[Note: Australia is an arid continent where immigration-fueled population growth, cornucopian economics, and political timidity are rapidly exhausting freshwater resources and accelerating the degradation of inland aquatic ecosystems. In these regards it is as close a match to our own American Southwest as one can imagine. The article below may serve as a mirror in which to examine ourselves and our own direction a bit more dispassionately. Its author, Professor W.D. Williams, is one of the world's foremost authorities on saline lakes. Having studied them for almost 40 years, having initiated in 1979 the triennial series of International Symposia on Inland Saline Lakes, having worked assiduously to facilitate interaction among salt lake scientists of all nations, and having founded the *International Journal of Salt Lake Research*, which he continues to edit, he has given a powerful impetus and coherence to this discipline. --Stuart H. Hurlbert, 1999. An html version is posted on the Salton Basin-Colorado Delta Mothersite, San Diego State University]

Australian Inland Waters: A Limited Resource

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Abstract: Significant changes to the nature of the inland aquatic environment in Australia have occurred during the past 200 years: the growth of the human population has had far-reaching, comprehensive, frequently irreversible and deleterious effects upon Australian lakes, rivers, streams and other water bodies. These effects continue and their rate accelerates. The major driving factor is the continuing increase in the size of the Australian population - a phenomenon exacerbated by the fact that Australia is the world's most arid inhabited continent. The increase in population size in Australia is due to immigration. Sensible water management needs to take account of the increasing pressure on the use of water by a larger and increasing population. The question arises: how large should our population be? The derivation of the answer must involve not only social, political and economic factors, but also environmental ones. The importance of environmental factors should not be underestimated and should be taken into account more seriously than it has been thus far.

Introduction

I first talked to ANZAAS some thirty years ago, shortly after arriving from another, smaller island. With the immodesty of youth, I spoke about the changing limnological scene in Victoria. The population of Australia was then about eleven million, salinisation was an unfamiliar word, global warming was science fiction, atmospheric concentrations of ozone were stable and uninteresting, and blue-green algal blooms were rare events. Much has changed in thirty years.

Today, with the immodesty of age, I want to update and extend what I said. First, I discuss briefly the general nature of human impacts on Australian inland waters. To provide focus, I go on to discuss impacts upon a particular type of inland water-body, salt lakes. Finally, I discuss one environmental determinant of increasing importance for our inland waters, the growth of our population.

I discuss the last matter because the environmental impact of future demographic changes in Australia often seems at best underestimated, at worst conveniently ignored, at least so far as their impact on inland waters is concerned. We continue to ignore them at our peril, however expedient or convenient it is to do so from a social, political, economic or religious viewpoint. The most blatant example of avoidance of global demographic issues for political and religious reasons is provided by the UNCED Rio conference.

The environmental importance of demographic issues has escaped concern even in some sections of the scientific community. At a recent conference of the Ecological Society of Australia, when the effects of humans on Australian ecosystems over the past two hundred years were discussed, the growth of the Australian population was not seen as a major issue (Hopkins et al., 1990)! Of course, there are many other groups of scientists for whom population growth is a matter of concern and seen as a major issue, and the Australian Institute of Biology in particular recognizes the key role of population growth in environmental management. I do not claim that demographic issues and their environmental importance have been and are unrecognized in the wider Australian community: that is far from the case. Griffith Taylor was keenly aware of demographic issues within an environmental context in the 1920s. In more recent times, the Australian Bureau of Statistics, amongst many governmental organizations, as well as numerous NGOs, recognize the environmental significance of demographic issues. The National Population Council has contributed much to debate in this area. The final report of its Population Issues Committee (Population Issues and Australia's Future) was published earlier this year. I do claim, however, that the community in general, and through it most of our politicians, are less aware than they should be. The only way to increase awareness is continually to raise demographic issues whenever suitable opportunities arise, ANZAAS provides such an opportunity, and although I know that other speakers have addressed demographic matters in general on this and previous occasions, and notably Professor Stone at the last ANZAAS conference, I make no apology for doing so again. If excuse is needed, may I quote the words of that practical visionary, William Blake: 'He who would do good to another must do it in Minute Particulars, General Good is the plea of the scoundrel, hypocrite and flatterer; For Art, and Science cannot exist, but in minutely organized Particulars.'

The minute particulars with which I concern myself are inland waters and especially salt lakes. I do not mean, of course, that Professor Stone and my other colleagues are scoundrels!

General Impacts

For present purposes, general impacts fall into three types according to origin. First, there are those which directly followed the advent of (largely) European colonists after 1788. They resulted in significant changes to the inland aquatic environment. In large part, they can be regarded as the harvest of unexploited resources both to support the geographical expansion of the colonists and provide supplies for the slowly increasing Australian urban population. Their effects were greatly compounded by poor management and the implementation of ill-considered projects.

Changes of this type have by no means stopped, but they have slowed and in many parts of at least the more densely settled parts of Australia a significant fraction of easily exploitable water resources has now been exploited to a degree in accord with present requirements. The effects have been far reaching, comprehensive, largely irreversible and usually deleterious so far as the natural character of inland bodies of water is concerned. Over large parts of Australia, the major rivers have been dammed or diverted, deep freshwater impoundments occur where none occurred before, wetlands have been drained, running waters bear heavy loads of pollutants, extensive areas of catchment basins have been salinised, floodplains have been alienated, blue-green algal blooms are a common occurrence, and introduced aquatic animals and plants are dominant or important elements of the biota. In short, over large parts of Australia, our inland aquatic environment has been seriously degraded despite our relatively low population density and brief duration of settlement.

Nevertheless, in areas outside those closely settled (and even within these areas) it is still possible to find bodies of water which retain significant non-economic values, that is, rivers, streams and lakes with a natural biota still largely unchanged and with significant recreational, educational, cultural and aesthetic values. They form a valuable part of our natural heritage that should not be lightly squandered. If anything, they are one of the few successful legacies of our slowness to change technologically and industrially compared with other Western countries.

The second type of impact is similar to the first in effect, but conceptually different in origin. It arises largely from the need for more intensive exploitation of available resources to provide for an increasing population either directly (as a source of domestic water) or indirectly (for the production of food, exports, goods, etc). In other words, impacts of this type result not from the need to provide water for development as from the need to provide water for maintenance. Of course, no clear distinction in space or time, let alone effect, exists between the first and second type of impact, but we may be sure that in the absence of better management and a significant rearrangement of how water is presently used, a larger Australian population will bring about increasingly greater impacts upon the aquatic environment. Further growth of our population will be accompanied by further degradation in the aquatic environment. Inevitably, for example, a larger population will mean that the painfully evolving balance now being struck between non-environmental and environmental allocations for water usage will be subject to less benign and more intense pressure than is presently the case. A key point here is that for each small incremental increase in population, there will be a large incremental effect on the environment because much of what is left is marginal and sensitive to disturbance. As such, it often occurs in less well-watered areas and is therefore more precious to its biota, more vulnerable to exploitation, probably much slower to recover from disturbance and the impacts are more likely to be irreversible due to the loss of naturally occurring biota in these marginal areas. Small rises in population will have a much more severe impact than in the past! A second key point is the current mismatch in the distribution of water resources and population in Australia. Further population growth would require a significant change in the distribution of population (especially to the area north of the Tropic of Capricorn) if environmental impacts were to be minimized. even so, such a redistribution would itself have substantial environmental effects in those areas as well as being very costly and of very dubious economic benefit.

A clear example of the impact of increasing population is provided by the Tully-Millstream project in northeastern Queensland. The Queensland Electricity Commission plans to generate additional electricity by diversion of certain waters on the Atherton Tableland. They want to do this to cope with projected growth in power demands. The diversions will have environmental impacts, though their importance is the subject to debate, not least because of some intrusion into the world Heritage area.

The third type of impact is essentially the same as the second, but indirect and globally driven: the likely environmental impacts of a burgeoning world population. Climatic changes from increasing carbon dioxide levels in the atmosphere, increased UVB radiation - but not lake acidification it seems so far - are impacts of this sort that may predict will affect the nature of some or all Australian inland waters. All reflect the immense size of the global human population, and the rate of resource use and environmental destruction.

Outside this simple typology lie some important impacts which are less directly related to the size of the Australian or global population. The most important are those from introduced plants and animals. Their variety and extent increase almost annually. At present, there are some 20 species of introduced freshwater fish, including several in the family Cichlidae. Given the power of the vociferous aquarist lobby, we can look forward to many more and their spread in northern Australia. We only narrowly escaped the introduction of the Nile Perch. *Potamopyrgus antipodarum* from New Zealand is invading many lowland bodies of water in southeastern Australia. The cane toad is a noxious species widespread and spreading in Queensland, parts of the Northern Territory and northern New South Wales. *Mimosa pigra* infests a huge area of the Top End and has the potential to invade most wetlands in the monsoonal region of northern Australia.

Impacts Upon Australian Salt Lakes

Let me illustrate these general remarks by considering impacts upon a particular type of Australian aquatic environment, salt lakes. I focus upon these for two reasons: first, saline water is much less useful than fresh water, and a priori, therefore, one would expect salt lakes to have sustained much less damage than rivers, streams and freshwater lakes; second, I know more about them.

Despite the first of these reasons (their relative lack of value), many Australian salt lakes have already suffered significant damage. This has resulted in particular from the impact of water diversions, changes to the nature of catchment/drainage basins, and pollution. Other impacts have occurred or are likely, not least from climatic change and increasing amounts of UVB radiation.

An important example of a salt lake damaged by water diversion is Lake Corangamite, Victoria. This lake is the largest natural, permanent body of water on continental Australia. It is rapidly decreasing in size and increasing in salinity because its major inflow, the Woady Yaloak Creek has been diverted into the Barwon River by the Rural Water Corporation of Victoria. Lake Corangamite is our largest permanent salt lake, a RAMSAR site, supporting significant numbers of birds, and has significant recreational, tourist, aesthetic, scientific and other values. Nonetheless, merely to decrease the possibility that the lake will flood surrounding agricultural land, the diversion scheme has operated since 1959. As a result, from 1959 to 1990 the level of the lake has dropped ~2 m and the salinity has risen from ~35 to ~60 g/L. Following these changes, islands that were nesting or refuge sites for ibis and other birds have disappeared, and the birds also, following predator access. More damaging is the increased salinity which has killed the major food items for the birds. Whether the Australian Government is now in breach of its international obligations as a signatory to the RAMSAR Convention is an interesting question. Whatever the case, we do not need to look to the Aral Sea to see what water diversion can do to a salt lake. We have an 'Aral Sea crisis' on our own doorstep. At the time of writing, the Victorian Parliament is considering whether the diversion should be allowed to continue.

As for catchment/drainage basin events, their impacts are less easily determined. Nevertheless, since salt lakes are hydrologically much more responsive to catchment events than freshwater lakes, with catchments often in semi-arid areas where habitats respond quickly to perturbation and recover far more slowly, if at all, considerable impacts have occurred. Two significant events have been grazing by domesticated mammals and rabbits and direct changes to the natural vegetation by man. Both have led to changes in the salinity, composition and seasonality of run-off. Overgrazing, vegetation clearance and salinisation result in severe erosion and overall 'desertification' (land degradation) in semi-arid catchments. Once dryland salting or scalding has occurred, recovery is virtually nil.

Of other impacts, particular mention is made of pollution because pollutants accumulate more in salt lakes than in freshwater ones. They do so because salt lakes, almost by definition, are the termini of hydrologically closed systems, whereas freshwater lakes are merely parts of hydrologically open systems. Lakes in the Western District of Victoria provide examples.

Again, salt lakes have not escaped the introduction of exotic species. The brine shrimp *Artemia* has been introduced into many coastal, solar salt fields and has already been found in at least one natural salt lake well inland. Regulations concerning the importation and distribution of its cysts seem to be particularly lax. Indeed, there seems to be no effective control. The particular danger is that *Artemia* will compete with and cause the extinction of our natural brine shrimp (*Parartemia* spp.) - all of which are endemic and the economic and scientific value of which remain almost totally unexplored.

Salt lakes will certainly not escape impacts from climatic change and increased UVB radiation. Because salt lakes represent a sensitive balance between many climatic parameters, relatively small changes in these will cause large changes to the natural character of salt lakes. Even relatively small rises in sea level will affect coastally located salt lakes such as those in southeastern South Australia. Decreased rainfall will lead to increased salinity, rainfall increase to freshening of salt lakes. Changes to the seasonal patterning of climatic events will lead to fundamental ecological changes. And, of course, since many salt lakes are shallow, the effects of any UVB radiation increase will be very great since the biota cannot sink to escape the damaging rays.

It is not suggested that damage inflicted on the natural character of Australian salt lakes is linked to the size of our population - except in the most direct way. Much of the damage can be ascribed simply to ignorance or

mismanagement. Nevertheless, the fact remains that even the least economically important fraction of our inland aquatic environment has sustained significant damage and is at risk of more as further pressure is placed upon the agricultural sector of our economy.

Demographic issues

Concern about the size of the human population is at least as old as our first civilization, the Sumerian one, some 6000 years of age. In the oldest written records we have, The Epic of Gilgamesh, note was made that: 'In those days the world teemed, the people multiplied, the world bellowed like a wild bull, and the Great God was aroused by the clamour.....So the gods agreed to exterminate mankind.'

The human global population then was probably no more than about 10 million. It is now about 5400 million. To maintain it, let alone sustain its growth, irreparable, unprecedented and accelerating damage to our planet is taking place. The growth is fueled by the difference between natality and mortality: more people are born and survive than die. The result of inexorable population growth is painfully obvious and distressing to all with any humanity: the world is full of starving people living in poverty. According to a recent report (Population Crisis Committee, 1992), 73% of mankind, 3900 million of our fellow human beings, live in conditions of moderate to severe human suffering. Some suffering is the direct result of political strife and recession, but a good deal can be attributed to the difference between immediately available resources and population size. At its simplest, it is the inability of Homo sapiens to escape the basic evolutionary tenet: all species tend to reproduce at a rate greater than can be supported by the environment.

Australia clearly stands outside this picture. We are not starving, we are not suffering, and our carrying capacity has not been reached. Also, although our annual population growth rate is high (three times any OECD country), growth results from immigration, not excessive natality. It might be helpful to have some specific figures (Table 1).

Table 1. Austalian population size as a function of different rates of natural increase and net migration.

Year	**Population (millions)**	**Annual growth rate (%)**		
		Natural Increase	**Net Migration**	**Total**
1972	13.3	1.2	0.6	1.8
1977	14.2	0.8	0.4	1.2
1982	15.2	0.8	0.9	1.7
1987	16.3	0.8	0.7	1.5
1991	17.3	0.8	0.6	1.5
Source: Australian Bureau of Statistics (Table 3.1, 1992)				

What of future trends? Accurate forecasting is difficult because of our inability to predict fertility rates (amongst other determinants). However, if assumptions are made involving various combinations of high and low fertility rates (1.8 and 1.7 children per female) and high and low immigration rates (125 000 to 80 000 per year), the following scenario emerges (Fig. 1).

These are projections from the Australian Bureau of Statistics. Even with low fertility and immigration rates, the Australian population will increase by ~30% in the next 30 years, that is to ~22.5 million. With high fertility and immigration rates, these values are higher, ~40% and 24 million. Simple extrapolation of the data for the period 1972-1991 provides a figure of 25.5 million by 2031, give or take a couple of million. Moreover, even if net immigration ceased forthwith, our population would continue to grow at a rate above the average for developed countries (~0.8% per annum). This is due to the age structure of the population which ensures twice as many births as deaths. If our current level of intrinsic fertility is maintained (and it is quite stable and perhaps increasing), it will be another 40 years before population growth would cease. Figures for the size and growth of the Australian population pale into insignificance, of course, against present world population size and its rate of increase (5.4 billion and 93 million per year)! Even so, they are not insignificant in terms of their likely impact on the Australian environment.

There is no doubt that Australia can support more people (40 to 400 million according to Borrie!), but the central question is why should it, when to do so will undoubtedly degrade our environment and can offer no significant relief to the global problem. There must always be, of course, room for humanitarian considerations, but future generations of Australians are unlikely to thank us for mindlessly squandering their natural inheritance simply because more Australians seemed like a good idea at the time and our intentions were good. The road to hell is paved with good intentions.

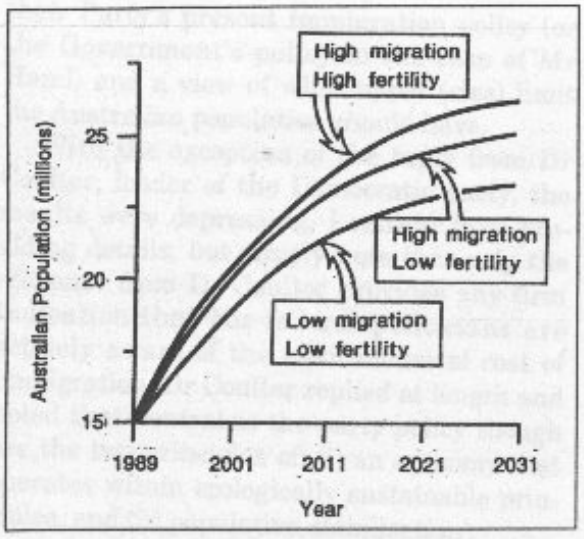

Figure 1. Australian population growth under various combinations of high and low fertility and immigration rates.

These considerations bear upon the concept of Ecologically Sustainable Development (ESD) and the question of when does economic development compromise ecological sustainability? The question of who decides is particularly important: but that is another issue where ANZAAS could have a bigger input. The Federal Government has recognized the principles of ESD and various working groups have already provided draft reports on particular issues involving ESD. However, in my view, population issues have been evaded (or at least in the draft strategy) and I'm not surprised that major environmental groups bocotted the August forum called by the Federal Government to discuss development policy on the grounds that it was a ploy to avoid spelling out environmental policies. Whatever the case, one of the findings has been that population increase will have serious environmental effects in urban areas.

The effects are likely to be equally serious upon the inland aquatic environment beyond urban areas given that water is a basic resource for urban populations. Several professional organizations are alarmed about the prospect and point out that if our population continues to grow at present rates, water supplies will soon become critically low and their quality will rapidly deteriorate. I share their alarm. It has been said that one of the most important global environmental problems of the near future will be the availability of water for human use. How much more important will this problem be in the world's driest inhabited continent? Unfortunately, as Benjamin Franklin noted some 250 years ago: 'When the well is dry is when we know the worth of water.'

What do our politicians think of these matters? To find out, I wrote earlier this year (May 1992) to the Minister for Immigration, the Shadow Minister for Immigration, and the leaders of the National Party and the Democratic Party. I pointed out that I was to lecture on water and the environment at ANZAAS and would consider *inter alia* the impact of humans on Australian water resources. I sought from them a statement on their Party's present immigration policy (or the Government's policy in the case of Mr. Hand) and a view of what upper (size) limit the Australian population should have.

With the exception of the reply from Dr. Coulter, leader of the Democratic Party, the results were depressing. I refrain from providing details, but simply note that only the response from Dr. Coulter provides any firm indication that our federal politicians are actively aware of the environmental cost of immigration. Dr. Coulter replied at length and noted that 'central to the party policy though are the two principles of: (I) an economy that operates within ecologically sustainable principles, and (ii) population stabilization'.

An earlier paper by Dr. Coulter argued for a net intake of 50 000 per year. Such an intake, Dr. Coulter argued, would result in a stable population of ~25 million in about 2050. Even this number, however - about 50% greater than the present one - was clearly recognized as a significant environmental stress.

I am not, I might add, a member of any political party.

To the Government's credit, its former Prime Minister, Mr. Hawke, did ask the National Population Council in 1990 to examine major issues which would arise from the increase in Australia's population. The final report of its Committee was published earlier this year. It seems to have provoked little response thus far, but is certainly of interest in the present context, given its influential status. Its findings, from the viewpoint of those concerned with the environment, were nevertheless disappointing. The Committee chose not to answer the question as to what level of population we should aim for, noting that it was 'inappropriate to enunciate an optimum population level'. The reasons advanced were plausible in the short term, but not in my view in the long term since they did not include any consideration of environmental issues. The claim by the Committee that many ecologists opposed to high population growth also now agree with them was supported by a single reference.

There was no comment of any substance by the Committee on the impact that a larger Australian population would have on water resources, our basic resource in shortest supply. The only comment that provides any comfort is the acknowledgment that population size can have effects on ecological systems that are 'not well-monitored by free-market prices'. At least it is comforting to note in the recently released report of the Economic Planning Advisory Council (EPAC), an influential advisory group to the Government, the conclusion that *inter alia* water resources are underpriced.

Concluding Remarks

To conclude this paper, I summarize the impacts that have so far been sustained by our inland aquatic environment, I provide some indication of what lies ahead and I make some suggestions.

In summary, despite the brief duration of our settlement and the relative sparseness of our population, human impact upon the Australian inland aquatic environment has been significant, widespread, largely irreversible and generally deleterious from an environmental viewpoint. The impact has been compounded by poor management. Thus, our generation inherited a degraded resource, has done little to restore it and will bequeath one even more degraded to the next. If we seriously wish to stop the degradation, we must face the fact that an important component of degradation is the size of our population. At the very least we must ask to what size should our population be allowed to grow.

What lies ahead obviously depends upon how we resolve this question. We could easily decide in an economic recession that economic development has priority over environmental protection. Indeed, that has already been said by one of our leaders. We could, just as easily, decide that future generations can take care of themselves, that ecological sustainability is simply academic rhetoric. Future generations are unlikely to thank us for knowingly having squandered their inheritance. And we could decide that our population be allowed to continue to grow. It is always easier to do nothing than to take decisions likely to be unpopular with many. If we opt for the easy path in all these decisions, yet further degradation of our inland waters lies ahead. What's more, this degradation will be more severe in area and irreversibility than ever before.

Perhaps I can obliquely illustrate what this may actually mean by referring to another semi-arid region of the world where populations have been allowed to grow, where close attention was not paid to the matter of ecological sustainability and where water resources were grossly mismanaged. I refer to the Aral Sea region. I have had first-hand experience of events in this region because of my membership of a UNEP working group.

Formerly, the Aral Sea had a commercial fishery which yielded about 44,000 tonnes a year. Its inflowing rivers were used for a moderate amount of irrigation, enough to support the local population and its islands and river deltas provided habitat for a rich community of animals and plants. Then, some three decades ago, the decision was made to irrigate substantially larger areas with apparently scant regard for the environmental effects of significant water diversions. The result? The level of the lake dropped some 15 m, the salinity rose threefold, large areas of the former lake bottom were exposed and most of the islands and almost all of the deltas disappeared. And the consequences? In brief, the fishery completely collapsed, the rich and diverse biota of the deltas and islands disappeared, the climate became more extreme, salts were blown from the dry bed on to surrounding pastoral land, the groundwaters became polluted from the pesticides used in the irrigation areas and salinisation and desertification of the catchment started. The effects of all this environmental degradation on the local population, where families are often larger than our own, have been devastating. Serious unemployment, severe health problems and life in a degraded environment is its common lot. We would do well to learn from the mistakes made in this region.

And so to the suggestions. The most obvious one relates to immigration. Given that immigration drives the growth of our population and that population size is an important determinant of our impact upon the aquatic environment, further consideration should be given to the environmental impact of immigration. Second, a thorough national audit (stock-taking) of our water resources is required. This should not be restricted to potable waters of the southeast but should include fresh and saline surface and groundwaters of arid and semi-arid areas. And finally, to raise an issue that has barely been mentioned but which lies central to the whole discussion, more effective management of our water resources should be put in place. More effective management could certainly minimize the impact of an increasing population. It would certainly have mitigated the damage already caused to our inland aquatic ecosystems. Major constraints to effective management, are, first, the lack of a stable commitment and consistent attitude from governments towards the funding, implementation and governance of aquatic research and investigations underpinning effective management and, second, the lack of reliable knowledge concerning the physical, chemical and biological nature of our water resources.

I trust that what I have said will have been of interest. I know that at least some of what I have said will not please some politicians, amongst others. And I hope that a little of what I have said will be a constructive addition to

debate in this area. Whatever the case, I firmly believe, together with that pragmatic conservationist N. W. Moore, that: 'there will always be a place for prophetic gadflies which sting complacent society into action.'

I'm sure the irony of my accent will not have escaped you. Thank you for listening to me.

Acknowledgments

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It was inappropriate to refer directly during the course of the lecture to the many references used in its preparation. However, the following references provide a list of sources that were particularly useful.

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