CANAL ESTATES

Ramsar Topics no. 1 - Final Report July 1998: Canal Estates / Marinas

Overview

When we established the Ramsar "Hot Topics" forum on World Wetlands Day this year, the first subject chosen was canal estates/marinas because of growing concern about the accelerating loss of wetland areas to these increasingly common developments along the shores of our rivers and estuaries. Concern has also been expressed about the long-term impacts of canal estates on the total environments of these aquatic ecosystems.When we launched this "Hot Topic", we said the following which should be remembered when reading this review of what we have found. "We are trying to locate any information which can help us all to understand where the truth lies on the canal estates/marinas question. Please note that we are not requesting statements of opinion or attitude towards canal estates/marinas. Our intention is to locate the science on the subject, not to conduct a global poll on what people think of them. We are very keen to obtain references to studies that have scientific rigour and have taken a dispassionate view of the "fors" and "againsts " of canal estates/marinas."

Over the past six months we have had brought to our attention some 24 references which have some relevance to the construction and operations of canal estates or marinas. We would like to thank those people who responded. We hope the bibliography will help others to locate references to further examine the issues relating to these development types.

So what have we found?

It is clear that a number of studies have examined the impacts of these modified or constructed "environments". Their conclusions are referred to in the following in more detail, but in essence it seems that canal systems which are not designed to allow a certain level of "flushing" can result in environmental problems. Factors such as the nutrient loading which may occur in the canal system and even wind direction may play a major role in determining the water quality, which in turn can affect the biological diversity and general amenity value of the canal environment and surrounds. There are these and many other factors which need to be considered in the design and impact assessment for canal estate developments as referred to in the following review.

The seemingly more recent trend in some countries to avoid single outlet canal systems in favour of dual or multiple outlet systems is clearly to be encouraged where canal estate developments are being considered. The higher levels of flushing should prove advantageous for maintaining water quality if the primary consideration is providing an artificial water system for leisure activities. Of course, it also should be recognised that in one case we are aware of (the state Government of New South Wales in Australia), the construction of canal estates has been banned for environmental reasons which are given below. While there are no signs that this action will be followed in other countries (so far as we are aware), it does indicate the level of concern which is apparent. It also highlights another aspect of canal estate construction which surprisingly has not been considered in the publications brought to our attention; that is, the cost-benefit analysis of installing an artificial canal system over retaining a naturally functioning ecosystem such as a wetland.

It would seem that this is an area where further research would be helpful to assist local decision-maker with what are sometimes difficult decisions. A theoretical situation is that of a local administration faced with deciding on whether or not to allow the conversion of an estuarine wetland area into a canal estate. On one side there are the local economic benefits, both short- (employment for local people) and long-term (increased trade for local businesses), and on the other side are the costs of losing an area which serves as a fish nursery, helps to retain the water quality of the area and attracts tourist trade because of these factors and its natural beauty. In the longer term, there is also the possibility that the condition of the canal system will decline, especially if it is poorly designed, and the costs of repairing the system will fall to the local taxpayers as a whole, not just the residents who enjoy the canal based facilities, and probably not the tourists who may also use these areas.

If, as seems to be the case in some areas, there are a number of canal systems constructed near one another, it would be valuable to know what the "carrying capacity" is for the typical estuary ecosystem -

is there a point where you simply have too many canals for the broader ecological processes to continue to operate? Are we, in effect, destroying the natural capital which made the construction of the canal systems so attractive in the first place. Overall, our focus on canal estates as the first Ramsar "hot topic" has shown there to be a body of expert information which will hopefully now be more available to those decision-makers who need it in order to make informed decisions. It has also been suggested that there are potential problems with these artificial environments unless they are carefully designed with local factors and long term maintenance strategies in mind. Importantly, there would seem to be an urgent need for studies to consider the overall costs and benefits of constructing canal estates.

A. What are canal estates?

Because various countries use different terminology, it is worthwhile to state exactly what is encompassed in the term "canal estate" in this review. Canal estates are common in the United States, Asia, Australia, and to a lesser extent in South Africa, the Caribbean and Pacific islands. They include waterfront housing, resorts and boat marinas constructed along artificial canal systems. They are commonly located in, or adjacent to, wetland areas along rivers, estuaries, coastal bays and shorelines. Typically canal estate developments use cut and fill construction techniques, providing fill material to elevate part of the land and reduce its susceptibility to flooding.

B. How do canal estates affect the environment?

In response to this "Hot Topic", we have identified a range of concerns regarding the construction and functioning of canal estates. In Australia, the Government of the state of New South Wales has put in place Environmental Planning Policy No. 50 which bans the construction of canal estates. In this Policy it states that canal estate developments can potentially have adverse environmental effects which in particular circumstances may include:

- Loss of wetland habitats and other sensitive aquatic systems, including reduction in the sustainable values of estuaries as highly productive nursery areas necessary for fisheries.
- Inadequate hydraulic functioning which may reduce water quality through poor flushing, cause sedimentation, or affect structural integrity.
- Impacts caused by storm-water and urban runoff, including erosion and sedimentation away from a canal estate development site.
- Impacts associated with imported fill
- Problems caused by disturbing acid sulfate soils
- Pollution by wastes from vessels.
- Ongoing impacts from maintenance, including maintenance dredging.

Canal estate developments can be found along rivers, estuaries, coastal bays and shorelines. These areas possess a typical morphology. As Maxted, Eskin and Weisberg (1997) state; "Atlantic coastal bays gradually decrease in depth from shallow, open water areas of less than 2 meters to intertidal mud flats and wetlands that define the shoreline. In contrast, dead-end canals contradict the physical characteristics of natural estuaries." As Maxted et al (1997) found in their study, "canal estates are often dredged to a depth greater than the adjacent estuary, creating a sill that inhibits tidal exchange. Canals are generally long and narrow, with a uniform width and depth, and have a single outlet. For these reasons, canals promote stagnation, poor water and sediment quality", as well as a depauperate biological community.

According to the United States Geological Service (1996), there are significant water-management issues and areas of concern related to flow-control measures in drainage basins, which are as follows:

- Because of the inextricable linkage between flow and transport, there could be contamination of the wetland from nutrient-enriched agricultural (nitrates or phosphates) or contaminant-laden land (metals or pesticides), which have the potential to alter plant life and affect biological communities
- What are the cause-and-effect relations between tides, winds, and altered freshwater flows on neighbouring wetlands, mangroves ecosystems, and coastal water bodies?
- What are the effects of outflows on salinity dynamics?
- What processes control the fate of nutrients or contaminants and govern their dispersal into neighbouring wetlands and adjacent ecosystems?z
- What are the consequences of various redesign alternatives on inflows to bays, sounds, and other coastal water bodies?

- How do the dynamics of outflows affect sheet flow through adjacent wetlands?

Other observed environmental effects include sudden fish kills in marinas and near-shore environments, usually as a result of low oxygen levels due to lack of flushing and pollution. The disturbance (draining or clearing for development) of acid sulfate soils can produce sulphuric acid, which then mobilizes aluminium, which is toxic to fish and has resulted in several fish kills in, for example, New South Wales in Australia.

C. Focus of studies

From the reference sources brought to our attention, the effects of canal estates on the ecological condition of the adjacent estuary was the focus of several studies (see below). Of primary importance is the quantification of the complex fluid dynamics of low relief environments. The United States Geological Service and the South Florida Ecosystem Program are working on the development of a computer model to simulate flow and analyse chemical transport between canals and wetlands. A National Oceanic and Atmospheric Association technical memorandum considered how mechanics, such as alignment of canal estates with prevailing summer winds and elimination of dead-end canals, could improve ecological conditions of the estates. Others focused on biological studies, studies of nekton (free swimming animals inhabiting middle depths of sea or lake), and benthic communities (Baca, Dingman and Lankford, 1988; Maxted et al, 1997; Morton, 1989, 1992; Smith, Hawes and Duque-Portugal, 1995; Weis and Weis, 1994).

D. What has been found - in short

In his study, Morton looked at hydrologic conditions and fish fauna occurring in an intensively modified estuary. Sediment was analysed and a stratified water column with respect to oxygen saturation values was found. Three studies looked specifically at sediment contamination by polynuclear aromatic hydrocarbons, copper and tributylin (TBT) commonly associated with boat marinas (McGee, 1995; Texas Water Commission, 1993; and Weis, 1994) as this contamination relates to the biological community. Their findings indicated low benthic community taxa richness and dominance by oligochaetes, many of which are considered pollution tolerant. The conclusion was that this could be due not only to pollutants, but also to designs which produce circulation problems as mentioned below.

Maxted et al (1997) compared the biological condition of canals with the surrounding water of coastal bays. They found that species richness, abundance, biomass, and the Shannon-Weaver diversity index for benthic macroinvertebrates were significantly lower in canals compared with coastal bays. Although preliminary, Baca et al(1988) corroborated these findings and suggested that species diversity and richness decline as one progresses toward the dead-end of the canal system.

Other studies indicate a decline in species richness, abundance and biomass typically during the summer months and suggest that a primary cause of that is oxygen depletion resulting from a combination of 1. decomposing organic sediment, 2. warm water, and 3. low circulation in dead-end canals.

During the summer, dissolved oxygen has been found to reach anoxic conditions in some canals. Smith et al (1995) studied the spatial variability in the nekton of a New South Wales, Australia, canal estate. They found "significant variation between end and main canal, as well as between sites within locations." However, these findings did not suggest a depauperate benthic community as has been indicated by others. Comparisons were also made using a wide variety of water and sediment quality measures to provide a comprehensive assessment of ecological condition. The design, according to Maxted et al (1997), of man-made, linear, dead-end channels dug deeper than the adjacent estuary produces poor flushing and circulation, which their study indicates has led to poor water quality, poor sediment quality, and a depauperate biological community.

E. What mitigation techniques are suggested to minimize potential negative impacts?

A suggested method for improvement of water quality could be to connect canals "in a loop to natural bodies of water" (Baca, 1988). The National Oceanic and Atmospheric Administration Technical Memorandum NMFS-SEFC-268 recommends that canal excavations be designed to maintain adequate oxygen levels by eliminating dead-end canals and aligning canals in such a direction as to receive maximum turbulent mixing from prevailing summer winds, and that canal depths not exceed the bordering bayou. This, their study concluded, would enhance circulation and provide adequate water quality essential for estuarine-dependent fauna. Maxted et al (1997) offers similar solutions, including locating canal estates near tidal sources and maximizing these connections to promote flushing, as well as maintaining certain channel shapes (e.g., low aspect ratio and rounded corners).

Mitigation techniques for the problem of low oxygen levels commonly occurring in marinas focus on knowing the system (i.e., its nutrient load) and long-term and short-term mitigation approaches. Use of aerators as preventive measures against fish kills has been shown to be a viable short-term approach to the problem, while a more long-term solution points toward circulation as a critical design feature. Other options are a reduction of sources of contaminants, use of buffer strips to act as contaminant filters, and an increase in sewage pump out stations.

As documented by Creagh (1993), the problem with acid sulphate soils can be neutralized to some extent with fine particles of lime. Leaching of the toxic chemicals can be arrested in some instances with the construction of interception banks and containment ponds. Depending on the type of development that may disturb a soil such as this, there exist various other mitigation techniques. However, the environmental devastation that can result from acid contamination of this nature cannot be overstated.

F. Where is the technology today?

Today, there continues to be a need for rigorous scientific investigation conducted over the long term. Smith et al (1995) state that there is a paucity of readily available information on the biota of canal estates t hat can be used to assist in assessing the effects of such developments. They note the following reasons for this: * studies limited to a single sampling time with no reference locations outside the canal estate (citing their own paper). * sensitivity to be able to detect differences between locations (citing their own paper); despite monitoring of aquatic ecology (New South Wales and Queensland), there is no adequate database available to define differences in biota among different parts of the waterways of canal estates. * sampling done without replication, therefore limiting the statistical comparisons that could be made. Morton (1989, 1992) is specifically cited. * non-independent sets of tests (i.e., comparisons of times and sites) which address neither variability at small spatial scales nor the extent to which fish vary in abundance through time between end-canal, flow through-canals and the estuarine channel. Again, Morton (1989) is cited.

Smith et al (1995) recommend that either a pilot study be carried out or that replicated sampling at several sites within each location be undertaken, with sampling of four or more sites within each location as well as external sampling through time. These would enable improved predictions of aquatic ecology of canal estates and thereby improve management of the impacts of human activities on estuaries.

Bibliography

- Amiet, L. 1957. A Wader Survey of Some Queensland Coastal Localities. The Emu Vol. 57.
- Annonymous, 1996. Watch on Fish Kills. The Courier Mail, Australia.
- Baca, B.J., J. S. Dingman, and T. E. Lankford. 1988. Evaluation of the Impacts of Dead-End Canals and Impoundments on an Estuarine Ecosystem. p. 201-212. In W. L. Lyke and T. J. Hoban (eds.), Proceedings of the Symposium on coastal Water Resources. American Water Resources Association. Herndon, Virginia.
- Bayley, P.B., 1991. The Flood Pulse Advantage and the Restoration of River -Floodplain systems. Regulated Rivers: Research and Management 6:71-86.
- Bayley, P.B., 1995. Understanding Large River-Floodplain Ecosystems. Bioscience 45: 153-158.
- Bon Voyage, Raby Bay, 1998. Site Map, Baby Bay Sales Office.
- Correspondence: Harding, J. Queensland, Australia.
- Creagh, Carson. 1993. Working Together with Acid Sulfate Soils. Ecoscience Vol. 77. Pp. 25-30.
- Galat, D.L., and A. G. Frazier (editor). 1996. Overview of River-Floodplain Ecology in the Upper Mississippi River Basin. Science for Floodplain Management into the 21st Century. U.S. Government Printing Office. Washington, D.C., 149 p.
- Greber, J. 1998. Canal Homes Face $3000 levy. The Courier Mail, Australia.
- Guillen, G., M. Ruckman, S. Smith, L. Broach. 1993. Marina Impacts in Clear Lake and Galveston Bay. Texas Water Commission, Special Report D7-001A.
- Hollin, Dewayne, J. Massey, J. Jacob and G. Treece. 1998. Methods of Reducing Water Quality Impacts and Fish Kills in Coastal Marinas. Sea Grant Marine Advisory Service.
- International Maritime Organization. An Environmental Guide for Marinas and Boatyards, Wider Caribbean Initiative for Ship Generated Waste.
- Marvin, K.T., K. N. Baxter, E.Scott. 1990. Effects of Aligning Waterfront Housing Development Canals with Prevailing Summer Winds and Installing a Circulating Canal and Culverts. NOAA Technical Memorandum NMFS-SEFC-268, 28 pp.

- Maxted, J. R., R. A. Eskin, S. Weisberg, F. W. Kutz. 1997. The Ecological Condition of Dead-End Canals of the Delaware and Maryland Coastal Bays. Estuaries, Vol. 20, no. 2. P. 319-327.
- McGee, B. L., C. E. Schlekat, D. M. Boward, and T. L. Wade. 1995. Sediment Contamination and Biological Effects in a Chesapeake Bay Marina. Ecotoxicology 4:39-59.
- Moreton Bay Marine Park Introductory Guide, 1997, Queensland Government, Department of Environment.
- Morton, R. M. 1989. Hydrology and Fish Fauna of Canal Developments in an Intensively Modified Australian Estuary. Estuarine, Coastal and Shelf Science 28:43-58.
- Morton, R. M. 1992. Fish Assemblages in Residential Canal Developments Near the Mouth of a Subtropical Queensland Estuary. Australian Journal of Marine and Freshwater Resources 43:1359-1371.
- New South Wales State Environment Planning Policy no. 50. Canal Estate Development.
- Public Works Department, New South Wales. June 1989. Canal Subdivisions- General Conditions and Guidelines.
- Richez, Gérard. 1992. Un port de plaisance sur un littoral deltaique: le cas de Port-Gardian en Camargue. Méditerrannée No. 3.4.
- Smith, Marcus P. Lincoln, P. M. H. Hawes, and F. J. Duque-Portugal. 1995. Spatial Variability in the Nekton of a Canal Estate in Southern New South Wales, Australia, and its Implications for Estuarine Management. Marine and Freshwater Resources 46, 715-21.
- U.S. Geological Survey, U.S. Department of the Interior. 1996. Coupling Models for Canal and Wetland Interactions in the South Florida Ecosystem.
- UNEP Environmental Impact Assessment for the Establishment of a Marina/Small Craft Harbor in Southwest Tobago. CEP Technical Report No. 29. 1994.
- Weis, J. S., P. Weis. 1994. Effects of Contaminants from Chromated Copper Arsenate-Treated Lumber on Benthos. Archives of Environmental Contamination and Toxicology, Vol. 26, pp. 103-109.

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