, Sweden (2016)
[34] Sörme et al (2014)

(Augustenborg, Malmö)[35]. The amount of waste was then calculated for specific protein-rich food products based on their share of the current diet (Table 11), and the contribution from Swedish-produced food was estimated using the self-sufficiency data shown in section 2.1, table 3.

Table 11 Amount of unnecessary waste (g/capita/day) of protein-rich food products.

	UNNECESSARY WASTED FOOD (TOTAL)	UNNECESSARY WASTED FOOD (FOOD PRODUCED IN SWEDEN)	AFTER 50 PERCENT REDUCTION (FOOD PRODUCED IN SWEDEN)
BEEF	1.4	0.8	0.4
PORK	2.2	1.7	0.8
CHICKEN	1.1	0.8	0.4
LAMB	0.1	0.05	0.03
DAIRY PRODUCTS	17.1	17.1	8.54
EGG	0.8	0.7	0.3
LEGUMES	0.3	0.2	0.1

Changes in the demand for agricultural land due to reduced waste of animal food were calculated using data on the current area demand per unit of beef, pork, lamb, chicken and milk in Sweden[36]. Changes in the area demand for cultivation of legumes were derived from hectare yields published by the Swedish Board of Agriculture.

Finally, the total change in production emissions ($\Delta\, ProdEm_{waste}$) from Swedish agriculture due to less food waste was calculated using the formula

III) $$\Delta\, ProdEm_{waste} = \sum (\Delta\, \mathrm{Area}_{crop,region} * Leach_{crop,region})$$

where

$\Delta\, Area_{crop,\, region}$ = *change in area demand per crop and production region*
$Leach_{crop,\, region}$ = *area-specific leaching/emission coefficient by crop and production region*

and the sum was taken over all food products in the waste, and crops and agricultural production regions involved in the production of each food product.

The assumptions regarding typical production regions and leaching coefficients made in the present study were almost identical to those made in the study of dietary changes (see section 2.2.2). However, the decrease in waste from legumes was assumed primarily to influence the land use in production region 3 (Öland) where the present production of legumes (brown beans) is concentrated. As already mentioned, we assumed that agricultural land no longer used for food production will be converted so that the leaching coefficient equals that of permanent grasslands.

[35] Andersson (2012)
[36] Cederberg et al. (2009)

3.2.2 Assessment of emissions from sewage systems

The calculation is built on a daily disposal of dairy products of 15 g per capita. We use data from Livsmedelsdatabasen and assume nitrogen content of 6 grams and phosphorus content of 1.05 g per kg milk (see also table 25 in Appendix 2). The removal in the sewage system is calculated as in section 2.2.3.

3.3 POTENTIAL EMISSION REDUCTIONS

Our calculations showed that a 50 percent reduction of the unnecessary food waste could free about 44.000 hectare of the current cropland for less intensive land use. Table 12 shows that this, after the nutrient leaching has stabilized at a lower level, could reduce the emissions of phosphorus and nitrogen caused by Swedish-produced protein-rich foods by, respectively, 6 and 470 tonnes per year.

In addition, the phosphorus emissions from sewage systems is calculated to be 5 tonnes per year (whereof 3 from on-site systems and 2 from municipal systems). The nitrogen emissions are 121 tonnes per year (14 from on-site and 107 from municipal systems. The fifty percent reduction of emissions is revealed in Table 12.

Table 12 Potential reduction of production emissions (tonnes/year) due to reduced food waste.

	LESS USE OF CROPLAND	LESS USE OF PERMANENT GRASSLANDS	EMISSION REDUCTION IN PRODUCTION		EMISSION REDUCTION IN SEWAGE SYSTEM	
	HECTARE	HECTARE	50 % WASTE REDUCTION		50% REDUCTION	
			TOTAL-N	TOTAL-P	TOTAL-N	TOTAL P
PRODUCTION OF PROTEIN-RICH FOOD, INCL. DAIRY PRODUCTS	442420	11970	470	6		
FLUID POURED INTO THE SINK					60	2.5

3.4 POTENTIAL NET LOAD REDUCTION

Due to retention in lakes and water courses the change in nutrient inputs into the sea will be smaller than the emission changes. Average retention coefficients were derived as in section 2.2.2 by comparing the gross and net loads from agriculture in the PLC5 report[37] for HELCOM assessments (Table 26 in Appendix 2). After taking retention into account, the potential decrease in the annual input for phosphorus was estimated at 6 (4 from production and 2 from sewage systems) and for nitrogen at 350 tonnes (300 from production and 50 from sewage systems).

3.5 SUMMARY IN BULLET POINTS

- *Unnecessary food waste contributes relatively little to the nutrient inputs into the sea.*

Reducing the amount of unnecessary food waste is both desirable and feasible. However, it cannot radically reduce the input of nutrients into the sea.

[37] Swedish Environmental Protection Agency (2008)

4. PHOSPHORUS ADDITIVES IN FOOD

Phosphorus occurs naturally in meat, milk and many other foods, but is also present in several widely used food additives. In particular, phosphorus compounds are used by the food industry as stabilizing agents, for preservation or to flavour beverages. A study of common food products in Finnish stores showed that melted cheese, cold-meats such as salami and boiled ham products can contain large amounts of added phosphorus[38]. Soft drinks such as cola, prepared frozen dishes, sliced cheese, yoghurt, pastries and bake-mixes can also contain substantial amounts of such additives.

Statistics on the supply of phosphorus additives to the Swedish food industry indicate an increasing use of such substances (Figure 8). By law, the food industry must declare which additives that occurs in packaged food, and the use of specific food additives is indicated by their E-numbers[39] in the product declaration. However, the quantity of added phosphorus in the Swedish diet is not very well monitored[40].

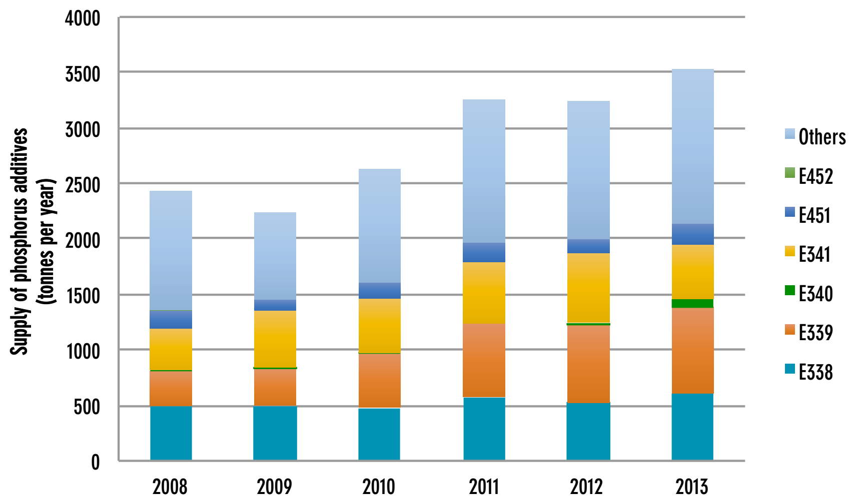

Figure 8 Supply of phosphorus additives (tonnes/year) to the Swedish food Industry 2008–2013[41]. Detailed documentation of the additives indicated by the different E-numbers can be found at the National Food Agency[42]. Data for phosphoric acid (E338, E339) added to beverages were not available.

[38] Karp (2013)
[39] National Food Agency, Sweden. http://www.livsmedelsverket.se/livsmedel-och-innehall/tillsatser-e-nummer/. Cited 20160127.
[40] Nordic nutrition recommendations (2012)
[41] Personal communication with Erik Diurlin. Data from the Product Registry of the Swedish Chemicals Agency.
[42] http://www.livsmedelsverket.se/livsmedel-och-innehall/tillsatser-e-nummer/sok-e-nummer/. Cited 20160127.

From a health point of view, a daily per capita intake of about 600 to 700 mg phosphorus is needed. The current average intake in Sweden is considerably higher and has been estimated at 1374 mg per person and day[43]. Only a minor fraction of this amount is permanently retained in the body. The remainder is released to sewage systems via urine and faeces and, despite substantial investments in wastewater treatment systems, emissions from such systems still constitute a major source of inputs into Swedish marine waters.

4.1 METHODS TO ASSESS EMISSIONS FROM PHOSPHORUS ADDITIVES

Two methods were used to assess phosphorus emissions caused by phosphorus additives in food. The first method was based on the supply of phosphorus additives to Swedish food manufacturers. The second was based on information about additives in specific food products.

Information on the supply of phosphorus additives to the Swedish food manufacturers was compiled using data from the product registry of the Swedish Chemicals Agency[44]. The phosphorus content of these products was then estimated using conversion factors published by the same agency[45]. The applied conversion factors are presented in Appendix 4.

To estimate the contribution of food additives to phosphorus emissions from Swedish sewage systems the total supply to the Swedish food industry was assumed to end up in sewage systems. More specifically, the supply was split among consumers connected to on-site sewage systems and municipal sewage treatment plants according to the number of people connected to the systems and the extent of utilization. Moreover, we made the same assumptions regarding nutrient capture rates of municipal sewage treatment systems and on-site sewage systems as in section 0. Data on the number of persons connected and nutrient capture rates are shown in Table 13.

Table 13 Average phosphorus removal efficiency and number of persons connected to on-site sewage systems and municipal sewage systems.

	PHOSPHORUS REMOVAL EFFICIENCY	PERSONS CONNECTED
	PERCENT	PERSON-YEAR EQUIVALENTS[46]
ON-SITE SEWAGE SYSTEMS	39	787 000
MUNICIPAL SEWAGE SYSTEMS	95	9 006 172

[43] National Food Agency (2012)
[44] Personal communication with Erik Diurlin, the Swedish Chemicals Agency. Data is gathered from the product registry of the Swedish Chemicals Agency.
[45] Recommendations of the National Food Agency (sanctioned 20160113) concerning Regulation (EC) No 1333/2008 of the European parliament and of the Council of 16 December 2008 on food additives.
[46] We used person-year equivalents because the number of full-time users of the systems is smaller than the number of persons formally connected.

To estimate emissions caused by specific products we used consumption statistics (official statistics from Swedish Board of Agriculture) and recommended dosage of phosphate from a major manufacturer (www.haifa.se). For the beverage Coca-Cola we used data on the content of phosphoric acid and production statistics published at the web-site of the company (www.coca-cola.se). Data on phosphorus content and consumption is summarized in table 14.

Table 14 Phosphorus content and annual consumption of selected food products

	E NUMBER	AMOUNT OF PHOSPHORUS ADDED TO PRODUCT	PERCENTAGE OF CONSUMED PRODUCTS WITH P-ADDITIVES	SWEDISH ANNUAL CONSUMPTION	REFERENCE
		(G P PER KG PRODUCT, LITRE FOR BEVERAGES)	PERCENT	KG (LITRE FOR BEVERAGES)	
COLA BEVERAGES	E338 E339	0.155	100	355 100 000	Average dosage based on Karp (2013) and www.coca-cola.se. Consumption data from Swedish Breweries (Sveriges Bryggerier).
MELTED CHEESE	E339 E452	4.9	100	9 700 000	Dosage data from www.haifa.com. Consumption data from Swedish Board of Agriculture.
CHICKEN, IMPORTED	E450 E451 E452	1.1	100	54 000 000	As above
COLD COOKED MEAT PRODUCTS	E450 E451	1.05	20	34 315 275	As above

Assumptions were also made regarding consumption and production of the selected products and the fraction of these products that contained phosphorus additives. *Cola beverages* contain 10–21 mg per 100 g of beverage[47] and an average value of 15.5 mg per 100 g of beverage was chosen. Data on the consumption of cola beverages was gathered from the trade association Sveriges Bryggerier. *All melted cheese* consumed in Sweden was assumed to contain phosphorus additives at levels recommended by a major supplier. C*hicken* is another product that may contain phosphorus additives. According to the sector association as well as a major producer no phosphate brines are injected into Swedish chicken[48], whereas imported chicken that accounts for 30 percent of the total consumption in Sweden could contain such additives. Information about added phosphorus in *cold cooked meat products* is scarce. The previously cited Finnish study[49] suggests that especially cold-cooked meats, such as salami and boiled ham, may contain substantial amounts. However, information on the web-sites of Scan and other major Swedish producers indicates that a majority of their sausages and cold-meats do not contain

[47] According to Karp (2013). Coca-cola (www.coca-cola.se, cited 20151015) declare a content of 16.4 mg per 100 g of beverage.
[48] Personal communication with Kinna Jonsson, Kronfågel, 20151027.
[49] Karp (2013)

any phosphorus additives. Therefore, we assumed that only 20 percent of cold cooked meat products consumed in Sweden contain such additives.

4.2 POTENTIAL EMISSION REDUCTIONS

Based on information about the total supply of phosphorus additives to Swedish food producers, it was estimated that this source contributes about 80 tonnes to the total annual phosphorus emissions from Swedish sewage systems (Table 15). Considering that international trade with food products probably results in a net import of phosphorus additives to Sweden the actual contribution to phosphorus emissions from Swedish sewage systems is most likely higher.

The total supply of phosphorus additives to Swedish food producers corresponds to a daily per capita intake of about 230 mg phosphorus per day. This is about 20 percent of the total phosphorus intake according to existing national food habit studies[50].

Table 15 Total phosphorus emissions (tonnes P/year) attributed to phosphorus additives in food.

TYPE OF TREATMENT PLANT	INPUT TO SEWAGE SYSTEMS	EMISSIONS FROM SEWAGE SYSTEMS
ON-SITE SEWAGE SYSTEMS	66	40
MUNICIPAL SEWAGE SYSTEMS	751	38
TOTAL	817	78

The contribution of additives in selected foods to the total intake of phosphorus is shown in Table 16. Altogether, the products investigated (cola beverages, melted cheese, imported chicken and charcuterie products) contribute about 55 mg phosphorus per person and day, or about 3–4 percent of the total phosphorus intake. The total contributions to emissions from sewage systems are shown in Table 17.

Table 16 Estimated contribution of food additives to the phosphorus intake via selected food products.

	TOTAL YEARLY INTAKE - SWEDISH POPULATION	DAILY INTAKE PER PERSON
	TONNES PHOSPHORUS PER YEAR	GRAMMES PHOSPHORUS PER PERSON AND DAY
COLA BEVERAGES	55	0.015
MELTED CHEESE	48	0.013
CHICKEN, IMPORTED	57	0.016
COLD COOKED MEATS	36	0.010
TOTAL	196	0.055

[50] National Food Agency (2012)

Table 17 Estimated contribution of additives in selected foods (cola beverages, melted cheese, imported chicken, and cold meat products) to emissions (tonnes P/year) from sewage systems.

	INPUT TO SEWAGE SYSTEMS	EMISSIONS FROM SEWAGE SYSTEMS
ON-SITE SEWAGE SYSTEMS	16	10
MUNICIPAL TREATMENT PLANTS	180	9
TOTAL	196	19

4.3 POTENTIAL NET LOAD REDUCTION

Due to retention in receiving waters, the net contribution of phosphorus additives to the input into the sea is smaller than the contribution to sewage emissions. Here, we made the same assumptions regarding retention as in section 2.2.3. Because municipal sewage systems are normally located close to the coast we assumed an average phosphorus retention of 15 percent for emissions from such plants. For on-site sewage systems, which are more scattered, we assumed an average retention of 30 percent.

After taking the retention into account we estimated that phosphorus additives in food contribute about 60 tonnes of phosphorus per year into Swedish marine waters (table 18). The selected food products were estimated to contribute about 15 tonnes.

Table 18 Net loads of phosphorus (tonnes/year) caused by phosphorus additives in food.

	ESTIMATE BASED ON PHOSPHORUS SUPPLIED TO THE FOOD INDUSTRY	ESTIMATE BASED ON CONTRIBUTION OF SELECTED FOODS
ON-SITE SEWAGE SYSTEMS	28	7
MUNICIPAL SEWAGE SYSTEMS	32	8
TOTAL	60	15

4.4 SUMMARY IN BULLET POINTS

- *Phosphorus additives in food constitute a non-negligible source of the phosphorus burden on sewage treatment systems and the nutrient input into the sea.*

The actual amount of phosphorus additives consumed by Swedish consumers can be higher than indicated by our calculations if the supply via imported food exceeds the export.

- *The use of phosphorus additives is increasing, and this is most likely related to increasing consumption of processed food.*

Phosphorus additives are used to stabilize, preserve or influence the flavour of food.

5. HORSE KEEPING

The number of horses has increased steadily in Sweden for several decades. There are now approximately 360.000 horses and a further increase is expected[51]. By way of comparison, the number of dairy cows is about 340.000. When comparing the environmental impact of horse keeping and other land use it is also worth noting that a dairy cow requires about four times more feed than a horse and relatively more concentrate feed.

Official statistics about nutrient emissions from horse keeping is limited to ammonia emissions[52]. However, horses also contribute to the nutrient loading of the sea through leaching from leys, permanent grasslands, paddocks, and cropland used to produce horse feed.

It has been suggested that grasslands where horses are kept can have relatively high leaching coefficients because the grazing is intensive[53]. It is also noteworthy that paddocks may receive an average of 60 kg phosphorus per hectare per year, thus exceeding the maximum permissible load (22 kg phosphorus per hectare) in farms with more than 10 animal units[54]. Emissions from paddocks can be particularly high after many years of operation with a high horse density[55].

5.1.1 Methods to assess emissions from horse keeping

Nutrient emissions from horse keeping were assessed using the previously described land use assessment technique (see section 2.3.2). In addition, special attention was paid to paddocks because recent studies suggest that such areas can be emission “hot spots” and targets for mitigation measures.

5.1.2 Method to assess emissions from grazing land, leys and cropland

Hay, silage and grazing make up the major part of the horse feed, but supplements in the form of grains and concentrated protein feeds are also used. For the sake of simplicity, our emission estimates were based on the assumption that horse feed consists of roughage (hay, silage and grazing) and grains.

The demand for feed is determined by horse weight. Based on data from a questionnaire[56] we assumed that 70 percent of the horses in Sweden are medium-sized warm blood horses (450–550 kg), and that 30 percent are category C ponies (200–250 kg). This resulted in an average horse weight of a little less than 420 kg. The demand for roughage is at least 1.5 kg dry substance per 100 kg horse per

[51] Swedish Board of Agriculture (2012)
[52] Statistics Sweden
[53] Parvage (2015)
[54] Swedish Board of Agriculture, Regulation 2004:62.
[55] Parvage (2015)
[56] Swedish Board of Agriculture (2012)

day[57], whereas the recommended amount of grain varies between zero and 0.4 kg per 100 kg horse and day. In our calculations, we assumed that the daily demand for roughage and grain is, respectively, 1.5 and 0.3 kg per 100 kg horse.

According to Cederberg and co-workers[58], 173.000 hectares of leys and 18.000 hectares of permanent grassland are used in horse keeping. Given a hectare yield of 5 400 kg per year and a grazing period of 105 days this land area can produce amounts of roughage sufficient to feed the horses for the remaining 260 days. Based on a hectare yield of oats amounting to 4.000 kg per year another 42 200 ha is needed to produce concentrate feed.

The total area needed for grazing and production of horse feed was split among eight Swedish production regions based on the number of horses in each region[59] (Appendix 5). Furthermore, average leaching coefficients were compiled for these regions[60] (Table 19). Finally, the anthropogenic leaching caused by horse keeping was computed by subtracting a background leaching equivalent to that of permanent grasslands.

Table 19 Leaching coefficients (kg/ha/year) used to calculate emissions from grazing and production of horse feed.

PRODUCTION AREA (SWEDISH NAME IN PARENTHESIS)	LEY		GRAIN (OAT)	
	P	N	P	N
CENTRAL DISTRICTS IN GÖTALAND (GÖTALANDS MELLANBYGDER)	0.09	7.8	0.15	27.2
PLAIN DISTRICTS IN NORTHERN GÖTALAND (GÖTALANDS NORRA SLÄTTBYGDER)	0.27	3.8	0.46	22.0
FOREST DISTRICTS IN GÖTALAND (GÖTALANDS SKOGSBYGDER)	0.30	6.2	0.64	27.1
PLAIN DISTRICTS IN SOUTHERN GÖTALAND (GÖTALANDS SÖDRA SLÄTTBYGDER)	0.20	11.3	0.41	40.0
FOREST DISTRICTS IN CENTRAL SWEDEN (MELLERSTA SVERIGES SKOGSBYGDER)	0.27	1.5	0.67	21.9
LOWER PARTS OF NORRLAND (NEDRE NORRLAND)	0.26	0.4	0.94	12.6
PLAIN DISTRICTS IN SVEALAND (SVEALANDS SLÄTTBYGDER)	0.30	1.7	0.54	12.9
UPPER PARTS OF NORRLAND (ÖVRE NORRLAND)	0.27	7.2	0.72	21.2

5.1.3 Method to assess emissions from paddocks

Phosphorus emissions from paddocks were estimated by combining information about land area and leaching coefficients. Parvage and co-workers have estimated the total area of paddocks to be about 34.000 ha, and 2.700 ha of this area was assumed to be used for feeding or excretion[61]. Moreover, the authors cited have estimated that the average leaching coefficient for all paddocks in Sweden is about 1.1 kg P/ha/yr. However, leaching coefficients for paddocks can vary strongly with soil type and land use. Table 20 summarizes the areas and leaching coefficients that were used to compute emissions from feeding and excretion areas in the present study.

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[57] As suggested by www.hastsverige.se.
[58] Cederberg et al (2009)
[59] The number of horses in Sweden's eight production areas has been estimated by Statistics Sweden. Data was provided by Jonas Hammarstrand, Statistics Sweden (20151123).
[60] Johnsson (2009). The background leaching for nitrogen was calculated based on the nitrogen concentrations available at http://www.smed.se/vatten/data/plc5.
[61] Parvage (2015)

Table 20 Areas and leaching coefficients (kg P/ha/year) used to calculate phosphorus emissions from hot spots in paddocks.

LAND USE	PERCENTAGE OF TOTAL PADDOCK AREA	LEACHING COEFFICIENT (KG P/HA/YR)	
		CLAY	SAND
FEEDING	3	1.6	2.3
EXCRETION	5	2.9	8.3

5.1.4 Estimated emissions from horse keeping

Table 21 shows that roughage production (including grazed fields), grain production and paddocks all make substantial contributions to the nutrient emissions from horse keeping. However, it is worth noting that the average emissions per ha are not very large. Horse keeping occupies about 7 percent of the total agricultural land in Sweden, but the emissions correspond only to about 5 percent of the total nutrient emissions from Swedish agriculture.

Table 21 Estimated emissions (tonnes/year) from horse keeping.

TYPE OF CROP OR LAND USE	TOTAL-P	TOTAL-N
HAY, SILAGE, ETC. (INCLUDING GRAZING)	28	800
GRAIN	22	940
PADDOCKS (FEEDING AND EXCRETION AREAS)	11.5	Not available
TOTAL	61	>1740

5.3. POTENTIAL EMISSION REDUCTIONS

Experimental studies have indicated that the leaching coefficients for those parts of the paddocks that are not used for feeding or excretion do not differ significantly from those of nearby reference areas. Therefore, we concluded that emission reductions can primarily be achieved by improving the management of hot spots. Table 22 shows much the phosphorus emissions could be reduced of the leaching coefficients were lowered to levels typical for permanent grassland.

Table 22 Potential emission reductions (tonnes/year) due to improved management of hot spots in paddocks.

LAND USE	EMISSION REDUCTION (TONNES P/YR)
FEEDING AREA	0.6
EXCRETION AREA	8

5.4 POTENTIAL NET LOAD REDUCTION

As in previous chapters, we used estimates of the gross and net loads of phosphorus and nitrogen[62] to derive average retention coefficients (Table 26 in Appendix 2). After taking this retention into account, we obtained the potential net load reductions presented in Table 23.

Table 23 Potential reduction of the phosphorus input into the sea by improved management of hot spots in paddocks.

LAND USE	NET LOAD REDUCTION (TONNES P/YR)
FEEDING AREA	0.4
EXCRETION AREA	5

5.5 SUMMARY IN BULLET POINTS

- *Emissions from paddocks can pose problems locally.*

Despite only making up 1 percent of the area used for horse keeping, feeding and excretion areas in paddocks contribute 11.5 tonnes or about 20 percent of the total phosphorus emissions from horse keeping. On sandy soils, the relative contribution can be even larger and negative effects can appear both in inland and marine waters.

- *The total emissions of nutrients from Sweden's horses are relatively small compared to the area used for horse keeping*

If land previously used for milk production or as cropland is taken over by horse keeping, the input of nutrients into the sea can decrease.

[62] Swedish Environmental Protection Agency (2008).

6. GENERAL CONCLUSION AND DISCUSSION

6.1 CALCULATED REDUCTIONS OF NUTRIENT INPUTS INTO THE SEA

The calculations for four societal phenomena revealed a substantial potential to reduce nutrient inputs into the sea by influencing choices by and behaviour of individuals and organisations. A lower intake of protein-rich food products could imply that, each year, approximately 200 tonnes less phosphorus and nearly 9000 tonnes less nitrogen would reach the sea (Table 24). This reduction is partly achieved because dietary changes can reduce the land area needed to ensure an adequate food supply. However, it is at least as important that a lower consumption of protein-rich foods will reduce the households' burden on municipal and on-site sewage systems. Moreover, it is worth noting that, although replacing certain types of animal protein with legumes can help to reduce nutrient inputs into the sea, it is more efficient to reduce the overall intake of protein.

Phosphorus compounds added to various food products to preserve or stabilize them or to create a tangy flavour represent another important phosphorus flow through society. If such food additives were replaced with other additives, or simply stopped being used, the annual input of phosphorus into the sea could be reduced by about 60 tonnes per year. Reducing the amount of unnecessary food waste is both desirable and feasible but will have a moderate impact on the input into the sea.

Horse keeping is a growing source of nutrient emissions, because the number of horses is increasing. In particular, feeding and excretion areas in paddocks constitute significant hot spots for phosphorus leaching. These areas also offer considerable possibilities to reduce nutrient inputs to inland lakes, rivers and into the sea. However, it is worth noting that, on average, nutrient emissions per hectare are not very high in horse keeping. Because horses primarily eat roughage, the average leaching coefficient for horse keeping, including feed production, is in fact slightly lower than in Swedish agriculture in general.

Table 24 Estimated potential to reduce the input of phosphorus and nitrogen (tonnes/year) into the sea by addressing food-related societal phenomena. The total potential includes reductions in both agriculture and sewage systems.

SOCIETAL PHENOMENON	POTENTIAL REDUCTION OF LOAD INTO THE SEA					
	N TONNES/YEAR			P TONNES/YEAR		
	AGRICULTURAL PRODUCTION	SEWAGE SYSTEMS	TOTAL	AGRICULTURAL PRODUCTION	SEWAGE SYSTEMS	TOTAL
PROTEIN INTAKE	5148	3674	8822	72	124	196
UNNECESSARY FOOD WASTE	300	50	350	4	2	6
PHOSPHORUS ADDED TO FOOD	–.	–.	–	–	60	60
HORSE KEEPING	n.a*.	–	n.a*.	5	–	5
TOTAL	5348	3724	9172	81	186	267

To put the abovementioned potential load reductions in perspective they can be compared with the load reductions needed to meet the Swedish reduction targets in the Baltic Sea Action Plan (BSAP). As mentioned in the introduction, the reduction targets for the yearly input to the Baltic Sea were about 1.866 tonnes of N and 194 tonnes of P[63] in 2010. The Swedish Marine and Water Management Agency estimates that the proposed programmes of measures are sufficient to achieve the nitrogen goal if they are decided and implemented. In contrast, the phosphorus input into the Baltic Sea needs to be further reduced by 100 tonnes until 2021[64]. Our calculations show that, even if it is taken into account that the numbers in table 24 refer to all Swedish marine waters and it may be difficult to achieve the entire calculated potential, a lower protein intake and removal of phosphorus additives in the food industry could be sufficient to fulfil the whole remaining phosphorus commitment in BSAP.

6.2 LIMITATIONS AND UNCERTAINTY OF THE STUDY

The societal phenomena in focus of the present study are quite complex and involve the behaviour of a great variety of actors. Therefore, it was necessary to make several simplifying assumptions. For example, we assumed that changes in consumption will be identical or similar for Swedish produced and imported products. Furthermore, we extrapolated results for specific agricultural production regions to the whole of Sweden and constrained our study to water-borne emissions to Swedish marine waters.

It can hardly be questioned that substantial dietary changes will influence the production of animal feed and food and thereby also alter the land use. However, it is difficult or almost impossible to predict how and where the land use will change. Instead of speculating about market trends and options for the farmer, we therefore used theoretically calculated background levels of the leaching coefficients to compute possible reductions of nutrient emissions.

[63] Swedish Agency for Marine and Water Management (2015)
[64] Swedish Agency for Marine and Water Management (2015)

It is thus important to regard the potential reductions of nutrient loads presented in this report as estimates of maximum reductions. The actual load reduction can be lower if the potential is not fully utilized due to goal conflicts or competing interests. In addition, it has to be taken into account that some changes in the input of nutrients into the sea may appear with substantial time lags or be strongly modified due to complex interactions in the current socio-economic systems. For example, it is not unlikely that the largest changes in land use will occur in low-productive agricultural land where the leaching coefficients are already relatively low.

Nevertheless, we claim that the potential load reductions presented in this report provide a correct ranking of the four investigated phenomena. Lowering the protein intake has a larger potential than eliminating phosphorus additives in food. Reducing unnecessary food waste or improving the management of feeding and excretion areas in paddocks have a rather small potential to reduce the total input of nutrients into the sea.

The effects of dietary changes were assessed for three alternative diets. Our calculations indicated that the high legume diet entailed the largest reduction potential, but the differences between the three diets are remarkably small. If we also take into account that cultivation of legumes normally takes place in a crop rotation scheme and that the leaching coefficients we assumed for legumes can be questioned as too low, the differences between the three diets may be even smaller. This strengthens our conclusion that reducing the total intake of high-quality protein is more important than replacing animal protein with plant protein.

If the daily intake of high-quality protein is reduced from 80 to 60 g per capita it is possible that the intake of some other food will increase so as to maintain the total energy content of the diet. This has not been taken into account in our estimates of load reductions. However, this does not jeopardise the major conclusions regarding effects of altered protein intake. First, the need for energy compensation can be questioned. Second, the bias introduced by not considering energy compensation is at least partly balanced by other simplifications. For example, we have not taken into account that the alternative diets require fewer animals and that this will reduce nutrient emissions.

So far this discussion of limitations and uncertainties has almost exclusively dealt with the potential impact of reducing the intake of high-quality protein. However, the three remaining societal phenomena also call for some comments.

The study of unnecessary food waste was constrained to protein-rich food products. Further studies would be needed to assess the role of unnecessary wastes from vegetables, fruit and cereals. The same holds true for the role of dairy products poured into the sink. It is also worth noting that our assumptions regarding the composition of unnecessary wood waste were based on a single study.

Data regarding the amount of phosphorus additives are also uncertain. In particular, there is a lack of data regarding the quantities of food additives in imported and exported food products. However, this does not influence the conclusion that food additives make a substantial contribution to the input of phosphorus to sewage systems. The total amount of phosphorus presently handled by the Swedish food industry is of the same order of magnitude as the previous use of phosphorus-containing chemicals in dishwasher detergents[65].

Our assessment of nutrient emissions from horse keeping emphasized that improved management of feeding and excretion areas in paddocks provides the major reduction potential. Although it can hardly be questioned that management of such hot spots can be improved we must admit that the reduction potential is uncertain. Data regarding the present practices in horse keeping are generally scarce.

6.3 CONCLUDING REMARKS

Both the on-going and the suggested programmes of measures by the Swedish water authorities to reduce nutrient inputs into the sea from the food and the agricultural sector are focused on so-called end-of-pipe solutions. Numerous detailed rules regulate how farmers must avoid nutrient emissions from the current production. In principle, it would be possible to achieve further reductions of the nutrient inputs into the sea by regulating where different types of food should be produced. It is a well-known fact that leaching coefficients for a given crop, or land use, can vary strongly both within and between production areas[66]. This report emphasizes that there are alternative management options in existence. Measures that come closer to the root causes of the nutrient inputs to the sea have a substantial potential. This is particularly true of two of the phenomena investigated: intake of protein and use of phosphorus additives in food.

A stronger focus on food consumption as a driver of nutrient flows through society and from society into marine environments implies that there are a number of actors that can fulfil the proposed dietary changes. In addition to individual consumers, retailers, cooks and chefs in media, etc., can also influence the intake of protein. Because there has long been an upward trend in the protein intake, and several increasingly popular diets are very rich in proteins, nutrient inputs into the sea may increase unless measures are taken.

In our previous report,[67] we cited a number of diet recommendations published by the Swedish Food Agency[68]. Consumers who would like to prioritize the climate issue are advised to reduce their consumption of animal products, especially red meat, and to choose products not requiring animal feed based on soy beans. To prioritize the issue of eutrophication and algal blooms, consumers are advised to reduce their consumption of animal products and, in addition, to choose products from farms that have joined special programmes to mitigate nutrient emissions.

The present study indicated that, from an eutrophication point of view, it is the high consumption of high-quality proteins that needs to be reduced and, in particular, the consumption of products that require large areas of ploughed land. Hence, the

[65] Product registry of the Swedish Chemicals Agency
[66] Johnsson (2008)
[67] Sundblad et al (2015)
[68] Wallman et al (2013)

requirements on diets suitable for mitigating eutrophication and climate change are similar but not identical. Production of beef based on grazing animals can be acceptable from an eutrophication point of view but is less climate-smart because of methane emissions from cattle. Replacing meat with vegetables will in general help to reduce nutrient inputs into the sea. However, a high intake of high-quality plant proteins, such as beans, is not necessarily better than consuming meat from grazing animals or chicken.

6.4 FUTURE STUDIES

The list of simplifying assumptions made in the present study is rather long. This implies that there is number of details that can be elaborated. However, even after many technical details have been addressed there will be important overarching issues that call for further analysis. We would like to mention the following:

- What additional policy instruments are needed to strengthen the relationship between sustainable consumption and sustainable production of food?
- What additional measures to reduce nutrient inputs to the sea will be needed if the Swedish production of food is increased to achieve a higher degree of self-sufficiency?
- How can mitigation of marine eutrophication and climate change be coordinated?
- How can the use of phosphorus additives in food be regulated on an international market?

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APPENDICES

1. APPENDIX: TECHNICAL TERMS USED IN THE REPORT

Below are key terms used in the report and their definitions, in English and Swedish.

ENGLISH/ENGELSKA	SWEDISH/SVENSKA
Societal phenomena Behaviours and structures influencing choices and activities .	Samhällsfenomen Beteenden och strukturer som påverkar aktörers val och aktiviteter.
Emissions Flows of substances or chemical compounds from human activities into air, water and soil.	Utsläpp Flöden av ämnen eller kemiska föreningar från mänskliga aktiviteter till luft, vatten och mark.
Gross load Total input of a substance or chemical compound from anthropogenic or natural sources into the natural environment.	Bruttobelastning Total tillförsel av ett ämne eller kemisk förening från antropogena eller naturliga källor till naturmiljön.
Net load Net contribution of one or more source to the input of a substance or chemical compound into a final recipient, e.g. a marine water body. Net loads represent emissions corrected for retention along a pathway.	Nettobelastning Nettobidrag av en eller flera källor till inflödet av en substans eller kemisk förening till en slutlig recipient, t.ex. ett havsområde. Nettobelastningar utgör emissioner korrigerade för retention längs en transportväg.
Retention Sorption or transformation of a substance along a pathway in the environment.	Retention Fastläggning eller omvandling av en substans längs en transportväg i miljön.
High-quality protein Protein source containing all, or nearly all, essential amino acids. Meat, dairy products and eggs, but also legumes, are examples of protein sources of high quality.	Högkvalitativt protein Proteinkälla som innehåller alla, eller nästan alla, essentiella aminosyror. Kött, mjölk och ägg, men även bönor och linser, är exempel på proteinkällor av hög kvalitet.
Leaching coefficient Coefficient indicating the annual leaching of a substance per area unit. Can be expressed in kg/ha/yr.	Läckagekoefficient Koefficient som visar det årliga läckaget av en substans per ytenhet. Kan uttryckas i kg/ha/yr.
Ley Arable land sown with grass, clover etc. and regularly ploughed and fertilized.	Vall Åkermark som sås med gräs, klöver etc. samt plöjs och gödslas regelbundet.
Extensive ley Extensively cultivated leys that are neither ploughed nor fertilized and less productive than ordinary leys.	Extensiv vall Extensivt brukade vallar som varken plöjs eller eller gödslas och är mindre produktiva än vanliga vallar.
Permanent grassland Natural grazing land that is neither ploughed nor fertilized.	Permanent gräsmark Naturbetesmark som varken plöjs eller gödslas.
Production regions Geographic areas used in official statistics to describe a country's agricultural production. Sweden can be split into 8, 18 production regions. PLC use 22 regions for leakage calculation (4 of the official 18 regions are further divided).	Produktionsområden Geografiska områden som används i officiell statistik för att beskriva ett lands jordbruksproduktion. Sverige kan delas in i 8, 18 produktionsområden. PLC beräkningar görs för 22 ”urlakningsregioner”, där 4 av de 18 produktionsregionerna delas i vardera två regioner.
Concentrate feed Grain, rapeseed, press cakes, mixes and other energy- and protein-rich feed.	Kraftfoder Spannmål, rapsfrön, presskakor från oljepressning, foderblandningar och annat energi- och proteinrikt foder.
Roughage (silage, hay) Feed consisting of grass, clover and other plants. Roughage is harvested on leys or directly grazed by ruminants (cattle, sheep, goats and horses).	Grovfoder (ensilage, hö) Foder som består av gräs, klöver och andra växter. Grovfoder skördas på vallar eller betas direkt av betande djur (nötkreatur, lamm, getter och hästar).
Paddocks Corrals where horses reside partly or most of the day. Can be fenced areas on leys and permanent grasslands or areas constructed to be well-drained.	Rasthagar Inhägnader där hästar vistas under hela eller delar av dygnet. Kan vara fållor på betesmarker eller anlagda väldränerade ytor.
Crop	Gröda
Oat	Havre
Grain	Spannmål
Food waste	Matavfall
Unnecessary food waste	Onödigt matavfall, även kallat matsvinn.

2. APPENDIX: PROTEIN INTAKE

Table 25 Content of protein, phosphorus and nitrogen per kg foodstuff. Source: Swedish Food Agency/Food database.

	PROTEIN (KG)	PHOSPHORUS (MG)	NITROGEN (KG)
BEEF (RAW, BONE-FREE)	0.2222	1901	0.036
PORK (RAW, BONE-FREE)	0.1919	1785	0.031
CHICKEN (RAW, BONE-FREE)	0.2413	1960	0.039
LAMB (RAW, BONE-FREE)	0.2013	1933	0.032
DAIRY PRODUCTS (MILK EQUIVALENTS)	0.0351	1020	0.006
FISH (SALMON, RAW, BONE-FREE)	0.2919	5500	0.047
EGGS (RAW)	0.184	2000	0.029
LEGUMES (WHITE BEANS, DRY SUBSTANCE)	0.22	4250	0.036

Table 26 Average retention of nitrogen and phosphorus derived from gross and net loads in the HELCOM PLC5 reporting (Swedish Environmental Protection Agency 2008)

	AVERAGE RETENTION (%)	
	NITROGEN	PHOSPHORUS
AGRICULTURE	36	34
ON-SITE SEWAGE SYSTEMS	39	29
MUNICIPAL WASTEWATER TREATMENT PLANTS	39	17

3. APPENDIX: RETENTION MAPS

Retention maps published by Swedish Environmental Protection Agency (2008).

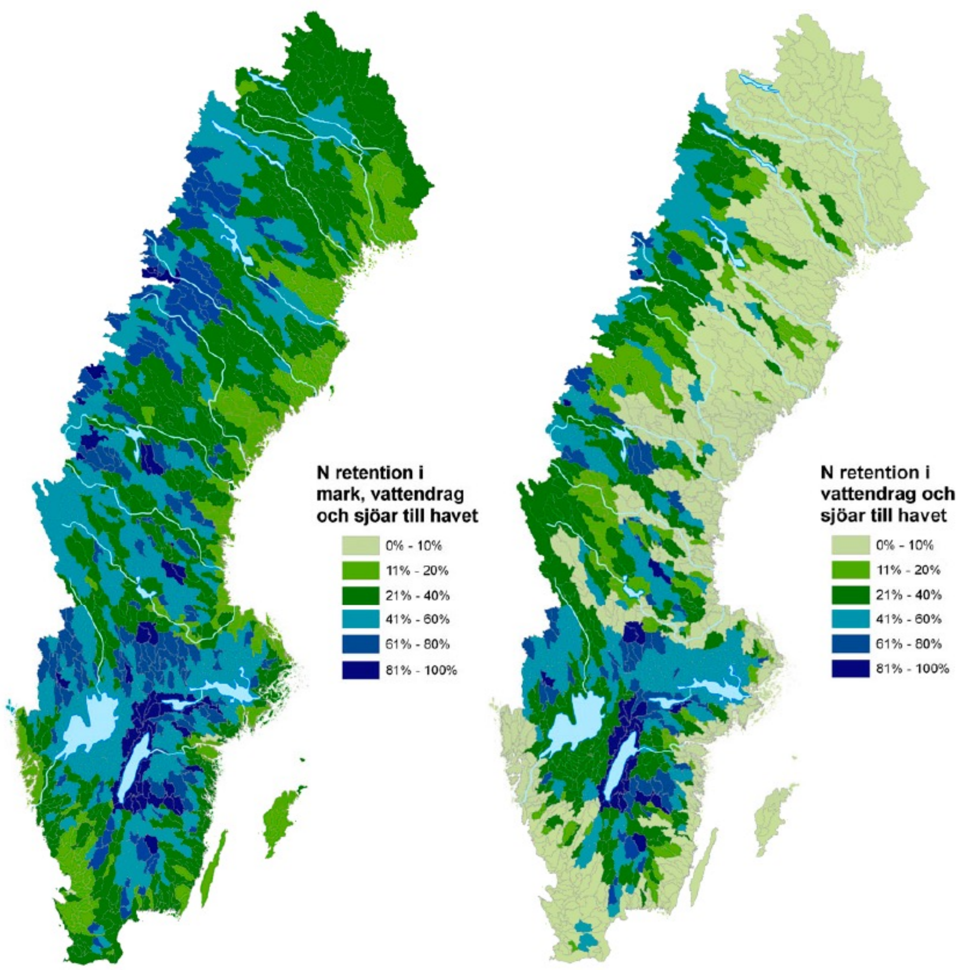

Figure 9 Nitrogen retention in soil, rivers and lakes along relevant pathways to the sea. The left map is to be used for leaching from agriculture and emissions from on-site sewage systems. The right map is to be used for emissions from municipal sewage systems.

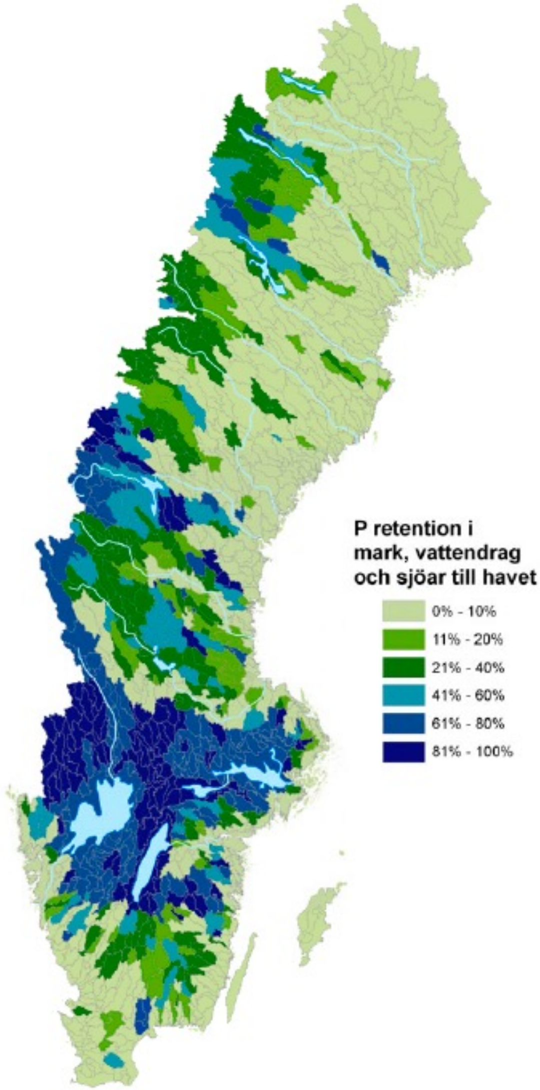

Figure 10 Phosphorus retention in soil, rivers and lakes along relevant pathways to the sea. To be used for all emission sources.

4. APPENDIX: PHOSPHORUS ADDITIVES

Table 27 Conversion factors used to calculate phosphorus amount in specific additives. The content of P_2O_5 in the specific additives (E-numbers) is calculated as averages of the conversion factors suggested by the National Food Agency[69]. The further conversion to P (0.4364) is based on chemical composition.

ADDITIVE	CONVERSION TO P_2O_5	CONVERSION TO P
	KG P_2O_5 PER KG ADDITIVE	KG P PER KG ADDITIVE
E338	0.724	0.32
E339	0.393	0.17
E340	0.418	0.18
E341	0.509	0.22
E343	0.576	0.25
E451	0.500	0.22
E452	0.659	0.29
E541	0.540	0.24
OTHERS	0.540	0.24

[69] Recommendations of the National Food Agency (sanctioned 20160113) concerning Regulation (EC) No 1333/2008 of the European parliament and of the Council of 16 December 2008 on food additives.

5. APPENDIX: HORSE KEEPING: NUMBER OF HORSES AND AREAS FOR ANIMAL FEED PRODUCTION AND GRAZING

Table 28 Number of horses and estimated area (hectare) for animal feed production and grazing in eight production regions.

	NUMBER OF HORSES (STATISTICS SWEDEN)	LEYS (INCLUDING GRAZING LAND) (CEDERBERG ET AL 2009)	PERMANENT GRASSLAND (CEDERBERG ET AL 2009)	CROPLAND – GRAIN CALCULATED*
(GÖTALANDS MELLANBYGDER)	31 288	14 925	1 553	2 427
PLAIN DISTRICTS IN NORTHERN GÖTALAND (GÖTALANDS NORRA SLÄTTBYGDER)	22 455	10 712	1 115	1 742
FOREST DISTRICTS IN GÖTALAND (GÖTALANDS SKOGSBYGDER)	94 533	45 095	4 692	7 333
PLAIN DISTRICTS IN SOUTHERN GÖTALAND (GÖTALANDS SÖDRA SLÄTTBYGDER)	36 524	17 423	1 813	2 833
FOREST DISTRICTS IN CENTRAL SWEDEN (MELLERSTA SVERIGES SKOGSBYGDER)	29 576	14 109	1 468	2 294
LOWER PARTS OF NORRLAND (NEDRE NORRLAND)	36 074	17 208	1 790	2 798
PLAIN DISTRICTS OF SWEDLAND (SVEALANDS SLÄTTBYGDER)	96 174	45 878	4 773	7 461
UPPER PARTS OF NORRLAND (ÖVRE NORRLAND)	16 038	7 651	796	1 244
TOTAL	362 662	173 000	18 000	28 133

*See Chapter 5 for details regarding the calculation of area for grain production.

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