Grain 7 bis: Aquaculture nutrition - Issues and Prospects

Responsable: Dr. Sadasivam Kaushik, INRA

My name is Sachi Kaushik, from INRA in Saint-Pée-sur-Nivelle (France), and I am the founder of the Fish Nutrition Laboratory.

What is the difference between feeding and nutrition?
The difference between feeding and nutrition is that feeding is about the search, delivery and ingestion of feed. Nutrition is about everything that happens once feed has been ingested: digestion, excretion, absorption and growth, using the nutrients provided by feed.

In terms of animal nutrition, what distinguishes aquatic animals from terrestrial livestock?
In terms of animal nutrition, fish differ from other animals. There are at least three differences. One relates to the aquatic environment, because expenses related to standing do not exist in aquatic animals. The second difference is the ability of fish and aquatic animals to adapt to their environment, temperature, for example: terrestrial animals need to maintain a constant temperature and therefore they spend a lot more energy. The third difference is about the handling of ingested feed, especially protein intake. The ingested proteins provide amino acids across the gastrointestinal tract. Amino acids then produce ammonia that is toxic and must be removed. In the case of terrestrial animals, including us, ammonia is converted into urea. For birds, ammonia is converted into urea and uric acid, while for fish and shrimps for example, ammonia is directly released into the aquatic environment in which they live, which requires a lower energy expenditure. These are the three major differences between the terrestrial and aquatic animals.
A fourth point is osmoregulation. The close link between the aquatic environment and the animals that live in it requires adaptation to osmotic regulation byÒ animals, which does not exist in terrestrial animals.

Do the various aquatic animals have the same feed and nutritional requirements than terrestrial livestock?
Fish, crustaceans and shellfish, that is to say, the aquatic animals, differ in different aspects from terrestrial animals. Firstly, land animals have a much lower need for protein than their aquatic counterparts. One must also distinguish between animals that are filter-feeders such as shellfish that have the ability to filter their food particles through their absorption system, from animals such as fish or shrimps that need to be fed. This is why in aquaculture, shellfish farming is generally considered differently from fish and crustacean aquaculture.
In terms of nutritional differences, of course there are! The first difference is the need in nitrogen, protein, which is higher for aquatic animals. The second difference is their

fatty acid requirements. On the other side, there is a great similarity between the terrestrial and aquatic animals with regard to the vitamins and minerals.

How to produce fish feed?

In the wild, fish either consume phytoplankton, zooplankton or even some other fish. When it comes to farming, feed must be provided to supply the nutrients that are necessary for survival, maintenance, growth and reproduction. So this requires various ingredients that provide the approximately forty nutrients and other essential nutrients needed for growth.

Feed formulation first requires a good knowledge of the nutritional needs of animals. Second, we must also know the ingredients we have, their composition, and their ability to provide different nutrients through the gastrointestinal tract. So you have to know the digestibility of feeds and ingredients that provide the essential nutrients.

Feed manufacturing can vary a lot. Let's take the example of carp culture in Asia. In this case, one uses very little processing, but just a mixture of two ingredients: cereal bran and oilseed cake for example. It is simply a mixture of two ingredients made available to fish. The second level concerns the manufacture of wet feed. Ingredients are simply mixed with a little moisture, water, and a binder, for making a paste that can be distributed. However, the majority of aquatic animal feeds are made through what is called an extrusion technology, which allows for producing floating, semi-floating or sinking pellets. This requires a fairly sophisticated technology, which allows bringing all essential nutritious feed in a compact form, adapted to the diameter of the mouth of the farmed animals.

As I said, there are several criteria to be considered. First, the size of feed pellets: it needs to be matching the requirements of animals. Second, nutritional needs may vary according to the age and the physiological status of the animals, and there must be corresponding feed formulations, with the various compounds, in particular in terms of protein. There may therefore be more or less differences by age and size of animals.

Should feed be adapted to the different development stages (*eg* larvae) or status (*eg* breeders) of fish?

First, consider the example of the larval stages. They have an extremely small mouth, so the feed particle size must be less than 50 microns. When animals grow, their ability to ingest larger pellets becomes more important. For broodstock, the pellet size is about 9 mm in diameter and when it comes to tuna farming, for example, it can be as large as 20 mm in diameter. So depending on the physiological stage, we can and must have feed with different diameters and size.

What are pro- and prebiotics? What is a premix?

Pre- and probiotics are feed additives bringing nutritional benefits, as they can improve the gut health by improving the microbial organisms, improving the use and absorption of nutrients and even sometimes having a beneficial effect on the health of animals that ingest it. A few are allowed at a European level, but not all. Abroad, various pre- and probiotics can be used whereas in Europe, very few are permitted by the EFSA (European Food Safety Agency).

A premix is a mixture of micronutrients. It is mainly made of vitamins, minerals and trace elements. The animals' requirements are known and a premix allows satisfying them. A premix is thus simply a vitamin and minerals mixture that provides all essential nutrients needed for a given age or size of fish.

Are biotechnologies being used for aquaculture feed?
Yes, for example, if one considers pond aquaculture, water fertilization is used to boost natural feed eaten by farmed fish, which is already a kind of biotechnology.
For the production of larvae, algae are used and improved, by changing their nutrient composition, enrichment of live prey such as brine shrimp or rotifers, which improves their nutritional value. There are also products of biotechnological origin, yeasts for example, which are produced and used as fish feed ingredients. So the use of biotechnology is also used in aquaculture, as it is in any other animal feed industry.

Does feed play a role on aquatic animals' health?
Absolutely! Feed first allows for survival, maintenance, growth, and of course, good health of farmed animals. A good feed formulation should allow for a good health and well-being of animals, what is called the physiological well-being of animals. So unquestionably, feed plays a role in animal health.
It is often said that when you have a good diet, you don't need any medication. Conversely, when you have a poor diet, even the best medicine will not bring anything to you. So really, feed brings a better health.

Aquaculture has been criticized for its use of fishmeal and fish oils. Why?
Aquaculture has often been criticized for its use of fishmeal and fish oils. There is a debate on this, but essentially in the developed countries. Indeed, for intensive fish production, it has become common in the last thirty years to use fishmeal and fish oils to provide the necessary nutrients. This production relies on industrial fisheries in Central America or the Nordic countries but the stocks are limited, and the available amount of fishmeal for example did not vary more than 5 million tons during the last twenty years. Regarding fish oil, the production has a lower limit of 1 million tonnes. So naturally, with the aquaculture growth observed in the meantime, the need for this type of ingredient could increase, so that many people have been wondering: are we making a responsible use of fishmeal and fish oils? In fact, for at least fifteen years, the research conducted, including at INRA and in Europe, has permitted to reduce drastically the use of fishmeal and fish oil in feed. For example, today, the production of Atlantic salmon requires less than 15% of fishmeal and fish oil, against around 50% twenty years ago. So there was a very significant decrease for species such as salmonids, marine fish or shrimp, but again, this very substantial reduction has occurred over the last 10 years.

Should we use animal or plant meals?
Should we use animal meals? I would not say: "we should", but we can very well use animal meals, particularly in a context of sustainability. These are terrestrial animals' products, derived from the human food chains, so human food by-products, which nutritional value is well recognized. There is no reason for not using them. Twenty years ago, we had problems with the use of these meals, resulting from the mad cow disease for example, or problems related to dioxin, but those problems are now resolved and, at least at the European level, the control is very strict and allows for developing and using properly these types of products.
In terms of sustainability, as I already said, the fishmeal and fish oils resources are scarce and valuable, and if aquaculture develops, it cannot rely solely on these ingredients. Plant proteins and oils are available in large quantities and they can be used for the production of fish or shrimp feeds. Regarding the proteins, there is no major

problem, except that plants produce anti-nutritional factors that must be eliminated by appropriate treatments. But for the vegetable oil, the fatty acid composition is very different from what can be obtained with aquatic marine oils. This is where we must be careful to ensure a sufficient amount of essential fatty acids in feed, allowing for a healthy fish but also for a good nutritional value for humans.
Should we use terrestrial plants or aquatic plants? We can very well use aquatic plants if they are available in sufficient quantity. Currently, as I have said for the replacement of fish oil and fishmeal, we are using terrestrial plants as a source of plant-derived proteins or vegetable oil. But of course we may use algae, microalgae and macroalgae, but so far, further investment is still needed before the supply becomes sufficient in the ingredients that we need. In the wild, fish rely on this type of ingredients but they are not directly consumed. They are consumed by different trophic levels: the phytoplankton is consumed by zooplankton, zooplankton consumed by fish. So we can recreate this. The use of microalgae is possible, so does the use of macroalgae but maybe it will take ten years before a genuine marine agronomy emerges.

Can we manufacture non-polluting feeds?
Aquaculture is often criticized for its environmental impact. Any animal production, as well as any life on Earth has an environmental impact, so aquaculture is not an exception. But for twenty years, there have been many improvements in the feeding of fish, which reduced suspended solids discharged by fish, decreased the excretion of ammonia or reduced the phosphorus rejected by fish. This has already translated into an improved nutritional value of feed on one side, the feed energy density, and the so-called low impact feeds. We cannot have a zero environmental impact, but a low environmental impact has already been practiced for ten years with regard to farmed fish in Europe and developed countries.

Do aquatic animals waste the feed they receive?
The animals are not wasting feed; the one wasting it is the one who distributes more or less feed than required to fulfill the nutritional and dietary requirement of farmed animals. For example, if feed is distributed in excess, the animals will not be able to consume all and of course, it will end up in the environment. There will also be a decrease in feed efficiency. So we should be familiar with the farmed species feeding patterns, the quantity of food that must be distributed with respect to the energy and nutrient requirement of animals. For this, there are models that can be used to properly adjust the amount of feed to distribute, the frequency of distribution following the natural feeding rhythm of animals that we farm. Of course we can reduce food waste, which has already been done for example with the salmon industry. Currently, the feed consumption ratio is lower than 1 for salmon and trout farming in Europe.

Are farmed fish healthy, tasty and as nutritious as wild fish?
Yes of course. The farming allows knowing the origin and the whole traceability of the species produced, ensuring a good health of animals and their nutritional value to humans. Is farmed fish good? It is a matter of taste, which can vary among populations. On a nutritional point of view, aquaculture or farming under controlled conditions helps to maintain a good nutritional value in terms of protein level but also in terms of essential fatty acids that are needed for human health. We did a lot of work on this topic and we frequently found that the nutritional value of farmed fish is even greater than what can be found in natural environments.

A second aspect that is not less important is the contamination. In the wild, we cannot have a control of possible contaminants that could be accumulated by fish, while in aquaculture, we can control, as it has been demonstrated over the last twenty years with dioxins or PCBs, for example.

How does the fish feeding affect the consumer health?

For a number of compounds such as fatty acids or certain micronutrients, there is a close relationship between what the animal consumes and its accumulation into the flesh. In this context, the nutritional quality of fish is highly dependent on the quality of their feed. For that reason, the health of consumers is closely related to the feeding of farmed fish.

This concerns both the positive aspects such as fatty acids but also the contaminants as I just said. Using vegetable oils for example, can reduce the presence of dioxins accumulated in wild fish for example. But, there is also a question: "when a diet rich in plant products is given, is the nutritional quality maintained? ". Yes and no. Regarding the protein part, there is no difference. However, when it comes to fatty acids, there may be significant changes in the fatty acid composition of farmed fish fed diets rich in vegetable oils, for example.

What we can do is called a finishing diet, with a short period during which fish receives a food rich in fish oil, which resets the fatty acid profile of the fish meat.

Grain 1 : Importance de l'aquaculture et enjeux du marché mondial des produits aquatiques

Responsable: Lionel Dabbadie

Introduction

> Activité plusieurs fois millénaire, l'aquaculture a connu une croissance et des bouleversements majeurs au cours du siècle écoulé. Si elle suscite souvent curiosité et enthousiasme, elle provoque aussi parfois des craintes et du rejet. On lui reproche ainsi pêle-mêle ses impacts sur l'environnement et la biodiversité, ses conséquences sociales, l'usage de matières premières non durables comme les farines de poisson, ou la qualité de ses produits, en oubliant que l'aquaculture est avant tout une activité traditionnelle, et remarquable par sa capacité à recycler les bio-ressources disponibles localement.
>
> Aujourd'hui, l'élevage des organismes aquatiques est devenue une activité économique majeure. Plus d'un poisson sur deux est issu de l'élevage. Est-ce une bonne chose ? Comment élève-t-on désormais les organismes aquatiques ? Que faut-il penser du poisson d'aquaculture ?
>
> C'est pour répondre à ces questions que ce module a été conçu, en dressant le panorama de l'aquaculture telle qu'elle est aujourd'hui pratiquée à travers le monde.

Les origines de la pisciculture

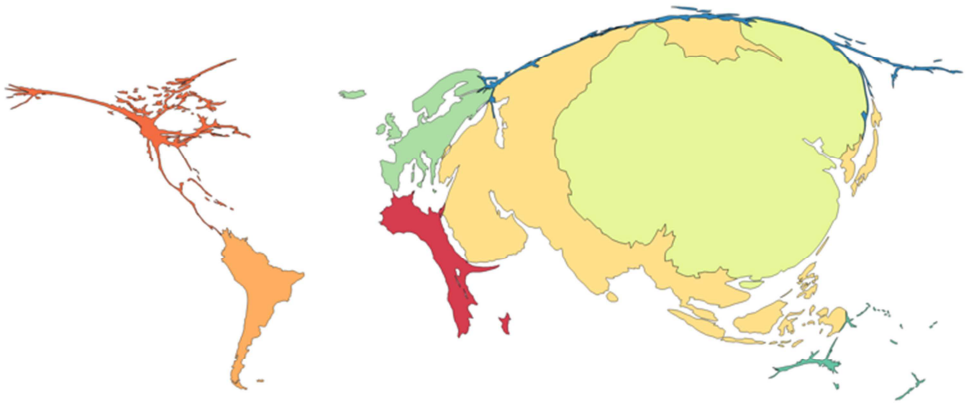
Souvent perçue comme une activité moderne, la pisciculture ou élevage des poissons, est en fait une activité multimillénaire.

On considère souvent qu'elle est apparue en Chine il y a 4 à 5000 ans, même si certains auteurs la verraient plutôt émerger en Mésopotamie, en Égypte voire en Australie. Ce qui est certain, c'est que le plus ancien traité de pisciculture connu a été rédigé en Chine par Fan Li en 475 avant JC, et qu'on retrouve des traces de pisciculture dans l'Antiquité. En France, la première implantation d'étang attestée par des documents date de 1220 dans la Dombes et c'est au Moyen-Âge, sous l'impulsion des ordres religieux, que la pisciculture s'est développée de manière déterminante, un peu partout en Europe.

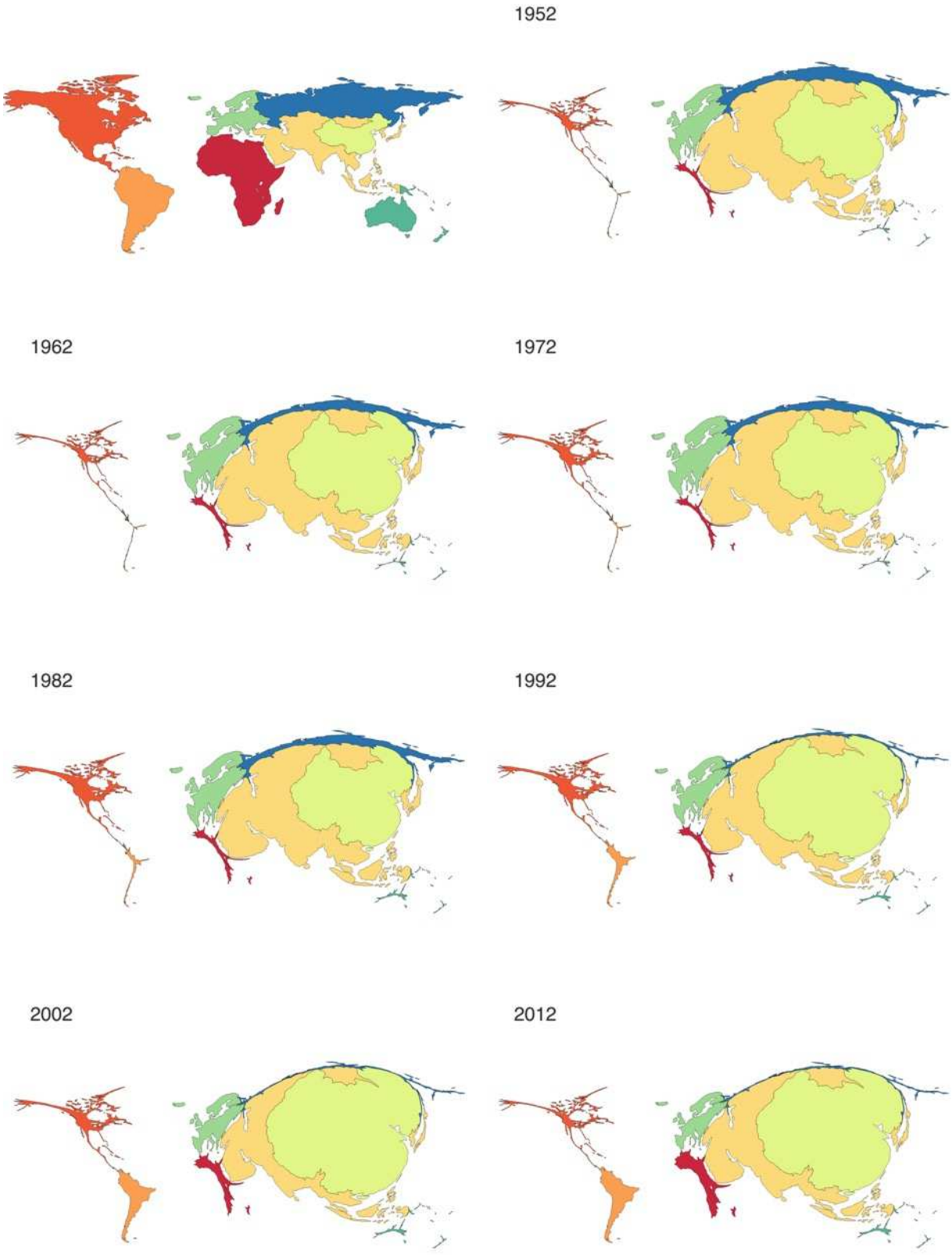
L'aquaculture n'a pourtant pas toujours bénéficié d'un soutien bienveillant. C'est même tout le contraire. Après le Moyen-Âge, les maladies associées aux étangs ont été mises en avant pour justifier leur assèchement et leur conversion en terres agricoles. Cette véritable chasse aux étangs a connu son paroxysme à la révolution française et même Danton s'est illustré dans ce débat anti-pisciculture en s'écriant à la Convention "Nous sommes tous de la conjuration contre les carpes, et nous aimons mieux le règne des moutons" !

L'importance actuelle de l'aquaculture

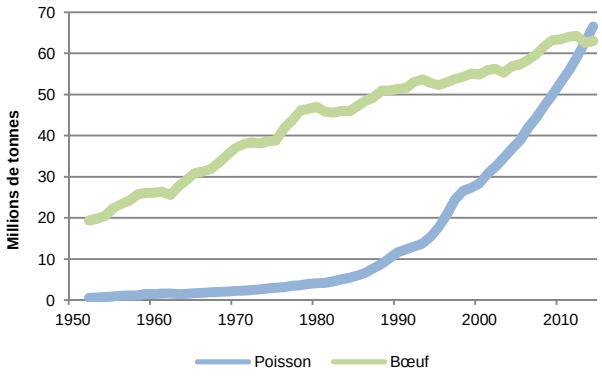
En 2012, l'aquaculture a produit un peu plus de 90 millions de tonnes, toutes espèces confondues, dont 44 millions de tonnes de poissons provenant à 87% d'Asie. La Chine contribue à elle seule à 55% de la production mondiale, l'Europe et l'Amérique chacune à 5% et l'Afrique, à 3%. Si la surface terrestre était proportionnelle à la production de chaque région, voici à quoi pourrait ressembler notre planète aujourd'hui:



Ce paysage aquacole a peu évolué au cours des 60 dernières années, même si entre 1950 et 1970, l'Europe, l'Amérique du Nord et l'Asie ont représenté l'essentiel de la croissance mondiale, alors que depuis les années 1990, c'est plutôt en Amérique du Sud et en Afrique que les dynamiques les plus notables sont observées.

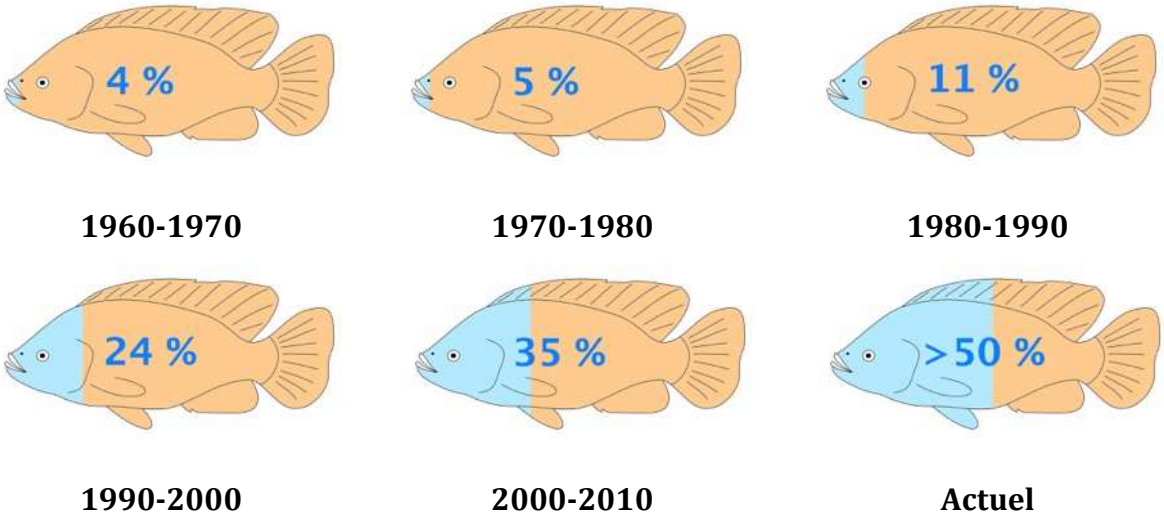


La pisciculture est le secteur des productions animales qui a connu la plus forte croissance au cours du dernier demi-siècle et depuis 2011, elle produit plus que l'élevage bovin.



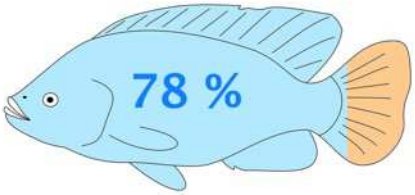
Évolution comparée de la production mondiale des élevages piscicoles et bovins entre 1950 et 2012 (Larsen & Roney (2013), Earth Policy Institute sur la base de données FAO, USDA)

> Elle a aussi rattrapé la pêche pour la fourniture des poissons destinés à l'alimentation humaine. Ainsi, si elle ne produisait qu'un poisson sur 25 consommés dans le monde dans les années 60, d'après les dernières estimations de la FAO, elle en produit aujourd'hui plus d'un sur deux.

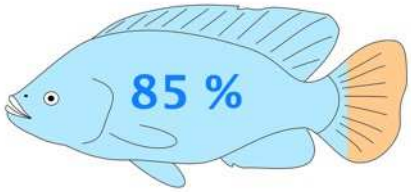


Importance de la pisciculture (en bleu) dans la consommation de poisson entre 1961 et 2011 (moyenne sur 10 ans, données FAO)

> La pisciculture est une activité largement dominée par les poissons d'eau douce qui représentent 85% du total. C'est aussi une activité tropicale puisqu'aujourd'hui, hors production chinoise, près de 8 poissons sur 10 viennent des pays chauds.



Production tropicale (bleue)
***vs.* Tempérée (beige)**



Production d'eau douce (bleue)
***vs.* Production marine (beige)**

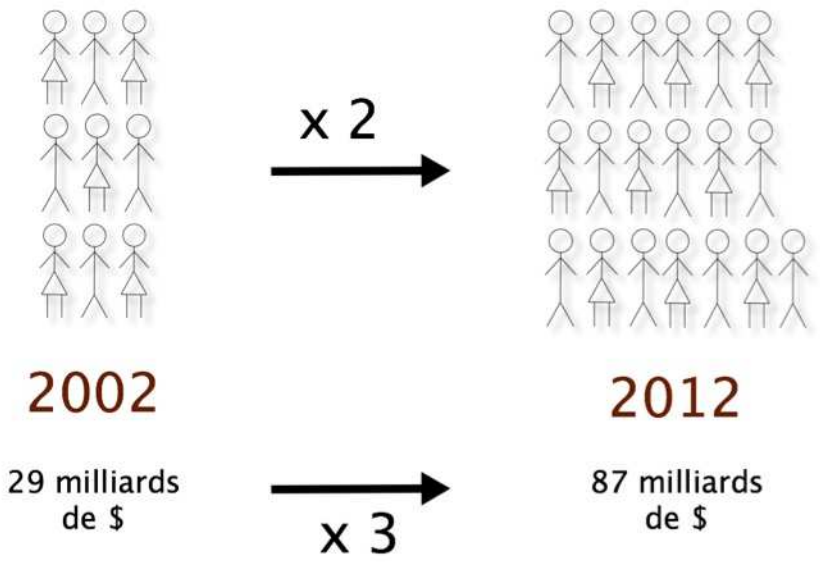
Son potentiel est beaucoup plus important que les quelques espèces qui dominent la production. A la différence de ce qu'on observe dans les autres formes d'élevage ou d'agriculture, de très nombreux organismes animaux et végétaux aquatiques sont élevés ou cultivés. La FAO en recense 567 en 2012, dont 354 sont des poissons. Ce nombre a augmenté de 170% en dix ans ! Toutefois, la production de la majorité de ces espèces reste encore insignifiante, puisque les dix poissons les plus importants représentent à eux seuls les trois-quarts de la production mondiale, que ce soit en eau douce ou en mer.

	2001	2008	2012
Poissons	131	212	354
Mollusques	42	67	102
Crustacés	27	42	59
Plantes aquatiques	8	15	37
Amphibiens et reptiles	2	3	6
	210	**340**	**567**

Rang	Nom	Production	% cumulé
1	Carpe herbivore	5 028 661	13%
2	Carpe argentée	4 189 578	25%
3	Carpe commune	3 791 912	35%
4	Tilapia du Nil	3 197 330	43%
5	Carpe Bighead	2 898 816	51%
6	Catla	2 761 022	58%
7	Carassin	2 451 845	65%
8	Pangas	1 649 547	69%
9	Rohu	1 555 546	74%

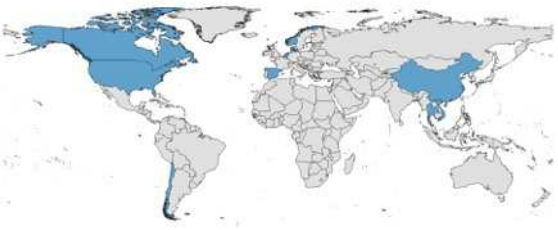
Rang	Nom	Production	% cumulé
1	Saumon atlantique	2 066 561	31%
2	Milkfish	943 259	45%
3	Truite arc-en-ciel	855 982	57%
4	Anguille japonaise	236 344	61%
5	Saumon Coho	171 681	63%
6	Sériole du Japon	160 396	66%
7	Dorade royale	159 731	68%
8	Loup européen	153 182	70%
9	Muge	141 731	73%

Sur le plan social, la pisciculture est une source vitale d'emplois, de nourriture et d'opportunités économiques, en particulier pour les petites communautés rurales des pays tropicaux. En 2012, près de 19 millions de personnes travaillent dans l'aquaculture, soit un quasi-doublement du nombre d'emplois directs en moins de 10 ans. Mais elle est aussi devenue une activité économique majeure, investie par des grands groupes multinationaux. En 2012, elle a ainsi généré un chiffre d'affaire de 87 milliards de dollars contre 29 milliards dix ans plus tôt.

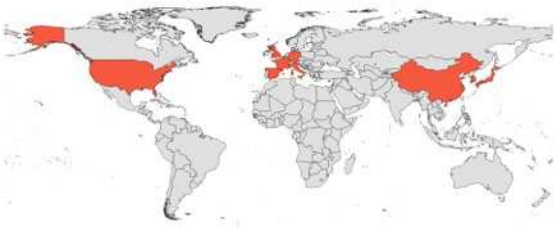


L'aquaculture est aussi une filière qui est entrée de plain-pied dans la mondialisation. Aujourd'hui, près de 40% de tout le poisson produit fait l'objet d'échanges internationaux, et plus des deux tiers en valeur des exportations des pays en développement sont destinés aux pays développés.

En volume, l'Asie est le premier exportateur mondial et l'Union Européenne, le premier importateur, mais les flux pourraient évoluer significativement à l'avenir puisque l'Asie devrait représenter 70% de la consommation mondiale de poisson d'ici 2030.

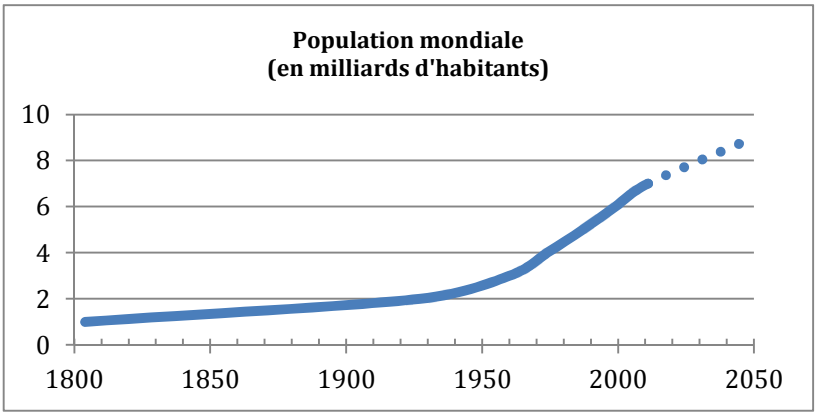


Top 10 des pays exportateurs



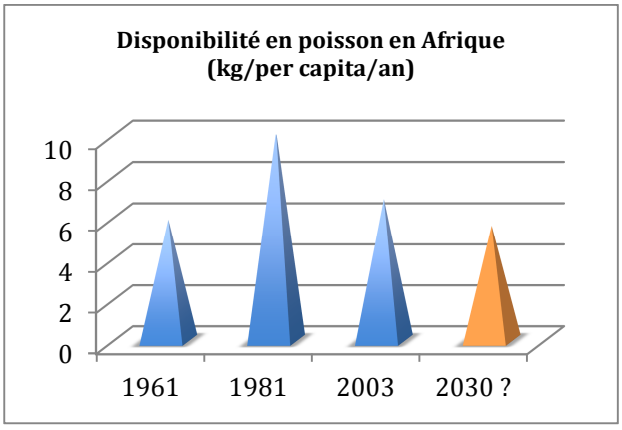
Top 10 des pays importateurs

Cela pose un véritable défi alimentaire car la demande globale en poisson va continuer à augmenter, pour des raisons démographiques, puisque la population mondiale devrait augmenter de 2 milliards de personnes d'ici à 2050, mais aussi en raison d'un changement de mode de vie car les consommateurs des classes moyennes apprécient de plus en plus le poisson.

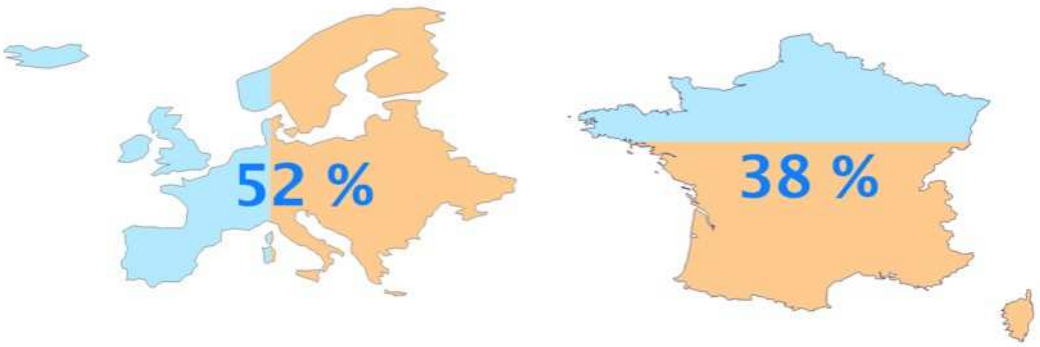


La FAO estime qu'à l'horizon 2030, la pisciculture devra assurer les deux tiers de la production piscicole mondiale pour répondre à la demande, du fait d'une relative stagnation des captures de la pêche, même si des marges de progression existent grâce à une meilleure gestion des stocks sauvages.

Une préoccupation concerne cependant l'Afrique Sub-Saharienne, qui pourrait se retrouver dans une situation critique si sa production piscicole n'augmente pas plus rapidement. La Banque Mondiale estime en effet que si rien ne change, la disponibilité en poisson va diminuer de 1% par an dans les années qui viennent pour atteindre 5,6 kg par personne et par an à l'horizon 2030, du fait d'une croissance démographique qui excède la croissance piscicole prévue sur le continent.



Une autre incertitude concerne l'Europe dont la dépendance en poissons pourrait aussi poser un problème de sécurité alimentaire si sa consommation ne diminue pas et que son taux de dépendance aux importations reste aussi élevé : en effet, pour satisfaire la demande du consommateur européen, un poisson sur deux doit être importé en 2014. Et la situation est encore pire en France, qui n'est auto-suffisante qu'à hauteur de 38%. Il faut dire que chaque français consomme en moyenne 34,6 kg de poisson chaque année, soit presque deux fois plus que le reste du monde qui se contente en moyenne de 18,9 kg par an.



Dans ces conditions, comment produire plus de poisson sans détruire l'environnement et sans surexploiter les stocks sauvages ? La question est d'autant compliquée que les effets difficilement prévisibles des changements globaux pourraient commencer à se faire ressentir dans quelques années. Nous l'abordons dans les vidéos suivantes.