The environmental management of prawn farming in Queensland – worlds best practice

Research Summary

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The emergence of prawn farming as an economically successful industry in coastal regions of Queensland over the past two decades prompted a comprehensive, multi-disciplinary study of intensive prawn pond ecosystems, their ecological impacts on downstream environments and the development of cost-effective effluent treatment systems.

The seven year study (1995-2002) focussed on the largest prawn farms in Queensland and New South Wales throughout the production cycle for several successive years. The study encompassed a range of latitudes, discharge environments (e.g. tidal creeks and estuaries) and both flow through and recirculating water management systems.

The study integrated the research skills of 30 scientists from several institutions including CSIRO, Australian Institute of Marine Science, University of Queensland, Queensland Department of Environment and Heritage, New South Wales Environment Protection Authority, Griffith University, University of Sydney, University of Technology, Marine and Freshwater Resources Institute, Victoria and the University of Maryland, U.S.A.

The multidisciplinary study was the most comprehensive analysis of the environmental management of prawn farming ever conducted. The team developed rigorous techniques for sampling eutrophic pond ecosystems including sediment and water column nutrients and microorganisms, pond biota and abiotic variables. The application of enriched isotope nutrient labeling techniques, pioneered by the team, permitted the first accurate quantification

of the fate of feed nutrients in an intensive prawn farming system and downstream from the farm. The integrated approach adopted throughout the study also permitted the team to produce a multi-author synthesis of the dominant ecological processes in intensive shrimp ponds and adjacent coastal environments. Beyond developing a quantitative understanding of these processes the team analysed pond effluent composition and designed a cost-effective effluent treatment system based on sedimentation processes. The introduction of settlement ponds has also provided industry the opportunity to recapture water nutrients using natural biological filters.

The results of the project have been communicated via 42 refereed scientific publications and four final reports (see references).

The key elements of the study were:

- prawn pond sediment and nutrient processes (*references* 1-22)
- composition of prawn pond discharges (23)
- discharge treatment systems and environmental management (23-29)
- receiving waters - assimilation and monitoring (30-40)
- synthesis of pond processes and environmental management (41-45)
- aquaculture land use planning (46).

The key outputs of these studies were:

- Prawn pond sediment and nutrient processes rigorously quantified and modelled (1, 18)
- Pond discharge composition rigorously quantified (22, 23)
- Published the first synthesis of the dominant ecological processes in ponds and adjacent costal environments (30)
- In collaboration with industry, designed and implemented cost-effective treatment system based on sedimentation processes (24, 25, 27).

Outcomes and implications:

- All Australian prawn farms use environmental management practices, including discharge treatment systems, which enable them to meet world best practice discharge water quality.
- Progressive advances in treatment systems and practices have enabled some farms to increase their total production area with no net increase in sediment and nutrient loads discharged into receiving waters.
- Increasing production area without increasing sediment and nutrient outputs has been achieved by increasing the area of treatment ponds (in some cases up to 35% of the total pond area). There is a major opportunity to develop the next generation of discharge treatment technology to reduce the required area of treatment ponds.
- The prawn farming industry has achieved an effective balance between economic gains and conserving ecosystems, including the world heritage listed Great Barrier Reef.

- With these operating practices and regulations in place, there is significant opportunity for the industry to expand without compromising the economic and environmental sustainability of the industry.
- Broad scale desktop analysis identified 594,000 hectares of potentially optimal pond aquaculture land along the Queensland coast that would not compromise the environmental standards for the region (46).
- A fine scale land use modelling case study that enabled the expansion of an existing prawn farm adjacent to the Logan River, optimising the economic benefits of land use in the regions with no increase in nutrient or sediment discharges to the Logan River (commercial in confidence).
- For example an increase from the current 717 hectares of prawn ponds, producing 2,940 tonnes valued at $40 million to 5,000 hectares of ponds producing 30,000 tonnes valued at $400 million - would correspond to less than 1.4% of the existing sugar cane production area. The 5,000 hectares could be located within any of the 594,000 hectares of potentially suitable land between the border of New South Wales and Northern Territory border (a total distance of 13,347 km).

Scientific publications and reports - Prawn pond nutrient process, downstream impacts and environmental management options

In ponds

1. Burford M.A., Lorenzen K., 2004, Modeling nitrogen dynamics in intensive shrimp ponds: the role of sediment remineralization, Aquaculture 229, 129–145
2. Burford M.A., Thompson P.J., McIntosh R.P., Bauman R.H., Pearson D.C., 2004, The contribution of flocculated material to shrimp (*Litopenaeus vannamei*) nutrition in a high-intensity, zero-exchange system, Aquaculture 232, 525–537
3. Burford, M. A. and Glibert, P. M., 1999. Short-term nitrogen uptake and regeneration in early and late growth phase shrimp ponds. Aquaculture Research 30, 215-227.
4. Burford, M. A. and Longmore, A.R., 2001. High ammonium production from sediments in hypereutrophic shrimp ponds. Marine Ecology Progress Series 224, 187-195.
5. Burford, M. A. and Williams, K. C., 2001. The fate of nitrogenous waste from shrimp feeding. Aquaculture 198, 79-93
6. Burford, M. A., 1997. Phytoplankton dynamics in shrimp ponds. Aquaculture Research 28, 351-3
7. Burford, M. A., 2001. Fate and transformation of dietary nitrogen in penaeid prawn aquaculture ponds. PhD Thesis, University of Queensland, Australia, 162 pp.
8. Burford, M. A., Peterson, E. L., Baiano, J. C. F. and Preston, N. P., 1998. Bacteria in shrimp pond sediments: their role in mineralizing nutrients and some suggested sampling strategies. Aquaculture Research 29, 843-849.
9. Burford, M. and Pearson, D.C., 1998. Effect of different nitrogen sources on phytoplankton composition in aquaculture ponds. Aquatic Microbial Ecology 15: 277-284.
10. Burford, M.A., Preston, N.P., Glibert, P.M., Dennison, W.C., 2002. Tracing the fate of 15N-enriched feed in an intensive shrimp system. Aquaculture 206, 199–216.
11. Burford, M.A., Sellars, M.J., Arnold, S.J., Keys, S.J., Crocos, P.J, Preston, N.P., 2004. Contribution of the natural biota associated with substrates to the nutritional requirements of the post-larval shrimp, *Penaeus esculentus* (Haswell), in high-density rearing systems. Aquaculture Research 35: 508-515.
12. Burford, M.A., Thompson, P.J., McIntosh, R.P., Bauman, R.H., Pearson, D.C., 2003. Nutrient and microbial dynamics in high-intensity, zero-exchange shrimp ponds in Belize. Aquaculture 219, 393–411.
13. Coman, F.E., Connolly, R.M., Bunn S.E., Preston, N.P., 2006. Food sources of the sergestid crustacean, *Acetes sibogae*, in shrimp ponds. Aquaculture 259: 222–233.
14. Coman, F.E., Connolly, R.M., Preston N.P., 2006. Effects of water exchange and abiotic factors on zooplankton and epibenthic fauna in shrimp ponds. Aquaculture Research 37: 1387-1399.
15. Gao, J. and Merrick, N.P., 1996. Simulation of temperature and salinity in a fully mixed pond. Environmental Software, 11(1-3): l73-8.
16. Jackson, C.J. and Wang, Y.G., 1998. Modelling growth rate of *Penaeus monodon* Fabricius in intensively managed ponds: effects of temperature, pond age and stocking density. Aquaculture Research 29: 27-36.
17. Peterson, E.L., 2000. Observations of pond hydrodynamics. Aquacultural Engineering 21: 247-269.
18. Peterson, E.L., Harris, J.A. and Wadhwa, L.C., 2000. CFD modelling pond dynamic processes. Aquacultural Engineering 23: 61-93.
19. Peterson, E.L., Wadhwa, L.C. and Harris, J.A., 2001. Arrangement of aerators in an intensive prawn growout pond having a rectangular shape. Aquacultural Engineering, 25: 51-65.

20. Preston N.P., Smith D.M., Kellaway D.M., Bunn S.E., 1996, The use of enriched 15N as an indicator of the assimilation of individual protein sources from compound diets for juvenile *Penaeus monodon*, Aquaculture 147, 249-259
21. Preston, N.P., Coman F.E. and Fry V.M., 2003. Shrimp pond zooplankton dynamics and the efficiency of sampling effort. Aquaculture Research 34 (5) :373-381

Pond discharge composition

22. Jackson C., Preston N., Thompson P.J., 2004, Intake and discharge nutrient loads at three intensive shrimp farms, Aquaculture Research, Volume 35, Issue 11, September, 1053-1061
23. Jackson, C.J., Preston, N.P., Burford, M.A. & Thompson, P., 2003. Nitrogen budget and effluent nitrogen characteristics of an intensive shrimp farm. Aquaculture 218: 397-411.

Treatment and environment management

24. Burford. M. A., Jackson, C. J. and Preston, N. P., 2001. Reducing nitrogen waste from shrimp farming: an integrated approach. In: The New Wave, Proceedings of the Special Session on Sustainable Shrimp Culture, Aquaculture 2001. eds. C. L. Browdy and D. E. Jory, pp. 35-43. The World Aquaculture Society, Baton Rouge, USA.
25. Jackson, C.J., Preston, N.P., Burford, M.A. & Thompson, P., 2003. Managing the development of sustainable shrimp farming in Australia: the role of sedimentation ponds in treatment of farm discharge water. Aquaculture 226: 23-34.
26. Jones, A. B. Preston, N. P., 1999. Oyster filtration of shrimp farm effluent, the effects on water quality. Aquaculture Research 30, 51-57.
27. Jones, A.B., Dennison, W.C. and Preston, N.P., 2001. Integrated treatment of shrimp effluent by sedimentation, oyster filtration and macroalgal absorption: a laboratory scale study. Aquaculture, 193: 155-178.
28. Ngo, H.H. and Vigneswaran, S., 1995. Application of floating medium filter in water and wastewater treatment with contact-flocculation filtration arrangement. Journal of Water Research – IAWQ, 29:9: 2211-2213.
29. Ngo, H.H. and Vigneswaran, S., 1996. Application of downflow floating medium flocculator/prefilter (DFF) –coarse sand filters in nutrient removal. Journal of Water Science and Technology, 33:8: 63-70.

Receiving waters – assimilation and monitoring

30. Burford M.A., Costanzo S.D., Dennison W.C., Jackson C.J., Jones A.B., McKinnon A.D., Preston N.P., Trott L.A., 2003, A synthesis of dominant ecological processes in intensive shrimp ponds and adjacent coastal environments in NE Australia, Marine Pollution Bulletin 46, 1456–1469
31. Costanzo S.D., O'Donohue M.J., Dennison W.C., 2004, Assessing the influence and distribution of shrimp pond effluent in a tidal mangrove creek in north-east Australia, Marine Pollution Bulletin 48, 514–525
32. Costanzo, S. D., 2001.Development of indicators for assessing and monitoring nutrient influences in coastal waters. PhD Thesis, University of Queensland, Australia.
33. Jones, A. B., O'Donohue, M. J., Udy, J. and Dennison, W. C., 2001. Assessing ecological impacts of shrimp and sewage effluent: biological indicators with standard water quality analyses. Estuarine, Coastal and Shelf Science 52, 91-109.
34. McKinnon, A. D. and Klumpp, D. W., 1998. Mangrove zooplankton of North Queenland, Australia I. Plankton community structure and environment. Hydrobiologia 362, 127-143.

35. McKinnon, A. D., Trott, L. A., Alongi, D. M. and Davidson, A., 2002. Water column production and nutrient characteristics in mangrove creeks receiving shrimp farm effluent. Aquaculture Research 33: 55-73

36. McKinnon, A. D., Trott, L. A., Cappo, M., Miller, D. K., Speare, P and Davidson, A., 2002. The trophic fate of shrimp farm effluent in mangrove creeks of North Queensland, Australia. Estuarine, Coastal and Shelf Science 55, 655-671

37. Trott A., McKinnon A.D., Alongi D.M., Davidson A., Burford M.A., 2004, Carbon and nitrogen processes in a mangrove creek receiving shrimp farm effluent, Estuarine, Coastal and Shelf Science 59,197e207

38. Trott L.A. and Alongi, D.M., 2000. The impact of prawn pond effluent on water quality and phytoplankton biomass in a tropical mangrove estuary. Marine Pollution Bulletin 40:947-951

39. Trott, L.A. and Alongi, D.M., 1999. Variability in surface water chemistry and phytoplankton biomass in two tropical, tidally-dominated mangrove waterways. Marine and Freshwater Research. 50:451-7

40. Wolanski, E., Spagnol S., Thomas, S., Moore, K., Alongi, D.M., Trott, L.A. and Davidson, A., 2000. Modelling and visualizing the fate of prawn pond effluent in a mangrove-fringed tidal creek. Estuarine, Coastal and Shelf Science, 50:85-97

Synthesis documents

41. Preston, N, Macleod, I, Rothlisberg, P, Long, B, 1997, Environmentally sustainable aquaculture production - An Australian perspective. In: Developing and sustaining world fisheries resources. The state of science and management. pp. 471-477.

42. Preston, N. P., Rothlisberg, P. C., Burford, M. A. and Jackson, C. J., 2001. The Environmental Management of Shrimp Farming in Australia. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Network of Aquaculture Centres in Asia-Pacific (NACA) Bangkok, Thailand, 9pp.

43. Preston, N.P. et al 2003. Pond and effluent management (Aquaculture CRC Ltd Project E187).

44. Preston, N.P., Jackson, C.J., Thompson, P.J., Austin, M. and Burford, M.A., 2000. Prawn farm effluent: origin, composition and treatment. FRDC 95/162 Final Report, Fishing Industry Research and Development Corporation, Canberra, Australia.

45. Trott L.A. and Alongi D.M., 2001. Quantifying and predicting the impact of prawn effluent on the assimilative capacity of coastal waterways (FRDC Project 97/212) and

Land-based mapping

46. McLeod, I., Pantus, F. & Preston, N.P. (2002) The use of a geographical information system for land-based aquaculture planning. Aquaculture Research 33: 1-10.