Aggregate Emission Data Estimation Technique Manual

For

The Aquaculture of

Barramundi
Prawns
Crocodiles
Pearl oysters
Red claw
Tropical abalone

In Tropical Australia

Version 1.0 – 27 June 2000

Emission Estimation Technique Manual
For Tropical Aquaculture

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1.0 Introduction

The purpose of this Emission Estimation Technique (EET) Manual is to assist State and Territory authorities in estimating emissions of listed substances for the National Pollution Inventory (NPI). This manual contains a general summary of the aquaculture industry in tropical Australia and describes the procedures and recommended methods for estimating emissions from Tropical Aquaculture Facilities.

The species covered by this manual are:
- prawns (*Penaeus spp.*)
- barramundi (*Lates calcarifer*) and other fin fish
- pearl oyster (*Pinctada spp.*)
- red Claw (*Cherax quadricarinatus*)
- donkeys Ear Abalone (*Haliotis asinina*)
- crocodiles (*Crocodylus porosis; Crocodylus johnstoni*)

The methods described in this manual are based on farming systems which are commonly used for the above species and may be used as a guide for estimating emissions from other species which use similar farming methods.

EET Manual: Tropical Aquaculture

This manual was drafted by the Northern Territory University on behalf of the Commonwealth Government (Environment Australia). It has been developed through a process of consultation with Queensland, West Australia and Northern Territory Fishery and Primary Industry departments and environmental protection authorities, and with the participation of industry representatives.

2.0 Definition of Aquaculture

For the purposes of this manual, aquaculture has been defined according to the definition used by the FAO for statistical purposes:

‘The farming of aquatic organisms including fish, molluscs, crustaceans, aquatic plants and (for the purposes of this project) crocodiles. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.’ (Seventh Session of the Indo-Pacific Fisheries Council (IPFC) Working Party of Experts on Aquaculture, 1988, Bangkok). <www.fao.org/docrep/t8582e/t8582e03.htm>

3.0 Overview of Aquaculture in Northern Australia

With the exception of pearl farming, which is concentrated in the Northern Territory and the Northern region of West Australia, the bulk of aquaculture activity in tropical Australia is conducted on the eastern coastal strip of Queensland. The reasons for this include the availability of suitable land, proximity to markets and access to labour. Aquaculture in tropical Australia remains small and, in most cases, is still in a rapidly developing phase. With the help of organisations such as State and Territory Departments of Primary Industries and Fisheries, Universities, Australian Institute of Marine Science (AIMS) and the CSIRO, methods of farming are constantly being modified to better suit local conditions, to give higher yields and to reduce effluent outfall.

3.1 Pearls

Measured on a dollar return basis, pearl farming is currently the largest aquaculture industry in tropical Australia (NT DPIF). Although pearl cultivation is the focus of considerable research, much of the research is ‘commercial in confidence’ and the pearling industry is often seen as somewhat secretive. Despite this, pearl farming is generally regarded as environmentally benign and seldom arouses suspicions regarding pollution.

3.2 Prawns

Prawn farming is a rapidly developing industry and, if projects mooted for the Northern Territory and West Australia are realised, may overtake pearls as the highest dollar earner of all the Australian aquaculture species in the next 10–15 years.

Of the species farmed in the tropics, prawn farming is perceived as having the greatest environmental impact. This perception is partially based on the Asian experience, where prawn farming is a very big business (one farm alone in Sumatra covers 10,000 hectares), but often a poorly managed one. The results of poor management and low environmental standards have led to considerable environmental degradation in several areas of Asia. In Australia prawn farms generally have a good environmental record, however they are often located in, or adjacent to, areas that are environmentally and/or politically sensitive (the Great Barrier Reef Marine Park, for instance). Public sentiment, especially from recreational fishers, is often roused against developments if there is any suggestion that they may impact on recreational areas.

Large amounts of money and effort are currently being expended on research into all aspects of prawn farming, including ways of reducing nutrient loads in effluent released into the environment. The industry is highly dynamic and growers seem willing to adopt new practices in all aspects of the industry, including waste management.

3.3 Crocodiles

Crocodiles are farmed for both meat and skins. In several cases, farms are also presented as tourist attractions. By comparison with overseas crocodile and alligator industry, the Australian industry is small (Vicki Simlesa NT DPIF). Future expansion will probably depend on streamlining and adopting new cultivation methods to enable local growers to be more competitive on the international market. Two of the future directions mooted for crocodile farming are the introduction of standardised, pelletised food and the reduction of the use of standing water in growing pens (Bernie Davis, Qld DPI, Oonoonba). If these measures are adopted in Australia, crocodile farming should cease to be an aquaculture activity and should be more properly regarded as an animal feed lot for the purposes of estimating effluent discharge.

At present, farm effluent from crocodile farms is generally retained either in settling ponds or septic systems within the farm boundaries. Notwithstanding the possible release of effluent from ponds during monsoonal flooding, crocodile farms are not generally sources of emissions. There may, however, be some issues to be addressed regarding the amount of ammonia that is volatilised from larger, intensive grow-out facilities.

3.4 Barramundi

Barramundi is currently the principal finfish farmed in tropical Australia. It is unlikely to be overtaken in the foreseeable future despite research being carried out on the culture of several other species of finfish. At present barramundi farming in the tropics is overwhelmingly concentrated in Queensland—there are currently three farms operating in the Northern Territory (NT DPIF, Aquaculture Branch) and one farm in north Western Australia (WA DPIF). This is set to change in the near future with a large cage culture system planned for the Tiwi Islands in the Northern Territory and possible expansion in West Australia. With only one exception—a small cage farm in the Hinchinbrook area—farms in Queensland use fresh water ponds from which effluent is usually discharged within the farm boundaries. Existing farms are small and have little pollution potential. This will change with the introduction of large marine projects

3.5 Red Claw

Red claw farming is mainly conducted in Queensland. The industry remains small despite an apparently good market potential and recent move to establish red claw farming in the Ord River region of Western Australia and in the Northern Territory. Farms are exclusively fresh water and wastewater is either recycled or discharged onto ground within the farm boundaries. Therefore, the potential for pollution from this industry is a very low.

3.6 Tropical Abalone

Tropical abalone is not at present farmed in Australia, except for some experimental work in Queensland and Western Australia on the donkey ear abalone *H. asinina*. This species is cultivated in Thailand and the Philippines and has potential for cultivation in tropical Australia.

3.7 Other Species

There are a number of marine and fresh water species currently under scrutiny for their aquaculture potential and it is likely that at least some of those being studied will prove viable. A few, such as eels and mud crabs, are already being produced and marketed on a small scale in Queensland.

3.8 Licensing

Licensing conditions for aquaculture vary considerably between Western Australia, Queensland and the Northern Territory. The industry in Queensland is tightly controlled, with farmers required to comply with legislations framed by local governments, state government (in the form of the Environmental Protection Authority) and commonwealth government (in the form of the Great Barrier Reef Marine Park Authority). The Queensland Environmental Protection Authority is responsible for licensing aquaculture operations. License conditions lay out the permissible effluent from individual farms and stipulate a regular outfall-monitoring program. Effluent is sampled by the farmer at the point where it leaves the farm and the samples independently analysed for **pH**; **Dissolved Oxygen**; **5-day Biochemical Oxygen Demand**; **Suspended Solids**; **Total Nitrogen** and **Total Phosphorus**. Effluent release times are also stipulated.

Western Australian licenses impose overall stringent monitoring and reporting conditions on all aquaculture and include monthly reporting requirements for **pH**; **Dissolved Oxygen**; **5-day Biochemical Oxygen Demand**; **Suspended Solids**; **Total Nitrogen** and **Total Phosphorus,** as well as **Temperature, Salinity** and **Turbidity.**

Water monitoring regimes and conditions in the Northern Territory are determined on a case–by–case basis and are less prescriptive than those in WA and Qld. At present assessment is under the Environmental Assessment Act, the Water Act and the Waste Management Act, however there is a need in the NT to develop baseline studies on background nutrient levels.

3.9 Farming systems

Broadly speaking, aquaculture farming systems fall into three categories:

• Intensive

Farming systems are considered intensive when animals are concentrated in high densities in ponds, tanks or cages. For example, in Taiwan a production rate for prawns of 12.6–27.4 tons/ha is considered intensive (Phillips et al. 1991,1993, from USAID/University of Rhode Island Project on Sustainable Aquaculture). Features of intensive farming are the need for artificial aeration, the regular input of food into the system and resultant high levels nutrients in the waste. Many intensive systems now incorporate some form of effluent treatment before the water is released into the environment. Intensive aquaculture may be equated to terrestrial feed lots.

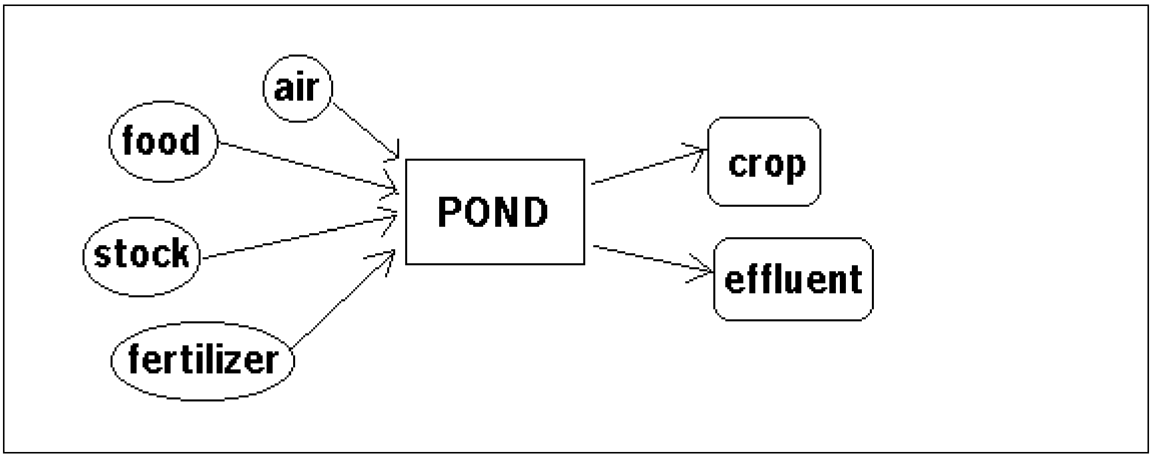


Figure 1. Intensive farming system. All of the stocks requirements are supplied artificially and the stock is closely managed.

In tropical Australia finfish, prawns and crocodiles are the most intensively farmed species.

• Semi intensive

Semi intensive systems employ ponds and cages, but seldom tanks, and involve a minimal level of intervention in the life of the stock. Stocking is at a lower density than in intensive systems, for example a semi intensive prawn farm in Taiwan would have a production rate of 4.1–11.0 tons/ha (Phillips et al. 1991,1993, from USAID/University of Rhode Island Project on Sustainable Aquaculture) and aeration and food input is minimal. Stock feed on plankton or bacteria that are encouraged to grow in the ponds by the addition of fertilizer and a growing medium such as hay or lucerne pellets. The terrestrial equivalent of semi intensive aquaculture is improved pasture farming of sheep or cattle.

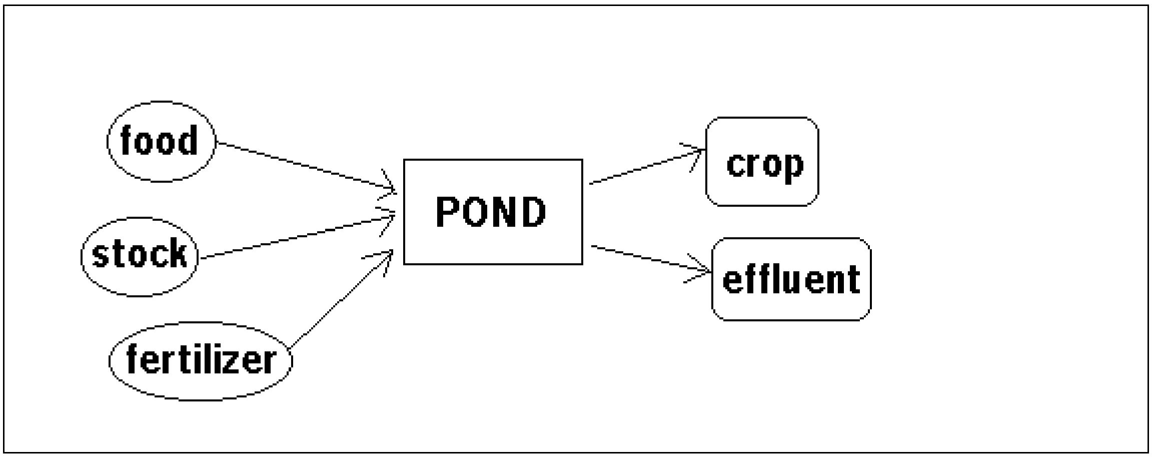


Figure 2. **Semi-intensive farming system.** Some artificial inputs, such as aeration, are limited or absent. Stock is managed.

In tropical Australia most red claw and, in some cases, finfish fingerlings are grown under this system. Although semi intensive systems are employed overseas for farming prawns, Australian prawn farmers generally use intensive systems.

In reality, the line between intensive and extensive systems is somewhat blurred. At the extremes the farming system being used is obvious, however in the middle ranges e.g. a farm with a prawn production rate of 12 ton / ha may fall into either category. New developments in farming systems will always create more intensive systems and as these come on line the definitions of intensive and semi-intensive systems may shift.

- **Extensive**

Extensive farming uses the natural environment. Generally stock are obtained from a hatchery, although in some cases wild spat or juveniles may be collected, and placed into a position where they can obtain all their needs from an unmodified or minimally modified environment. Intervention by the farmer is limited to (sometimes) providing shelter or holding structures and (sometimes) cleaning benthic growth and debris from the animals. The terrestrial equivalent of extensive aquaculture is open range ranching.

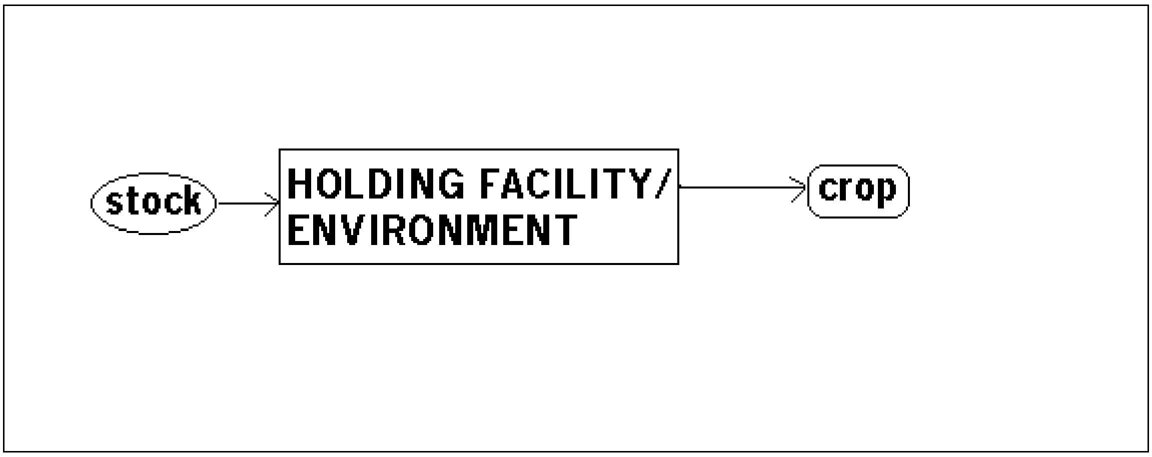


Figure 3. Extensive farming system. Artificial input is limited or absent. Active stock management is minimal

In tropical Australia pearl farming is the only extensive farming currently being conducted.

3.10 Hatcheries

Hatcheries are a vital component of aquaculture. These are usually separate from the farms and are often owned and operated as separate enterprises that supply stock to farms for grow-out. Generally hatcheries operate in a highly intensive fashion for short periods and may then be idle until the next spawning. Food in the form of zooplankton and phytoplankton are grown on site on demand. Tests on pearl shell hatcheries in Western Australia have shown that the discharge water quality is very similar to, and can actually be better than the inflow water (Enzer Marine Environmental Consulting, 1998).

In some species, for example barramundi, larval production may go through an semi-intensive nursery phase, where larvae are stocked into ponds that have been heavily fertilized to encourage algal and zooplankton blooms. Use of such ponds is episodal and at the end of each run most fertilizer has been converted into food that has, in turn, been consumed by the barramundi. (Steve Peucker, personal communication).

4.0 Effluent discharge

Aquatic species are generally very susceptible to chemical pollution, hence, by its very nature the aquaculture industry is largely self-regulating as far as pollutants are concerned. In general, chemical use in aquaculture is kept at a minimum and effluent is usually comprised principally of the **nutrients** and **suspended solids**. Suspended solids are considered a significant effluent by the aquaculture industry and are reportable under both Qld and W.A. licensing rules, however at the present time they are not included under the current NPI listing.

4.1 Chemical use in aquaculture

There is a range of minor-use chemicals that are added for special purposes. These include:

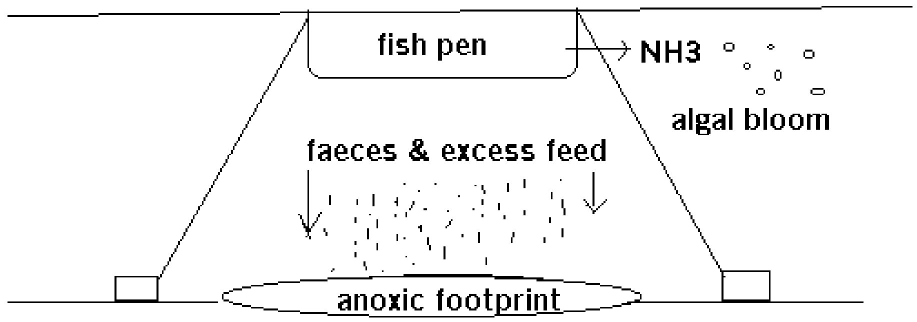
- antibiotics which may be used to control outbreaks of disease. Use of these are regulated by veterinarians;
- ‘tea seed cake’ containing the natural product saponin used to kill fish in prawn ponds;
- colouring which may be added for final conditioning in prawns.

These are generally complex materials and may contain minor NPI substances, however even under the most liberal use they will not reach reportable levels.

Chlorine (Cl), which is used for cleaning and sterilizing, may reach aggregate emission levels equal to reportable thresholds in larger facilities. This is especially true for some crocodile farms where there is regular use of chlorine for cleaning pens and abattoir facilities. There are reports of the use of **Copper Sulphate ($CuSO_4$)** for cleaning and the control of fungal diseases on crocodile farms, however this use is now very minor and appears to be largely discontinued on most farms. Similarly the use of **Acetic Acid (ethanoic acid)** in prepacking treatment of crocodile meat seems to be being phased out in favour of chlorine.

4.2 Abnormal-condition pollutants

Production of **hydrogen sulphide** may occur when conditions in a pond or in the substrate below a cage become anoxic. Hydrogen sulphide is toxic and its presence is detrimental to the profitable management of an aquaculture farm. It is rare, but its occurrence in cages can present a problem. A build up of detritus composed of uneaten food and faecal matter can occur on the seabed under the cages and can become anoxic unless dispersed. The first the farm manager may know of this is when bubbles of hydrogen sulphide appear on the surface. If the natural current is not strong enough, large farms may use underwater ‘fans’ to disperse the detritus. Environmental reactions in detrital build-up vary with conditions. At present there appears to be very little data based on tropical conditions, and even if there were it is likely that detrital build up will react differently from site to site.



$2CH_2O + SO_4 \rightarrow \mathbf{H_2S} + 2CHO_3$ $\Rightarrow$ **hydrogen sulphide**

$CO_2 + 8H \rightarrow CH_4 + 2H_2O$

Figure 4. Formation of anoxic foot prints under cages (from 'Aquaculturists guide to harmful Australian microalgae', Gustaaf Hallegraeff, 1991).

Strong currents or underwater fans (Malcolm C.M. Beveridge, Cage aquaculture, 1987) usually disperse build-up of detritus under cages and prevent the production of hydrogen sulphide. If a build-up occurs hydrogen sulphide may adversely affect fish stocked in the cage or pen.

Acid sulphate problems can occur when naturally anoxic soils with high organic content are disturbed—mangrove soils typically have a high acid sulphate potential. Acid sulphate soils produce **sulphuric acid** when disturbed and as a result lower the pH of the water. This is detrimental to any aquaculture venture and today developers test soils before digging ponds, but this has not always been the case. There is some concern that ponds which have become unusable and been abandoned due to acid sulphate problems are continuing to produce acid which is escaping to the environment. There has been very little work done on abandoned ponds to assess the extent of this problem.

Ammonia is the first by-product of aquaculture. It is excreted by the animal and, under normal circumstances, is rapidly converted to useable NO_3 by the action of bacteria in the water. The nutrient is then taken up by mangroves, seaweeds or phytoplankton and returned to the food chain. Excess ammonia can damage gill filaments and its removal from an aquatic system is imperative, however ammonia production is normally low and should not pose a problem for most aquaculture.

Crocodiles are an exception in aquaculture. Because they are air breathing, ammonia removal is not as important as in other forms of aquaculture. Crocodile excreta is very high in ammonia, estimated at up to 90% of all waste products (Charlie Manolis, personal communication). The smell of ammonia is very noticeable in climate controlled enclosed pens, which suggests that there is a high level of volatilisation.

4.3 Associated emissions

There may be **sources of emissions associated with running a large aquaculture farm, but not directly resulting from aquaculture**. Examples of these may include:

- the use of fuel for generators, outboard motors and other equipment;

- disposal of waste and sewage from workers camps or villages;
- operations of an abattoir and the associated disposal of carcasses or other by-products.

A survey may need to be carried out to assess the extent of such facilities (Appendix 1) and relevant NPI manuals should be referred to regarding these activities.

4.4 Nutrients

Nutrients fall into **category 3** substances and form the bulk of aquaculture effluent. **Total Nitrogen (N)** and **Total Phosphorus (P)** are the main nutrients produced by any aquaculture farm. Initially, estimates are made of the effluent from the ponds, tanks or cages and not necessarily from the farm. These estimates may be viewed as a measure of the potential of the farm to discharge effluent into the environment. In a cage system all of the effluent from the cage will be carried into the surrounding water by currents. In lined ponds and tank systems there will be some volatisation, however there will not be (or should not be) sediments. Faeces and uneaten food are flushed out regularly and discharged with wastewater. In a pond system the nutrients will leave by a number of pathways (figure 5).

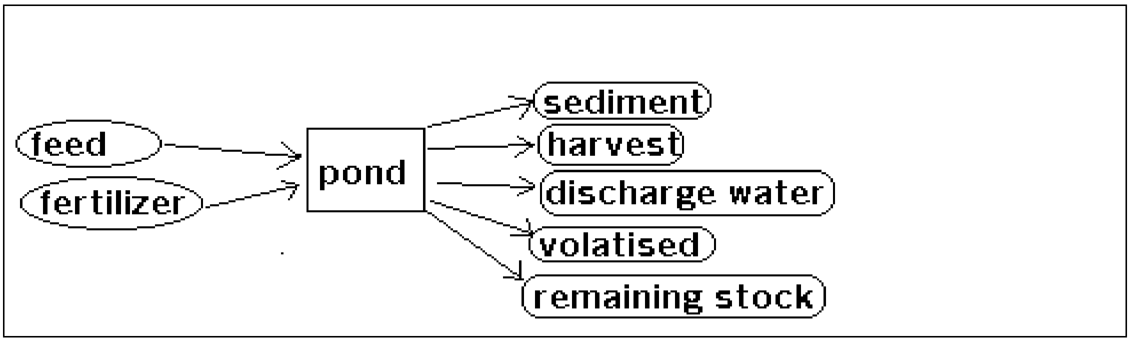


Figure 5. Nitrogen pathways from a prawn pond. (from Jackson, CSIRO, 2000). ‘Sediment’ is removed from ponds after harvest and reused on the farm (rebuilding banks, as fill, gardens, etc.). ‘Remaining stock’ is that stock left on the farm after harvest and will remain fairly constant. Nitrogen volatilised as either ammonia or nitrogen (P is not volatilised) does not enter a natural water body.

It must be remembered that conditions vary widely between regions. Asian farms will differ from Australian farms, and conditions in the cooler regions of southern Qld and northern NSW will differ significantly from tropical Australia. This variation comes about because of climatic conditions, substrate makeup and farming methods. For instance, farming methods will likely be similar in tropical Australia to those in subtropical Australia, however climatic conditions (rainfall, evaporation, water temperatures) in tropical Australia will more closely resemble those in Asia, and substrates will probably be unique to each region. Sample figures from different regions are shown below.

Table 1. Examples of Total N and Total P pathways from ponds reported under different conditions. (S.W. Australia from Jackson, CSIRO, 2000; Thailand from Mathew et al.) n/a = not available.

The variations in the figures may be due to different sampling methods, however the agreement on the content of the harvest suggests that the discrepancies may be due more to differing conditions.

Nutrient destination		sediment	harvest	discharge water	volatilised	Remaining stock
S.W.Australia	Total N Total P	14% n/a	22% n/a	57% n/a	3% —	4% n/a
Thailand	Total N Total P	31% 84%	21% 6%	35% 10%	13% —	0% 0%

Phosphorus that is bound into the sediment appears to remain bound and is unlikely to leave the farm.

Recently there have been several studies on the reduction of effluent discharge (e.g. the work done by Nigel Preston at the CSIRO) by using nutrient soaks such as mangroves, molluscs and settlement ponds. If a farm has the potential to discharge large volumes of nutrients they may be required to use such soaks in the future.

5.0 Estimating emissions

This section describes techniques for estimating category 1 emissions and the category 3 nutrients Total N and Total P.

Information on NPI substances is contained in the **NPI Guide** handbook.

5.1 Estimating category 1 emissions

Steps in working out emissions of category 1 substances are laid out in the NPI guide.

Estimates of category 1 substances are based on the facilities total use of a substance.

5.2 Estimating category 3 emissions

Remember: Estimate emissions of category 3 substances to natural water bodies only. Do not include emissions to ground water or sewers.

There are three Emission Estimation Techniques (EETs) which may be applicable to estimating category 3 substances (nitrogen and phosphorus) produced in aquaculture:

1. **Sampling or direct measurement**
2. **Mass balance**
3. **Emission factors**

If you estimate emissions by using any of these EETs your data will appear on the NPI data-base as being of 'acceptable reliability'. Similarly, if emissions are estimated using any other approved method they will appear as being of 'acceptable reliability'.

This manual seeks to provide best practice and the most effective estimation techniques for estimating aquaculture emissions of NPI substances, however it must be remembered that aquaculture is a rapidly evolving industry and new farming techniques may alter the characteristics of aquaculture effluent. The failure to include in this manual an EET for an NPI substance does not mean that estimations of aggregate emissions need not be made for that substance

Remember that you are able to use emission estimation techniques that are not out-lined in this document. If you wish to use an alternative method you must obtain the consent of your relevant environmental authority. For example, if you have developed site-specific emission factors, you may use these if approved by your relevant environmental authority.

5.2.1 Direct measure

Generally direct measurement is regarded as being best practice in estimating the aggregate emissions. It is the most accurate method for determining emissions and, where possible, should be used in preference to other methods. In many cases direct measurement and reporting of effluent loads is already a requirement of the aquaculture license and, where this is the case, this same data can be used to satisfy the NPI. The following calculation should be employed.

$$E_N = C_N * F / 10^6 \qquad \text{(Eq.1)}$$

Where E_N = discharge of total nitrogen to water, kg/year
C_N = total nitrogen concentration in the effluent, mg/L
F = flow rate of effluent, L/year
10^6 = conversion factor, mg/kg

$$E_P = C_P * F / 10^6 \qquad \text{(Eq.2)}$$

Where E_P = discharge of total phosphorus to water, kg/year
C_P = total phosphorus concentration in the effluent, mg/L
F = flow rate of effluent, L/year
10^6 = conversion factor, mg/kg

When either the input of Total N and Total P or the amount of Total N and Total P that is removed with the crop are not known (as is currently the situation with crocodile farming, for example), direct measurement may be the only viable option to estimating emissions.

Direct measure may not have a high degree of accuracy where wastewater is released as the result of flooding. Tropical Australia is annually affected by predictable monsoonal flooding, the monsoons begin about November each year and heavy rains will generally have begun to cause flooding by late December. Samples would need only be taken from holding or retention ponds once a year, when they are full and overflow is imminent. Samples are analysed for Total N and Total P, the total levels of these nutrients in the farm can then be estimated by the following calculation:

$$E_N = C_N * V \qquad \text{(Eq.3)}$$

Where E_N = potential discharge of total nitrogen as effluent, mg.
C_N = total nitrogen concentration in water held on farm, mg/L
V = volume of water held on the farm, L

$$E_P = C_P * V \qquad \text{(Eq.4)}$$

Where E_P = potential discharge of total phosphorus as effluent, mg.
C_P = total phosphorus concentration in water held on farm, mg/L
V = volume of water held on the farm, L

There are significant flaws to this method of estimating aggregate emissions:

- Retention ponds may receive water from a large catchment area. This may include neighbouring farms, roads, parking lots and bushland. These are significant sources of nutrients and other emissions). Tropical Australia is a wet/dry tropic, which means that there is a long dry season as well as a long wet season. During the dry season there is a considerable build up of litter and high-nutrient material in bushland and farmland, and chemicals (oils and rubber) build up on roads and car parks. With the first rains, much of this will be washed into the pond and will be included with the aggregate emissions.
- Flow rates will be erratic and fluctuate with flooding events. Unless there is a specific formal outfall with a water meter installed, it may be difficult to determine the amount of water, and hence the nutrient load, that escapes the farm.
- After the first flood, rainwater will dilute the farm water and nutrient loads will fall as the wet season progresses.

5.2.2 Mass balance

'Mass Balance' seeks to balance the amount of a substance that is going into a system with the amount coming out. In this case the amount of Total N and Total P that is going into the pond needs to be balanced with the amount coming out as product and effluent—Total N and Total P put into a system must ultimately come out in one form or another.

Intensive farming systems use food conversion ratios (FCR) to determine economic performance. Conversion ratios measure the amount of food required to gain one kg of weight in the crop, e.g. a feed conversion ratio of 1.5 means that it takes 1.5 kg of food to get a growth of 1 kg. It has been suggested that food conversion ratios may be used for estimating wastes, however they are not ideal (Boyd, 1990) as they compare wet product, which is ~25% dry matter, to dry feed, which is ~90% dry matter. Measured on a dry matter basis, this means that the 1.5 conversion ratio quoted above becomes:

$$(1.5 \times 90\%) / (1 \times 25\%) \quad = \quad 1.35 / .25 \quad = \quad \text{conversion ratio dry matter } 5.4$$

For mass balance to be accurate, the Total N and Total P being put into the system via food and fertilizer, and the amount of Total N and Total P being removed with the harvested crop, must be known. The Total N and Total P content of food and fertilizer is known and, in most cases, is shown on the bags. If it is not shown on the bags, the company supplying the feed will provide you with the information. Similarly the Total N and Total P content of the crop is usually known from trial data—check with your local Department of Primary Industries and Fisheries if you do not have this. In the absence of species specific data, average contents of finfish have been calculated across a range of fresh water fish.

Table 2. Average percentage of N and P in finfish and prawns (Finfish from Boyd 1990; Prawns from Jackson, 2000).

Species	**dry matter content**	**Total N (g/kg) Wet weight**	**Total P (g/kg) Wet weight**
Finfish	**25%**	**25**	**7.5**
Prawns (*P.monodon*)	**26%**	**29**	**3.4**

The calculation to determine the Total N and Total P released as effluent is a simple deduction of that coming out as crop plus that remaining in sediment, in remaining stock and volatilised to the atmosphere, from the total being added in feed and fertiliser. Note that the nutrient load of the intake water is not included—this means that **only the amount of nutrient that is produced in the aquaculture process is estimated.**

The following formula may be used to estimate the aggregate emissions of Total N.

$$N_E = N1 + N2 - (NC + NS + NV + NRS) \qquad \text{(Eq.5)}$$

Where: N_E = total nitrogen in effluent
N1= the amount of total N contained in feed (from bag or manufacturer)
N2= the amount of total N contained in fertiliser (from bag or manufacturer)
NC= the amount of total N contained in the crop (from DPF)
NS= the amount of total N contained in the sediment (from table 1)
NV= the amount of total N volatilised (from table 1)
NRS = the amount of total N contained in the remaining stock (from table 1)

The following formula may be used to estimate the aggregate emissions of Total P. Note that P is not volatilised.

$$P_E = P1 + P2 - (PC + PS + PRS) \qquad \text{(Eq.6)}$$

Where: P_E = total phosphorus in effluent
P1 = the amount of total P contained in feed (from bag or manufacturer)
P2 = the amount of total P contained in fertiliser (from bag or manufacturer)
PC = the amount of total P contained in the crop (from DPF)
PS = the amount of total P contained in the sediment (from table 1)
PRS = the amount of total P contained in the remaining stock (from table 1)

5.2.3 Emission factors

These may be used if there is a comparable system in operation from which the effluent is known. In some cases (e.g. prawns) effluent characteristics have been closely studied and the results of those studies may be used. Care must be taken to ensure that data are applicable to the farming system where the estimates are being made.

5.3 Estimating techniques appropriate to specific farming systems

Estimating effluent techniques are generally applicable to farming systems rather than to individual species because, although the species may be very different, the same principles apply.

5.3.1 Intensive systems and Semi-Intensive systems

The best practice for estimating aggregate emissions from either intensive or semi-intensive systems is by direct measure. This is not, however, always practicable, so in default accurate estimates may be obtained in most cases by mass balance.

Mass balance

Aggregate emissions from intensive and semi-intensive ponds may be estimated using the formulae presented above. Examples based on the figures produced by the CSIRO are shown below. Because of similarities in climate, it may be more relevant to base calculations for the far north of Australia on the figures from Thailand (Mathew et al.) where there are no specific regional data available. Note that in an intensive pond there may not be any nutrients introduced as fertilizer. In this example it is assumed that 150 kg of pellets with a Total N content of 50 g / kg (7.5 kg N in 150 kg of pellets) have been fed to obtain 100 kg of product.

Example 1. Calculating Total N effluent from 100 kg (wet wt.) of barramundi in an intensive pond system using equation 5.

N1 = 50g/kg x 150kg/crop = 7.5 kg (Total N in feed to produce 100 kg crop)
N2 = 0
NC = 25g/kg x 100kg/crop = 2.5 kg (Total N in 100 kg crop)
NS = 7.5 kg x 14% =1.05 kg (Total N incorporated into sediment)
NV = 7.5 kg x 3% = 0.225 kg (Total N volatilised)
NRS= 7.5 kg x 4% = 0.300 kg (Total N in remaining stock)

$$\begin{aligned} \mathbf{N_E} &= \mathbf{N1 + N2 - (NC + NS + NV + NRS)} \\ &= \mathbf{7.5 + 0 - (2.5 + 1.05 + 0.225 + 0.3)} \\ &= \mathbf{7.5 - 4.075} \\ &= \mathbf{3.425\ kg\ N/100\ kg\ crop} \end{aligned}$$

Example 2. Calculating Total N effluent from 100 kg (wet wt.) of prawns in a semi-intensive pond system using equation 5.

N1= 50g/kg x 150kg/crop = 7.5 kg (Total N in feed to produce 100 kg crop)
N2= 200g/kg x .002kg/crop = .0004 kg (Total N in fertiliser to produce 100 kg crop)
NC = 29 g/kg x 100kg/crop = 2.9 kg (Total N in 100 kg crop)
NS = 7.5 kg x 14% =1.05 kg (Total N incorporated into sediment)
NV = 7.5 kg x 3% = 0.225 kg (Total N volatilised)
NRS= 7.5 kg x 4% = 0.300 kg (Total N in remaining stock)

$$\begin{aligned} \mathbf{N_E} &= \mathbf{N1 + N2 - (NC + NS + NV + NRS)} \\ &= \mathbf{7.5 + 0.0004 - (2.9 + 1.05 + 0.225 + 0.3)} \\ &= \mathbf{7.5004 - 4.475} \\ &= \mathbf{3.0254\ kg\ N/100\ kg\ crop} \end{aligned}$$

For tanks or lined ponds the same calculations are used, however the 'fertiliser', 'sediment' and 'remaining stock' components are omitted as they are not present in these systems.

Example 3. Calculating Total N effluent from 100 kg (wet wt.) of barramundi in lined ponds or an intensive tank system using equation 5.

N1 = 50g/kg x 150kg/crop = 7.5 kg (Total N in feed to produce 100 kg crop)
NC = 25g/kg x 100kg/crop = 2.5 kg (Total N in 100 kg crop)
NV = 7.5 kg x 3% = 0.225 kg (Total N volatilised)

$$\begin{aligned} \mathbf{N_E} &= \mathbf{N1 - (NC + NV)} \\ &= \mathbf{7.5 - (2.5 + 0.225)} \\ &= \mathbf{7.5 - 2.725} \\ &= \mathbf{4.775kg\ N/100\ kg\ crop} \end{aligned}$$

Calculations for cage cultures are further simplified as 'fertiliser', 'volatization', 'sediment' and 'remaining stock' are all omitted.

Example 4. Calculating Total N effluent from 100 kg (wet wt.) of barramundi in cages using equation 5.

N1 = 50g/kg x 150kg/crop = 7.5 kg (Total N in feed to produce 100 kg crop)
NC = 25g/kg x 100kg/crop = 2.5 kg (Total N in 100 kg crop)

$$\begin{aligned} \mathbf{N_E} &= \mathbf{N1 - (NC + NV)} \\ &= \mathbf{7.5 - 2.5} \\ &= \mathbf{7.5 - 2.5} \\ &= \mathbf{5.0kg\ N/100\ kg\ crop} \end{aligned}$$

Emission factors

Because of the likelihood of considerable variations between calculations for temperate, sub-tropical and tropical conditions, it is not recommended that emission factors be used except to gain a very broad idea of your emissions.

As a general rule of thumb prawn farms produce a total of about 1–2 kg of N/ha/day and 0.1–0.2 kg of P/ha/day (Jackson, 2000).

It has been estimated that effluent from finfish cage culture is in the order of 75–95 kg N and 10–20 kg P/tonne of fish produced (Enell and Lof, 1983 from Pillay, 1992). Care should be taken, however, when referring to any data on cage culture as it is virtually all derived from temperate systems (the figures above relate to northern Europe) and may vary considerably under tropical conditions.

5.3.2 Extensive systems

There is no input of N or P into the system. No calculations are required.

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Appendix A - Aquaculture survey
For the National Pollution Inventory

Premises Information

Business Name ………………………………………………………………

Address ………………………………………………………………
………………………………………………………………
………………………………………………………………

Contact Person ……………………………………… **Ph. No** ……………..…..
Fax ………………..….

Produce from farm (barramundi, prawns, pearls, crocodiles, etc)
……………………………………………………………………………………

Please list chemicals do you use on the farm site (please specify, including sterilizers, antibiotics / antifungals, fish kills, anaesthetics, herbicides, insecticides and all minor use chemicals, **but excluding fertilizers used in ponds**).

Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...
Chemical ………………………………………. Annual usage …………...

Do you fertilise ponds? Y / N

What type of fertilizer do you use (including brand)? ……………………. …………………….

What is your annual usage of fertilizer? …………………….
What is the Nitrogen content of your fertilizer? …………………….
What is the Phosphorus content of your fertilizer? …………………….

Please describe the feed used (formula, manufacturer, Nitrogen content [if known], Phosphorus content [if known]):
……………………………………………………………………………

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

What is your annual usage of stock food?

Formula 1	…………….Tonnes
Formula 2	…………….Tonnes
Formula 3	…………….Tonnes

What is your annual production (fish, prawns, etc) …………….Tonnes

Do you operate a generator on the farm site (including on board mother boat)? Y / N
If so, what is the generating capacity? ……………………
Do you operate outboard or other small motors on the farm site? Y / N
If so, what is the capacity and approximate number of hours operated / year?
Motor 1: Type (outboard/ pump/etc)……………...Horse power ……Hours ……
Motor 2: Type (outboard/ pump/etc)……………...Horse power ……Hours ……
Motor 3: Type (outboard/ pump/etc)……………...Horse power ……Hours ……
Motor 4: Type (outboard/ pump/etc)……………...Horse power ……Hours ……
Please supply details of additional motors on a separate sheet
What is the fuel storage capacity on the farm site, including mother boats:
1: Diesel ………….litres
2: Leaded petrol ………….litres
3: Unleaded petrol ………….litres
4: 2 stroke ………….litres
5: Other(please specify) .. ……….litres

<u>*ALL INFORMATION WILL BE TREATED AS***</u>**
<u>*CONFIDENTIAL***</u>**