New Zealand Freshwater Research Report No. 4

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National Institute of Water & Atmospheric Research Ltd
Te Tari Taihoro Nukurangi

Guidelines towards a conservation strategy for the Canterbury mudfish (*Neochanna burrowsius*)

G.A. Eldon

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by
G.A. Eldon

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SUMMARY

Natural populations of Canterbury mudfish (*Neochanna burrowsius* (Phillipps)) today are known at less than 20 localities, many of which are vulnerable to land use changes. Management options for safeguarding the species include protection and resuscitation of known habitats. A review of existing natural populations of mudfish is presented, with specific suggestions for management. Other feasible species recovery options are translocation and captive breeding; guidelines and examples are presented. Further research topics which may aid a species recovery programme include some aspects of breeding, spawning migration, co-habitation with other species and monitoring methods. Genetic diversity is a subject which may require special attention.

1. INTRODUCTION

This report has been prepared for the Department of Conservation (DOC), in response to concern about the survival prospects for the Canterbury mudfish (*Neochanna burrowsius* (Phillipps)). Appendix I is the schedule of information requested by DOC.

The mudfish can utilise habitats which are inhospitable to other fishes because of periodic low dissolved oxygen levels (Eldon 1979a). In certain circumstances this ability adapts to survival in drought conditions. Since European settlement, it is probable that drought conditions have largely replaced hypoxic conditions as a limiting factor in competition from other species in mudfish habitats. Meredith (1985) stated:

> "In considering the critical habitat requirements of the mudfish, one important point to consider is whether the present habitat is representative of that in which the mudfish developed its amphibious potential. Since the mudfish is now rare and confined to limited populations in widely spaced localities, certain factors must be contributing to its decline. Observations of the three habitats mudfish were sampled from, revealed that these are not as they would have been even one hundred years ago, as they have been extensively modified by man. This has changed not only the vegetation patterns but also the climatic and hydrological features. The swamp forest conditions described for the brown mudfish (Eldon 1978b) may be more representative of early Canterbury conditions. Canterbury was once covered in lowland Kahikatea forest, few remnants of which remain today. Thus it may be misleading to consider adaptations of mudfish in relation to their present habitat, even though past conditions may be hard to predict." (p. 180-181).

2. POPULATION STATUS

2.1 Official recognition

The Canterbury mudfish is listed by Miller (1977), in the International Union for Conservation of Nature and Natural Resources (IUCN) "Red Data Book" Vol. 4, *Pisces*, under the definition: "Taxa with small world populations that are not at present endangered or vulnerable, but are at risk. These taxa are usually localised within restricted geographical areas or habitats or are thinly scattered over a more extensive range."

2.2 Numbers and distribution

Concern about the survival of the Canterbury mudfish was first highlighted by Skrzynski (1968). In his opinion, the Canterbury mudfish was not common even in the early days of European settlement, though settlement did have an adverse effect on the species. He suggested that the fish may have gone into decline ".... with the changes in the climatic-vegetation pattern ...." some 500-800 years ago. The basis for these assertions is at best, uncertain. There were vast areas of swamp in pre-European Canterbury and it seems unlikely that the mudfish was then rare. Less controversially, Skrzynski also thought ".... it seems unlikely that *G. burrowsius* [*N. burrowsius*] will continue to survive on the Canterbury Plains with the land continually being modified."

Skrzynski's paper was followed by considerable activity in searches for further mudfish populations (Cadwallader 1975, Eldon 1979a), and the number of sites where mudfish had been found increased from nine to 21. However, return visits to several of the earlier known sites, including the type locality, and also to some more recently-discovered sites, have failed to produce mudfish. The habitats have been so grossly modified by drainage for grazing and agriculture, that they no longer support the species.

Since the 1970s, searches for habitats have declined, but some reports of findings have been followed up. One new population has been discovered in the

Waianiwaniwa River catchment. Also, there have been attempts to establish populations. Overall, however, additions to the number of sites supporting mudfish have been counterbalanced by expired populations such as Clearwell (see section 4.5.4).

Today, Canterbury mudfish are known from fewer than 20 localities, occurring in an area between the Ashley River catchment in North Canterbury and the Waitaki River catchment in South Canterbury. Most of the known natural populations are believed to exceed 100 adult fish at any time, but numbers fluctuate considerably. Almost certainly, the species has been more abundant and more evenly distributed within its range than at present, though its original range may have been similar.

2.3 Monitoring

Comprehensive population censuses are expensive, and not really practicable; nor are they strictly necessary. The simplest, most cost-effective way of determining the "health" of a mudfish population is to inspect the habitat for free-swimming fry and/or juveniles during the spring and early summer. Because the juveniles are diurnal and pelagic, they are easy to observe. Adults, on the other hand, are nocturnal and extremely cryptic.

3. MANAGEMENT OPTIONS FOR RECOVERY

There are several potential management options for improving the survival prospects for the species:

(a) Identify land tenure for known habitats, and secure land-use control wherever possible.

(b) Encourage the voluntary creation of protected areas under convenant systems such as that administered by the QEII National Trust.

(c) Fence out stock from riparian zones of known habitats to protect them from pugging by stock. Adverse effects of pugging are particularly obvious in drought, mainly from compacting of the substrate which renders it impenetrable to the fish.

(d) Investigate any likely habitats for which there are at present no records of mudfish, and which have not been surveyed already. Although extensive searches have been made in the past, unknown populations may still exist.

(e) Establish new populations by translocation from existing wild stocks, or stocking from captive breeding stocks.

4. HABITAT FACTORS

4.1 Optimum habitats

Optimum habitats for Canterbury mudfish should have the following features:

(a) They should support high production of small invertebrates as a food source.

(b) They should be free of other species of fish.

(c) They should be well-oxygenated during the breeding season - August to December. This may result from wind action or flowing water.

(d) A good growth of macrophytes should provide cover and a spawning substrate. In the absence of macrophytes, lush bankside vegetation impinging the water column, or fibrous willow roots, may serve the same functions.

(e) They should have continuous permanent water or pockets of permanent water. In the absence of permanent water there *must* be a natural soft, damp substrate totally protected from stock, or a coarse cobble substrate with damp subsurface material in which fish may aestivate during droughts.

4.2 Habitat protection

To maintain healthy stocks of Canterbury mudfish, their habitats need protection from certain land use practices. The most common are:

(a) Draglining and channelising for drainage or diversion for improved machinery access. As well as disturbing the permanent water supply and/or compacting the naturally soft, damp substrate, this can lead to invasion by other species of fish, particularly trout and longfinned eels.

(b) Dewatering resulting from improved drainage elsewhere lowering the water table.

(c) Stock encroachment, particularly where it involves the pugging of the land in ephemeral habitats. Mudfish naturally penetrate soft materials, and thus sometimes survive droughts, protected from desiccation by sun and wind. If the substrate is too compact, the fish can not withstand dewatering.

(d) Raising of the water table as a result of irrigation schemes. This may result in mudfish habitat becoming suitable for other species of fish hitherto excluded, e.g., trout, longfinned eels.

(e) Estrangement of wetlands from a periodic water source by river flood protection schemes.

4.3 Criteria for ranking known habitats for protection

A mudfish population will be particularly suitable for reserve status when the habitat meets the optimum criteria listed above and when it can be protected from the land use practices also listed above. Nevertheless, if the riparian land owner is not co-operative then the site cannot be considered. Therefore land ownership and land use must be taken into account at an early stage, as well as the presence of a suitable wetland or watercourse.

The following discussion of locations known to support (or to have recently supported) mudfish populations, includes reference to all these factors as necessary.

4.4 Critical protection/management issues for known habitats of importance

Four locations are considered to be very important in terms of supporting mudfish populations. Management considerations are discussed. All map references apply to sheets in the series NZMS 260.

4.4.1 Dog Kennel Stream, South Canterbury

Map reference J40, 543.928 and vicinity. Dog Kennel Stream was one of only two waters listed solely for their intrinsic biological/ecological values by Teirney *et al.* (1982) in their submission on the draft inventory of wild and scenic rivers of national importance.

There are large numbers of mudfish in the headwaters of this stream, which comprises pools of permanent water alternating with impermanent runs. The lower reaches are channelised and flow only in winter. The mudfish habitat is therefore free of immigration by diadromous fish, which fail to negotiate the lower reaches. The only species known to share this habitat with mudfish is the upland bully (*Gobiomorphus breviceps*), and it is rare there.

Existing land use is evidently acceptable, as mudfish are still common. To maintain this situation, the upper catchment needs protection from any major change in land use, and riparian zones would benefit from fencing to protect banks and instream habitat from stock. I understand that initial moves have already been made towards creating a reserve for mudfish at Dog Kennel Stream, and that there is a good relationship between DOC (G.Crump, Timaru office) and landowners.

4.4.2 Hororata River, North Canterbury

Oxbow in the vicinity of L36, 322.353. Much of this habitat is on road reserve which is heavily grazed, apparently without authority. The reserve is most unlikely ever to be taken up for roading, and its acquisition as a reserve for mudfish is recommended. Many years ago liaison took place between the Ministry of Agriculture and Fisheries, the Malvern County Council, the North Canterbury Catchment Board, the Department of Lands and Survey, and local landowners, with the view to having this habitat protected. The demise of the Department of Lands and Survey, followed by other local government and departmental upheaval caused the project to lapse. Now it would appear possible to re-activate the proposal, and DOC's Christchurch office already has data pertaining to it (Files RSG 019 and 1.18.17).

The habitat of the oxbow itself is not extensive, but during floods, the mudfish population spreads into a variety of neighbouring ephemeral habitats - springs and scour holes.

The most critical factor needing attention is the permanent exclusion of stock. In addition, control of noxious weeds and willow will be an on-going management problem. The most likely possible future threat to the habitat is from river entrainment works upstream of the oxbow. It would be essential to have a firm understanding with the Canterbury Regional Council that no such work would be undertaken.

4.4.3 Mounseys Stream, North Canterbury

Wetland area in the vicinity of Rampaddock Road, L35, 350.684. Much, if not all, of this habitat is believed to be Maori leasehold. It is used chiefly for horse grazing. However, small copses of podocarp trees have been well fenced in recent times, and are now protected from encroachment by stock. Mudfish occur in one of these copses, but the habitat is very limited and extends beyond the fence both upstream and downstream. The extent of the range of mudfish in this area has not been surveyed but they occur in seepage streams and minor ditches, though not in the larger waterways bisecting the wetland.

Critical to management/protection of this area is probably the enthusing of local Maori. It may be possible to arrange a land swap, so that the entire wetland/podocarp complex is conserved as a single unit.

4.4.4 St Andrews area

Unnamed stream and tributaries in the vicinity of J39, 668.311. Mudfish were once very abundant in this waterway. In October 1982, it was possible, to obtain 50 yearling fish in a matter of minutes, using a pole net.

Suggestions for the conservation of this population were drawn up for the first draft of this report. However, apparently the landowner has had the habitat draglined. Its status now seems highly compromised.

4.5 Other known "natural" habitats

These are listed in geographical order, north to south, with suggestions for action regarding the management of mudfish populations, where appropriate. All map references apply to sheets in the series NZMS 260.

4.5.1 Waianiwaniwa River

Roger Knowles discovered mudfish in this sub-catchment of the Selwyn River in 1990. They were subsequently confirmed to occur near the historic Homebush homestead (L35, 287.477), and may be present elsewhere. The waterways are so modified and the flow is now so ephemeral that it is at present difficult to assess the importance of this locality. It requires further investigation.

4.5.2 Gawler Downs, Hinds River catchment

It is approximately 20 years since mudfish were collected at this mid-Canterbury high altitude (>500 m) site. Few fish were found, and it is probable that the flax wetland was drained long ago. It should be revisited.

4.5.3 Mayfield

A number of springs in the Mayfield area once held mudfish (sites 5-7 in Eldon *et al.* 1978). Observations in recent years by Peter Howden (pers. comm.) have failed to locate any fry in these springs, which have been subjected to several years of intense drought. I was unable to find any fish on a visit during the summer of 1992-3.

4.5.4 Clearwell

The once large population at this site (Eldon *et al.* 1978) is now extinct, owing to the illegal realignment of a watercourse on another property.

4.5.5 Ashburton County stockwater race system

Mudfish are found from time to time in stockwater races of mid Canterbury. While it is pleasing to know that the species persists in such places, the races are too strictly managed (e.g., regular weed clearance) to provide really worthwhile habitats in the long term. In the event of a future upturn in the New Zealand farming economy, it is probable that the stockwater race system will be piped. If this eventuates, some arrangement should be made to retain open water in one of the better mudfish locations.

4.5.6 Timaru area

Paraka Stream (J38, c. 635.544) and Rosewill Stream (J38, c. 626.514) both held mudfish some years ago. They were unlike other mudfish streams, being severely modified, and it is understood that DOC Timaru has very recently surveyed these streams for mudfish, without success. It would be regrettable if mudfish had died out recently at these locations, and it may be possible to re-establish both habitats by resuscitating the streams with riparian vegetation and protection from stock. If the fish do not recolonise from local survivors, the species could be re-introduced.

4.5.7 Pareora River

The Pareora River, South Canterbury, is typical of the smaller Canterbury rivers which have associated spring systems where mudfish are found. Often trout are prevalent and mudfish few. In this case, mudfish have been recorded in unnamed tributaries at J39, 668.333 and 653.334. Their numbers and extent are not known.

4.5.8 Otaio area

Prior to 1975, mudfish were present in some pools of an impermanent, unnamed stream along Horseshoe Bend Road (J39, 602.224 and thereabouts). However, they were not common. Perch (*Perca fluviatilis*) were present in other pools. Local wisdom had it that perch had once been very common, but were on the decline owing to falling water levels. If this was correct, perch may have now vanished entirely, in which case mudfish numbers could have increased. This depends on just how severe the water shortage is in the catchment.

4.5.9 Buchanans Creek, Willowbridge

This habitat, near Waimate (J40, 617.017), was first recorded by Cadwallader, 1975. It was once extremely important and supported a very large population of mudfish (Eldon 1979c). In about 1975, Cadwallader recommended it for reserve status, and the former Lands and Survey Department began investigations in this regard. The Department ran up against stiff opposition from landowners, and on my recommendation the scheme was put in abeyance until further studies of mudfish could be carried out. Consequent on those studies, this habitat was considered less important than Dog Kennel Stream, and subsequent events have not changed my views.

The Buchanans Creek population depends on the maintenance of a dam, installed to store water for sprinkler irrigation. Below the dam the stream always had a permanent flow and supported a number of other fish species, including brown trout. Trout surmounted the dam during their winter spawning migrations, but upstream, the waterway dried up each summer, eliminating fish species other than mudfish. The commissioning of the Glenavey irrigation scheme changed this situation. The ground water level rose as a result of irrigation, and the headwaters of Buchanans Creek became permanent water, with resultant reported permanent colonisation by brown trout. It is highly probable that mudfish persist in springs feeding the creek, which may be too small for trout habitation, but there can be little doubt that this population will be far less numerous and extensive than previously. In addition, riparian land ownership is still a problem.

4.5.10 Pikes Point Stream

Pikes Point Stream at J40, 526.913, close to Dog Kennel Stream, could be an important habitat. However, we have no recent information on it. Mudfish occurred there with koura (*Paranephrops zealandicus*); this crustacean is believed to have once been commonly associated with mudfish.

4.6 Potential techniques to restore degraded habitats

4.6.1 Stock exclusion

Although mudfish can survive droughts without free water, they do this only under very favourable conditions. They have no special adaptations for withstanding droughts, as is known, for example, for some species of lungfish, which seal themselves into a sort of cocoon. However, the family Galaxiidae (including the mudfishes) is unusually well-adapted to air breathing (Meredith 1985, chapter 9). Survival in a drought is a matter of happenstance for mudfish. Their normal behaviour is to hide in thick vegetation, or beneath other cover. If the water level then drops, the fish survive only if the hiding place remains safe and humid.

It follows, therefore, that the fish stand no chance of survival if adequate cover is unavailable, and this is usually the situation in modified habitats. Where stock have pugged the substrate it becomes too hard for the fish to enter; where stock have grazed the vegetation, it is too short to protect from wind and sun, and desiccation quickly follows.

Restoration of habitat therefore requires above all, exclusion of stock.

4.6.2 Restoration of wetlands

Where land ownership or control of land use is possible, previous mudfish wetland habitat can be restored.

Wetlands typically have been drained by a series of lateral ditches feeding a main drain, which may or may not have been a watercourse originally. Restoration is possible by simply damming the main drain allowing water to back up and flood the drained wetland, inundating the ditches which may be deep enough to retain water during a prolonged drought. The dam may be constructed in such a way as to exclude other fish from entering the habitat from downstream. This strategy was adopted at Steventon (section 5.3.1 (2)), although the habitat was primarily for birds.

Where access to the habitat by other species of fish is not an issue, it may be unnecessary to build a dam. Simply refraining from continual drain cleaning operations will allow the wetland to reform, and fencing it off will prevent stock from trampling and pugging.

4.6.3 Vegetation

Notwithstanding the comments above, when considering habitat restoration it may be a mistake to plant the riparian zone with tall vegetation. This mistake was made, on my own ill-considered advice, at a new habitat established at Tai Tapu (see section 5.4).

5. TRANSLOCATION

5.1 Translocation to establish new populations

This is entirely practicable and there are several examples of success (see section 5.3.1).

The simplest method of translocation is to move fry or small juveniles still in the free-swimming mode. This has several advantages over moving adult mudfish.

(a) Fry or small juveniles can be removed from the natal population with minimal effect to that population, as fry production is normally far greater than the capacity of the habitat to support them.

(b) The selection of males and females is random, since the two sexes are equally subject to capture. This is not always the case with adult captures.

(c) Obtaining fry/juveniles for translocation is far easier than obtaining adults, although there is a limited season - spring/early summer - when it is possible.

Often, fry can be obtained without the need to handle them, by simply dipping a bucket into the water. If a white or light-coloured bucket is used, it is possible to obtain a rough count of fry by decanting them slowly into another container.

Juveniles (older fish with well-developed escape ability) require a fine-meshed net for capture, but are still very easy to obtain compared with the cryptic adults.

Technically, it is possible to transfer adult fish, but the chances of depleting the source population are far greater. Also damage to the individual fish is a possibility. Unless yearling fish are particularly abundant - and this can happen - adults must be captured by electric fishing or trapping.

5.2 Translocation to augment existing populations

This is unnecessary, and should not be pursued. *Neochanna burrowsius* is well able to fully populate any suitable habitat available to it. The fish spawns for the first time towards the end of its first year of life. It produces many eggs and the numbers of fry are usually enormously in excess of those the habitat can support. If the population is heavily reduced, either the habitat is no longer capable of supporting the original numbers, or the reduction is a natural cyclical event and numbers will recover eventually.

5.3 Successful liberations

5.3.1 Steventon Station

Mudfish liberations were made between 1984 and 1989 in two habitats on Steventon Station, in the North Canterbury foothills, upper Selwyn River catchment (L35, 17.50).

1. Fish were established in the first habitat by 1987; this was a previously degraded headwaters spring and wetland area which was recovering after it had been fenced off to exclude stock. Fry are still found in this habitat each spring (Graeme McArthur, pers. comm.).

2. The second habitat (Fig. 1) was a wetland, rehabilitated by damming a small stream, and covenanted to the QEII Trust. Several liberations of adults and fry were made here before adult fish were discovered in April 1992 (Graeme McArthur, pers. comm.). Possibly it is too early to be certain of the success of this second venture, but it seems likely that the fish have established themselves.

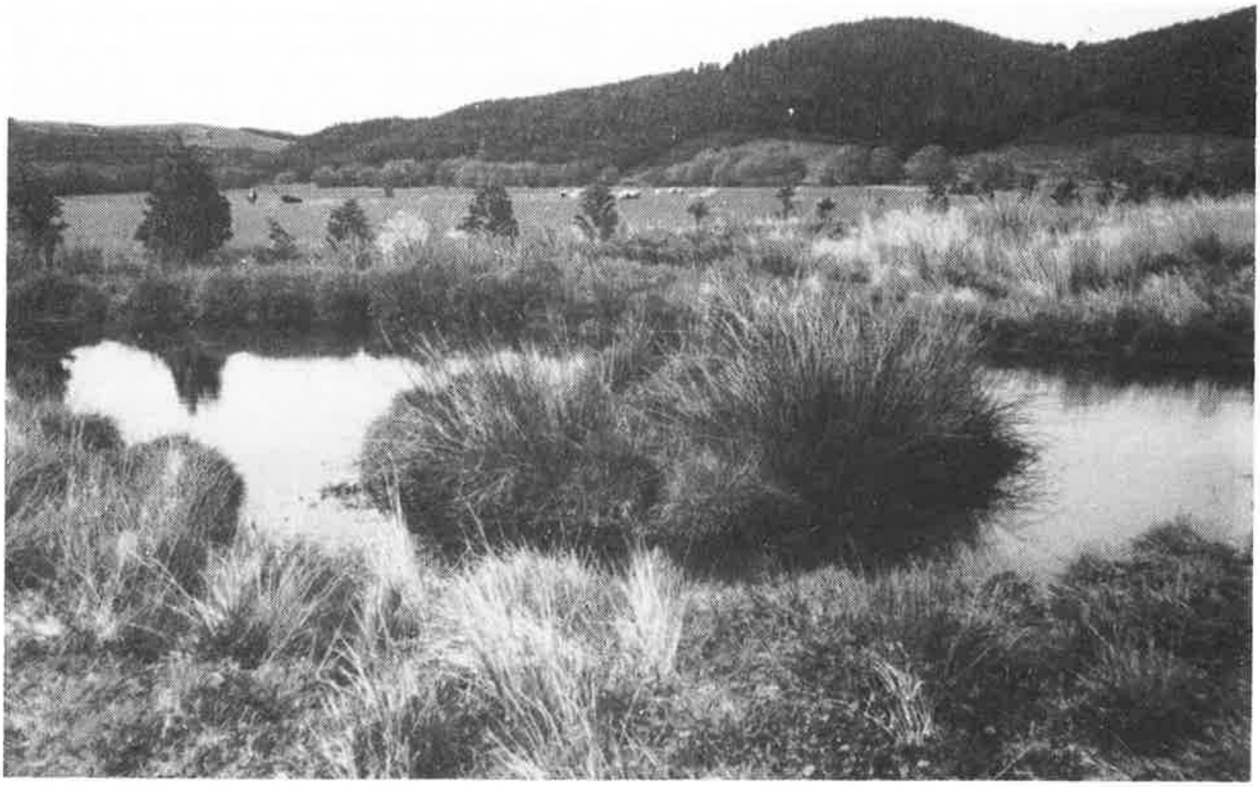

FIGURE 1. Part of the wetland at Steventon at which mudfish liberations commenced in 1987. Adult fish were found there in 1992 (G. McArthur, pers. comm.). (Photo 1987)

5.3.2 Christchurch Botanical Gardens

Fry were stocked in three ponds of the Botanical Gardens in 1979. They became established in only one, tiny pond, and were breeding there for a number of years, though probably never more than half a dozen adult fish were present.

It was possible for the fish to spread into further ponds in the gardens, via a culvert, but so far as is known this never happened. From time to time, goldfish, perch and trout are present in some ponds, and the potential for mudfish there is minimal. This information is provided simply for the record.

5.3.3 Peacock Springs, Christchurch

A small detached pond (Fig. 2) in the Wildlife Trust reserve was cleared of eels and trout, and stocked with mudfish in 1986 (Eldon 1988). The pond is fed by Waimakariri River water filtering through a gravel bank from a water race which supplies a salmon farm. The water likewise escapes by seepage. A few fry are produced there each spring. A trapping and electric fishing exercise in April 1989 gave a minimum count of 60 confirmed adult fish - three times the number of the original release. However, this is probably less than 50% of the number actually present. It is unlikely that the number of fish will increase further; the water is often silty, not very productive, and there are few invertebrates which the fish need for food (Eldon 1979b).

The pond is theoretically safe from development, but in practice the water level is subject to interference from the running of the nearby salmon farm. The water level is currently much lower than when the pond was stocked, but is higher than it was following alterations to the salmon farm which occurred subsequent to the stocking. Provided that the salmon farm remains in current ownership, a repeat of the dewatering is unlikely to occur.

5.3.4 Taiko, South Canterbury

A very minor watercourse on the property of Mr J. Moran, Robinson's Road (J38, 528.514), had been stopped with three minor earth dams, providing a string of small impoundments which appeared to offer splendid mudfish habitat. Only upland bullies were present prior to 1982, when 50 yearling mudfish were liberated in the uppermost impoundment.

Newly-hatched fry were present in two impoundments in October the following year, and in all three impoundments the year after that. Regular visits then

FIGURE 2. The pond at Peacock Springs (Isaac Wildlife Trust) contains a small population of mudfish following a single release in 1986. (Photo 1987)

ceased, but fry were distributed over a linear distance of 3 km in 1987, and fish continue to be found (M. Webb, pers. comm., J. Moran, pers. comm.).

5.3.5 Other liberations

Several other attempts have been made to establish populations, in the Ohoka, Glen Elg, Tai Tapu, Halswell, Lowcliff and Cave areas. Most were failures.

Only Tai Tapu was a short-term success. The banks of a 0.5 hectare stagnant pond were planted with trees shortly after the pond was stocked with fry and juveniles in 1984. Initially, results were promising and breeding took place in 1985 and 1986. As the trees grew, however, they sheltered the pond to such an extent that there was no wind agitation of the water. Added to this, the considerable leaf litter rotting in the water created anaerobic conditions which probably prevented successful breeding. There were no fry in 1987 or 1988, and in 1989 a trapping project procured no fish.

A liberation of 74 adult fish was made in Queen Anne's Lagoon, at Cheviot, in winter 1988. This habitat is north of the known range of mudfish, and much thought was given to the project before it was undertaken.

Queen Anne's lagoon is an extensive impoundment (c. 20 hectares) created apparently for aesthetic purposes. It is an unusual water body, holding only a very few common bullies (*Gobiomorphus cotidianus*), and many shortfinned eels *(Anguilla australis)*. The eels are commercially fished, however; the annual catch is about 0.5 tonnes (D.J. Jellyman, pers. comm.) so that there are few large, potentially piscivorous fish. There are very few macrophytes, and the banks are grazed short. Though it is unlikely to support mudfish, it was stocked because it was the largest habitat available. If mudfish do establish there, the potential population size is enormous.

Apart from a visit in December 1990, when nothing was found, this liberation has not been followed up.

5.4 Criteria for selection of new habitats

Overseas, the translocation of endemic species has been known to cause the demise of other endemic species, e.g. Barlow *et al.* (1987). The risk of this with Canterbury mudfish is virtually non-existent. Risk could pertain only to another species of mudfish, a new species, or a species with extremely limited range.

All the mudfishes have distinct ranges of distribution, and translocation of one species to the range of another would be easily avoided. Potential liberation sites for Canterbury mudfish should be within its known range, where "range" refers to the species' altitudinal distribution as well as its geographical distribution. Other risks can be minimized by first surveying the fauna of any water selected for a liberation and determining that there are no "at risk" species present.

Promising potential habitats are not easy to find. In 1982, *The Christchurch Press* ran an article on behalf of Fisheries Research Division, entitled "Wanted: a pond for a mudfish". The article described plans to liberate fish in farm ponds, and generated a reasonable response from the public. Thirty suggestions were made for liberation sites. Of these, nine were outside the range of mudfish and were not pursued, and a further three were clearly unsuitable.

All of the remaining 18 waters were visited, but only five were deemed promising, and were stocked. At only two sites were mudfish populations ultimately established, but these were very well worthwhile. A further site stocked at that time was one considered unpromising. Here, success was short-term only.

The criteria applied for selection were basically those listed in section 4.1 above, together with a reasonable expectation that the habitat had a long-term future. That only five proffered sites came anywhere near meeting these simple requirements indicates the difficulty in finding potential habitats. The most common failing was unrestricted access to trout, together with the habitat's suitability for trout.

A not-altogether incidental facet of this exercise was the number of people with "ulterior motives" in suggesting waters for stocking. These were never stated, but could be inferred. DOC officers who may become involved in translocation should be aware of "politics". A pond created for some other purpose - e.g., duck shooting - may have been constructed without local body authorisation. The presence of a "rare and endangered" species might make life easier in the event of trouble! This may not be a problem if the ends justify the means, but it is as well to be aware of pitfalls.

5.5 Sites for translocation

Of the sites rejected in 1982, three may be worth reconsideration if they are still available. The names supplied are those relevant in 1982. The sites are:

(a) Darfield. A pond at the termination of a stockwater race at "Centre Farm", property of K.H. Jarman, Essenden Road (L35, 338.411).

(b) Cave.

(i) Pond with spring on property of Gerry Ulrich (no map reference available).

(ii) Ephemeral stream bed and pond on the property of P.A. Connor, Main Road, Cave (no map reference available).

However, probably the greatest potential for increasing the population base of Canterbury mudfish lies with garden ponds. In the absence of other fish, and given a modest semblance to natural conditions, mudfish maintain themselves brilliantly with total lack of attention. If they prove able to do this even sometimes, in the presence of goldfish, many potential small habitats would be available.

It is pertinent here to discuss the failure of mudfish to spread through the pond system at the Christchurch Botanical Gardens (section 5.3.2). These ponds exist primarily for aesthetic purposes; they are of uniformly shallow depth, and host not only goldfish and sometimes other fish, but great numbers of ducks. In natural numbers, ducks pose no problem to mudfish, but in the artificial densities at which they occur in the gardens, they ensure that there is virtually no macrophyte growth in the ponds. Additionally, the ponds are well flushed with spring or bore water, and there is little in the way of invertebrate life which mudfish need for food.

5.6 Selection of stock for translocation

There is considerable literature now on genetically individual stocks within a single species, particularly for salmonids, e.g., Gall *et al.* 1992, Ryman and Stahl 1981, Utter *et al.* 1989. Identification of separate populations of mudfish, and possibly tracing the history of species dispersal, could be compromised by translocation.

Just how seriously this needs to be considered, when translocation of a rare and endangered species is concerned, may be controversial. In any event, most of the liberations described in sections 5.3 and 5.4 above, were made without consideration for stock integrity, which was not then raised as an issue.

Most liberations were made from a captive breeding stock. These were originally kept captive to aid in their study (Eldon 1979a,b,c). Liberations were never anticipated, and the origin of the fish was not recorded.

In only two of the above cases were liberations from stock of known origin, and the criteria used for selection were their source in the same overall catchment (section 5.3.4, Taiko, ex St Andrews), and their source populations most able to withstand extraction (section 5.3.5, Cheviot, ex Hororata and Oxford).

5.7 Numbers for liberation

Under certain circumstances, males will greatly outnumber females in captured samples of adult Canterbury mudfish. This is because males are far more mobile than females during the breeding season. However, the actual sex ratio in populations is very close to 1:1, and in the following discussion it can be assumed that 50% of fish were females.

The highly successful Taiko population was established with 50 yearling fish translocated during October. It is not known whether these fish had then already spawned, but that is highly probable. It is likely, therefore that these fish did not breed at Taiko until spring of the following year, when well-grown fry were observed in October. The habitat was open, but all the fish were liberated in the smallest impoundment on the principle that they would be less likely to disperse before breeding.

Habitat (1) at Steventon was stocked with only very few fish ex-captive stock (the number is not known as a consignment of 50 juveniles was divided between two habitats and I was not present). The habitat was open at one end.

Habitat (2) was subjected to a series of liberations. It seems likely that liberations of an unrecorded number of fry in spring 1984, six pre-spawning adults in August 1986, 12 pre-spawning yearlings in July 1987, and fewer than 50 juveniles in December 1987, were all unsuccessful. Establishment seems to have followed liberation of 88 juveniles in December 1989. However, the habitat is open and fairly extensive; it is possible that an earlier liberation was successful but undetected.

The Peacock Springs population was established from 20 large adults, ex-captive stock. These fish were liberated, pre-spawning, in July, but a consequent major fall in the water level left all the macrophyte beds exposed to the sun and air throughout the spawning season. So gross was the dewatering that it seemed possible that no fish would survive, but the water level partially recovered, and breeding took place the following year. The habitat was closed and not extensive.

The initially successful Tai Tapu colony was established with the release of between 50 and 100 newly-hatched fry in October, with a follow-up of 25 juveniles in December. The habitat was closed and not extensive.

6. CAPTIVE BREEDING

6.1 Potential

There are examples of fish species which are extinct in the wild, but extant in artificial culture: *Gambusia amistadensis* (Miller 1977); *Melanotaenia eachamensis* (Caughey *et al.* 1990). Other extinct species could have been maintained in captivity, had they been collected in time, and numerous endangered species in North America and Australia are being bred in captivity largely because of the threat to wild stock (see *Journal of Fish Biology 37, Supplement A*, 1990).

Captive rearing and breeding is practicable for the Canterbury mudfish, at both the laboratory and household level. I have maintained stocks continuously for some fourteen years.

6.2 Translocation from a captive source

Two of the new populations (Steventon and Peacock Springs) were established from captive stock. Several small lots of about six fish have also been given to aquarists and garden pond owners. No records were kept of these, and there has been no "feed-back". In the case of fish placed in ponds, it would be possible for them to exist unseen unless particular endeavours were made to observe them.

6.3 Techniques

There are no special techniques required for rearing mudfish. Any reasonably competent aquarist could do it, and it is not a function of this report to teach basic aquaculture. Breeding requires only a little more attention. Provided a spawning medium (macrophytes, roots, algae) is supplied, the fish will spawn in due course.

The rearing of large numbers of mudfish for liberation into the wild, however, is probably not cost-effective compared with translocation from a wild stock. If production in captivity is preferred, it would best be undertaken in a semi-self-maintaining outdoor facility, with minimal or nil supplementary feeding. Fry could then be liberated direct into the wild while still very small, or transferred to interim rearing tanks for liberation at a late juvenile stage. This step would require a number of containers, and would be relatively labour intensive.

A very small outdoor facility exists on the NIWA Freshwater campus in Christchurch (Eldon 1985, 1986). It has maintained a population of Canterbury mudfish, without supplementary feeding, for nine years and was one source of supply of fish liberated elsewhere. It is a shallow, unlined pond in a naturally boggy area, but needs frequent attention to keep up the water level during summer. Ideally it could be enlarged, lined with Butynol rubber sheeting, and provided with its own water supply. A pond of 10 x 5 x 0.4 m could be constructed on this site for under $2,500 for materials, plus labour. Work would entail excavating the hole and hand-finishing to provide a smooth surface to support the Butynol. Also a low "coffer dam" should be raised between the pond and two nearby "dangerous goods" stores. Alternatively, the stores could be moved. A surrounding fence would be unnecessary for water kept to under 0.4 m deep.

The cost of installing a rearing facility elsewhere would vary according to site, but given a suitable water supply, it is difficult to envisage expenses over $20,000.

6.4 Home aquaria and private ponds

There has been a recent surge of interest among aquarists in New Zealand in keeping native fishes. Home aquaria generate enormous enthusiasm in their followers. Mudfish, being cryptic, lethargic and nocturnal, test this enthusiasm to the full, and only the most dedicated aquarists persevere with them. Even so, home aquarists have the ability to retain, in aggregate, sufficient numbers of individuals to ensure their preservation.

A potential problem with private aquarists is the unwanted spread of species to new areas where they may adversely affect other native fauna. Much depends on the responsibility of aquarists. Given the difficulty in acquiring some of our rarer species (and even some of the common ones!), it is unlikely that they will be irresponsibly disposed of. Even so, it is probable that eventually species will turn up outside their natural range. This is not axiomatically a disaster, although it could be deleterious.

From time to time there have been suggestions concerning controls over keeping native fish in aquaria. In my view, it would be counterproductive to burden the hobby with more regulations. Amateurs can do much to relieve the pressure on endangered species if those species can be bred in captivity. The Canterbury mudfish is a prime example of such a species.

Home culture buffers wild stocks against disaster. It provides a ready supply of legal and relatively easily obtained specimens, thereby forestalling any "black market" which seems to be the inevitable result of species protection. It also encourages interest in native fauna and provides extra knowledge from diverse observations.

It is unlikely, however, that home-reared mudfish could be used routinely for official translocation. There would be considerable expense, for coordinating and quarantining.

7. RESEARCH NEEDS

7.1 Life history and ecology

The biology and ecology of the Canterbury mudfish are well understood (Eldon 1979a,b,c, Meredith 1981, 1985, Meredith *et al.* 1982). There are, however, areas in which research could assist in a species recovery strategy.

For example, the degree of oxygen saturation required for successful breeding, is not known. Data show that adult mudfish can survive in habitats where low - even zero - oxygen levels sometimes occur (Eldon 1979a). However, low oxygen levels are not a feature of the breeding season, and in the wild, the fry of Canterbury mudfish are normally found only in flowing (= oxygenated) water (pers. obs.). This applies also to black mudfish, *N. diversus* (Thompson 1986). Also, Canterbury mudfish tend to spawn in vegetation close to the surface, where oxygen levels are highest.

Canterbury mudfish are quite capable of successfully reproducing in artificial ponds without flowing water, and also in tanks where aeration is supplied. However, if a large stagnant pond were to be considered for stocking, spring-time low oxygen levels could be a limiting factor to the success of the enterprise. I believe that this was the factor which caused the ultimate failure of a new population at Tai Tapu (see section 5.3.5).

A study of the phenomenon of spawning migration, as observed at Clearwell (Eldon *et al.* 1978), could be of interest. However, the Clearwell population is now extinct. Migration may occur in other habitats, but there is no indication that it is essential to the survival of other populations.

There is a need to determine the ability of mudfish to form and maintain populations in the presence of other species, particularly goldfish. There are numerous garden ponds in Canterbury, which in aggregate could possibly support many mudfish. Because mudfish are cryptic, they do not appeal much to pond owners, even those with a conservation bent. Goldfish (*Carassius auratus*) are the traditional New Zealand garden pond fish, being large, harmless, colourful and visible. I have kept goldfish and mudfish together in a large garden pond for several years, but the mudfish may have died out following a reduction in water level and volume to comply with an edict of the Christchurch City Council.

7.2 Population monitoring

If adult population censuses are deemed essential, research is needed to determine the best method of achieving these. Estimating numbers from declining catch by repeated electro-fishing is too harmful to both fish and habitat, and some form of mark-recapture method using traps appears to be the most promising technique. Mark-recapture methods, however, require considerable effort plus practical and statistical competence. A mark-recapture programme applied to mudfish is likely to be a prolonged procedure, complicated by the requirement that each trapping sequence must be conducted under similar conditions of flow, temperature and light, etc.

One obvious task which needs to be undertaken is a thorough survey of Queen Anne's Lagoon, to determine whether mudfish have become established there.

7.3 Genetic diversity

This is a controversial subject. It could be argued that there are no research needs: work already done shows the feasibility of translocation, and if further populations are deemed desirable, and habitat can be found, liberations should be approved.

On the other hand, it could be also argued that the shifting of stocks from one locality to another is highly undesirable for genetic reasons. When a species is greatly reduced in numbers, there is a consequent lessening of genetic diversity. When the different populations are fragmented and isolated from each other, as is the case with Canterbury mudfish, the genetic make-up of those populations is likely to be distinct. This distinction is a useful tool for research in zoogeography and species dispersal. A literature search is required to determine possible consequences of translocation of fish in these circumstances.

8. ACKNOWLEDGEMENTS

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APPENDIX I. Schedule of information requested by the Department of Conservation for development of a recovery plan for the Canterbury mudfish.

CANTERBURY MUDFISH RECOVERY PLAN DEVELOPMENT

Objectives

To provide the Department of Conservation with the necessary specialist and technical information to develop a recovery plan for the Canterbury mudfish (*Neochanna burrowsius*).

Procedure

The consultant will be required to provide information to enable the preparation of a recovery plan in accordance with the Department's recovery plan guidelines. The following information is seen as being specifically required for development of a plan.

Population status and monitoring

- Assess the current status and degree of threat to the survival of the Canterbury mudfish.
- Determine appropriate population monitoring techniques, and indicate how often and when this should be done.
- Identify critical research needs.

Management options for species recovery

- Discuss management options for the recovery of the species. Prioritise the options in terms of their urgency of implementation and feasibility. Indicate which actions should be pursued concurrently.
- Identify critical research needs.

Habitat factors

- Identify the key physical, chemical and biological characteristics of optimum mudfish habitats.
- Develop criteria to rank the known habitats for protection priority. Identify the critical protection/management issues for each habitat.
- Outline potential techniques to restore degraded mudfish habitats.
- Identify critical research needs.

Translocation

- Discuss the potential of translocation as a technique to re-establish populations in new habitats or to augment existing populations. Include any experience to date.
- Develop criteria for the selection of new and existing habitats for translocation.

- Identify locations where translocation would be a suitable management technique.

- Outline translocation processes and factors that must be taken into account for successful translocation and monitoring of population development.

- Develop criteria for the selection of stock for translocation.

- What is known about the numbers of fish required to successfully establish populations in new habitats?

- Identify critical research needs.

Captive breeding

- Discuss the potential for captive breeding as a management technique for the conservation of the Canterbury mudfish and factors that must be taken into account in undertaking such a programme.

- Discuss the use of captive bred populations as a source of stock for translocation.

- Outline the techniques for successful captive rearing, maintaining brood stock and larval production. An estimate of costs associated with captive breeding should be provided.

- Assess the appropriateness of small private home aquaria, fish ponds and farm ponds, etc, as useful mechanisms for captive rearing.

- Identify critical research needs.

Other information relevant to recovery plan development

- Provide other information considered necessary to formulate a recovery plan for the Canterbury mudfish.

Liaison

- Respond to Department of Conservation enquiries associated with the development of the recovery plan including participation as a member of a recovery group convened to facilitate this.