THE EFFECTS OF IRRIGATION ON WETLAND ECOSYSTEMS IN DEVELOPING COUNTRIES – A LITERATURE REVIEW

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1. INTRODUCTION

At the request of Dr. David Molden of the International Water Management Institute (IWMI), Drs. Hector Galbraith of Galbraith Environmental Sciences and the University of Colorado and Annette Huber-Lee of the Stockholm Environment Institute-Boston have conducted a review of the scientific and “gray” literature to evaluate the extent to which irrigation has been shown to affect wetland ecosystems in developing countries. Within this general charge, to focus the review on providing answers that may be useful in developing alternative future strategies for irrigation implementation, and to assist in mitigating potential future ecological impacts, each reviewed document was evaluated in terms of the information that it provided pursuant to ten questions:

1. Did the project described result only in ecological costs, or were there also benefits?

2. What were the ecological effects that were caused by irrigation and could they be distinguished from effects due to other anthropogenic or natural stressors?

3. Are there taxonomic relationships between costs/benefits and project types, scales, and management regimes?

4. Do the data and information presented in the report facilitate the identification of quantitative relationships between intensity of use (e.g., amount of withdrawal) and degree of ecosystem impact?

5. Which components/activities of the project contributed most to the costs and/or benefits?

6. Did the resulting end-use of the irrigation water (i.e., the crop type) affect the costs and/or benefits?

7. Did scale matter, and do smaller projects result in proportionately less impact?

8. Did the surrounding habitat (i.e. arid vs. non-arid) matter in whether costs or benefits were incurred?

9. What were the effects on services provided by the wetland ecosystem?

10. Is it possible to identify indicators of ecological costs and benefits that could be used either at small or large spatial scales, or at both?

To the extent possible we attempted to focus on all potential types of impacts of irrigation on wetlands. These include both the effects of water withdrawals upstream of the wetland, and irrigation activities within the wetland, itself.
Much pertinent information is contained in gray literature sources that are difficult to identify and locate. Thus, the process of reviewing all potentially relevant documents is not yet complete. Indeed, it is unlikely to ever be so. However, we believe that the most important documents have been reviewed and the main results have already emerged (particularly in the areas of data gaps and information needs). We believe that it would be beneficial to provide these to IWMI at the commencement of their proposed Comprehensive Assessment of World Water Resources. We anticipate that these results will contribute to the knowledge base of the comprehensive assessment.

2. DOCUMENTS REVIEWED

Relevant documents were identified by first conducting a literature search under the keywords: irrigation and wetlands. This computerized search identified an initial total of 93 references. The majority of these were rejected from further consideration either because: a) they did not apply to developing countries; b) they were obviously journalistic or non-scientific in nature; or c) they were derived from primary studies, the results of which were reported in original documents that could be obtained. This left a total of 16 reports that were potentially useful. Hard copies of these reports were obtained from the University of Colorado libraries, or by contacting the authors directly. Once obtained, the reference list for each report was examined to determine if additional and pertinent reports that had not been found in the original search were available. These were then obtained, whenever possible.

An additional search procedure was to contact known participants in the field and ask them to identify documents and/or data sets that they considered important. The individuals who were contacted and responded, and their affiliations are shown in Appendix A to this report.

A total of 29 documents were obtained and reviewed. A bibliography of these documents, together with notes on their findings, is presented in Appendix B to this report.

2.1 Biases

While we originally intended to review only documents that applied to developing countries, it quickly became obvious that important data existed in reports from the U.S. and Australia. Where these were obtained during our document selection process, we have included them in the review. However, no thorough or systematic review of the developed country literature has yet been performed. This is important, as it may introduce a bias into the results: most of the practical attempts to integrate agricultural and ecological concerns have taken place in the developed world, and most of studies of the ecological benefits of irrigation have also been carried out there (e.g., the wildlife resources associated with the irrigated farmland in the Central Valley of California, or the rice fields of Louisiana). On the other hand, costs, rather than benefits, have been the main foci of developing world studies. Thus, focusing entirely on developing world
information may bias the results of any review toward the ecological costs of irrigation and downplay the potential benefits.
3. RESULTS

Six main results have emerged from the literature review:

1) Irrigation or activities associated with irrigation can cause adverse impacts to wetland ecological resources ranging from localized and subtle, to long-distance and severe.

2) Irrigation or activities associated with irrigation can also result in the creation or enhancement of important wetland ecological resources.

3) Depending on the irrigation activity and scale, irrigated agriculture and ecological resources can coexist in potentially sustainable fashions.

4) The confounding effects of “natural” or other anthropogenic stressors are not often evaluated when the effects of irrigation on wetlands are being assessed.

5) The potential longer-term ecological benefits of water storage schemes are rarely investigated. Any measurement of impact usually stops once the project is implemented.

6) Too few detailed case studies exist that allow us to draw clear relationships between specific activities, management objectives, natural climatic variability, scale of project and ecosystem impacts. Thus, important data gaps exist.

Each of these conclusions is examined in greater detail below.

3.1 Irrigation or activities associated with irrigation can cause adverse effects to wetland ecosystems.

Irrigation schemes or water diversions for irrigation have undoubtedly caused adverse effects to wetland ecosystems. At their most severe, these effects have included the submersion of wetlands, or their replacement by upland vegetation communities (or by essentially unvegetated land in the case of the Aral Sea), with consequent effects on the biota that depend on these wetlands and the services that humans hitherto derived from the systems. Documented examples include the Aral Sea literature (Kotlyakov, 1991; Micklin, 1988; Precoda, 1991), the impacts of water diversions on wetlands in the Murray-Darling Basin in Australia (Lemly et al., 2000; Kingsford and Johnson, 1998) and impacts on the Hadejia-Nguru wetland complex (Lemly et al., 2000).

The ecological impacts of irrigation or water diversions for irrigation can occur a short distance from the dam or irrigation site, or many miles downstream. For example, sediment trapping in the irrigation ditches of the Nile Delta, and by the High Dam at Aswan are both apparently contributing to the erosion of wetlands in the Nile Delta 800 km downstream. Also, the size of the marine harvest of prawns off the coast of Mozambique is positively correlated with the flow entering the sea from the Zambezi
River (Gammelsrød, 1996). Recent declines in marine prawn populations (and impacts to the commercial prawn fishery) have been ascribed to reduced flows from the Zambezi River due to barrages and dams in Mozambique (Gammelsrød, 1996).

When viewed against the backdrop of wetland hydrologic needs, the ecological impacts caused by schemes such as the Aral Sea diversions, the Murray-Darling irrigation projects or the Kano River Irrigation Project on the Hadejia-Nguru wetlands are not unexpected. They are largely a function of the scale of water diversion. Large projects that divert the majority of the flow of the feeder streams will necessarily result in large impacts to associated wetlands. Although no quantitative relationships have been established, and the resilience of any particular wetland ecosystem will vary depending on other anthropogenic and natural stresses, it seems likely that diversions of 10% or less may be ecologically sustainable in some wetlands (though perhaps not all), whereas diversions of >50%, as have occurred in many schemes, will probably not be. Also, it is at least possible that the relationship between the scale of the withdrawal or diversion and the ecological impact may not be linear. The first quartile of the flow diverted may have much less effect than (say) the 2nd or 3rd. This, if so, is both good and bad news: up to a certain limit, withdrawals may be sustainable; however, exceeding that limit might result in disproportionate and unexpected effects.

Unfortunately, too few rigorous studies have been performed to determine what levels of withdrawals may be protective of the environment. Nevertheless, this is the crucial question determining the likelihood of coexistence of ecological resources and irrigated agriculture. How much water can be diverted and used without the risk of unacceptable ecological impacts? This question automatically focuses attention on the resilience of wetland ecosystems. Resilience will be a function of a number of important site-specific factors, including the type of wetland and its intrinsic robustness, and the existing level of stress (natural and anthropogenic). Unfortunately, while resilience is an important and much-discussed ecological principle, how to measure it has not received enough attention. By failing to monitor the ecological consequences of the implementation of irrigation projects, we have lost an important opportunity to understand the relationships between levels of stress (e.g., water withdrawals) and ecosystem resilience and impacts.

Apart from failing to realize the ecological consequences of the scale of diversions (or realizing, but ignoring them), the other main problem that has contributed to impacts is a failure to plan at the level of the watershed. Obviously, the effects of the Aswan Dam on the Nile Delta 800 km away, or the effects of the Zambezi flows on the marine prawn fishery were not adequately considered when the potential impacts of the dams were being evaluated.

Almost all of the literature reviewed concerned situations in which upstream withdrawals had affected downstream wetlands. However, in some cases, extractions may take place in the wetland itself, to irrigate either surrounding upland areas or other parts of the same wetland (the situation that may pertain in many Southern African dambos). To what extent do these activities have similar effects as upstream extractions? If the water being extracted from the wetland is for irrigation of adjacent uplands but return flows are large,
the impacts may be less severe. Also, if the water is being shunted around different parts of the wetland (rather than being moved to non-wetland habitats), consequences may also be less severe. In these situations, a number of important site-specific considerations arise: what is the loss to evaporation of the return flow? To what extent are different parts of the same wetland ecosystem functionally equivalent and does removing (or returning) water to one or more parts preserve the whole? Unfortunately we do not yet have information or data that could be used to answer these important questions.

3.2 Irrigation or activities associated with irrigation can result in the creation or enhancement of important wetland ecological resources.

Few published examples have been found where water storage for irrigation unambiguously created valuable wetland habitat in the developing world. This does not mean that such benefits do not occur (see the discussion in Section 2.1 of the bias inherent in focusing only on developing world studies). Water storage tanks in Sri Lanka undoubtedly provide functional and valuable habitat for wetland organisms. Observations over only a few hours at one such tank during December 2000 resulted in 22 species of herons, shorebirds and waterfowl being recorded (Galbraith unpublished data). Tanks elsewhere in Sri Lanka are known to support a similar diversity of wetland birds (Galbraith unpublished data). It is likely that water storage schemes elsewhere, also provide important wetland services, though, to date, no systematic review of these has been reported.

In at least two cases, the application of irrigation flow has resulted in valuable wetland habitat being created in the developed world. Both of these involved rice farming in the United States. Rice fields in the Central Valley of California and in Louisiana provide important habitat for waterbirds and shorebirds (Day and Colwell, 1998, and Remsen et al., 1991, respectively). The populations of birds that these areas support are likely to be of at least national importance.

By its nature, rice farming is most likely among the various uses to which irrigation water is applied to result in new valuable wetland habitats. The instances cited above lend support to this. However, as yet, these ecological benefits have not been catalogued in any systematic way.

3.3 Wetland ecological resources and irrigated agriculture may coexist under certain circumstances

The examples in Section 3.1 notwithstanding, not all irrigation schemes have adversely affected associated wetland ecosystems. Examples include the cultivation of dambos (shallow, channel-less, seasonally inundated depressions) in Southern Africa, where up to 30% of dambo area may be irrigated without adversely impacting the system (Faulkner and Lambert, 1991). Also, Lankford and Franks (2000) argue that coexistence of wetlands and irrigation for rice is possible in at least some parts of Tanzania, providing that the spatial and temporal variability in the water needs of the wetland are understood and accommodated into the agricultural planning. The key in this case is flexibility in
being able to change seasonal allocations of water based on flow data; during dry years, a
greater proportion of the flow may be allocated to protect wetland core areas. During wet
years, irrigation may be increased without jeopardizing the wetland ecosystem. In both
cases, adverse impacts are avoided by allocating an adequate amount of water to the
wetland and by planning for the entire watershed.

A modeling study conducted by De Voogt et al. (2000) predicted that for the important
Turkish wetland bird breeding site, Kus Cenneti, irrigated agriculture and wetland
ecosystem resources could coexist. Currently the wetland is being adversely affected by
low flows due to diversions during the bird breeding season (also the main irrigation
period). De Voogt et al. estimate that the wetlands could be maintained by allocating
river water flow to them. This would result in a predicted loss of yield in the agricultural
system of a few percent during dry years and no loss in wet years. In this model, the
water needs of the wetland were not estimated in great detail. It is possible that if
temporal and spatial estimates of nature’s “demand” were studied more closely, the
integration of agriculture and wetland values could be made more compatible and the
small predicted yield losses reduced even further. Also, the crops that are currently grown
in the area are “thirsty” – cotton and grapes. Institutional encouragement to switch to
other crop types might make enough water available for both the farmers and the
wetlands.

3.4 Confounding effects of natural and other anthropogenic stressors

Natural factors such as drought may confound the evaluation of the ecological impacts of
water withdrawal and use for irrigation. An example is the ecological impact to the
Hadejia-Nguru wetland complex in Nigeria (Hollis et al., 1993a; Lemly et al., 2000). The
latter study reports declines in the avian populations using the area and implicates water
storage schemes as the main causes. However, this area suffered severe droughts during
the 1980s and 1990s when precipitation was markedly reduced (Hollis et al., 1933a), after
many years of above average rainfall in the 1950s, 1960s, and 1970s. The extent to which
these natural events contributed to the waterbird population reductions has not been
assessed.

Anthropogenic stressors unrelated to irrigation may also complicate the evaluation of
water management and ecological costs and benefits. For example, the barrage schemes
on the Zambezi River may well be contributing to reductions in marine prawn harvests.
However, no attempt has yet been made to determine the extent to which overfishing is
also important. To what extent does overgrazing contribute to the decline in the Hadejia-
Nguru wetlands? Any evaluation of the effects of irrigation must, necessarily, include
the examination of the contributions by all major stressors. This has important practical
applications: if the costs associated with all stressors at a site are additive, perhaps the
costs that could, potentially, be incurred by irrigation could be mitigated by lessening the
effects of other stressors.
3.5 Potential longer-term benefits

Usually, the measurement of impacts or benefits due to irrigation project implementation ends with the project installation. However, one study shows that under some circumstances ecological benefits may accrue over the longer term. Masundire (1996) documents initial impacts and longer term consequences of the Kariba Dam. The creation of the Kariba Dam was preceded by an intensive effort to capture and relocate wildlife whose home ranges would be inundated by the dam. In this sense, the building of the Kariba Dam was an adverse ecological impact. However, once the area was flooded, it became an important water source for wildlife in an otherwise arid environment. Indeed, so successful has it become in attracting grazing animals and their predators during the dry season that it is now a major site for ecotourism. Thus, the Kariba Dam has been both an ecological cost and a benefit. This illustrates the difficulty in easily assigning “cost-benefit scores” on the basis of change from pre-impact conditions, without also taking into account the post-impact conditions.

3.6 Important data gaps exist

While the literature that currently exists allows us to determine that adverse and beneficial effects to wetland ecosystems have occurred due to irrigation and associated activities, many of the questions raised in the introduction to this review cannot be addressed. This is because few detailed and long-term studies of the costs and/or benefits of irrigation schemes have been performed in developing countries. Beyond determining that extracting or diverting too much water is likely to have deleterious effects, most existing studies do not provide information that is detailed enough to allow us to describe cause-effect linkages or to assist in avoiding future mistakes.

Important questions that remain unanswered include:

- What environmental factors affect how much water can be withdrawn for human use without unacceptable adverse ecological impacts being incurred (see Section 3.1)?

- What environmental cues (indicators) may tell us whether or not we are stressing the wetland-watershed system to the extent that important costs may be incurred?

- In drought-prone areas, how could water resources planning be integrated with the protection of wetland ecosystems?

- While existing schemes may have caused adverse ecological impacts during their implementation, what benefits (see the Kariba Dam illustration in Section 3.2) have accrued since then, i.e. in the longer term?

- How can we ensure that “small is beautiful”? Specifically, in localized and small-scale systems such as dambos we have an opportunity to merge ecological and agricultural functions. How do we do so?
Existing data show that rice irrigation may also provide opportunities to conserve (or create) important ecological attributes. What tools and approaches can be developed that will facilitate this?

The implementation of existing irrigation projects could have provided important data to address the above questions. Yet, unfortunately, they did not do so. The reasons for this lack of follow-up are interesting as the following quote by Gilbert F. White (1988) illustrates:

“To my knowledge there has not yet been a thorough, comprehensive post-audit of any major water project.

Any such effort is impeded by factors that work in combination to discourage comprehensive study. Public criticism ... tends to narrow or muffle the study of impacts by proponents. Once the project is completed, critics lack incentives for study ... they have lost the battle and have little interest in learning that any attacks were unfounded. Proponents tend to look only for vindication ...”

The only way in which we can redress this balance and fill important data needs is to treat future irrigation schemes as “natural experiments” that should be studied from before implementation to completion and beyond to gather data that will help us determine cause-effect relationships. Also, existing schemes should be revisited in a case-study approach to fill in some of the information gaps that should have been addressed during project planning and implementation. The IWMI proposed Comprehensive Assessment (in particular, using case studies to develop the Knowledge Base component) provides us with an opportunity to answer some of the important questions that the existing literature cannot address and begin to move forward toward more effective planning and implementation of irrigation schemes.
4. REFERENCES


APPENDIX A

INDIVIDUALS CONTACTED DURING PROCESS OF LITERATURE SEARCH
<table>
<thead>
<tr>
<th>Individual</th>
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<tr>
<td>Ger Bergkamp</td>
<td>IUCN</td>
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<td>Nick Davidson</td>
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<td>Peter Drooger</td>
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<td>Alfred Duda</td>
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<td>Alan Hall</td>
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APPENDIX B

DOCUMENTS REVIEWED AND SYNOPSISES OF FINDINGS*

* Documents are grouped by site wherever possible
ARAL SEA


- In 1992 small earthen dam built to contain flows in Small Aral. Breached after 9 months.
- Water level increased by more than 1 meter in 9 months.
- Salinity fell and fish extended their ranges and birds returned to area.
- Situation reverted after dam broke.


- Due to diversions and dewatering of wetlands, 550,000 ha of reedswamp habitat in Amu Dar’ya delta destroyed.
- Prior to diversions 319 bird and 70 mammal species lived and nested in Amu Dar’ya delta. 168 and 30 (respectively) do so now.


- Prior to 1960s, deltas of two main feeder rivers were ecological oases in otherwise arid habitats, providing many services including pastureland, reeds for construction, fish harvest, etc.
- Prior to 1960’s irrigation withdrawals from feeder rivers approximated 40km³ pa and area irrigated was 5 million ha. By 1987 104 km³ withdrawn and 7.6 million ha irrigated.
- Surface area and volume of Aral Sea reduced by 40% and 66%, respectively by water diversions from Amu Dar’ya and Syr Dar’ya Rivers for irrigation.
- Salinity in remaining waterbody has increased from 10 g/L to 27g/L.
- Diversions have exposed 27,000 km2 of salt-crusted sea bottom – little revegetation occurring.
- 24 of 24 native fish species apparently extinct
- Commercial fishery of 48,000 metric tons now collapsed.
Area of natural lakes in Syr Dar’ya delta decreased from 500 km² to few tens of km² and 11 of 25 largest natural lakes in Amu Dar’ya delta dried up.

Area of riparian Tugay forest in Amu Dar’ya delta reduced by about 50% as depth to watertable increased by 3-8 meters.


Some revegetation by tamarisk, salicornia, and other salt-tolerant species occurring on exposed bed of Aral Sea


Prior to water diversions, an important fishery for sturgeon, carp, and bream existed, over 1 million musk rat pelts were taken annually, reeds provided raw materials for building and cardboard/paper manufacture, and Tugay riparian forest provided year-round grazing.

Before 1960’s agriculture was local in scale and confined to river valleys where moisture was abundant. This may have resulted in local loss of wetland habitat but not great reduction in water going into Aral Sea.

Reedswamp that once covered 700,000 ha are now confined to about 30,000 ha close to man-made lakes.

Withdrawal canals may be creating new wetlands (e.g., Karakum and Bolshoy Andizhansk Canals). However, these may be highly saline.

**NILE DELTA**


Decreased sediment deposition is leading to erosion of Nile Delta wetlands.

Reduced sediment loads due to High Dam and trapping of sediments in delta irrigation canals.

Irrigation of delta causing eutrophication and contamination of wetlands.

Both sites are Ramsar designated as of International Importance

Highly important for migratory bird populations (most of which breed in Europe)

Sedimentation and closing off of channels connecting wetlands to sea is resulting in drying up of wetlands.

Heavy fertilizer and pesticide loads now entering wetlands associated with the two lakes.

Effects on bird populations or wetland habitats as yet unclear


After closure, fish species diversity downstream of dam decreased from approximately 47 species to 14-25 species.

HADEJIA-NGURU WETLANDS


Baturia wetland reserve within the Hadejia-Nguru wetland complex being impacted by reduced seasonal flooding due to drought and water storage schemes.

Vegetation (trees and shrubs) showing signs of water stress

No evidence presented that any additional ecological injury being inflicted.


Revenues from proposed and existing irrigation projects in Hadejia-Nguru area would recoup only 14% of losses due to wetland destruction.


Previous to dam construction 300-2,000 km² flooded in wet season.

Highly important for migratory birds – 320,000 in 1997.

5th most important wetland site for Palearctic migrant birds
- Tiga Dam completed in 1974. Supplies water to Kano River Irrigation Project (14,000 irrigated ha). Hadejia Valley Project barrier under construction – will irrigate 8,000 ha.

- Flooding to wetlands already reduced by 17%

- Seasonally flooded wetlands drying up (e.g., Baturai Wetland Reserve) and depth to groundwater increasing

- Waterbird diversity and numbers falling, particularly cranes, storks and pelicans. No attempt made to distinguish between effects of recent droughts and water storage.

- Plans for new dam at Kafin Zaki may reduce flows by a further 50%


- Tiga dam has resulted in 50% loss of wetland habitat and drop in water table of 25 meters in places.


- Nguru Lake and Marma Channel in Hadejia-Nguru wetlands designated site of international importance for waterfowl and other wetland resources.

**COEXISTENCE OF IRRIGATED AGRICULTURE AND WETLANDS**


- Modeling (SLURP model) demonstrated that coexistence of important Turkish wetlands and irrigated agriculture possible by allocating river flow to wetlands during summer.

- Effect on agricultural yields fairly small (few percent at worst).

- Agricultural losses might be reduced further by switching to less “thirsty” crops.

- An ecologically safe irrigation level may be 10% of catchment area or 30% of dambo area.


- At present 20,000 ha of dambos cultivated in Zimbabwe.
- Also used for domestic water and livestock grazing.
- Unless over-cultivated, seems to be sustainable use of wetland resources.


- Report describes morphology and vegetation of dambos
- Typically they are areas dominated by hydrophytic vegetation amid Brachystegia or Miombo woodlands.
- The main threats to dambos are human-caused fires, overgrazing, and cultivation leading to erosion.


- Populations of large wildlife species were displaced by flooding of their ranges during construction of the Kariba Dam
- The dam subsequently became an important water source for wildlife
- The wildlife attracted to the dam in the dry season are the basis for a local ecotourism industry.


- Valley bottom wetlands (fadamas, dambos, bas fonds, wadis) comprise 5-10% of land in African savanna.
- Provide opportunities in arid areas to diversify crops, increase yields, and complement dry land farming.
- Typical management involves building small dams at head waters, berms and raised beds further down to manage water flow.
- Ecological costs of irrigation in these areas are uncertain – needs to be studied more effectively at catchment level.

**AUSTRALIA**


- Ramsar site
- 130,000 ha in extent
- Dependent on flow from upstream
- Most important wetland site for waterbirds in Australia
- 70% of flow regulated for agriculture (mainly cotton)
- Flow reaching wetlands reduced by 60%
- Marshes have shrunk by 50-60%
- Over 11 years, 100,000 fewer nests of storks, spoonbills, etc.
- Breeding of some species has become more irregular


Four case studies of impacts in Murray Darling Basin:

1) Barmah-Millewa Forest and Moira Marshes.

- Ramsar site
- 90,000 ha in extent
Mix of rush/sedge marshes, wet grasslands, hydrophytic woodlands

Dependent on water flows from upstream

Annual flow into wetland reduced by about 50% by diversions for irrigated agriculture.

Diversions have also shifted main period of flooding from spring to summer.

Has resulted in vegetation community alterations: those dependent on frequent flooding replaced by communities that can tolerate more arid conditions; trees are weakened and more vulnerable to insect attack.

Fish, waterbird, reptile, and leech populations have decreased.

2) Chowilla Floodplain.

Ramsar site

17,700 ha in extent

Dependent on water flows from upstream

Diversions for agriculture have reduced flows to wetland by >50%.

Area flooded reduced from 33% of site to 5%.

Salinity has increased – killing trees in some areas.

Biomass and abundance of aquatic invertebrates (e.g., 18 gastropod species) have declined.

Native fish populations have declined (no data cited).

3) Gwyder Wetlands

Proposed for Ramsar designation

24,000 ha in extent

Dependent on water flows from upstream

Mainly sedge/rush swamp

55% of inflow diverted for irrigated agriculture (mainly cotton)
Cover by hydrophytic vegetation has decreased by 66% (converted to upland plant communities)

4) Macquarrie Marshes

- Ramsar site
- 130,000 ha in extent
- Dependent on flow from upstream
- Most important wetland site for waterbirds in Australia
- Dams installed beginning in 1960’s
- 70% of flow regulated for agriculture (mainly cotton)
- Flow reaching wetlands reduced by 60%
- Marshes have shrunk by 50-60%
- Abundance and species richness of waterbirds has been reduced. Smaller colony sizes and less frequent breeding.
- Hydrophytic woodlands reduced in area by 14%

RICE PRODUCTION AND WETLAND ECOLOGICAL RESOURCES


- Ricefields in California Central Valley important migration and wintering habitat for shorebirds and waterfowl
- Conventional harvesting and burning creates most suitable habitat.


- Coexistence of rice irrigation and wetlands feasible if the temporal and spatial dynamics of the wetland flows are acknowledged and irrigation planning accommodates them.
In wet years there is water for both uses. In dry years enough water must be allowed to reach wetlands to maintain core areas – irrigation may have to be cut back in dry years.


- Rice growing region supports important populations of shorebirds, waterfowl, and herons.
- Approximately 225,000 shorebirds may winter in area making it one of most important ornithological sites in U.S.

**GENERAL**


- Irrigation drains, if left vegetated, may fulfill one of functions of wetlands – water purification.


- The commercial harvest of marine prawns at the Sofala Bank, Mozambique, is positively correlated with the flow entering the sea from the Zambezi River.
- The flow from the Zambezi River has been reduced by about a factor of three due to building of dams.
- The reduced flow has been accompanied by reductions in the prawn harvest.