Guidelines for managing cropping on lakes in the Murray-Darling Basin

Sue Briggs & Kim Jenkins

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Sue Briggs and Kim Jenkins
National Parks and Wildlife Service
C/- CSIRO, PO Box 84
Lyneham, ACT 2602
email: s.briggs@dwe.csiro.au
kjenkin2@metz.une.edu.au

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The photograph on the front cover shows a flooded lake with fringing black box. Photo: W. Lawler.

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Contents

Introduction

Lakebed cropping is a form of farming on lakes in the Murray-Darling Basin (Figure 1) and elsewhere. Lakes are cropped when soil moisture levels are high after floodwaters recede or following rain. These guidelines apply to lakebed cropping throughout the Murray-Darling Basin, although lakebed cropping is most commonly practised in inland New South Wales, in both the Central and Western Divisions.

In the last 50,000 years the lakes of the Murray-Darling Basin have gone through periods of prolonged inundation, as well as times of extreme dryness (Bowler 1990). Today, the lakes of the Murray-Darling Basin flood for months to years and then stay dry for months to decades before reflooding. Water regimes in lakes in the Western Division of New South Wales are classified as dry or mainly dry, intermittently, and permanently flooded (Seddon *et al.* 1997). Salinities range from fresh to salt. Twelve percent (70 out of 567) of lakes in the Western Division of New South Wales which are over 100 ha in area are cropped. Lakes most commonly cropped are the intermittently flooded, fresh, riverine category; 25 percent of these lakes larger than 100 ha in the Western Division of New South Wales are cropped (Seddon *et al.* 1997). The ecological interest and economic value of such lakes lie in their dual, wet/dry nature.

Farming dry wetlands following natural flooding has been practised in many parts of the world for thousands of years (Arnon 1972). In inland New South Wales, lakebed farming in its current form began as the big floods of the mid-1970s receded. The realisation that cropping lakebeds was practically possible and financially rewarding encouraged graziers and farmers to grow crops on lakebeds. Floodplains in inland New South Wales and elsewhere in the Murray-Darling Basin are also cropped after flooding, and sometimes after rainfall. This study did not specifically address floodplain cropping but many of the results can be applied to this form of cropping.

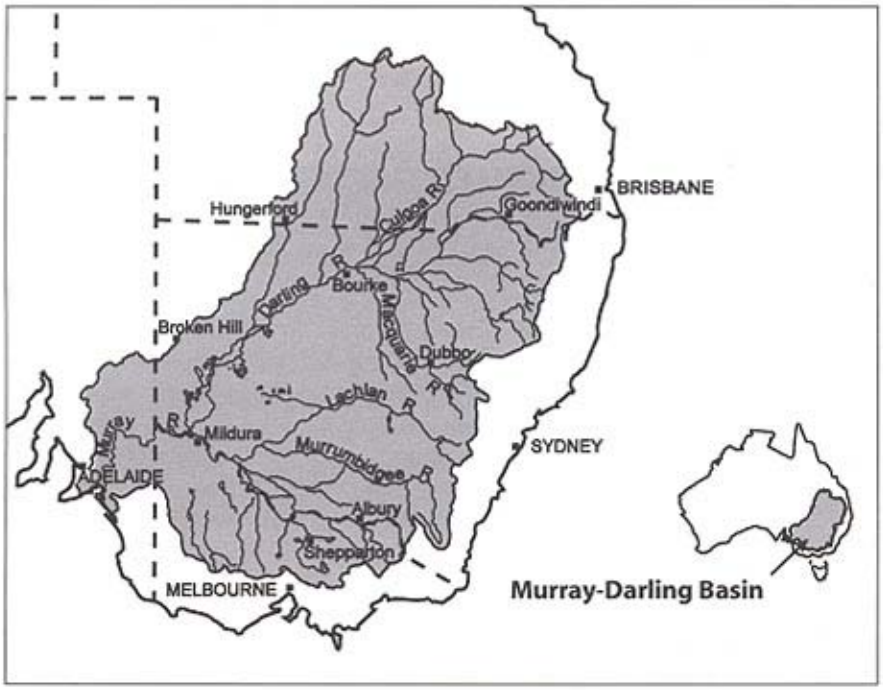


Figure 1

Map of Murray-Darling Basin showing major rivers.

Lakes are cropped following floodwater recession and following rainfall. In arid areas, cropping following rainfall is rarely possible. In semi-arid and more humid areas cropping after rainfall is more common. A lake can be cropped after a flood recedes in one year, and then following good rain in another year. Most lakebed cropping is organic. Sometimes, but not frequently, perennial vegetation (usually lignum *Muehlenbeckia florulenta*) is removed. Unless otherwise stated, the recommendations in this report apply to organic lakebed farming where perennial vegetation is not removed (except scattered, young lignum plants). Where appropriate, we also make recommendations for forms of lakebed farming that are not organic or where perennial vegetation has been removed.

Most lakebed cropping is sporadic. Crops are not planted every year. As the lake dries the farmer follows the receding waterline, cultivating the soil. Often, lakes do not dry at the right time to sow a summer or a winter crop. In these cases crops are not sown until the next suitable time for sowing. A lake can dry out over a year or longer. When this happens, cultivation and cropping are also spread out. Summer and winter crops are sometimes grown on different parts of the lake. The success of crops usually depends on follow-up rainfall in the growing season, especially in arid areas. Crops are sown repeatedly, sometimes every year, where lakes are cropped on rainfall. In comparison, cropping is sporadic, like the flooding and drying of the lakes, when crops are only sown on soil moisture from receding floodwater. Crops planted on lakebeds include wheat, barley, safflower, canola, mustard, forage and grain sorghum, sunflowers, oats, chickpeas and dryland cotton.

Compared with other cropping, most forms of lakebed farming have relatively low ecological impacts. Although it can be risky, cropping on lakebeds generally brings large economic benefits to the surrounding region. Hence, the ratio of economic benefit to ecological cost of lakebed farming is often high. It is an important form of diversification in arid and semi-arid rangelands. When managed to be ecologically sustainable, lakebed cropping provides benefits to rural communities in rangeland areas, and is in keeping with the objectives of ANZECC and ARMCANZ (1996).

W. LAWLER

Lake with crop in foreground. Flooded lake in background.

Lakebed cropping is a good example of how there can be a wide range of ecological effects from what many people assume is one activity. Lakebed cropping is not one activity. On the contrary, the term covers six broad types of cropping, with a correspondingly wide range of ecological effects. The type of cropping should be determined before applying these guidelines. Ecological impacts of cropping lakes range from minimal to high, depending on the type of lakebed cropping being practised. Frequency of cultivation and cropping is the main factor which affects the degree of ecological impacts of lakebed cropping.

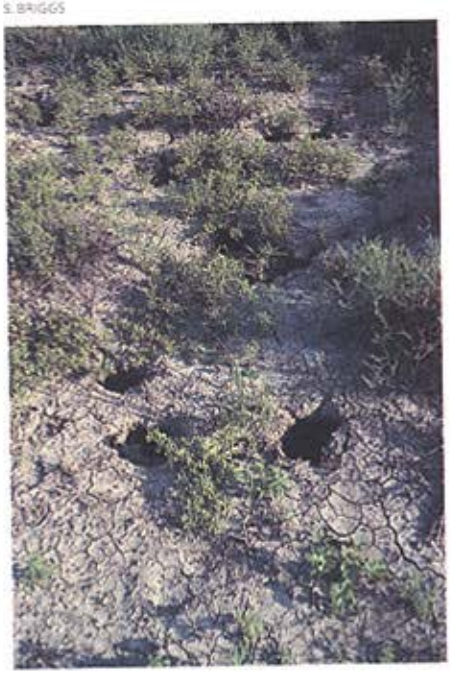
Types of Lakebed Cropping

1 Cropping once following recession of floodwater. In this type of truly opportunistic lakebed cropping a crop is sown once only on a lake as it dries following a flood (different types of crops may be sown on different parts of the lake). The ground is not ploughed following harvest of the crop, and no further crop is sown until the lake refloods and then dries. This type of lakebed cropping follows natural or semi-natural flooding on a lake, not deliberate release of water. The crop is sown onto bare ground and no vegetation is cleared to sow it. The normal vegetation of the lake regrows after the crop is harvested. This is the most common form of lakebed cropping in the Western Division of New South Wales. It has very low ecological impacts.

2 Cropping once following rainfall. This is also an opportunistic form of lakebed cropping but it has greater ecological impacts than once-only cropping following floodwater recession, because annual vegetation is usually removed to sow the crop. In this type of cropping, a crop is sown once following rain, the ground is not ploughed following harvest of the crop, and no further crop is sown until after the next major rains. This type of lakebed cropping is fairly rare. It has higher ecological impacts than once-only cropping following floodwater recession, because vegetation is usually removed and the lake is ploughed while cracks are present. It has lower impacts than the other forms of lakebed cropping.

3 Cropping following floodwater recession or rainfall, followed by ploughing for a second crop. In this type of lakebed cropping the ground is ploughed following harvest of the first crop in the expectation that a second crop will be planted. The success of the second crop depends on soil moisture, which in turn depends on rainfall. The ground is usually left to revert to normal lake vegetation after the second crop. This type of lakebed cropping has greater ecological impacts than either of the types listed above, because the ground is ploughed twice rather than once, and the return to native vegetation and recolonisation by small mammals and reptiles is delayed by post-harvest cultivation and the second crop. Sometimes the ground is cultivated following harvest of the first crop, but a second crop is not planted due to lack of rain. Ploughing following harvest of the first crop without planting a second crop has similar ecological impacts as ploughing and then planting a second crop, because the ground stays bare until rain in both cases.

S. BRIGGS



Holes in a dry lakebed. These holes form naturally as soils dry. They provide habitat for small mammals and reptiles.

4 Repeated cropping between floods, interspersed with cultivation of the ground to keep it bare between crops. Often the first crop is sown following floodwater recession, and then the lake continues to be cropped and cultivated. Native vegetation does not recolonise the lake as the ground is kept bare between crops. As with the above forms of lakebed cropping the lake still floods and dries naturally or semi-naturally. This type of lakebed cropping has higher ecological impacts than the above three types of cropping, because the ground is ploughed repeatedly. Native vegetation and holes and cracks in the lakebed soils do not reform between crops. This type of lakebed cropping only occurs in higher rainfall areas, and in the Western Division of New South Wales is largely confined to the north-eastern section.

5 Cropping following occasional water release. Lakes which are cropped following an occasional, artificial release of water are usually cropped following flood recession and sometimes following rainfall, as well. Cropping following occasional water releases is a rare form of lakebed cropping. We only encountered it after the main field work for the project ended, and we did not study its ecological impacts directly. The ecological effects of this type of cropping depend on how frequently it occurs. Cropping following an occasional water release (no more than once every 10 years) is likely to have low ecological impacts. Cropping following more frequent water releases than this may have moderate to high ecological impacts. Releases of water for this type of lakebed cropping are likely to cause ecological effects, in addition to those from cropping. Because we did not study the ecological effects of this type of cropping directly, management guidelines are based on general investigations into wetland ecology, as well as on our lakebed cropping research.

6 Cropping following regular, usually annual, water releases. This is a highly managed form of lakebed cropping. It has high ecological impacts compared with the other forms of lakebed cropping (except for repeated cropping interspersed with cultivation to keep the ground bare). This type of lakebed cropping has additional ecological impacts due to the changed water regime. We did not study this form of lakebed cropping directly, and our recommendations about managing it come from general investigations into wetland ecology as well as from our lakebed cropping research. This is a rare form of cropping on lakebeds; it occurs more frequently on floodplains.

Two further types of cropping are sometimes, erroneously, called lakebed cropping. The first of these is irrigated cropping on lakebeds which is similar to irrigated cropping elsewhere. It has high ecological impacts. Irrigated cropping on lakebeds should not be referred to as lakebed cropping. These guidelines do not apply to managing irrigated cropping on lakes or anywhere else. Nor do these guidelines apply to cropping on lakes from which water has been permanently or nearly permanently excluded. This form of dryland cropping also has high ecological impacts compared with the six types of lakebed cropping listed above.

The guidelines that follow are based on Briggs (1994) (which deals with lakebed cropping in the Rotten Plain Land System associated with the Narran River), Jenkins and Briggs (1995) (which deals with lakebed cropping on the lakes of the Darling Anabranch), Jenkins and Briggs (1997), reconnaissance trips to the lakes along Teryaweynya and Willandra Creeks and to the Lowbidgee, and prior and current research by the authors on wetland ecology. Numbers, types and areas of lakes cropped in the Western Division of New South Wales are given in Seddon *et al.* (1997).

The results and recommendations in Briggs (1994) and in Jenkins and Briggs (1995) were presented and discussed at meetings with landholders and agency representatives in 1994 and 1995. In addition, the results of our work on lakebed cropping have been published in a variety of forms and have had good media coverage (see References and Further Information). Radio interviews, newspaper articles and seminars about the project up to July 1995 are listed in Jenkins and Briggs (1994). Since that date we have given two radio interviews (3MA Mildura, 2WEB Bourke), one television segment on ABC Landline, one audio tape interview (Basin Talk), one video interview (Tributaries) and 12 seminars on the project. Unless otherwise stated, supporting material for the findings and recommendations that follow come from Briggs (1994) and Jenkins and Briggs (1995), or from anecdotal information and our research on inland lakes and similar wetlands.

The findings listed below apply to the forms of lakebed cropping that do not involve artificial releases of water, unless stated otherwise. Different findings for different forms of cropping are identified. If we state only one finding, then it applies to the four types of lakebed cropping that do not use deliberate releases of water for cropping. These guidelines are written for several audiences. The main target groups are landholders, sharefarmers and agency staff. Agency staff include people dealing with technical issues of lakebed cropping, people implementing policy and people preparing policy. Some recommendations will be more relevant to some of these target groups than to others.

W. LAWLER

Lake being ploughed in preparation for crop.

W. LAWLER

Floodplain cropping with deliberate releases of water.

Soils and Crops

Soil is the basis of agricultural production and ecological sustainability. Soil needs to be maintained in good condition both physically and chemically, so that crop yields and levels of protein in grain do not decline. If soil management techniques are not sustainable, and crop yields or protein levels decline, then farming systems on lakes are likely to require chemical inputs. This is undesirable ecologically and economically. Organic carbon and structural stability are good measures of soil physical condition, and an index of crop yield and protein level is a good measure of soil nutrient status.

S. BRIGGS

Collecting soil sample on dry lake.

Findings and Interpretations

- Cropping and ploughing dry lakes repeatedly between floods reduce levels of organic carbon and total nitrogen, and lower structural stability in their surface soils. These reductions are caused by ploughing, not by cropping. Lakes that are ploughed and cropped only once between floods do not have reduced levels of organic carbon or lower structural stability in their surface soils. Organic carbon and structural stability in soils below 10 cm depth are not affected by cropping and ploughing in either frequently or infrequently cropped lakes. We do not know how regular releases of water into lakes affect soil structural stability and levels of organic carbon.
- Ploughing and cropping lakes, with no change in water regime, have not increased dispersion of lakebed soils to date. This means that, while repeated cropping and cultivation have reduced the size of larger soil particles, these activities have not broken down the smaller soil particles. Increased dispersion of soils is undesirable, as it leads to surface crusting and loss of soil structure. Effects on soil dispersion of lakebed cropping following regular releases of water have not been measured.
- Lakebed cropping has not lead to the formation of plough pans. This is probably because lake soils move a lot as they expand and shrink with changing moisture levels.
- Yields of wheat and percentages of protein in crops sown on lakebeds have not declined in the twenty years since lakebed cropping commenced.
- Lakebed soils have high levels of exchangeable calcium and free calcium carbonate (the nodules can be seen readily in the soil). Calcium binds soil aggregates and reduces or prevents dispersion of clay particles. High levels of calcium in lakebed soils are likely to be the major reason why soil dispersion has not increased in frequently farmed lakebeds.
- The amount of total nitrogen used by a wheat crop is less than 1% of the total nitrogen pool in the soil. Reductions in total nitrogen in lakebed soils which are repeatedly cropped and ploughed are likely to be caused by loss from cultivation, rather than from plant uptake.
- Erosion risk on lakebeds is low because of their grey clay soils.
- Frequent cropping on lakebeds interspersed with cultivation is not always practised organically. Cropping on lakebeds once following floodwater recession is usually practised organically. Cropping following deliberate releases of water is usually, but not always, carried out organically.

Soils and Crops

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S. BRIGGS

Collecting soil sample on dry lake.

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Recommendations

- Selling organic grain from lakebed cropping is not always easy because of the unpredictable timing of the harvest. Ways of overcoming this problem could be investigated. Water which enters lakes should not carry levels of pesticides which are unacceptable for organic production of crops.
- Depletion of total nitrogen levels in lakebed soils is not yet a problem. Agronomic research on lakebed soils should therefore focus on management of available nitrogen. This is especially so in lakes which are ploughed and cropped repeatedly.
- Where rainfall is high enough for repeated cropping, cultivating lakebed soils between crops (bare fallowing) is reported to result in higher subsequent yields. The reasons for this are not known with certainty. If bare fallowing increases yields because of soil moisture retention only, then it may be unavoidable if repeated crops are to be grown on lakebeds. If bare fallowing increases yields largely because of enhanced release of nitrogen then it is unwise, because most of the released nitrogen is likely to be surplus to crop needs or lost before the crop is able to use it. Replicated field experiments with controls are needed to determine why crop yields in lakebeds increase following long bare fallowing. Lakebed soils need to be managed according to the results of these trials.
- Lakebed farmers should monitor their crop yields (especially wheat) and protein percentages of the grain. This should be done on a paddock basis. Wheat yield and protein levels can be multiplied together to produce an index which tracks soil nitrogen availability.
- We do not know how flood patterns in lakes affect their nitrogen dynamics. Flooding and drying of lakes may restore and recycle their soil nutrients. Flooding may cause loss of nitrogen, may encourage nitrogen fixation, or may do both. Research is needed to determine how periodic flooding, especially from deliberate water releases, affects levels of total and available nitrogen in soils.
- Conservation farming, i.e., minimum tillage with stubble retention, may be less ecologically damaging to lakebeds than bare fallowing. Minimum tillage sometimes requires use of herbicides, which can present ecological problems. We do not recommend use of herbicides on lakebeds. If they are used three conditions must apply: (i) Laboratory and field trials should be carried out to determine impacts of herbicides on terrestrial and aquatic animals (including invertebrates) of lakebeds. Areas of cropped lakebed need to remain free from herbicides to facilitate this. (ii) The herbicides must have low persistence, and low toxicity to test organisms including native fish and frogs. (iii) The herbicides must be spread from the ground, not from the air, to avoid spray drift into surrounding areas.

S. BRIGGS

Lakebed that is being bare fallowed between crops.

Table 1

Degrees of ecological impacts of different types of lakebed cropping. Impacts assume cropping is organic (no herbicides or fertilisers) and that perennial vegetation, including lignum, is not removed. This assumption does not apply to irrigated or dryland cropping on lakebeds.

Type of cropping	Frequency of cultivation/cropping
One crop following floodwater recession	Occasional, higher where lakes flood more frequently
One crop following rainfall	Occasional, higher in higher rainfall zones
Second crop after first crop following floodwater recession or rainfall	Infrequent
Frequent cropping and cultivation	Frequent
Cropping following occasional water release[C]	Infrequent
Cropping following regular water release	Frequent
Irrigated cropping[D]	Frequent
Dryland cropping [DF]	Frequent

[A] Ploughing lakebeds reduces rotifer numbers, but lakebed cropping without altering water regimes is likely to have minimal effects on waterbirds.

[B] Water flows can be temporarily excluded from lake by banks.

[C] Cropping occurs after natural floods as well as following water release.

[D] Included for comparison only. These guidelines do not deal with these forms of cropping.

[E] From McKenzie *et al.* (1991).

[F] Cropping on lakes from which water has been deliberately and permanently (or near permanently) excluded.

Effects on soil	Ground vegetated between crops	Soil cracks reform between crops	Impact on dryland wildlife	Impact on wetland wildlife[A]	Flood regime	Overall ecological impact
Low	Yes	Yes	Low	Low[A]	Not altered[B]	Low
Low	Yes	Yes	Medium	Low[A]	Not altered	Medium
Low	Sometimes	Sometimes	Medium	Low[A]	Not altered[B]	Medium
High	No	No	High	Low[A]	Not altered[B]	High
Probably low	Yes	Yes	Medium	Low[A]	Medium alteration	Medium
Unknown	No	Not usually	High	Medium	Large alteration	High
High[E]	No	Not usually	High	High	Very large alteration	Very high
Probably high	Not usually	Not usually	High	Very high	Very large alteration	Very high

Water Regime

None of the lakes in our main study areas flooded during the field component of the lakebed cropping work. We were, however, able to study historical water regimes on these lakes, and on other wetlands. These interpretations are based on this information, and on observations and work on wetland water regimes from related studies.

Findings and Interpretations

- Most lakebed cropping is carried out on lakes with natural or semi-natural water regimes, i.e., their water regimes have been altered by river regulation and extraction of water from rivers for irrigation or by local structures, but their water regimes are not deliberately managed for cropping. Sometimes, banks are constructed to keep water from a crop until it is harvested.
- Deliberate releases of water are made into some lakes, so a crop can be grown when the lake dries.
- Ecological impacts of releasing water for lakebed cropping will depend on the quality and quantity of water released, and on how often the releases are made. The degree of the impacts depends on the degree of change in the water regime of the particular lake.

Recommendations

- Water of poor quality, especially water that is more saline than usual, should not be released into lakes.
- All releases of water into lakes should be similar to natural flood durations and timing. These vary considerably in Murray-Darling lakes.
- Releases of water should not be used to flood lakes for short periods which are outside the normal range of flood durations, in order to wet the soil to grow a crop.
- Water should not be run from one lake to another for flood irrigation.
- Water should not be impounded in lakes by regulators to facilitate lakebed cropping. Regulators on lakes should be set as close to natural sill height as possible to allow floodwaters to enter and leave lakes. Regulators should be designed to allow fish passage.
- Banks on lakes to protect crops should be breached where the natural watercourses cross them, after the crop is harvested. Such banks should only be built in cases of extreme necessity, and after complying with relevant legislation.

K. JENKINS

Bank built on lake. Such banks can be used to exclude water from crops.

Plants

We did not directly study impacts of lakebed cropping on plants. However, our work provided information relevant to managing lignum and Menindee nightshade *Solanum karsense* on lakebeds, and coolibah *Eucalyptus coolabah* and black box *E. largiflorens* woodlands around lakebeds.

Findings and Interpretations

- Lakebeds are naturally treeless. They are ringed by woodland, usually coolibah in the north and black box in the south of the Murray-Darling Basin.
- Lignum which has been cleared reshoots rapidly on lakes following flooding and subsequent drying. Thick, old growth lignum takes many years, and probably decades, to grow to this state.
- Menindee nightshade grows readily after lakebed crops are harvested. Its growth appears to be enhanced by the disturbance of the soil caused by cultivation. It is not adversely affected by once-only cropping following floodwater recession. It continues to grow on lakes which are cropped and cultivated frequently.

Recommendations

- We recommend against widespread clearing of old growth lignum, but see no problem with removing scattered bushes that come up in lakes following flooding and drying. These scattered bushes can be blade ploughed, but not poisoned.
- The status of Menindee nightshade as a threatened species in the vulnerable category in New South Wales could be reviewed.
- Perennial vegetation (lignum, black box, coolibah, river red gum *Eucalyptus camaldulensis*) should not be killed by prolonged inundation of water in lakes, including ponding or transmitting water for cropping.

K. JENKINS

Scattered lignum bushes that have regrown since cropping.

S. BRIGGS

Menindee nightshade growing through crop stubble on dry lake.

W. LAWLER

Thick clumps of lignum. This type of lignum should not be cleared for lakebed cropping.

Wetland Animals

S. BRIGGS

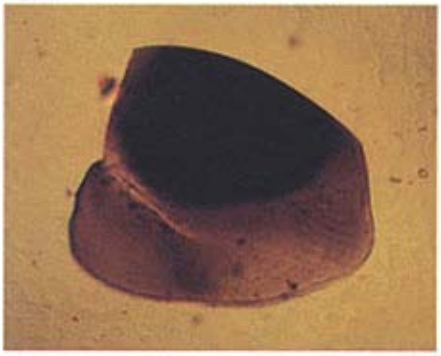
Collecting dry soil from under a sorghum crop for flooding in order to investigate emergence of aquatic invertebrates.

Wetland invertebrates which have eggs or other resting stages in dry lake soils between floods are the main wetland animals which could be affected by lakebed cropping. When lakes flood, these invertebrates emerge and multiply in the temporary waters, providing food for fish and filter-feeding waterbirds. Farming dry lakebeds places the resting eggs of wetland invertebrates in close proximity with the machinery used to cultivate soil, and to sow and harvest crops. Lakebed cropping could affect resting stages of wetland invertebrates or alter their habitat. Effects of farming dry lakes on eggs or other resting stages of invertebrates can be investigated by collecting dry soil from cropped and uncropped parts of lakes, flooding it, and recording the invertebrates which emerge and multiply in the samples. Waterbirds and fish are other important components of the wetland fauna of lakes.

Findings and Interpretations

- Similar numbers of cladocerans (water fleas, a type of crustacean), ostracods (a microscopic mussel-like crustacean) and copepods (a microscopic prawn-like crustacean) emerged and multiplied from soil which was collected from cropped and uncropped parts of lakebeds, and then flooded.
- Fewer rotifers (microscopic aquatic invertebrates) emerged and multiplied from soil collected in cropped parts of lakebeds than from soil collected in uncropped parts of lakebeds, and which was then flooded. Eggs of rotifers are very different from those of cladocerans. Eggs of rotifers may be more fragile and less resilient to cultivation than the eggs of crustaceans.

R. SHIEL



A resting egg from a cladoceran Alona *sp. These lie in the soil of dry lakebeds.*

R. SHIEL

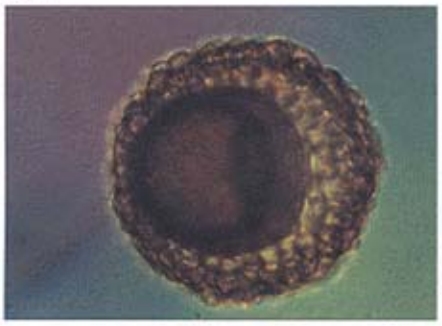
An adult cladoceran Biapertura rigidicaudis *found in lakes in the Murray-Darling Basin.*

- The numbers of aquatic invertebrates which emerged and multiplied from soil collected from lakes and then flooded varied considerably between lakes, regardless of cropping regime. This could be due to differences between the collection sites within the lakes or to differences between lakes. This topic is being investigated at present by the second author.
- We were not able to investigate direct effects of lakebed cropping on waterbirds or fish. Waterbirds should not be adversely affected by lakebed cropping if appropriate water regimes are maintained, organic farming is practised and perennial vegetation is not cleared.
- Fish could be adversely affected by reduced numbers of rotifers on farmed lakebeds. As with waterbirds, fish are likely to be adversely affected by changed water regimes, by pesticides or herbicides, and by clearing perennial vegetation on lakebeds. The converse also applies.

Recommendations

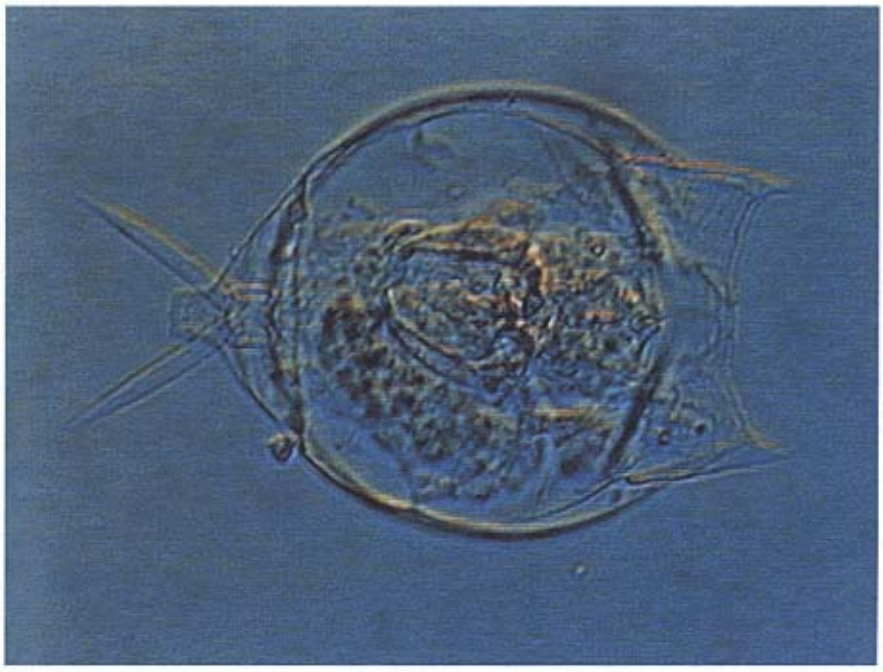
- Patches in lakes should be left uncropped to retain the resting eggs of aquatic invertebrates. This is a precautionary approach and may be modified with future results. In addition to the uncropped band left around the edge of lakes (see Dryland Animals), 5% of the lake area should be left uncropped elsewhere in the lake, wherever most convenient (Figures 2,3)(see General Recommendations for more details).
- Effects of deliberate releases of water for lakebed cropping on waterbirds, fish and aquatic invertebrates should be investigated.

R. SHIEL



A resting egg from a rotifer Asplanchna *sp. These lie in the soil of dry lakebeds.*

R. SHIEL



An adult rotifer Lecane ohioensis *found in lakes in the Murray-Darling Basin.*

Dryland Animals

Several species of native small mammals and reptiles, and a number of species of birds live in dry lakebeds. The reptiles and small mammals inhabit the abundant holes and cracks in dry lakes. Reptiles also shelter under bushes. Shrub-dwelling species of terrestrial birds inhabit lakebeds.

Findings and Interpretations

- Uncropped and cropped parts of lakebeds have fewer numbers and species of birds than surrounding woodlands. Most species of terrestrial birds in and around lakebeds are in the black box or coolibah woodland which surrounds lakes, or in adjacent woodlands on red soil.
- The habitat of shrub-dwelling species of birds, particularly white-winged fairy wren *Malurus leucopterus*, is removed by frequent cropping and cultivation of lakebeds, and by permanent removal of perennial shrubs. Effects of loss of this habitat on shrub-dwelling birds depend on amounts of shrub habitats in the region outside lakebeds, compared with amounts of shrub habitat lost on the lakebeds. Effects on terrestrial birds of once-only cropping on lakebeds following flood recession are minimal.
- Dense growth of coolibah and black box trees around lakebeds and on floodplains can impede movements of domestic stock. Coolibah and black box self-thin with time from almost 3000 stems per hectare after germination to around 90 stems per hectare after 100 years of growth (Maher 1995). Preliminary results from our studies suggest that species diversity of terrestrial birds in coolibah woodland falls when densities of trees are lower than around 25 trees per hectare.
- Frequent cropping of lakebeds interspersed with cultivation adversely affects the small mammal *Planigale gilesi*, as well as several species of reptiles. Individuals of this planigale are largely confined to cracking grey soils on lakebeds and floodplains. Frequent cropping and cultivation in the transitional soils around the edges of lakes adversely affects three

J. SEDDON

Giles planigale, a small marsupial whose main habitat is dry lakes and floodplains.

J. SEDDON

Earless dragon. Dry lakes provide habitat for this lizard.

further species of native small mammals, the planigale *Planigale tenuirostris,* and the dunnarts *Sminthopsis crassicaudata* and *Sminthopsis macroura*. Conversely, once-only cropping following floodwater recession has minimal impacts on native small mammals and reptiles, providing the ground is not ploughed after the crop is harvested. Small mammals reinvade holes and cracks in crop stubble in lakes after harvest.

- Effects of cropping following deliberate releases of water on small mammals and reptiles will depend on how frequently water is released and the lake is cropped, as well as whether the ground is ploughed or not between crops. Small mammals and reptiles reinvade lakes when they dry out following floods. They are unlikely to be able to move in and out of lakes when they are flooded annually, especially if they are cropped or kept bare between floods.

Recommendations

- Coolibah and black box woodlands should not be cleared for cropping, or other purposes. Conversely, some degree of thinning may be ecologically desirable. Relationships between density and size of coolibah trees and their wildlife need to be determined. Ecological impacts of thinning coolibah to different densities should be ascertained from these relationships and management guidelines then developed.
- A band of land around the perimeter of all lakes needs to be left uncropped and unploughed. This will include the transitional soils between cracking grey clay soils on lakes and fringing coolibah or black box at the edges of lakes, as well as some grey, lake soil. This recommendation applies to all forms of lakebed cropping. In addition, patches of grey clay soils on the lake side of this band need to be left unfarmed on lakebeds with repeated cropping and cultivation (Figures 2,3)(see General Recommendations for more details).

S. BRIGGS

Coolibah woodland at edge of lakebed.

General Recommendations

- Whether small mammals and reptiles are present on dry lakes (and floodplains) in the less arid parts of the Murray-Darling Basin, including the Central Division of New South Wales needs to be investigated.
- Parts of lakes that have never been cropped provide valuable reference areas against which to measure changes in the soil, vegetation and wildlife of cropped parts of lakes. They should not be cropped, used for vehicle access, or heavily grazed by domestic or native animals. Land on lakes which has not been cropped, but which has been used for vehicle access, should not be used as reference areas.
- Trial cultivation and cropping of small areas of lakebeds should generally be permitted. Trials are useful to test the feasibility of cropping and cultivation practices before they are carried out on a broader scale, and for scientific research into effects of lakebed cropping. Lakebed soils recover from one or two crops and cultivations, providing permanent vegetation is not cleared.
- Conditions on permits for managing lakebed cropping need to take into account which type of lakebed cropping is being proposed. The less frequently lakes are farmed, the more relaxed the permit conditions can be.
- Landholders should develop cropping plans on their lakes, and then submit them to the relevant agency for approval. Approval should be rapid when recommended guidelines are followed. Where more than one landholder occupies a lake, they will need to consult each other before submitting their application to crop.
- Landholders should include environmental conditions for cropping and cultivation in the financial contract with their sharefarmer. The contract should stipulate the environmental conditions that apply to cropping on each lake or group of lakes.

K. JENKINS

Uncropped strip in lakebed that has been used for vehicle access.

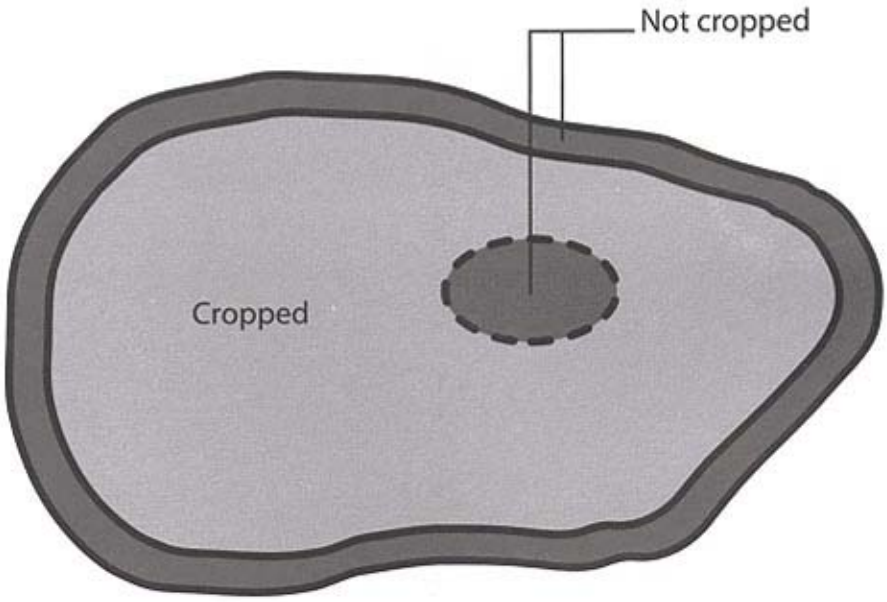


Figure 2

Recommended layout of uncropped areas on lakebeds which are cropped once-only following flooding and drying, and which are not cultivated after the crop is harvested.

- At least 15% of lake area needs to be left unfarmed on lakes which are cropped once-only following flooding and drying, and which are not cultivated after the crop is harvested (Figure 2). This 15% should comprise firstly, a band of uncropped land around the perimeter of the lake, on the lake side of the woodland (usually black box or coolibah, or river red gum). This uncropped band around the lake should comprise 10% of the area of the lake. Its width will vary between 100 and 200 m, depending on the total area of the lake. The other 5% of uncropped area should be elsewhere in the lake. This 5% can be left uncropped where it is most convenient to do so.
- At least 25% of the area of lakes which are cropped and cultivated repeatedly between floods needs to be left unfarmed (Figure 3). This 25% should be made up of 20% of the lake area in a wider perimeter band than on lakes cropped and cultivated once only following floods, or comprise the same width of band as on these lakes plus adjacent patches of cracking grey soil on the inside of the band. These patches need to be at least 1000 m x 500 m (50 ha) in area to accommodate the habitat needs of small mammals. The other 5% should be placed where it is most convenient to leave an area uncropped on the lake.
- Investigations are needed into ecological effects on lake soils, plants and wildlife of cropping following water releases.
- Lakebed cropping should be managed within ecological guidelines to be technically and ecologically efficient. The goals should be to minimise ecological damage while maximising the net value of crops. Lakebed croppers who have high returns per hectare will generally be more inclined to leave uncropped areas for wildlife habitat than farmers whose returns are low, and who are in financial difficulty.

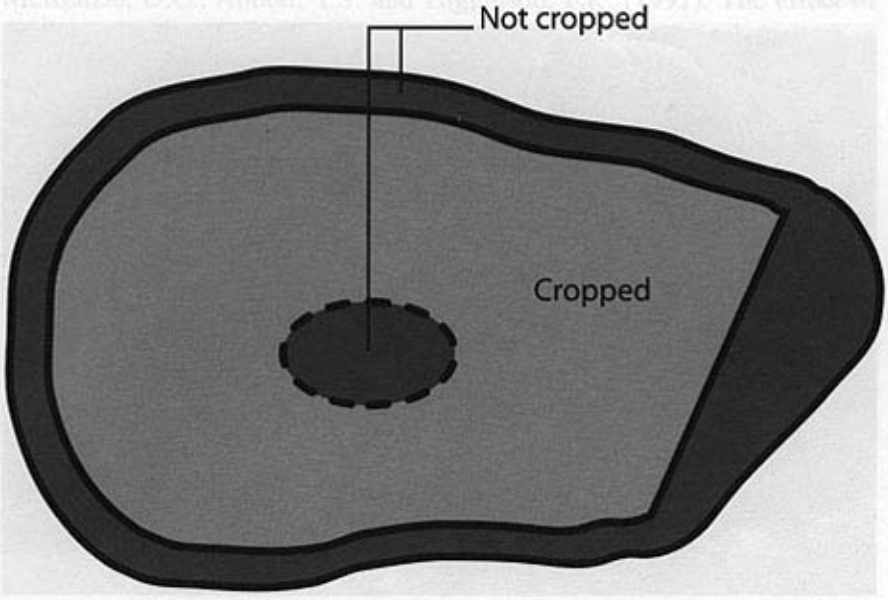
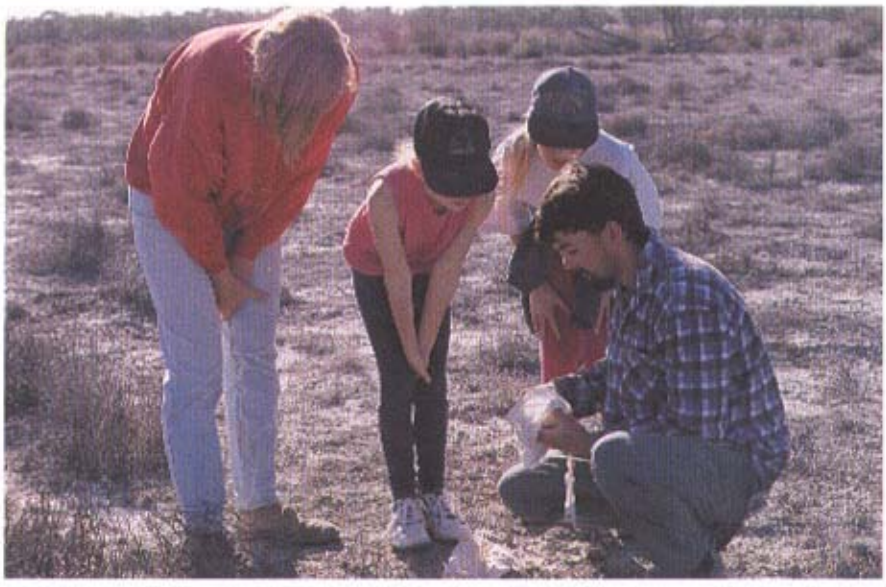


Figure 3

Recommended layout of uncropped areas on lakebeds which are cropped and cultivated repeatedly between floods.

- Governments need to ensure that regulations for lakebed farming are clearly and fairly specified, enforced consistently, and subject to pre-stated ecological obligations, are guaranteed for known, reasonable periods of time. Policies must be consistent within ecological guidelines, and the decisions of previous governments honoured. There need to be incentives and rewards for lakebed farmers to maintain the productivity and habitat value of their lakebeds.
- Where possible, self-regulatory, self-enforcing and self-financing policies should be used for managing lakebed farming. Individuals are generally more directly accountable for their actions than governments. People need information for management planning in order for self-management systems to work.
- Governments need to highly value the concept of land stewardship. Most owners (including landholders with long-term leases) of lakebeds feel a close affinity with their land, and a strong sense of stewardship over it. This character in many landholders needs to be acknowledged, and should be taken into account when drawing up policies for lakebed cropping. These policies need to recognise that the management actions of landholders who have knowledge of their land and its plants and animals, and who regard themselves as stewards of their land for the next generation are likely to be compatible with conservation and sustainable resource use.
- Above all, the quality of landscapes, soil, water and air in and around lakebeds needs to be conserved, and ecosystem functioning and diversity need to be maintained. Irreversible actions that diminish future options for land uses on lakebeds should be avoided.



Involving landholders in investigations of ecological impacts of lakebed cropping is essential.

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