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ASSESSMENT OF IMPACTS FROM A WASTEWATER DISCHARGE IN A WHOLE-OF-CATCHMENT CONTEXT

A STUDY OF THE IMPACT OF DISCHARGES FROM GISBORNE RWP IN VICTORIA ON THE HEALTH OF JACKSONS CREEK

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ABSTRACT

Wastewater discharges represent a pollution point source that creates several challenges for waterway managers. Existing guidelines and licensing requirements tend to be quite prescriptive and do not adequately consider the fact that the impact of discharges will vary between streams depending on the condition of the receiving environment and what other modifying factors (e.g. physical condition and pollutants) are present.

In this paper we discuss the value and benefits of considering an integrated whole-of-catchment approach to assess the impacts of recycled water discharges in a catchment that is already highly modified and degraded. Using a weight of evidence (WoE) approach, key stressors were identified within the catchment and assessed relative to beneficial (i.e. maintenance of environmental flows) and harmful (i.e. introduction of pollutants) impacts from recycled water discharges.

INTRODUCTION

In Victoria, wastewater regulation is based on discharge licenses, as issued by the Environmental Protection Authority Victoria (EPA, 2011), which require the licensee to comply with a set of water quality objectives based on the State Environment Protection Policy (SEPP, Waters of Victoria) (EPA, 2003a,b). The SEPP objectives outline specific values for physicochemical factors such as nutrients and conductivity in the discharge, as well as a requirement that the discharge does not cause acute toxicity within a defined area (the mixing zone), immediately downstream of the discharge location (EPA, 2004). The SEPP objectives have some flexibility in terms of being regionally specific, as well as considering existing background levels to some extent when setting allowable value ranges. This approach, however, is still very much focused on the environment downstream of the discharge point, without considering the state of the waterbody due to upstream catchment activities (sources of diffuse pollution), including the presence of urban population centres for which these wastewater treatment facilities service.

Furthermore, while the focus (and regulation) is generally on the adverse impacts of discharges (e.g. the introduction of excess nutrients that promote algal blooms or increase biological oxygen demand), wastewater discharges may also provide positive benefits to a waterway, such as important flow contributions in low rainfall catchments, regulated reaches of waterways and chronically water-stressed environments. Hence, wastewater discharge licenses do not always align with the ecological values and objectives they are designed to protect. The re-use of recycled water in waterways to provide environmental flows is recognised in Clause 31 of the SEPP WoV (2003), so long as the benefical uses of the receiving waters are not detrimentally affected from the recycled water supplies. This policy acknowledges the benefit of recycled water releases to waterways in some circumstances.

In addition, completely missing is any consideration of emerging contaminants of concern (including endocrine-disrupting chemicals). Many of these emerging chemicals are micropollutants (including hormones, pesticides, pharmaceuticals and personal care products), which are likely to have greater long-term impacts on ecological health than other pollutants associated with wastewater discharges such as nutrients and faecal coliforms (Petrie *et al.*, 2015). Micropollutants can be biologically active at very low concentrations and many are deliberately designed to be resistant to degradation, and therefore can persist in wastewater and are not effectively removed by standard treatment processes (Siegrist and Joss, 2012; Boxall *et al.*, 2014).

We believe that better environmental outcomes could be achieved if wastewater discharge regulation was more flexible, by considering environmental impacts in an integrated catchment management (ICM) framework. This would involve incorporating existing knowledge of the whole catchment to prioritise objectives and management decisions. The underlying principles of ICM consider sustainable development, community empowerment, integrated management and targeted investment of resources in an efficient, transparent and accountable way (DELWP, 2015). Land, water and biological resources are considered together, in order to achieve the overall objectives of ICM, which are to enable sustainability, protection and improvement of these resources.

The Centre for Aquatic Pollution Identification and Management (CAPIM) has been developing novel tools for pollution identification and biological assessment that can isolate the effects of individual and specific types of stressors. Here we present an example of how this approach can be used to identify impacts from wastewater discharges, and also to assist in prioritising the management of pollution issues in a catchment affected by multiple stressors. It is an example of how we can achieve better environmental outcomes by considering licensed discharges as just one of multiple stressors within a catchment.

The Upper Jacksons Creek Catchment is 30km north-west of Melbourne, Victoria, and its major stream, Jacksons Creek, is a major tributary of the Maribyrnong River (Figure 1). The dominant land use within the catchment is pastoral agriculture, while some of its headwater tributaries are forested. Significant and growing urban centres are present within the catchment, and increasing urbanisation in these centres is likely to increase impacts on aquatic ecosystem health in the future.

The overall state of Jacksons Creek is classified as 'Poor' according to the Index of River Condition, which is largely due to significantly altered hydrology from a large on-stream reservoir, and poor condition of both aquatic and riparian vegetation (Melbourne Water and Port Phillip and Westernport Catchment Management Authority, 2007). Historical data on water quality, macroinvertebrate assemblages and fish assemblages have shown that the condition of the catchment has deteriorated with changes in land use, removal of riparian and in-stream vegetation and increasing urbanisation, while deterioration in water quality has also been linked to modified flow conditions such as cease-to-flow events during the recent Millennium Drought (2001–2009) (Townsend *et al.*, 2015). Discharge from the RWP contributed an average of 0.96 ML/day, ranging from 11.9–35.2% of total stream flows between 2000–2011 (GHD, 2013a).

Here we present findings from a study that CAPIM undertook to investigate the impacts of the recycled water discharge from the Gisborne Recycled Water Plant (RWP) on the health of the Jacksons Creek aquatic ecosystem. We have used an integrated, multidisciplinary approach to assess the ecological health of biota from the top of the catchment through to Jacksons Creek upstream of the Sunbury township, which is about 7km downstream of the RWP discharge point. This approach enabled us to identify the priority issues impacting ecosystem health, as well as determine the specific impacts of discharges from the Gisborne RWP on the ecological health of Jacksons Creek.

Our approach incorporated water and sediment chemistry analysis, laboratory-based toxicity testing of site waters and sediments, field surveys to assess the health and condition of a range of taxa, and caging studies with snails and shrimp to determine the effects of short-term instream exposures to Jacksons Creek water at various sites throughout the catchment (Kellar *et al.*, 2015). Through assessing the whole catchment using an integrated approach, we were able to assess the impacts of the wastewater discharge in the context of the surrounding environment, which considers other potential sources of pollutants and environmental stressors as well as land use practices in the catchment.

METHODOLOGY

Sampling was completed over two seasons: Round 1 (spring-summer), October–December, 2013; and Round 2 (autumn), March–April, 2014. An integrated approach incorporating an extensive literature review of the catchment, as well as multiple laboratory and field tests, were used to identify areas within the Upper Jacksons Creek Catchment that were polluted, and to determine

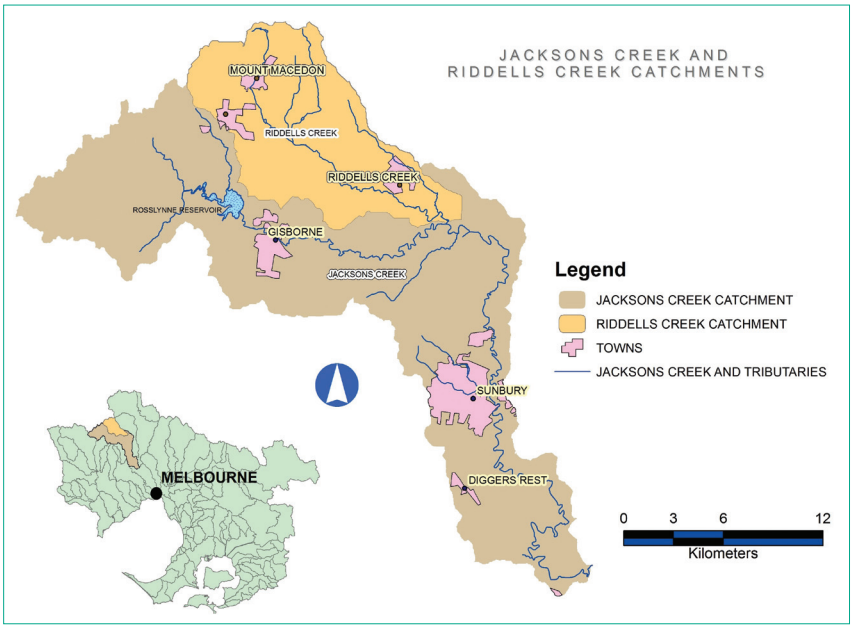

Figure 1. Upper Jacksons Creek Catchment.

Table 1. Summary of results from catchment-wide biological study.

Indicator	Land Use			
	Upstream of reservoir	Urban	RWP	Agriculture
	2 sites within Jacksons Creek	2 sites within Jacksons Creek	Outfall and 1 site immediately downstream of outfall	3 sites within Jacksons Creek, 1 tributary
Chemistry (exceeds SEPP indicators, and/or ANZECC 95% trigger values) *exceed PNECs	Nutrients (water) Pesticides (sediments)	Nutrients (water) Metals (water and sediments) Pesticides (water and sediments) Hydrocarbons (sediments) *E. coli* (water) Total estrogens (water)*	Nutrients (water) Metals (water) Pesticides (sediments) Hydrocarbons (sediments) Total estrogens (water)*	Nutrients (water) Metals (water) Pesticides (water) Hydrocarbons (sediments) *E. coli* (water)
Toxicity (at least one endpoint significantly affected)	Invertebrate toxicity	Phytotoxicity Invertebrate toxicity	Phytotoxicity Invertebrate toxicity	Phytotoxicity Invertebrate toxicity
Biological Impairment (at least one endpoint significantly affected)	Reduced macroinvertebrate diversity Altered snail reproduction	Reduced macroinvertebrate diversity Increased chironomid mouthpart deformities Reduced snail survival Altered snail reproduction Significant biomarker response (shrimp)	Reduced macroinvertebrate diversity Reduced snail survival	Reduced macroinvertebrate diversity Increased chironomid mouthpart deformities Reduced snail survival Altered snail reproduction
Overall Assessment	Potential adverse biological effects predicted	Significant adverse biological effects predicted	Potential adverse biological effects predicted	Potential adverse biological effects predicted (Jacksons Creek) Significant adverse biological effects predicted (Riddells Creek)

Trigger value. Concentration above which toxicity is likely.
PNECs – Predicted No Effects Concentrations. Concentration below which no toxicity is likely.

likely causes of biotic stress in the species tested. A weight of evidence approach, following that of Kellar *et al.* (2014), was used to identify the main stressors affecting aquatic ecosystem health, their impacts on stream values, catchment sources of stressors and the contributions of the recycled water discharges to biological impairment (Kellar *et al.*, 2015).

RESULTS

The whole Upper Jacksons Creek Catchment is impacted by a number of stressors that are likely to contribute to adverse ecological impacts (Table 1; Figure 2). Some biological impairment was evident in the upstream 'reference' areas; however, it was not consistently observed in all fauna. In contrast, biological impairment was more consistent downstream of the Gisborne township and also downstream of the Gisborne RWP. Fish and macroinvertebrate assemblages showed low abundance and diversity. Fauna either collected from, or deployed to, various sites within the catchment displayed signs of biotic stress and increased mortality, and both water and sediments

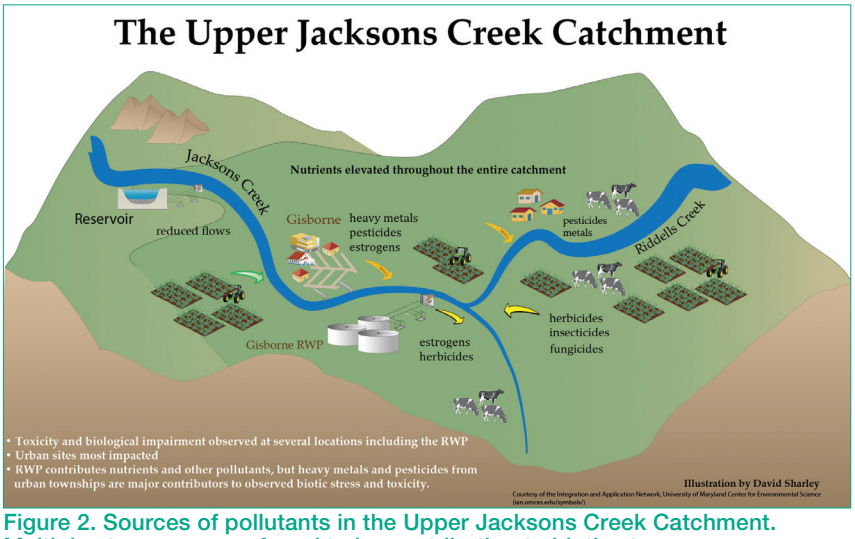

Figure 2. Sources of pollutants in the Upper Jacksons Creek Catchment. Multiple stressors were found to be contributing to biotic stress.

were toxic to microalgae and/or macroinvertebrates (chironomids, amphipods) (Kellar *et al.*, 2015). In addition, several areas were identified where specific metals and pesticides were measured at high concentrations (above ANZECC guideline values), and likely contributors to the biological impairment observed. Nutrients were elevated throughout the entire catchment and often exceeded ANZECC guideline values (ANZECC/ ARMCANZ, 2000). The results clearly indicate that there are multiple stressors affecting the biota within Jacksons Creek, and while some specific pollution hot spots were detected (Gisborne and Riddells Creek township), impacts were observed throughout the catchment, probably reflective of the lasting impacts of low flows associated with the Millennium Drought.

The results from the current study support previous data collected from the Upper Jacksons Creek Catchment, suggesting that flow conditions have a major effect on water quality and the condition of faunal assemblages within the catchment (GHD, 2013a, 2013b). However, it was also apparent that pollutants (particularly pesticides) were contributing to ecological impairment within the catchment, as evidenced by water and sediment toxicity in microalgae and macroinvertebrates, deformities in chironomids collected from different areas, and mortality in snails deployed to sites within cages (Kellar *et al.*, 2015). With increasing urbanisation predicted for Gisborne, New Gisborne and Riddells Creek, the severity of pollution and the subsequent impacts within the Upper Jacksons Creek Catchment are expected to increase, particularly within Gisborne and from the Gisborne RWP (due to greater discharge volumes).

There is a need for cross-agency effort between CMAs and water authorities to address major issues in the catchment. For example, lowering nitrogen concentrations in discharges will have no benefit to the aquatic ecosystem, since other nitrogen inputs are present upstream. In this case, targeting nitrogen in headwaters from agriculture and urban runoff would lead to more tangible outcomes.

Impact of the recycled water plant

The Gisborne RWP was shown to have both positive and negative effects on Jacksons Creek. We observed a reduction in deformity rates in chironomids sampled downstream of the RWP (as compared to chironomids collected from urban areas upstream), suggesting the RWP discharge dilutes urban pollutants from upstream. Furthermore, at the site immediately downstream of the RWP we observed the greatest number of native fishes, including several Southern pygmy perch that were not observed in any surveys conducted between 2004–2012, suggesting the RWP discharge is providing a beneficial flow to support recolonisation of areas that were unable to support aquatic fauna during the Millennium Drought.

However, several pollutants were detected in the RWP discharge (metals, herbicides, hydrocarbons and estrogens) and some toxicity and biological impairment was observed as well. In particular, the RWP was a source of herbicides, although these were present as a result of onsite weed management at the RWP. This has subsequently been rectified through changes in weed management practices and plant operations. A specific group of contaminants associated with RWP discharges are endocrine-disrupting chemicals (EDCs), which are compounds that can interfere with normal hormone function in organisms (Colborn *et al.*, 1993). Recycled water discharges, and in particular domestic effluents, often contain compounds such as natural estrogens (17β-estradiol, estrone, estriol), synthetic estrogens (17α-ethinylestradiol) and compounds with estrogenic activity (e.g. alkylphenol ethoxylates, some pesticides, BPA, plasticisers) (Jobling *et al.*, 1995; Meesters and Schroder 2002; Ying *et al.*, 2002a; Ying *et al.*, 2002b).

Some reproductive impairment, suggestive of exposure to estrogenic compounds, was observed in snails and mosquito fish sampled in Gisborne (upstream of RWP), as well as from the bottom of the catchment. However, further investigation using additional species and more sensitive EDC-related endpoints is necessary to confirm these observations. Due to low fish abundance we were unable to measure specific endpoints (i.e. vitellogenin induction and gonadal changes) that could confidently determine if EDCs are an issue at the RWP. It is possible that endocrine disruption could be an issue, given the number of pesticides used across the catchment with known endocrine disruptive effects (bifenthrin, o-phenylphenol, atrazine), and the high concentrations of natural estrogens detected at the RWP and sites within Gisborne upstream of the RWP. Therefore, experimental work to identify endocrine disruption in biota from the Upper Jacksons Creek Catchment is certainly worthy of further investigation.

Nitrogen can be a major pollutant in sewage effluent. In this study, however, nitrogen concentrations remained similar upstream and downstream of the RWP, and were not considered a major factor affecting ecosystem health.

Identified stressors and impacts on values

Based on a series of chemistry-, toxicity-, biological impairment- and reproductive-indicators (Kellar *et al.*, 2015), a number of stressors have been identified within the Upper Jacksons Creek Catchment that are likely to be impacting stream values (Table 2).

Nutrients were elevated throughout the catchment and, therefore, reducing nutrient concentrations from the Gisborne RWP would have no substantial benefit to downstream aquatic ecosystems. In contrast, maintaining flows, addressing urban pollution and improving riparian habitat will improve the ecological health of Jacksons Creek. These findings are further supported by a catchment rainfall runoff model that was developed as part of the study (Arora *et al.*, 2015), which indicates that total nutrient loads will actually decrease with future urbanisation, due to changes in land use.

The lack of environmental flows during droughts, and degraded riparian habitats due to exotic species (willows), bank erosion and direct access of cattle to Jacksons Creek (Figure 3), have been identified as issues relating to the quantity and quality of aquatic habitats available,

Table 2. Identified stressors and impacts on values within Jacksons Creek.

Stressors	Impact on Values	Catchment Source	Contributions from Gisborne RWP
Nutrients	Nuisance plant growth	Agriculture, urban runoff, RWP, stock access to stream	Low (since already elevated upstream)
Toxicants			
- Heavy metals	Reductions in macroinvertebrate diversity	Urban runoff, roads, stormwater, Gisborne landfill	Reduces impacts (through dilution effect)
- Hydrocarbons	Reductions in macroinvertebrate diversity, anaerobic sediments	Urban runoff, roads, vehicles, stormwater, Gisborne landfill	Reduces impacts (through dilution effect)
- Pesticides (insecticides)	- Reductions in macroinvertebrate diversity, may also impact fish	Urban runoff, agriculture	No effect
- Pesticides (herbicides)	Toxic to algae. Indirectly impacts macroinvertebrate and fish diversity	Urban runoff, agriculture, Gisborne RWP	Impacts observed (effects were detected, however appropriate management actions were taken to remove this as a source). No ongoing impacts expected, but further monitoring recommended
- Endocrine-disrupting chemicals (EDCs)	Reductions in fish diversity and impaired reproduction. Potential impacts on other biota (eg. platypus, turtles)	Gisborne RWP and urban runoff	High. RWP identified as an obvious source of EDCs to the catchment
Stream Hydrology			
- Water harvesting	No permanent water affects entire ecosystem (eg. macroinvertebrates, fish, platypus)	Rosslynne Reservoir	High. Additional sources of flow
- Urban runoff	Low due to small size of urban catchment	Gisborne and Riddells Creek townships	Nil
Riparian habitat	Reductions in macroinvertebrate diversity and fish habitat, loss of amenity	All	Nil
Stream banks	Low	All	Nil
Stream bed and instream barriers	Reductions in fish movement	Rosslynne Reservoir, stream gauging weir at Gisborne RWP, several weirs and barriers downstream of study area	Nil

while heavy metal and pesticide pollution from Gisborne and Riddells Creek townships have been identified as key issues relating to the quality of water available in the catchment.

Priority actions

Based on the results of this study, we identified a number of priority actions related to specific stressors that could be taken to improve the ecological health of Jacksons Creek (Table 3). Maintenance of environmental flows, especially during drought conditions, is needed to ensure suitable habitat is maintained. Similarly, revegetation and stream frontage management could be used to improve the degraded riparian vegetation that occurs throughout the catchment.

Reducing urban pollution (e.g. heavy metals and pesticides) to the creek could be addressed by locating point sources of pollution and pre-treating stormwater prior to discharging it into streams, for example through constructed wetlands. Water-sensitive urban design (WSUD) could be implemented to reduce pollutant loads and to ensure best practice urban development.

The Gisborne RWP was identified as a source of some pollutants to Jacksons Creek, particularly steroidal estrogens. Therefore, ongoing monitoring of the RWP discharge would enable the pollutants (including micropollutants) being discharged to be characterised, in order to determine if they are likely to be having any adverse biological effects. While improved flows seem to have contributed to an increase in fish abundance, and some recolonisation of native species, several instream barriers are known to exist throughout the Upper Jacksons Creek and

Figure 3. Direct access of cattle to Jacksons Creek contributes to degraded riparian vegetation and reduced water quality.

Maribyrnong Catchments. Removal of such barriers would encourage fish movement into the upper catchment and assist with recolonisation. Finally, the implementation of best practice agricultural management strategies would assist to minimise the input of nutrients and pesticides from agricultural activities.

Benefits of using an integrated catchment approach

Here we have presented an assessment of impacts from a wastewater discharge as one example of an integrated catchment management approach that could also be utilised in other ecosystems that are impacted by multiple chemical and physical stressors. The study demonstrates the importance of considering all potential factors in catchments impacted by multiple stressors, rather than solely focusing on specific sources such as wastewater discharges.

This approach enables priority actions to be implemented to improve the ecological health of the whole catchment, rather than just the discharge receiving environment. This allows for a greater overall environmental benefit to the catchment at a more economical cost. This approach has been widely recognised around the world and trialled both overseas and in Australia. Recently, a five-year program was initiated in the Dandenong Creek catchment to provide better environmental and economical outcomes; it involves pollution abatement and aesthetic and habitat improvements, rather than an expensive sewer upgrade that is not the main cause of pollution (Kellar *et al.*, 2014).

Table 3. Priority actions identified for the improvement of ecological health in Jacksons Creek.

Stressor	Explanation/Comment	Recommended Action
Flows	Absence of flows during Millennium Drought would have led to loss of fish and other aquatic organisms	Ensure environmental flows are maintained during droughts
Degraded riparian vegetation	Degraded throughout catchment. Several exotic species and unimpeded access of cattle to stream banks	Riparian revegetation and stream frontage management program
Urban pollution	High concentrations of heavy metals and synthetic pyrethroids were detected around the Gisborne township	Locate point sources and rectify the problem
Urban growth	Gisborne, New Gisborne and Riddells Creek townships will continue to expand	Implement proper water-sensitive urban design (WSUD)
Gisborne RWP	Micropollutants in discharges are likely to impact aquatic vertebrates (fish, platypus, turtles)	Measure concentrations of EDCs in discharge and ensure they are at acceptable concentrations
Instream barriers	Various barriers (Rosslynne Reservoir, stream gauging weir at Gisborne RWP, several weirs and barriers downstream of study area) impede fish movement	Remove barriers where practicable and/or build fish ladders to assist movement
Agriculture	Source of nutrients and potentially pesticides	Ensure best practice management

Jacksons Creek downstream of the confluence with Riddells Creek, in the Upper Jacksons Creek Catchment, north-west of Melbourne.

The integrated catchment approach is much more flexible and tailored to the specific environment under investigation when compared with traditional licensing approaches that are based on SEPP objectives, ANZECC trigger values and risk assessments. We believe that this approach needs to be incorporated into regulatory licensing, whereby each catchment is assessed based on its individual priorities and requirements (e.g. environmental flows, water use, urban growth, pollution reduction) to ensure the best environmental and economical benefits are achieved. Currently, in the above example, compliance with the licence agreement (nutrient objectives) does not protect environmental values within the catchment. As such, specific management requirements/needs/priorities can be determined case by case, for the environment to be protected. This approach enables identification of priority actions to improve the ecological health of the whole catchment (as opposed to just in the discharge-receiving environment), and is much more flexible and tailored to the specific environment under investigation when compared with traditional licencing approaches that are largely based on SEPP objectives and ANZECC trigger values.

The Upper Jacksons Creek Catchment has also been used recently as an example for assessing the potential use of environmental offsets in environmental management (Berg, 2015; Feldman *et al.*, 2015). This concept is based on quantifying all social values and environmental benefits that a waterway provides, and balancing the costs of pollution reduction against other environmental management options (i.e. riparian revegetation). Options are assessed in terms of triple bottom line (TBL) principles to provide net positive environmental outcomes at a lower cost than traditional management options, such as upgrading a treatment plant or installing new infrastructure to divert wastewater away from a waterway.

CONCLUSION

Using a WoE approach, we were able to identify various sources of pollution in the Upper Jacksons Creek Catchment, and link these to biological impacts such as increased toxicity and rates of deformities, elevated detoxification responses and changes in survival, reproduction and development in various taxa. Toxicity and biological impairment were observed in some organisms at the RWP, and some pollutants were detected in the discharge. However, the impacts were small relative to other impacts throughout the catchment. We identified the main sources of pollution as being from the Gisborne township and the two urban stormwater drains. Many of the contaminants detected are common in urban water bodies and associated with urban growth. Therefore, it is anticipated that concentrations are likely to increase within the catchment as urban growth continues.

The CAPIM study describes the relative impact of discharge from the Gisborne RWP when compared with other stressors in an integrated catchment context. The whole Upper Jacksons Creek Catchment is impacted and, while the RWP discharge contributes nutrients and other pollutants to Jacksons Creek, other stressors from different sources are likely to be having greater impacts on ecological health. A final consideration is that land use in the catchment is changing as a result of increasing urbanisation, leading to increases in polluted urban runoff and wastewater discharge volumes, and since upstream of every wastewater treatment plant there is an urban area, it is important to consider impacts within a whole of catchment context.

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