ENVIRONMENTAL CARRYING CAPACITY FOR AQUACULTURE

Are there limits to the amount of fish or shellfish we can produce from aquaculture in a particular area or water body?

Yes.

The success of aquaculture depends on the ability of the market to absorb increased production. It also depends on the capacity of the environment to absorb wastes or remove disease organisms. Both of these limit the amount of fish or shellfish we can produce profitably in a particular place.

Why worry about environmental capacity?

The environment has limited capacity to absorb wastes from aquaculture. This is commonly referred to as *environmental capacity*. If this capacity is exceeded, water quality declines, disease organisms thrive, and aquaculture production may decline or collapse. Many people have lost money and become indebted as a result. This has happened throughout the world, including some parts of Vietnam.

Who does it belong to?

Environmental capacity is common property or resource. It is one of nature's free services. It tends to be over-exploited because no individual or group owns it or takes responsibility for it. Usually it is only when environmental capacity has been exceeded that its value becomes clear to those who depend upon it, and the right to use it becomes an issue.

Rough estimates of environmental capacity - carbon

1. Food and faeces are rich in carbon. It is estimated that for every tonne of fish or shrimp produced in aquaculture we produce more than 500kg o organic matter, corresponding to roughly 200kg of carbon. If we include the plankton that blooms on the nutrients these figures may be more than doubled.
2. Once this has settled on the bottom, and if it is well dispersed, it can decay at the rate of around 5 grams per m2 per year.
3. Therefore, if waste were discharged into a semi closed lagoon, we would need at least 4 hectares to effectively assimilate the waste for every tonne of fish or shrimp produced.

Can we estimate the capacity of the environment for aquaculture production?

Yes – in some situations – but only very roughly.

The theory is simple:

1. *Calculate waste production per unit aquaculture production.*
2. *Calculate the rate of waste breakdown, removal or flushing*
3. *Calculate the aquaculture production that would generate waste at the same rate as the capacity of the environment to remove it.*

The boxes provide examples of rough calculations for each of these, but they may be highly inaccurate. Ideally we should make more accurate calculations for particular aquatic systems.

For some simple aquatic systems (such as simple lagoons or canals), we can calculate roughly the amount of waste entering the water; and we can calculate the amount that can be flushed out or absorbed by natural processes. If the amount entering exceeds the amount being flushed out or absorbed, then water quality will decline and disease may increase.

Unfortunately, many lakes, wetlands, lagoons and estuaries are complex. Flushing of wastes or disease organisms may be very good in one part and very poor in another. Water may flow to-and-fro or in circles. Vegetation may help settle and absorb wastes in some areas. Calculations based on averages may be inaccurate in these circumstances.

Can we increase the carrying capacity of the environment for aquaculture production?
Yes – almost infinitely.
We can do this in at least four ways:

1. *Decrease the waste produced per kilogram of fish or shellfish produced*.
   Better quality feeds and improved feeding practices greatly improve food conversion efficiency (food given/weight of production). Better water quality reduces stress, disease, and also improved food conversion efficiency.

2. *Reduce the amount of waste that is discharged to the environment*.
   - Water can be discharged to a settling pond before being discharged to the wider environment. This may only be necessary toward the end of a production cycle when most of the organic matter and nutrients are released.
   - Pond mud can be removed at the end of a production cycle and sold or disposed where nutrients are not a problem, or where they are needed.
   - Pond mud can be treated by drying and turning between crops.

3. *Disperse the wastes more widely.*
   Farms can be sited in areas where wastes are rapidly flushed away. Farmers and/or government can design water canals to make sure that there is plenty of flushing, and that wastes are not recycled to themselves or other farmers.

4. *Maintain or improve the capacity of the environment to assimilate waste*.
   Mangrove forest and other wetland plants absorb low concentration organic wastes very effectively. Mangrove can function as a natural settling basin, and may assimilate 200kg of nitrogen and 20kg of phosphorus per hectare per year. Government and farmer groups should strive to conserve significant areas of these natural treatment beds, and make sure that waste water from fish farms is dispersed at acceptable concentrations.

5. *Treat waste water and recycle to production ponds*.
   A combination of settling, sediment removal and heavy aeration may allow water to be recycled to production ponds, with the added benefit of reducing the likelihood of introducing disease organisms in the water supply.

Where does the waste go?

As much as 80% of the nitrogen in the feed and 90% of the phosphorus is wasted in intensive fish or shrimp culture. Much more is wasted in lobster culture.

Of the waste nutrients generated, 70-90% may end up in the sediment of ponds.

If we keep the sediment in the pond, and treat (dry) it between crops, or remove it to a safe place, we *can increase carrying capacity fivefold.*

What should be done to ensure that aquaculture does not exceed environmental capacity?

- Ensure that those using the capacity of the environment for aquaculture and other productive activities are aware of its value and limits, and are made responsible for it.

- Introduce initiatives to promote the practices described above, which will effectively increase carrying capacity.

- If possible, make rough estimates of environmental capacity for particular lagoons, estuaries, rivers and lakes, and gain broad agreement as to how this capacity is to be allocated to different users, and managed in the long term.

- Set in place simple monitoring schemes (based ideally on simple and easily observed indicators) so that the accuracy of environmental capacity estimates can be improved, and precautionary measures introduced in good time to prevent environmental damage and production collapse.

Caution
The figures given in this leaflet are very rough, and the actual values for any particular aquaculture system and aquatic system are likely to be different.

The TROPECA project aims to improve the accuracy of these approaches to the estimation of carrying capacity.

Rough calculation of carrying capacity:
maximum acceptable nutrient load and corresponding shrimp aquaculture production for semi-closed lagoon system

Nitrogen in feed (g/kg)	70
Nitrogen in shrimp (g/kg)	30
Food conversion ratio (FCR)	2
Flushing rate (per day)	1
Lagoon size (ha)	500
Lagoon average depth (m)	1.5
Current N ambient conc. (mg/l)	0.2
Acceptable N concentration (mg/l N) (an environmental quality standard or EQS)	0.4

Calculation

Calculated parameter	*formula*	*result*
pollution rate kg N/ mt production	(N in food – N in shrimp)*FCR[1]	80
Lagoon volume (m3)	Area*depth*10,000	7,500,000
Flushed volume per year (m3)	volume*flush rate*365 days	2,737,500,000
Environmental capacity (for N)	(EQS-ambient)*flushed volume	547,500
Maximum shrimp production (mt/yr) within EQS	environmental capacity/ pollution rate	6,844

1. *A slightly simpler calculation is possible for rivers where the flushed volume per year can be estimated as the total river flow for the year*
2. *A similar calculation may be undertaken for phosphorus. P in pellet feed is 1-2%; P content of shrimp (fresh weight) 0.2%*