Habitat Restoration and Management: A Trial of an Investment-Based Approach - Final report for a non complete report

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Habitat Restoration and Management: A Trial of an Investment-Based Approach

Final Report for a Non Complete Report

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Objectives:

1. Develop an appropriate monitoring methodology for assessing the progress of fisheries habitat restoration within the trial wetland area (Black Swamp);
2. Describe the nature of fish communities, sediments and benthic flora present at and adjacent to the site prior to reflooding;
3. Assess changes in fish communities, sediments and benthic flora within and adjacent to the trial area in the years following reflooding;
4. Assess the effectiveness of the restoration of fish habitat in Corner Inlet and the likely benefits to commercial and recreational fisheries.
5. Assess the effectiveness of the investment-based approach as a management tool for the restoration of fisheries habitats.

OUTCOMES ACHIEVED TO DATE

It is considered that the outputs of this research will provide useful baseline catch information to fisheries managers on the structure of fish assemblages in mangrove habitats in southern Australia. The current understanding of fish use in temperate mangrove habitats in Australia, and elsewhere in the world, is limited. Given the recent shift in focus of fisheries management agencies to assigning blanket conservation values to particular vegetation types, the findings of this research are of particular relevance. The current study also identified the clear need to further investigate the dynamics of fish-habitat associations in temperate estuarine environments, and the importance of habitat in regulating fish stocks.

KEYWORDS: Mangrove, Restoration, Fish Habitat, Fisheries, Black Swamp.

1 NON-TECHNICAL SUMMARY

Worldwide, wetlands are under a range of anthropogenic stresses including reclamation and run-off from land-based activities. There is increasing attention directed at the restoration and rehabilitation of degraded wetland habitats. Wetlands are considered to be important for a range of ecological and economic reasons including fisheries production. However, most restoration projects to date have focussed on silviculture, environmental mitigation and coastal stabilisation rather than fisheries benefits or ecosystem function.

Black Swamp (Corner Inlet, Victoria) is an area that was reclaimed in the 1920s for pastoral land, *via* the construction of a seawall preventing tidal access. Before reclamation, this area was believed to contain monospecific stands of *Avicennia marina* and was considered an area of critical importance for juvenile fish (particularly school and gummy sharks). There are plans for this area to be re-flooded for the purposes of providing nursery habitat for species of significance to commercial and recreational fisheries. It was proposed to allow mangrove colonisation to occur naturally. Re-establishing tidal flow to previously reclaimed areas should result in the movement of fish into these areas.

The original aim of the project was to assess the effectiveness of habitat restoration on local fisheries. FRDC project 2000/179 was funded to assess the function of the mangrove habitat at Black Swamp, trialling an investment based approach for rehabilitating wetland habitats and to monitor the effect of the restoration on fish assemblages. A separate NHT funded project was responsible for all aspects of the implementation of the actual habitat restoration.

Restoration of tidal flow to Black Swamp was to have been completed in early 2002, however, difficulties in obtaining agreement/permission from all affected landowners has prevented this from occurring and it appears unlikely that restoration will commence in the foreseeable future. Baseline sampling commenced in August 2001 on the basis that 2 to 3 sampling episodes would be carried out prior to re-flooding to provide a baseline dataset. Despite the delay in re-flooding, the baseline sampling continued on a quarterly basis until November 2002 on the understanding that re-flooding of the Swamp was imminent. With the delay in re-flooding and the proposed suspension of the monitoring project, there was also uncertainty as to the applicability of the current dataset to be used as baseline data given the delay (likely to be 12-18 months) between its collection and the re-implementation of the monitoring program.

A third party reviewer, Dr Rod Connolly, was commissioned by FRDC to examine the implications of a delay in re-introduction of tidal water to Black Swamp, and other issues that have arisen with respect to the study methodology and results to date. Dr Connolly did not consider it important to undertake any further pre-flood sampling and, thus, no further sampling was done after the November 2002 episode. Several alterations to the current experimental design and suggestions for post flooding sampling were presented. However, it was considered by Dr Connolly, that the existing data might, in itself, provide useful information on the utilisation of mangrove habitat in southern Australia.

Given the lack of research on fish use of mangrove forests in temperate regions of southern Australia, the data collected thus far are interesting. Species richness and total abundances found in the current study were notably low with 17 species in total captured at Mosquito and Old Hat Creeks. Only two species of fish (yellow-eye mullet and toadfish) were caught in any number, and accounted for 77% of total abundances. Several fish species of commercial significance were captured in the current surveys, including: yellow-eye mullet, greenback flounder (*Rhombosolea tapirina*), sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*), short-finned eel (*Anguilla australis*), and southern blue-spot flathead (*Platycephalus speculator*). The Old Hat Creek location had consistently higher numbers of species and individuals than the Mosquito Creek location on all sampling occasions.

The low catch returns are likely to reflect low numbers of fish utilising mangrove areas, and possibly sampling error. In the case of sampling error, it is possible that some fish may have remained within small pools within the mangrove forest at low tide, and therefore avoided capture. However, based on visual observations of only low numbers of fish in these shallow pools during low tide, it is considered likely that the large majority of fish within these sampling cells would have been captured.

The low numbers of fish captured are therefore likely to be representative of low actual abundances of fish utilising these mangrove areas. These results challenge the paradigm that all mangrove forests represent important fish habitats. This paradigm is based on studies done in tropical and sub-tropical areas, which, due to the inherent difficulties in sampling mangrove areas, are typically poorly replicated in time and space. With few notable exceptions, previous studies rarely compared multiple habitat types.

This study also highlighted the importance of tidal inundation in mangroves to the utilization of fish in these habitats. During spring tides, mangroves at Old Hat and Mosquito Creeks were flooded by water of up to 30 cm in height at the seaward fringe of mangroves (i.e. at the deepest point). Furthermore, vertical root structure provided by mangrove pneumatophores (which can often extend between 0 and 15 cm or more above the sediment in *A. marina*), coupled with the infrequent nature of Spring tide inundation further restricted the space available for fish utilization in these temperate mangroves.

Due to the limited timeframe and spatial replication of the present study, it is not possible to determine whether the strength of fish-habitat associations varies among different geographic regions (i.e. differences between tropical and temperate wetlands). Furthermore, there are presently insufficient data to draw conclusions on the processes controlling fish-habitat associations in Australian estuaries, and the scale at which these processes are operating. There is a clear need to further investigate the dynamics of fish-habitat associations in temperate estuarine environments, and the importance of habitat in regulating fish stocks.

2 ACKNOWLEDGMENTS

This project was developed and designed by Robert Tilbury and Dr Darryl McPhee who, along with Ross Bennett, were instrumental in setting up a schedule of regular collection of samples. Our thanks also to several staff of WBM Oceanics who edited this final report and provided useful suggestions. Dr Rod Connolly of the Griffith University School of Environmental and Applied Science also provided a thorough review of this project, providing many useful comments. Our thanks also to Jane Harris (FRDC) and Bob MacDonald (Southern Shark and Gillnet Fishermen's Association) for their assistance over the duration of the project.

3 BACKGROUND

This project is supported by a proposal developed by the Southern Gillnet Fishermen's Association (SGFA) to trial investment in contracted fisheries habitat management. The trial involves contracting land owners/managers to manage/restore critical coastal nursery habitat for fish species important to both inshore and offshore commercial and recreational fisheries. To the SGFA this represents the trialling of investment in public resources upon which they, and other fishers, rely.

This trial was designed to attract ongoing annual investment from commercial and amateur fishers and others concerned with the conservation of coastal wetlands. This was to be achieved by demonstrating efficient management (contracted on a per hectare per annum basis) and strong public relations benefits from such investment in the restoration and management of a public resource.

Worldwide, wetlands are under a range of anthropogenic stresses including reclamation and run-off from land-based activities. There is increasing attention directed at the restoration and rehabilitation of degraded wetland habitats. Wetlands are well documented as being important for a range of ecological and economic reasons including fisheries production. However, most restoration projects to date have focussed on silviculture, environmental mitigation and coastal stabilisation rather than fisheries benefits or ecosystem function (Ellison 2000).

The monitoring of the rehabilitation of these wetlands and the diversity of species that benefit from it is critical to attracting future investors and demonstrating the viability of this approach to coastal wetland restoration and management.

The former estuarine area proposed for restoration is Black Swamp in Corner Inlet, Victoria. Black Swamp was isolated from tidal influence in the early 1920's by the building of a seawall and the installation of floodgates to prevent tidal seawater inflow, while allowing freshwater outflow. This process resulted in tidal mangrove and saltmarsh habitats being replaced by pasture for cattle and a small brackish wetland. The former estuarine area was known by Inlet fishermen and other locals to support snapper, king george whiting, mullet and possibly adult and juvenile school and gummy shark. Local residents report seeing large sharks in the area and local fishers believe the area was a school shark nursery. In addition, it provided habitat for a large range of juveniles of many species of fish targeted by amateur and commercial fishers.

The proposed restoration of Black Swamp involves opening the existing floodgates and/or removing sections of the seawall to reinstate the former tidal regime, allowing estuarine communities to recolonise the area. The trial involves restoring approximately 150 ha of former coastal wetlands that were was almost exclusively comprised of *Avicennia marina* (Grey mangrove).

Knowledge of the natural dynamics in both fisheries and habitats underpins any assessment of threats and methods for conservation or rehabilitation (Cappo *et al*. 1998). Monitoring changes in Black Swamp and its surrounds will provide valuable insights into the dynamics of nursery areas of school shark and other fish. Examining existing fish (including school shark) nursery areas and determining the key features of these habitats may provide a basis for evaluating the potential for rehabilitation of other sites as nursery areas.

This trial was intended to act as a model to attract investment in the restoration and management of habitat from commercial and amateur fishers and others with a stake in coastal wetlands elsewhere in Australia. It could then potentially have acted as a model to attract investment in the restoration/management of coastal wetlands both in Australia and internationally.

4 NEED

The loss and compromise of habitat is a problem that affects all Australian commercial and recreational fisheries (Zann 1996). A recent review (funded by FRDC) of fisheries habitat research in Australia (Cappo *et al*. 1998) found that more action is needed to rehabilitate degraded habitats, of which coastal wetlands were particularly important. Cappo *et al*. (1998) also found that understanding impacts on fish stocks was hampered by lack of knowledge regarding natural variation in populations and habitats.

Priorities for further habitat research have been emphasised by Cappo *et al*. (1998) and are reflected in FRDC's Ecosystems Protection Program. This project has particular implications for protecting and enhancing fisheries habitats in the following specific areas:

1. Defining and monitoring the utilisation of a major habitat type in the coastal zone and assessing the role of that habitat in fisheries production;

2. As a trial for a self-sustaining management strategy that will actively encourage fisheries habitat rehabilitation, regardless of the site/fishery involved; and

3. By providing a direct benefit to fisheries habitats and therefore the associated fish stocks in the local region.

There is currently specific concern in the Southern Shark Fishery regarding the status of school shark stocks, with catches falling steadily from 2026 tonnes in 1986 to 749 tonnes in 1997 (Walker 1998, Punt and Walker 1998). However, there is a differential between the status of school shark stocks and those of gummy shark, which are considered to be stable. Thus there is a clear need to introduce measures which assist in rebuilding school shark stocks without adversely affecting sustainable catches of gummy sharks. There is also an identified need to protect school shark pre-recruits, which appear to be increasingly hard to find.

School sharks give birth during November and December in protected bays and channels on low-energy coastlines in Victoria and Tasmania (Olsen 1954; Stevens and West 1997). Although newborn sharks are found outside these areas, school shark nursery areas are regarded as important habitat for this species. This nursery habitat type has suffered significant loss throughout southern Australia, initially as a result of farming practices and subsequently from coastal development. Hence, in addition to concerns about the effects of fishing on the breeding stock, there is concern that loss of school shark nursery habitat may be causing further stock reduction or inhibiting management attempts at rebuilding the stock. Thus, there is a need to protect, restore and/or enhance nursery habitats for juvenile school shark as part of a strategy to improve recruitment to the fishery and contribute to restoring stocks.

Many of the important nursery areas for school shark (and other fish species) have been altered through human activities. For example, the ‘State of the Marine Environment Report for Australia’ indicates that several of the most important school shark nursery areas have lost large areas of seagrass. In Victoria, Western Port Bay has lost 17,800 hectares (and 85% of the seagrass biomass) and, in Tasmania, the Pittwater Estuary has lost 1201 hectares and Norfolk Bay has lost 2148 hectares.

Action to arrest the trend in degradation of school shark ‘critical habitat’ and to rehabilitate lost habitat is essential if school shark is to be a resource that can be used sustainably. The shark fishing industry initiative to inundate Black Swamp with seawater is the first attempt at rehabilitation of a school shark nursery area. This initiative will also provide additional habitat and potential nursery area for other commercial (MacDonald 1997) and recreational (Hall and MacDonald 1986) species abundant in Corner Inlet (Gunthorpe and Hamer, 2000). Some of these other species which have high commercial value or are sought after by recreational fishers include snapper, gummy shark, southern garfish, greenback flounder, flathead and King George whiting.

Corner Inlet was considered to be a suitable location for trialling restoration of coastal wetlands and estuarine fish habitats, given:

- it was formerly acknowledged as an important juvenile school shark nursery habitat;
- the drained coastal wetlands of Corner Inlet formerly provided nursery areas and adult habitat for many other fish species utilised by commercial and recreational fishers;
- extensive areas of such habitat have been lost in the inlet through the construction of sea walls, resulting in mangrove, seagrass and saltmarsh communities being converted to pasture;
- there is significant potential for restoration of additional areas of the inlet outside the specific area involved in the trial;
- the project has generated widespread local support and enthusiasm from a variety of stakeholders, including offshore and inshore fishermen, landholders, local council and the community; and,
- nationally there may be hundreds of drained coastal wetlands that could be restored and managed through a similar approach should the trial prove successful. This wider potential application is demonstrated by the breadth of support for this project from fisheries managers in other states.

5 OBJECTIVES

The aim of the project was to assess the effectiveness of habitat restoration on local fisheries. Specifically, the objectives were to:

1. Develop an appropriate monitoring methodology for assessing the progress of fisheries habitat restoration within the trial wetland area (Black Swamp);

2. Describe the nature of fish communities, sediments and benthic flora present at and adjacent to the site prior to reflooding;

3. Assess changes in fish communities, sediments and benthic flora within and adjacent to the trial area in the years following reflooding;

4. Assess the effectiveness of the restoration of fish habitat in Corner Inlet and the likely benefits to commercial and recreational fisheries.

5. Assess the effectiveness of the investment-based approach as a management tool for the restoration of fisheries habitats.

6 METHODS

6.1 Fish Sampling

6.1.1 Summary of Experimental Design

The schematic in Figure 6-1 shows the hierarchical fish sampling design used in this study.

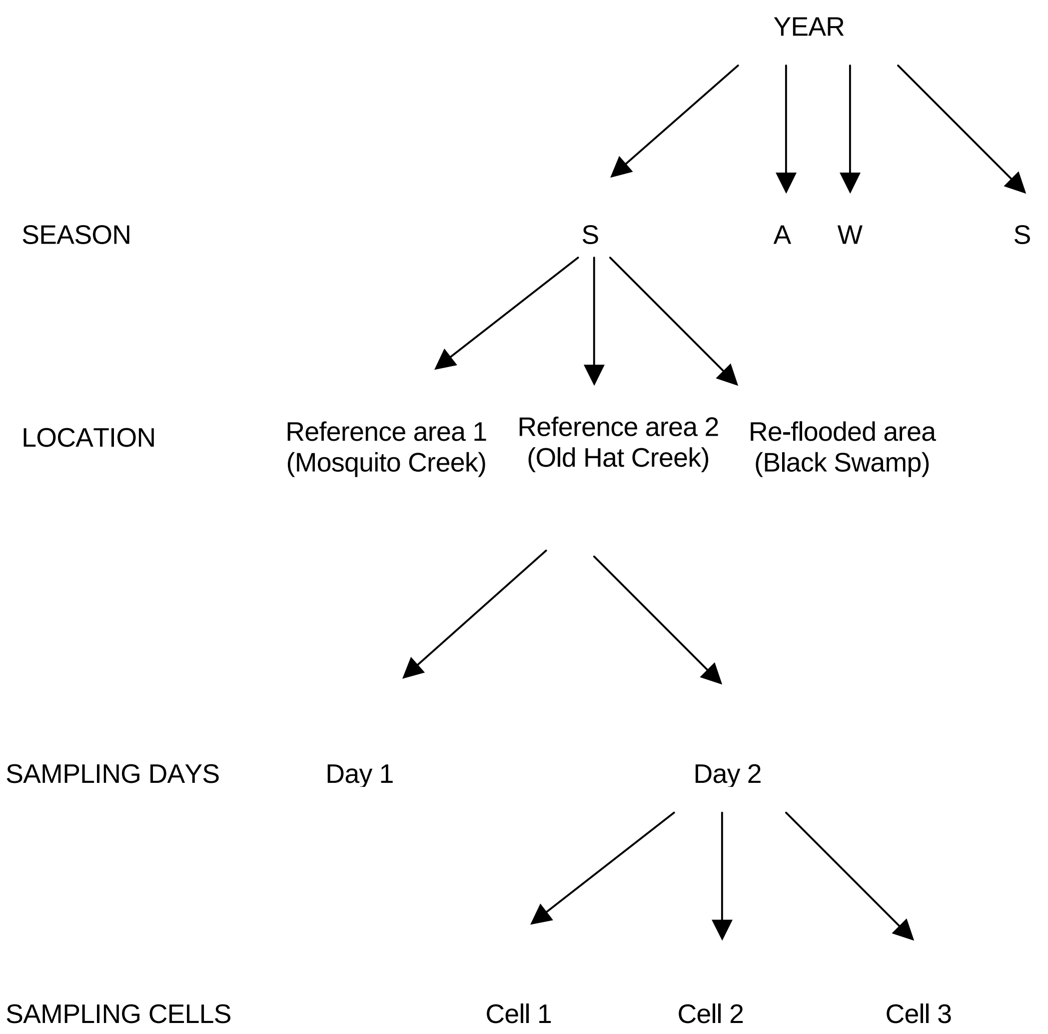


Figure 6-1 A schematic diagram of the experimental design

6.1.2 Selection of Sampling Sites

As per FRDC approved alterations to the sampling design, areas of mangrove habitat were not sampled immediately 'adjacent' to Black Swamp. Primarily, this was due to the fact that any significant stands of mangroves were absent immediately adjacent (i.e. next to) the seawall. Instead, two reference locations were chosen to be sampled at: (1) Mosquito Creek (situated ~ two (2) kilometres north of Black Swamp), and; (2) Old Hat Creek (situated ~ six (6) kilometres north of

Black Swamp) (Figure 6-4). These two reference sites were chosen as they were perceived to be similar in forest structure to mangroves forests that inhabited Black Swamp prior to the reclamation of this land during the 1920's; Mangroves at Mosquito and Old Hat Creeks are currently comprised exclusively of low closed *Avicennia marina* forest (Grey Mangrove). These sites were also considered to share topographical similarities and would also receive comparable tidal exchange as Black Swamp, (i.e. following the removal of the seawall). These inferences were based on the consultation of historical photos, literature, current aerial photos and inspections of the sites, which provided evidence of the similarity of these mangrove forests and the associated structural features of these habitats.

Black Swamp currently consists of terrestrial vegetation and one small area of brackish wetland (approx. 20 m^2), which occurs adjacent to the floodgates. However, when re-flooded, Black Swamp would consist of a vegetated intertidal area that drains into a narrow sub-tidal channel approximately two (2) metres wide and one (1) metre deep. It is generally considered that fish enter and exit mangrove areas via these channels (e.g., Laegdsgaard and Johnson, 1995).

6.1.3 Timing of sampling

Initial observations showed that the mangrove forest was only fully inundated during spring tides of at least 2.2 metres (Port Welshpool datum). Thus, sampling was targeted around these spring tides.

The initial frequency of sampling was two days at each site every three months. Sites were not sampled on consecutive days as previous work has shown that sampling at the same site on consecutive days with the apparatus being used results in depletion of the second day's sample (Halliday and Young, 1996), i.e. Mosquito Creek was sampled on nights 1 and 3 and Old Hat Creek was sampled on nights 2 and 4.

After 12 months the sampling frequency was reviewed and it was found that the catches from the second night of sampling were not independent of the first nights catch and so from August 2002 sampling effort was reduced to one night per site per quarter.

6.1.4 Netting Approach and Apparatus

The fish capture netting approach used was that of "block-netting" (e.g. Burchmore *et al*., 1984; Morton, 1990; Halliday and Young, 1996). This technique involves establishing a series of permanent fences running perpendicular to the shoreline to enclose a pre-defined intertidal area.

The technique has advantages over other methods of sampling such as seine netting and beam trawling. They include, allowing for sampling over a known area of habitat, which allows determination of the total fish density per unit area, the ability to catch a wide size range of both pelagic and demersal fish including those that are larger and more mobile, and being efficient within highly structured habitats such as mangrove forests.

6.1.4.1 Construction of cells

At each of the two reference sites three adjacent cells were established (Figure 6-2 and Figure 6-3). The cells were constructed of permanent fences made from nylon hail net 18-mm stretched mesh and 1.2 metres high and extending from low tide level to high tide level (i.e. the upper and lower margin of the mangrove fringe) The netting material was supported and kept taut by wooden stakes spaced at intervals of approximately five metres. The netting itself does not entangle or enmesh fish. The permanent fences were set 25 metres apart and extend from the sub-tidal edge of the mangroves to the spring high tide mark. The lengths of the fences were approximately 25 metres at Mosquito Creek and 30 metres at Old Hat Creek. Importantly, during non-sampling periods fish can move in and out of the sampling area.

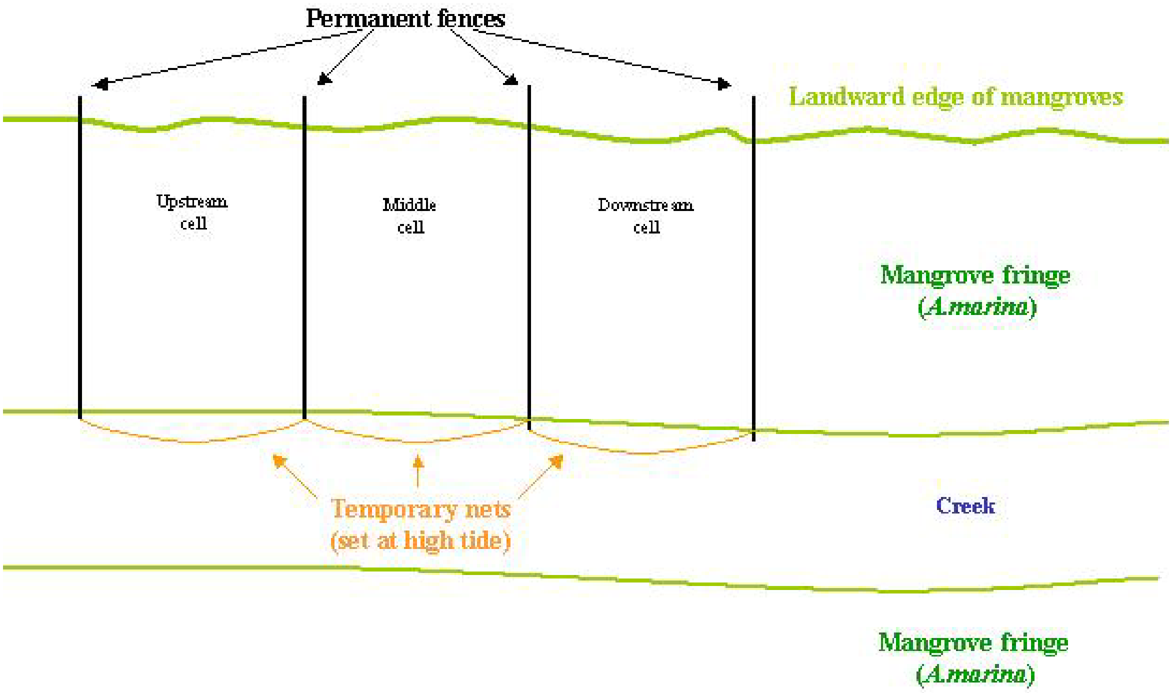
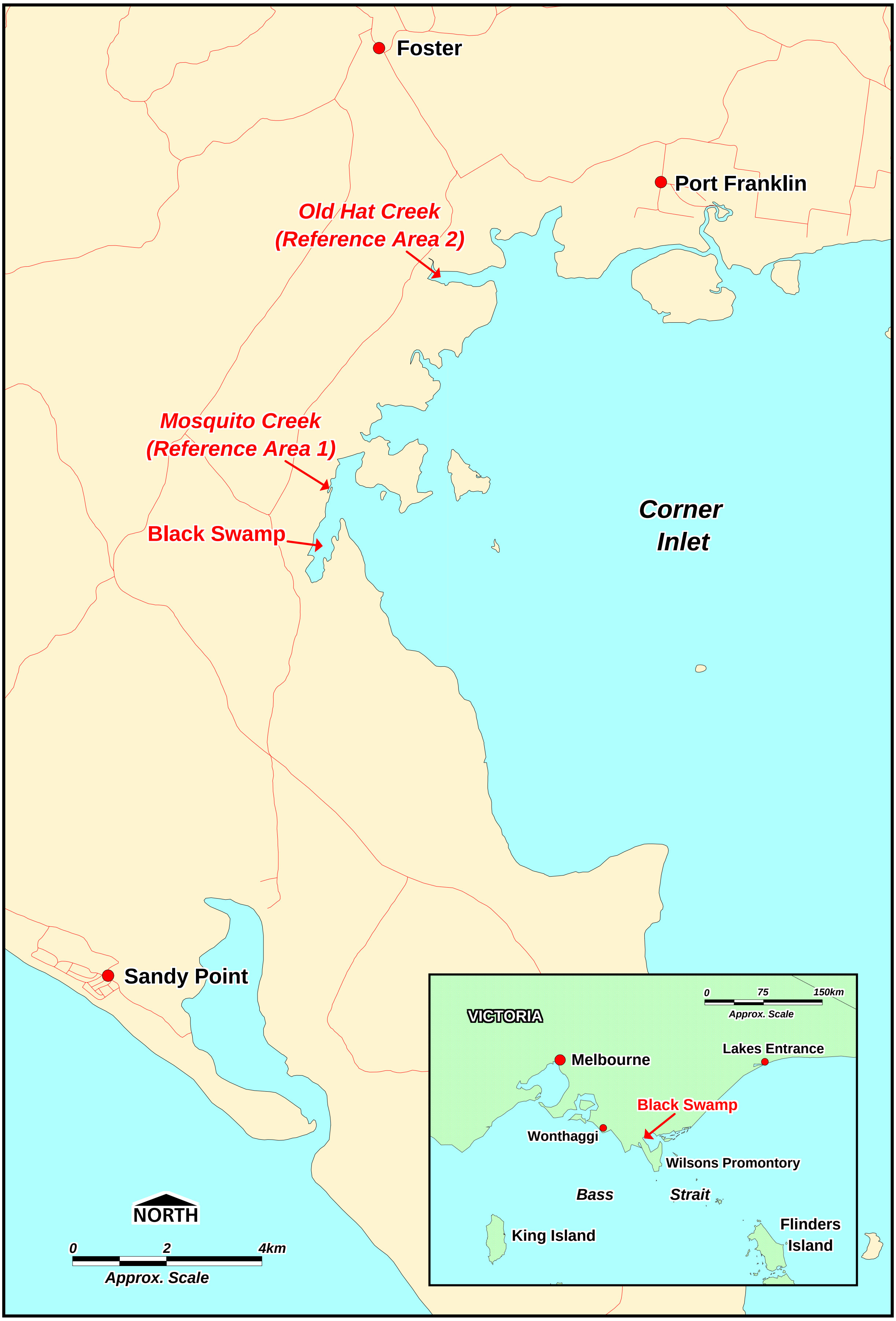


Figure 6-2 A schematic diagram of the block netting arrangement

Figure 6-3 Permanent fence making up one side of a sampling cell at Reference Location (2): Old Hat Creek (landward end)



Location of Black Swamp and Reference Areas at Mosquito Creek (1) and Old Hat Creek (2) within Corner Inlet, Victoria. Figure 6-4

6.1.4.2 Setting the nets

During the sampling period, a monofilament net was placed across the mouth of each cell (on the sub-tidal edge) at high tide. The nets were 30 metres long with a mesh size of 10 mm and a drop of two metres and were deployed from a small dinghy. Each net had a cod end in the centre, which was approximately five (5) metres in length. As the tide ebbed, fish moved from the mangrove areas and were trapped in the net and captured. Most fish moved along the net and into the cod-end, which remains submerged at low tide, without becoming entangled in the net mesh.

Discussions with local fishers indicated that fish moved out of the mangroves immediately after the top of the tide. During sampling, care was therefore taken to ensure that all nets were set prior to start of the ebb tide run-out. At each Reference site, tidal flow was readily discerned within the creek, ensuring that nets were not set after the tide had started to ebb. To date, the best (i.e. highest) tides for fishing occurred in the early morning. On those occasions when two suitable tides occured in a single day the early morning tide was chosen for sampling.

A pilot field trial of techniques for setting and retrieving the nets was conducted in August 2001. Results from the trial, along with discussions with commercial fishers led to the refinement of the nets and the way they were set prior to the October 2001 sampling trip. To ensure the foot of the net remains in contact with the substrate at all times, mangrove pneumatophores growing across the mouth of each cell were regularly trimmed to prevent entangling the net. The foot of each net was well weighted to ensure there were no openings through which fish could have escaped.

6.1.4.3 Emptying the nets

Nets were emptied when the lead-line became visible above the water level – generally the bottom of each tide. The lead-line was checked to ensure no fish remain outside the cod-end and to assess how well each net closed off each cell. The cod-end of each net generally remains below the low tide level ensuring fish within the cod-end remain submerged. Fish were emptied from the cod-end into a water-filled container prior to being identified to species, measured (cm standard length) and released. Nets were then retrieved, checked for holes and prepared for their next use.

Figure 6-5 Emptying monofilament nets set at Reference Location (2): Old Hat Creek

6.1.5 Additional investigations

In light of the consistently low catch rates at the two reference locations, a number of additional investigations were conducted in an attempt to assess the effectiveness of the sampling technique.

6.1.5.1 Cast netting

In October 2001 and February 2002, a cast net was used to sample within the channel of Old Hat and Mosquito Creeks. Ten casts were made at each Location on each sampling occasion to provide an indication of fish abundance in each of the creeks. Table 6-1 shows the results of the cast netting at each location.

Results from the cast netting exercise indicate that fish abundance within each creek was quite low. This was consistent with the low catches recorded from the block net sampling.

Table 6-1 Total Fish Captures from cast netting carried out in October 2001 and February 2002 at Old Hat Creek (OHC) and Mosquito Creek (MC)

	OHC	MC	OHC	MC	MC	OHC
Cast	**21/10/01**	**22/10/01**	**23/10/01**	**24/10/01**	**03/02/02**	**04/02/02**
1	0	0	4 tailor	0	0	0
2	0	0	1 toadfish	0	0	0
3	0	0	0	0	0	0
4	1 toadfish	2 toadfish	0	0	0	0
5	0	1 toadfish	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	1 goby
10	1 toadfish	0	0	0	1 toadfish	0

6.1.5.2 Catch efficiency

In October 2001 a preliminary investigation into the catch efficiency of the block nets in Mosquito Creek was carried out. The 4 tailor captured during the cast netting exercise were released into the Downstream cell at Mosquito Creek. All four were recaptured when the net was emptied at low tide indicating the block netting technique had a high efficiency. It is acknowledged that the small number of fish used in this test limits the confidence with which any conclusions can be made about the efficiency of the technique.

6.1.6 Statistical Procedures

Data were analysed using multivariate and univariate procedures. Differences in fish assemblages were examined with multivariate procedures described by Clarke (1993). For all analyses, raw data were initially transformed (4^{th} root) and a similarity matrix was generated using the Bray-Curtis measure of similarity.

Spatial variation in the fish assemblages was presented graphically using multidimensional scaling (MDS) ordinations (Clarke 1993). A stress value was presented for the ordination as a measure of how well it satisfied all the conditions of its rank similarity matrix. This value is not indicative of any measure of environmental-stress, rather, a value of < 0.1 indicates that the ordination has represented accurately the relationships among the samples, but values closer to 0.2 indicate that the ordination may have misrepresented the data in high dimensional space.

Groupings produced by cluster analysis (group average cluster analysis procedure; Krebs 1989; Clarke and Warwick 2001) at different levels of similarity were superimposed on nMDS ordinations. This approach allows a check of the adequacy of the ordination in presenting multivariate patterns in 2-dimensional space; and also provides a semi-quantitative basis for identifying patterns in assemblages structure.

Patterns in community structure were analysed using a number of diversity indices, including Shannon diversity *H'* (Log_e), number of species (*S*) and Pielou's evenness (*J'*).

6.2 Habitat Characteristics

6.2.1 Marine Benthic Flora

Tidal wetlands (i.e. mangroves and saltmarsh) at each reference location (i.e. adjacent sites) were characterised in terms of their species composition according to Walker and Hopkins (1984) classification of vegetation structural formations. Seagrass, mangrove and saltmarsh communities of Corner Inlet were characterised through a series of searches and reviews of the most current literature and marine vegetation mapping.

6.2.2 Characterisation of Sediments

A qualitative assessment of the nature of the surface sediments at each location was recorded based on standard geotechnical classifications (e.g. sandy clay – see McDonald *et al* 1984 pp. 94-5) with other factors (eg. strongly anoxic sediment) recorded where required.

7 RESULTS

7.1 Habitat Characteristics

7.1.1 Current Wetland Habitats

Mangrove and saltmarsh habitats within the Corner Inlet/ Nooramunga region were mapped in 1998 by the Victorian Marine Board for the purpose of oil spill response planning and the development of the Oil Spill Response Atlas (OSRA). Seagrass extent and species distributions were mapped by Roob *et al*. (1998) as part of the Victorian Marine Habitat Database.

Corner Inlet was a shallow, largely enclosed embayment, which contained a diversity of intertidal and subtidal wetland habitats, notably: mangroves, saltmarsh and seagrass (Table 7-1). The reclaimed area at Black Swamp was located in the north-east corner of Corner Inlet and consisted of terrestrial vegetation (i.e. grazing land) and one small area of brackish wetland (approx. 20 m^2) which was situated adjacent to the seawall floodgates. If re-flooded, however, Black Swamp would consist of a vegetated intertidal area that would drain into a narrow sub-tidal channel approximately two (2) metres wide and one (1) metre deep.

Mangrove forests within Corner Inlet were at the lowest end of the diversity scale in Australia, with only one (1) of 39 taxa being present, namely: *Avicennia marina* (the Grey or White mangrove). Mangroves in this region form low and dense closed forests, between 1 and 3 metress in height, and generally inhabit the zone between Mean Sea Level and Highest Astronomical Tide. They shared the upper intertidal niche with numerous saltmarsh species, notable examples including *Sarcocornia quinqueflora*, *Arthrocnemum arbuscula* and *Juncus maritimus*. Tidal inundation of these areas was greatest around Spring tides, where approximately 30 cm of water covered the sediment surface at the deepest point (i.e. the seaward mangrove fringe).

Of these two habitat types, saltmarsh dominated in terms of its ground coverage extent in Corner Inlet. The lower intertidal zone (typically below mean sea level) was typically inhabited by two seagrass species, namely: *Heterozostera tasmanica* and *Zostera muelleri*. Combined, these two species represented the most abundant seagrasses in the region, accounting for 73 % of the current aerial extent (Roob *et al.* 1998). Subtidal regions were typically occupied by *Posidonia australis* and *Halophila australis*.

Areas of mangrove and saltmarsh located nearest to Black Swamp occured approximately 1-2 km to the north (i.e. at Mosquito Creek – Reference Area 1) and northeast (i.e. to the east and west of Port Franklin). To the south of Black Swamp, no significant areas of mangrove or saltmarsh existed along the coast of Corner Inlet.

With the exception of few small patches, seagrasses were largely absent within a 2-3 kilometer band along the coastline between Black Swamp and Old Hat Creek in the north west region of Corner Inlet. To the east and south east of these unvegetated coastal areas, seagrass beds were dense and occured in multispecific communities.

Historically, the greatest threats to intertidal fish habitats (i.e. mangroves and saltmarsh) has been the clearing and/ or impounding of these areas for agricultural use (grazing). While these physical disturbances are not thought to comprise a significant threat at the present time, many sea walls are still present within the inlet, including at the mouth of Black Swamp.

Table 7-1 The extent and composition of tidal wetland/ fisheries habitats in the Corner Inlet/ Nooramunga region, Victoria.

Wetland Habitat	Total Area in Corner Inlet/ Nooramunga (Hectares)	Species	Source
Mangroves	2, 572	*Avicennia marina*	Marine Board of Victoria 1998
Saltmarsh	5, 060	*Sarcocornia quinqueflora* *Arthrocnemum arbuscula* *Juncus maritimus*	Marine Board of Victoria 1998
Seagrass	10, 999.15 21.02 3, 196.41 675.47	*Zostera muelleri* *Heterozostera tasmanica* *Halophila australis* *Posidonia australis* Mixed species communities	Roob *et al* 1998

7.1.2 Sediment Characteristics

Mosquito Creek

At the seaward margin of the mangroves, sediments consisted of fine unconsolidated marine clay to a depth of approximately 1m. This clay was underlain by a medium-grained (1-10mm diameter) alluvial gravel. Progressing landward through the mangroves the clay layer reduced in depth and more gravel was evident at the surface.

At the landward margin of the mangroves and on the claypan immediately behind the mangroves, the clay layer was reduced to only 5-100mm deep and much of the surface had a gravel texture and appearance.

Old Hat Creek

At the seaward margin of the mangroves, sediments consisted of fine unconsolidated marine clay to beyond the depth of probing (at least 1-1.5m), but increasing in compaction with depth. Progressing landward through the mangroves the clay layer continues, although becoming progressively compacted and more consolidated. At the landward margin of the mangroves the clay was firm enough to walk on without sinking. Sediments in this area were consolidated by the growth of salt couch and other salt marsh species.

7.2 Fish Sampling

7.2.1 Sampling Design and Implementation

Restoration of tidal flow to Black Swamp was to have been completed in early 2002, however, difficulties in obtaining agreement/permission from all affected landowners prevented this from occurring and it appeared unlikely that restoration will commence in the foreseeable future. It was therefore proposed that the monitoring project be suspended indefinitely.

Baseline sampling commenced in August 2001 on the basis that two (2) to three (3) sampling episodes would be carried out prior to re-flooding to provide a baseline dataset. Despite the delay in re-flooding, the baseline sampling continued on a quarterly basis until November 2002 on the understanding that re-flooding of the Swamp was imminent. With the delay in re-flooding and the proposed suspension of the monitoring project there is uncertainty as to the applicability of the current dataset to be used as baseline data given the delay (likely to be 12-18 months) between its collection and the re-implementation of the monitoring program.

A third party reviewer, Dr Rod Connolly, was commissioned to examine this, and other issues that have arisen with respect to the study methodology and results to date. This review, including future recommendations made by Dr Connolly are included in Appendix D of this report.

The following factors were examined in the review:

- **General methodology**: a review of the statistical validity of the sampling design of the project;
- **Results to date**: Catches from the baseline sampling carried out at the two Control sites were lower than expected. There was some concern that the low abundances will restrict the ability to detect a difference between sites and/or time periods. The review examined if this was the case and made recommendations as to whether sampling should continue on the basis that catch rates would continue to be small. Should it be deemed inappropriate to continue sampling, the reviewer assessed the potential for publication of the existing dataset
- **Delay in re-introduction of tidal water to Black Swamp**: The review assessed whether data collected to date could still be considered relevant baseline data if the re-flooding of Black Swamp is delayed for 12 to 18 months. This aspect of the review also assessed the need for additional baseline sampling immediately prior to flooding (eg one quarterly sampling episode to be conducted prior to re-introduction of tidal water to Black Swamp).

Essentially, Dr Connolly did not consider it important to do any further pre-flood sampling and, thus, no further sampling was done after the November 2002 episode. Several alterations to the current experimental design and suggestions for post-flooding sampling were presented and are detailed in the reviewer's report (Appendix D). It was considered by the reviewer, however, that the existing data might, in itself, provide useful information on the utilisation of mangrove habitat in southern Australia, the current understanding of which is limited.

7.2.2 General

Fish catches from baseline sampling conducted from October 2001 to November 2002 at Mosquito Creek and Old Hat Creek are summarised in Table 7-2. Data were pooled across sampling cells and between sampling days. Raw data are provided in digital form with this report (see Appendix C). No univariate statistical analyses were done due to consistently low numbers of fish captures, and the associated low statistical power of tests.

Table 7-2 Total number of individuals captured at Mosquito Creek (MC) and Old Hat Creek (OHC) on each sampling occasion.

FAMILY and *Species*	**Common name**	**Oct-01**		**Feb-02**		**May-02**		**Aug-02**		**Nov-02**		**TOTAL**
		MC	**OHC**	**MC**	**OHC**	**MC**	**OHC**	**MC**	**OHC**	**MC**	**OHC**	
ANGUILLIDAE												
Anguilla australis	Short-finned eel*	0	2	0	1	0	0	0	0	0	0	**3**
GALAXIIDAE												
Galaxias maculatus	Jolly-tail	1	0	0	0	0	0	0	0	0	0	**1**
SCORPAENIDAE												
Centropogon australis	Eastern fortesque	0	0	0	1	0	1	0	0	0	0	**2**
PLATYCEPHALIDAE												
Platycephalus speculator	Southern blue-spot flathead*	0	1	0	0	0	0	0	0	0	0	**1**
PERCICHTHYIDAE												
Macquaria novemaculeata	Australian bass*	1	0	0	0	0	0	0	0	0	0	**1**
POMATOMIDAE												
Pomatomus saltatrix	Tailor*	0	3	0	0	0	0	0	0	0	0	**3**
GIRELLIDAE												
Girella tricuspidate	Luderick*	0	0	0	0	0	1	0	0	0	0	**1**
MUGILIDAE												
Mugil cephalus	Sea mullet*	1	5	3	2	0	0	0	0	0	0	**11**
Aldrichetta forsteri	Yellow-eye mullet*	43	24	21	7	0	37	0	1	18	2	**153**
Myxus elongatus	Sand mullet*	0	0	0	0	0	1	0	0	0	0	**1**
BOVICHTHYIDAE												
Bovichthys variegates	Dragonet	0	0	0	1	0	0	0	0	0	0	**1**
GOBIIDAE												
Favonigobius lateralis	Long-finned goby	0	1	0	3	1	4	0	0	0	0	**9**
Nesogobius pulchellus	Castelnau's Goby	0	0	0	0	1	0	0	0	0	0	**1**
PLEURONECTIDAE												
Rhombosolea tapirina	Greenback flounder*	1	0	0	4	0	0	0	1	4	4	**14**
MONOCANTHIDAE												
Scobinichthys granulatus	Rough leatherjacket*	0	0	1	0	0	0	0	0	0	0	**1**
Brachaluteres jacksonianus	Pygmy leatherjacket	0	0	0	0	0	1	0	0	0	0	**1**
TETRAODONTIDAE												
Tetractenos glabar	Smooth toadfish	24	166	11	41	0	0	0	5	3	36	**286**
TOTAL		**71**	**202**	**36**	**60**	**2**	**45**	**0**	**7**	**25**	**42**	**490**

Asterisk (*) denotes species of economic importance

Sampling at Old Hat Creek and Mosquito Creek between October 2001 and November 2002 yielded a total of 490 fish from 17 species and 13 families. Overall, the total number of captures at Old Hat Creek (356 individuals representing 13 species) was higher than Mosquito Creek (134 individuals representing 9 species). The number of individuals (Figure 7-1) and species (Figure 7-2) was also typically higher at Old Hat Creek than Mosquito Creek on each sampling occasion. The exception to this was in November 2002, with the same number of species (3 species) captured at both locations (Figure 7-2).

Toadfish (*Tetractenos glabar*) and Yellow-eye mullet (*Aldrichetta forsteri*) numerically dominated the fish assemblages at both locations on all sampling occasions. These two species comprised ≥78% of the total fish abundance during each sampling period at each location. Ten of the captured species were of direct economic importance, namely Yellow-eye mullet, Greenback flounder (*Rhombosolea tapirina*), Sea mullet (*Mugil cephalus*), Sand mullet (*Myxus elongatus*), Luderick (*Girella tricuspidate*), Australian bass (*Macquaria novemaculeata*), Tailor (*Pomatomus saltatrix*), Rough leatherjacket (*Scobinichthys granulatus*), Short-finned eel (*Anguilla australis*) and Southern blue-spot flathead (*Platycephalus speculator*). Most species captured were present as juveniles although some adult Yellow-eye mullet (26-31 cm SL) were also captured.

7.2.3 Patterns in Community Structure and Diversity

The graphs below show the total number of individuals (Figure 7-1), total number of species (Figure 7-2), Shannon diversity (Figure 7-3) and Pielou's evenness (Figure 7-4) for each site and sampling occasion (data pooled across cell blocks within sites).

Figure 7-1 shows that the highest number of captures recorded at both sites occurred on the second night of sampling of the October 2001 sampling episode. On other sampling occasions, fish captures were higher on the first compared to the second night of sampling. At both sites, the winter (May and August) sampling episodes yielded far lower catches than October/November and February sampling episodes.

The mangrove forests of the study area had impoverished fish assemblages. Species richness was consistently low (0-6 species/site/sampling episode) numbers of species recorded on each occasion. As shown in Figure 7-2, species richness was highest (8 species) during the February 2002 survey at Old Hat Creek. The number of species at sites where fish were captured (i.e. excluding Mosquito Creek, August 2002) ranged from 2 to 8. With the exception of the November 2002 sampling episode, the number of species was consistently greatest at Old Hat Creek, the most distal site to Black Swamp of the two Reference Locations.

Species diversity, as measured using the Shannon *H'* and Pielou's *J'* indices, was relatively similar across sites and sampling episodes. The numerical dominance of two species (Toadfish *Tetractenos glabar* and Yellow-eye mull*et aldrichetta forsteri*) resulted in consistently low Shannon diversity values on all occasions.

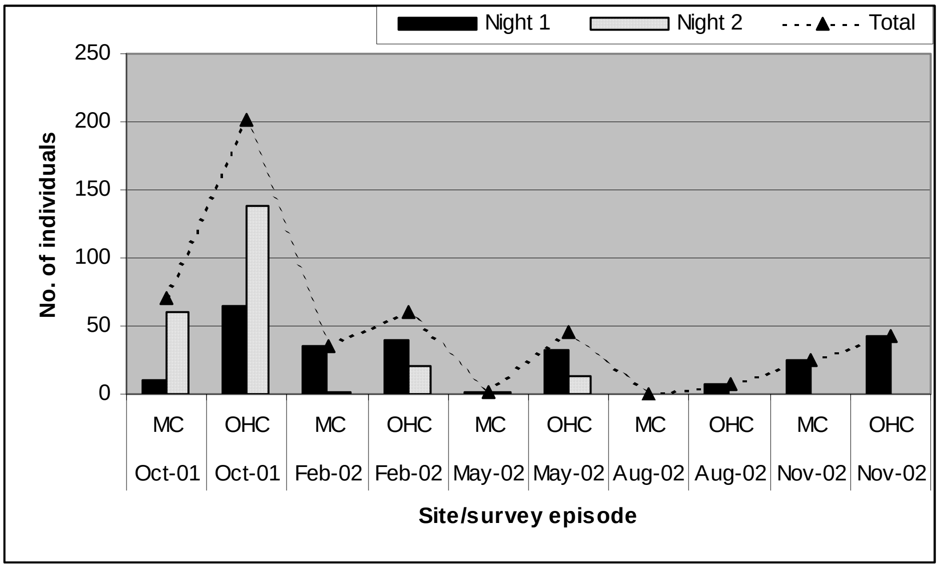


Figure 7-1 Total Fish Captures at (1) Mosquito Creek (MC) and (2) Old Hat Creek (OHC); between October 2001 and November 2002.

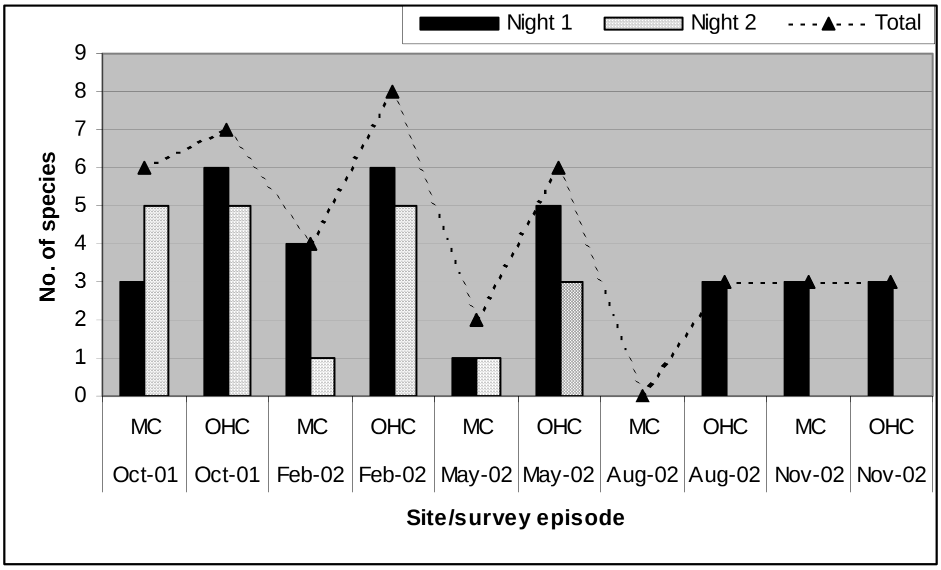


Figure 7-2 Total no. of Species Captured at (1) Mosquito Creek (MC) and (2) Old Hat Creek (OHC); between October 2001 and November 2002.

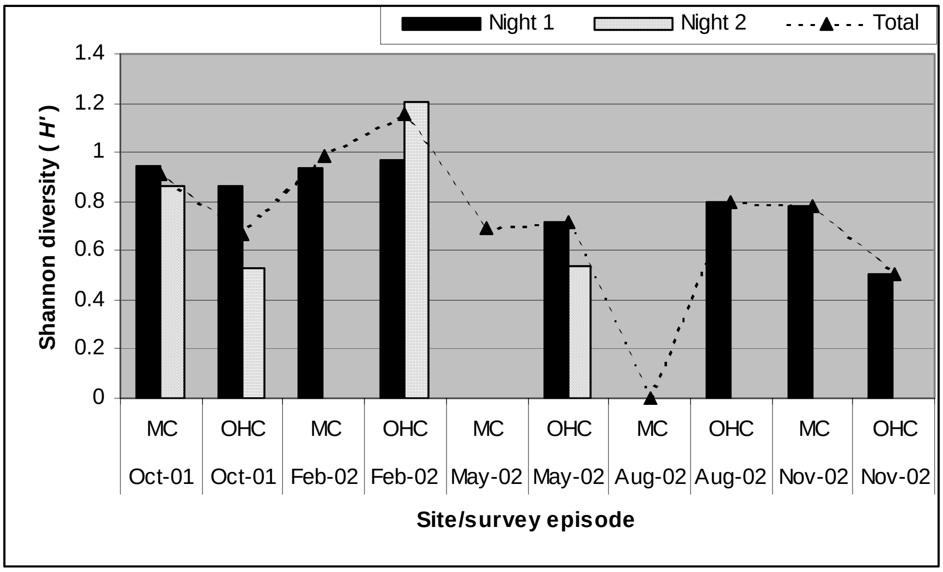


Figure 7-3 Shannon Diversity [H'(Log_e)] of fish catches at (1) Mosquito Creek (MC) and (2) Old Hat Creek (OHC); between October 2001 and November 2002.

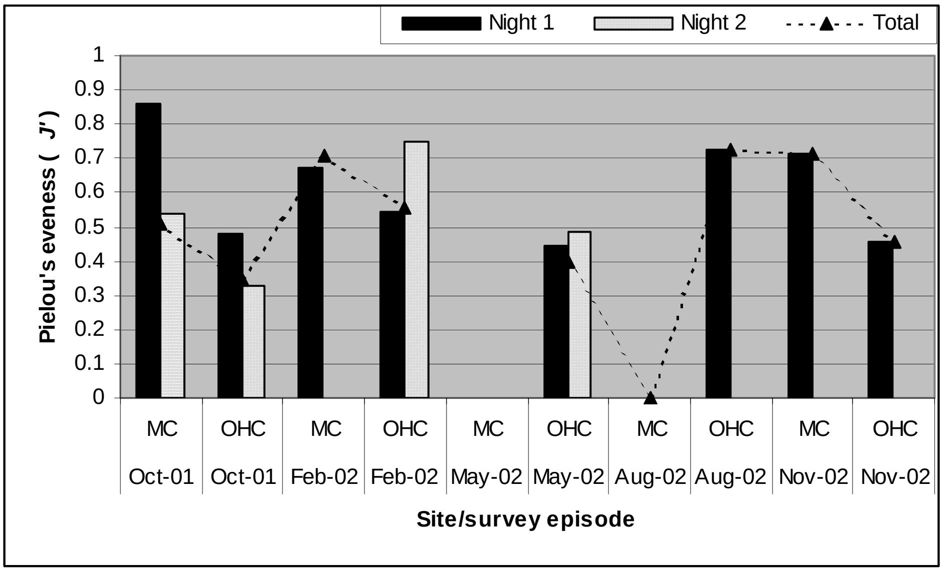
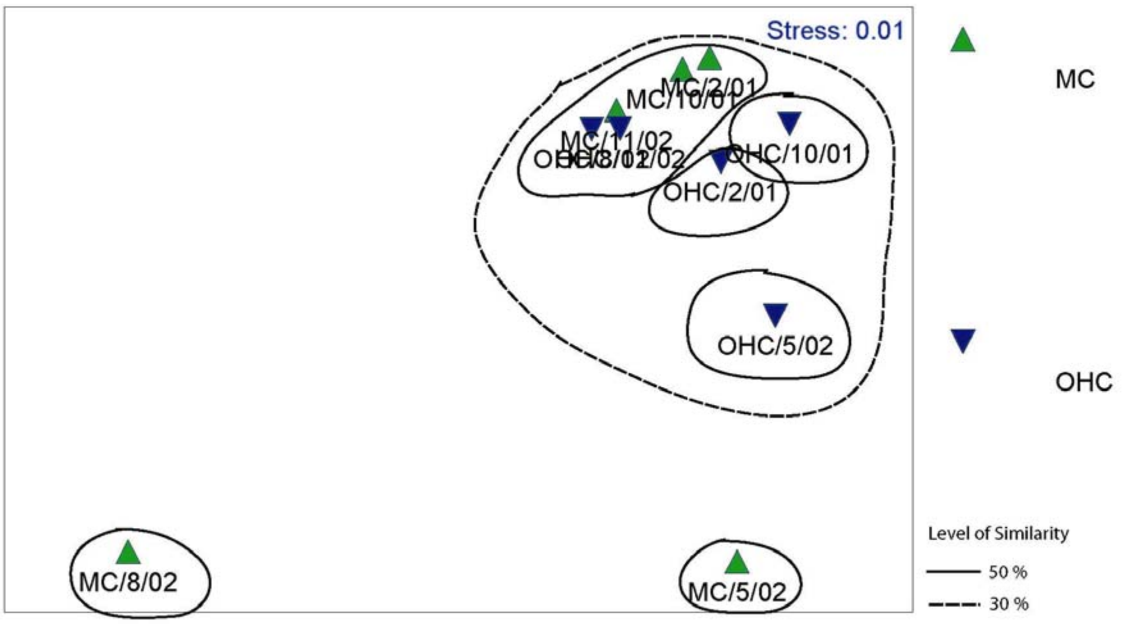


Figure 7-4 Pielou's evenness (*J'*) of total fish catches at (1) Mosquito Creek (MC) and (2) Old Hat Creek (OHC); between October 2001 and November 2002.

Figure 7-5 presents the results of nMDS performed on 4th root transformed abundance data for each site and sampling occasion. Mosquito Creek and Old Hat Creek did not form entirely separate groupings at the 30 or 50 % level of similarity, indicating that there were no differences in fish community structure between sites. Furthermore, no consistent pattern in temporal variation in fish community structure was evident within sampling sites.



Labels: MC = Mosquito Creek; OHC = Old Hat Creek; numbers after location label represent month and year sampling episode.

Figure 7-5 nMDS ordination with groupings produced by cluster analysis (average linkage method) superimposed.

8 DISCUSSION

Wetland habitats (i.e. mangroves, seagrass, saltmarsh, mudflats) are utilised by many fish species of direct commercial and recreational fisheries value (Robertson and Duke, 1987; Morton, 1990; Robertson & Alongi, 1995). Studies done in tropical and sub-tropical mangroves forests have recorded rich and abundant fish assemblages (eg. Blaber *et al.*, 1990 a, b; Salini *et al.*, 1990; Morton 1990; Brewer *et al.*, 1991; Laegdsgaard and Johnson 1995; Halliday and Young, 1996; Kathiresan and Bingham 2001). Comparatively few studies have been done in temperate Australian mangrove forests (eg. Bell *et al.*1984; Clynick and Chapman 2002).

On the basis of these studies, there is a widely accepted view that mangroves and other estuarine wetland vegetation are critical habitats for fish species of direct commercial value (Odum and Heald, 1975a; Morton, 1990). The loss of mangroves and other estuarine vegetation, due to a variety of human pressures, has been cited as a major cause of reductions in estuarine fish stocks in Australia. Implicit in this argument is that habitat is a major limitation on fish populations.

Consequently, legislation has been enacted in most Australian states the preserve and protect existing estuarine vegetation, primarily for the purpose of maintaining fish stocks. Furthermore, the last decade has seen increased interest by fisheries managers in rehabilitating damaged estuarine wetland areas (review by Skilleter 1998).

Several fish species of commercial significance identified by MacDonald (1997) and Hall and MacDonald (1986) in the Corner Inlet region were captured in the current surveys, including yellow-eye mullet, greenback flounder (*Rhombosolea tapirina*), sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*), short-finned eel (*Anguilla australis*), and southern blue-spot flathead (*Platycephalus speculator*). The greenback flounder, sea mullet and tailor captured were all juveniles. Notably, no sharks were recorded in the current survey.

The low catch returns are likely to reflect low numbers of fish utilising mangrove areas, and possibly sampling error. In the case of sampling error, it is possible that some fish may have remained within small pools (mostly ray wallows) within the mangrove forest at low tide, and therefore avoided capture. However, based on visual observations of only low numbers of fish (2 individuals) in the shallow pools during low tide, it is considered likely that the large majority of fish within these sampling cells would have been captured. The low numbers of fish captured are therefore likely to be representative of low actual abundances of fish utilising these mangrove areas.

The low numbers of fish recorded in the present study challenge the paradigm that all mangrove habitats represent important fish and shark habitats. Compared to tropical and sub-tropical mangrove communities in Queensland, species richness (17 species recorded) and abundances at Corner Inlet were low. Two species of fish were consistently numerically dominant: Toadfish (*Tetractenos glabar*) and yellow eye mullet (*Aldrichetta forsteri*), comprising ≥78% of the total fish abundance during each sampling period at each location. All other species were represented by ≤4 individuals on each occasion. Although far from conclusive given the limited spatial replication of the sampling program and the absence of sampling in other habitat types, the low catches recorded in the present study do not support the argument that mangrove forests consistently represent important fish habitats.

There is an emerging view that not all mangrove forests have fish habitat values (reviewed by Skilleter 1998). For example, in one of the few studies of temperate mangrove forests in Australia, Clynick and Chapman (2002) found mean abundances and richness of fish were similar between mangroves forests and adjacent mudflats within Sydney Harbour. On the basis of these results, they concluded that the small mangrove forests sampled were not more important fish habitats than unvegetated substrates.

Due to the limited timeframe and spatial replication of the present study, it is not possible to determine whether the strength of fish-habitat associations varies among different geographic regions, that is, between tropical and temperate environments. Mangrove forests in temperate areas are generally smaller, both in terms of patch size and canopy height and have lower species richness than tropical and subtropical forests. The composition and richness of fish assemblages also varies between tropical and temperate estuaries. Geographic variations in both habitat and fish community structure may result in quite different patterns in fish-habitat associations between geographic regions (Clynick and Chapman 2002). Further studies in other temperate mangrove forests are required to test whether this is a general pattern in temperate regions.

Skilleter (1998) argues that the available data does not support the assumption that all sites containing a particular type of habitat are of equal value as a nursery, and are therefore of equal value for conservation. For example, McNeil *et al* (1992) found enormous variation in fish assemblages among and within (temporal) seagrass beds in Botany Bay, New South Wales. McNeil *et al* (1992) also found that one seagrass bed in particular received larger numbers of recruits (up to 73 times greater) than nearby beds, and thus may function as a population 'sink' for fish. This 'hotspot' for recruitment was thought to be particularly important in terms of its conservation value over nearby sampled areas.

This is partly analogous to results of the present study, as more fish were captured at Old Hat Creek than Mosquito Creek on all sampling occasions. Several factors are thought to produce this 'patchiness' of habitat usage by fish in mangroves over space and time. These include, for example, the proximity of mangroves to seagrass beds (the latter may act as sources and sinks of migrating larval, juvenile and adult populations), local recruitment supply or spawning (a function of the local hydrodynamics, currents etc.), and the intra- (seasonal) and inter-annual variation in recruitment supply (*see* Skilleter 1999 *for a review*). Ultimately, the processes that determine the 'value' of a particular patch of habitat, and the spatial and temporal scales at which any patterns might exist are not well understood and require further investigation.

One potentially critical factor influencing the habitat value of a particular mangrove area is the degree to which it is tidally inundated. At Old Hat and Mosquito Creeks, mangrove forests were inundated only during spring tides, and only to water depths of 0.3 m at the seaward fringe of mangroves (i.e. at the deepest point). Within mangrove forests, mangrove pneumatophores extended up to 0.15 m above the substrate, thereby providing <0.15 m of open water at the top of the spring tide. The limited available open water habitat within mangrove forests, together with the infrequent tidal inundation (Spring tide only), would appear to greatly limit the fish habitat values of these mangrove forests. It should be recognised, however, that these mangrove forests are likely to have other important roles in the maintenance of the local and broader coastal ecosystems of the region.

Few published studies have examined temporal patterns in fish-habitat associations in temperate Australian estuaries. The results of the present study recorded consistently low numbers of fish species at both locations on all sampling occasions. Within both locations, the number of individuals was higher in warmer compared to cooler months. Further sampling over time would be required to determine whether there are distinct seasonal changes in fish abundances.

The shark fishing industry initiative to inundate Black Swamp with seawater is the first attempt at rehabilitation of a potential school shark nursery area. It is notable that not a single individual of the target species in this study (School and Gummy sharks) was captured in the mangroves. This result, however, is unlikely to be representative of the habitat use of these sharks in the Corner Inlet region, given the small sample size (i.e. cell block sizes) and the local area of potentially suitable habitat. It is extremely difficult to make comments on the habitat usage of mangroves by school and gummy shark populations without further replicated sampling at more locations within the desired area (*see* Section 9-2).

It is debatable whether local fishers were correct in suggesting the sharks entered the mangrove forests, or were simply observed in the shallow waters of Corner Inlet. The current understanding of Gummy shark ‘nursery’ areas in shallow waters of southern Australia is limited (Kaihola 1993). Several school shark shallow water ‘nursery’ areas have been identified in Tasmania and in areas near Portarlington and Port Phillip Bay in Victoria (Kaihola 1993). These sharks are thought to remain in coastal waters until the late summer months and gradually move to deeper coastal waters to over-winter.

9 RECOMMENDATIONS FOR FUTURE MONITORING

The aim of this section is to outline an appropriate sampling design that could provide a statistically valid representation of the long-term monitoring of progress following tidal restoration to Black Swamp – a potential fisheries habitat.

9.1 Fish Sampling

Quantitative fish sampling is extremely difficult in mangrove habitats. The block netting method adopted in this study has been demonstrated to provide a sound sampling method in mangrove forests (see Halliday and Young 1996), despite being difficult to initially set-up. The present study replicated the scale of nets/netting within locations, and between locations within times of study. However, sampling cells within locations cannot be considered independent samples, as the walls of each cell were directly adjacent to, and therefore were potentially affected by, the walls of the adjacent cell. This does present restrictions of the types of analyses that can be employed. Any future sampling programs should consider the potentially confounding effects of block-netting with respect to pseudo-replication of samples within sites.

A simplified survey design, examining the recolonisation (i.e. habitat use) of fish assemblages of the reflooded habitat over time, would be favourable and would require less sampling effort and spatial replication to achieve a similarly robust result. A comparison of fish utilization of adjacent habitats would still be possible and may be made in the future, following significant revegetation of wetland habitats of the flooded site to that comparable vegetation structure (expected to occur >10 years following tidal restoration). This further sampling episode would measure the ‘recovery’ of fish populations at Black Swamp relative to adjacent areas in Corner Inlet. Such a design, however, is suggested to adopt Wilson’s (1998) definition of ‘recovery’, which is a “lack of temporal change of biological variables at impact sites relative to control sites; said another way, recovery is thought to be complete when the impact site temporal trends parallel those at the reference site”. Therefore, replication of such a sampling design would have to occur at both multiple spatial and temporal scales.

9.1.1 Sampling Method

The netting approach used in the current study was that of “block-netting” (e.g. Burchmore *et al*., 1984; Morton, 1990; Halliday and Young, 1996). This technique proved to be successful and has advantages over other methods of sampling such as seine netting and beam trawling. They include; allowing for sampling over a known area of habitat (which allows determination of the total fish density per unit area); the ability to catch a wide size range of both pelagic and demersal fish including those that are larger and more mobile; and being efficient within highly structured habitats such as mangrove forests. It is therefore recommended that this method be employed in any future sampling designs, with one major modification: that Spatially independent replicates should be established in place of the previous sampling design where net walls of sampling cells were not independent (i.e. they had common walls). While this modification would increase the initial work effort to establish these blocks, it will remove any pseudoreplication as in the current study.

The cells were constructed of permanent fences made from nylon hail net 18-mm stretched mesh and 1.2 metres high and extending from low tide level to high tide level (i.e. the upper and lower margin of the mangrove fringe) The netting material was supported and kept taut by wooden stakes spaced at intervals of approximately five metres. The netting itself does not entangle or enmesh fish. The permanent fences are set 25 metres apart and extend from the sub-tidal edge of the mangroves to the spring high tide mark. The lengths of the fences would be approximately 25 metres. Importantly, during non-sampling periods fish can move in and out of the sampling area.

9.1.2 Selection of Sampling Sites

Four or more sampling locations within intertidal area should be established within Black Swamp following the restoration of tidal flow to this area.

9.1.3 Post Flooding Sampling

It is recommended that monitoring episodes of re-flooded areas be undertaken at 1, 2, 5 and 10 years after flooding, accounting for prediction that the rate of change in species composition and abundance will slow with time.

One sampling event is suggested for each monitoring occasion, as replicates will not be independent of one another. Furthermore, observations of areas of mangrove habitat within Corner Inlet showed that these forests were only fully inundated during spring tides of at least 2.2 metres (Port Welshpool datum). Thus, sampling must be targeted around these spring tides, consistent with the timing of sampling of the present study.

9.1.4 Fish Habitat Usage in Adjacent Wetland Areas

A comparison of fish habitat use in adjacent areas could be used to test the hypothesis that after a certain time, the flooded site will contain the same species and abundances of fish as other coastal areas of Corner Inlet. This would require sampling several adjacent, near and far sites, and comparing all sites in a one-way ANOVA model to see if the flooded site is different to all other sites. This can be done at a single time (but this should be many years after flooding, once marine vegetation has established at the flooded site).

If any comparisons between Black Swamp and adjacent wetland areas are to be made, their structure (i.e. species composition, and physical structure) and extent must first be assessed, as for any valid comparison to be made, sites must be of similar vegetation structure/habitat type (i.e. comparing mangroves and mangroves not intertidal mudflat and mangroves).

Multiple sites must be selected and must be situated either side (north and south) of Black Swamp to avoid any potential gradients of fish habitat usage along the shore.

9.2 Sediment and Wetland Vegetation Monitoring

9.2.1 Sediments

Quantitative monitoring assessments of Total Organic Carbon (TOC) and Particle Size Distribution (PSD) of sediments within sampling areas would be of benefit to future study outcomes during fish assessments (i.e. at each sampling occasion). It is also recommended that sampling be undertaken immediately prior to and shortly after tidal restoration. Aside from the pre-flooding sediment-sampling episode, the frequency of post-flooding sampling should be consistent with the timing of fish monitoring episodes (i.e. 1, 2, 5 and 10 years). It is suggested that replicated sampling of sediments will occur within each netting block.

9.2.2 Wetland Vegetation

Monitoring surveys of the structure and composition of recruitment (if any) in wetland vegetation (i.e. mangroves and saltmarsh) at Black Swamp are recommended to occur consistent with each fish assessment (i.e. at 1, 2, 5 and 10 years). This information is important as it provides a measure of changes to the structural complexity of the habitats as they become more suitable for fish utilisation. Furthermore, vegetation mapping using aerial photography should coincide with each sampling event.

10 PROJECT SUMMARY

10.1 Benefits and Adoption

This project provides quantitative data on the utilisation of temperate mangrove forests by fish, the current knowledge of which is limited. This study represents the most comprehensive assessment of fish-mangrove associations in Victorian waters to date.

Studies done in tropical and sub-tropical environments have found that mangrove forests represent important fish habitats. On the basis of these findings, fisheries managers throughout Australia have focused management efforts on the protection of these and other estuarine wetland habitats. Results of the present study support the emerging view that not all mangrove forests have equal fish habitat values.

Rehabilitation efforts of degraded wetland areas are commendable, and could potentially result in positive flow-on effects to estuarine ecosystems and fisheries productivity. Mangroves forests form a complex three-dimensional environment that provide breeding, growing, refuge, and feeding zones for marine organisms, some of which later migrate to adjacent coastal waters or to the ocean. Mangroves are also extremely productive and can provide organic matter that drives of detrital-based estuarine ecosystems.

Notwithstanding their potential values, the current knowledge base on fish-habitat associations in temperate environments is presently so lacking that there is a risk that rehabilitation effort may be misdirected, resulting in minimal measurable benefits to fish stocks. These information gaps must be recognised by fisheries resource managers when assigning conservation values to wetland habitats, and when directing rehabilitation efforts to degraded areas.

10.2 Further Development

There is a clear need for further investigations of the fish-habitat associations in temperate estuarine systems and for further studies on patterns of estuarine habitat use by temperate fish at different spatial and temporal scales. This information will be useful for determining how and why different estuarine habitats are utilised by different fish species, which will assist managers in identifying and prioritising funding for future rehabilitation works.

10.3 Conclusions

The shark fishing industry initiative to inundate Black Swamp with seawater was the first attempt at rehabilitation of a potential school shark nursery area. While no adult or juvenile school or gummy sharks were captured in this baseline survey, this result does not preclude the mangrove forests of Corner Inlet as a potential habitat for these individuals. In fact, it is extremely difficult to make comments on the habitat usage of mangroves by school and gummy shark populations without further replicated sampling at more locations within the desired area.

Wetland habitats (i.e. mangroves, seagrass, saltmarsh, mudflats) are utilised by many fish species of direct commercial and recreational fisheries value. The current study recorded several fish species of fisheries value at Mosquito and Old Hat Creeks, namely: yellow-eye mullet, greenback flounder, sea mullet, tailor, eel, and southern blue-spot flathead. Overall, the results of the present study challenge the paradigm that all mangrove habitats represent important fish habitats. Compared to tropical and sub-tropical mangrove communities in Queensland, species richness (17 species recorded) and abundances at Corner Inlet were low. Furthermore, two fish species were consistently numerically dominant: Toadfish (*Tetractenos glabar*) and Yellow eye mullet (*Aldrichetta forsteri*), comprising ≥78% of the total fish abundance during each sampling period at each location. All other species were represented by ≤4 individuals on each occasion.

This study supports the emerging view that coastal areas containing a particular type of wetland habitat, for example mangroves, are not of comparative equal value as a nursery, and are therefore not of equal value for conservation in terms of their fisheries 'values'. Due to the limited timeframe and spatial replication of the present study, however, it is not possible to distinctly determine whether the strength of fish-habitat associations varies among different geographic regions, that is, between tropical and temperate environments. The processes determining the 'value' of a particular patch of habitat, and the spatial and temporal scales at which any patterns might exist are not well understood and require further investigation.

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APPENDIX A: INTELLECTUAL PROPERTY

No saleable items were developed during this project

APPENDIX B: STAFF

WBM Oceanics Staff that were employed on the project using FRDC funds were: Mr. R. Tilbury, Mr. R. Bennett, and Dr Darryl McPhee.

Staff who assisted on the project using non-FRDC funds included: Dr Darren Richardson, Mr. D. Pedersen, Mrs. M. Ginty, Mr. D. Lanigan and Mr. M. Holton.

APPENDIX C: RAW FISH CATCH DATA FROM MOSQUITO AND OLD HAT CREEKS BETWEEN OCTOBER 2001 AND NOVEMBER 2002

Date		21/10/01	21/10/01	21/10/02	22/10/01	22/10/01	22/10/01	23/10/01	23/10/01	23/10/01
cell		MU	MM	MD	HU	HM	HD	MU	MM	MD
month		Oct01	Oct01	Oct01	Oct01	Oct01	Oct01	Oct01	Oct01	Oct01
night		1	1	1	1	1	1	2	2	2
code		MU/Oct01/ n1	MM/Oct01/ n1	MD/Oct01/ n1	HU/Oct01/ n1	HM/Oct01/ n1	HD/Oct01/ n1	MU/Oct01/ n2	MM/Oct01/ n2	MD/Oct01/ n2
		MU1	MM1	MD1	HU1	HM1	HD1	MU2	MM2	MD2
Species	**Total catch**									
Tetractenos glabar (smooth toadfish)	286	0	1	3	22	8	16	9	4	7
Galaxias maculatus (galaxid)	1	0	0	1	0	0	0	0	0	0
Mugil cephalus (sea mullet)	11	0	0	0	2	0	0	1	0	0
Aldrichetta forsteri (yellow-eye mullet)	153	0	0	5	13	0	0	0	0	38
Favonigobius lateralis (goby)	9	0	0	0	0	1	0	0	0	0
Rhombosolea tapirina (greenback flounder)	14	0	0	0	0	0	0	0	0	1
Pomatomus saltatrix (tailor)	3	0	0	0	0	0	0	0	0	0
Platycephalus speculator (southern blue-spot flathead)	1	0	0	0	0	1	0	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0	0	0	0	0	0	1
Anguilla australis (eel)	3	0	0	0	1	0	0	0	0	0
Scobinichthys granulatus (Leatherjacket)	1	0	0	0	0	0	0	0	0	0
Bovichthys variegatus (thornfish)	1	0	0	0	0	0	0	0	0	0
Centropogan australis (fortesque)	2	0	0	0	0	0	0	0	0	0
Myxus elongatus	1	0	0	0	0	0	0	0	0	0
Brachaluteres jacksonianus	1	0	0	0	0	0	0	0	0	0
Mudskipper	1	0	0	0	0	0	0	0	0	0
Luderick	1	0	0	0	0	0	0	0	0	0
Unknown 1	3	0	0	0	0	0	0	0	0	0

Date		24/10/01	24/10/01	24/10/01	3/02/02	3/02/02	3/02/02	4/02/02	4/02/02	4/02/02
cell		HU	HM	HD	MU	MM	MD3	HU	HM	HD
month		Oct01	Oct01	Oct01	Feb02	Feb02	Feb02	Feb02	Feb02	Feb02
night		2	2	2	1	1	1	1	1	1
code		HU/Oct01/n2	HM/Oct01/n2	HU/Oct01/n2	MU/Feb02/n1	MM/Feb02/n1	MD3/Feb02/n1	HU/Feb02/n1	HM/Feb02/n1	HD/Feb02/n1
		HU2	HM2	HD2	MU3	MM3	MD3	HU3	HM3	HD3
Species	**Total catch**									
Tetractenos glabar (smooth toadfish)	286	42	50	28	2	7	2	6	17	6
Galaxias maculatus (galaxid)	1	0	0	0	0	0	0	0	0	0
Mugil cephalus (sea mullet)	11	1	2	0	1	1	0	0	0	0
Aldrichetta forsteri (yellow-eye mullet)	153	1	1	9	15	0	6	1	3	0
Favonigobius lateralis (goby)	9	0	0	0	0	0	0	0	0	1
Rhombosolea tapirina (greenback flounder)	14	0	0	0	0	0	0	4	0	0
Pomatomus saltatrix (tailor)	3	0	0	3	0	0	0	0	0	0
Platycephalus speculator (southern blue-spot flathead)	1	0	0	0	0	0	0	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0	0	0	0	0	0	0
Anguilla australis (eel)	3	0	0	1	0	0	0	0	0	0
Scobinichthys granulatus (Leatherjacket)	1	0	0	0	0	1	0	0	0	0
Bovichthys variegatus (thornfish)	1	0	0	0	0	0	0	0	1	0
Centropogan australis (fortesque)	2	0	0	0	0	0	0	0	0	1
Myxus elongatus	1	0	0	0	0	0	0	0	0	0
Brachaluteres jacksonianus	1	0	0	0	0	0	0	0	0	0
Mudskipper	1	0	0	0	0	0	0	0	0	0
Luderick	1	0	0	0	0	0	0	0	0	0
Unknown 1	3	0	0	0	0	0	0	0	0	0

Date		5/02/02	5/02/02	5/02/02	6/02/02	6/02/02	6/02/02	29/05/02	29/05/02	29/05/02
cell		MU	MM	MD	HU	HM	HD	MU	MM	MD
month		Feb02	Feb02	Feb02	Feb02	Feb02	Feb02	May02	May02	May02
night		2	2	2	2	2	2	1	1	1
code		MU/Feb02/n2	MM/Feb02/n2	MD/Feb02/n2	HU/Feb02/n2	HM/Feb02/n2	HD/Feb02/n2	MU/May02/n1	MM/May02/n1	MD/May02/n1
		MU4	MM4	MD4	HU4	HM4	HD4	MU5	MM5	MD5
Species	**Total catch**									
Tetractenos glabar (smooth toadfish)	286	0	0	0	6	2	4	0	0	0
Galaxias maculatus (galaxid)	1	0	0	0	0	0	0	0	0	0
Mugil cephalus (sea mullet)	11	0	0	1	1	0	1	0	0	0
Aldrichetta forsteri (yellow-eye mullet)	153	0	0	0	0	0	3	0	0	0
Favonigobius lateralis (goby)	9	0	0	0	2	0	0	0	1	0
Rhombosolea tapirina (greenback flounder)	14	0	0	0	0	0	0	0	0	0
Pomatomus saltatrix (tailor)	3	0	0	0	0	0	0	0	0	0
Platycephalus speculator (southern blue-spot flathead)	1	0	0	0	0	0	0	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0	0	0	0	0	0	0
Anguilla australis (eel)	3	0	0	0	1	0	0	0	0	0
Scobinichthys granulatus (Leatherjacket)	1	0	0	0	0	0	0	0	0	0
Bovichthys variegatus (thornfish)	1	0	0	0	0	0	0	0	0	0
Centropogan australis (fortesque)	2	0	0	0	0	0	0	0	0	0
Myxus elongatus	1	0	0	0	0	0	0	0	0	0
Brachaluteres jacksonianus	1	0	0	0	0	0	0	0	0	0
Mudskipper	1	0	0	0	0	0	0	0	0	0
Luderick	1	0	0	0	0	0	0	0	0	0
Unknown 1	3	0	0	0	0	0	0	0	0	0

Date		30/05/02	30/05/02	30/05/02	31/05/02	31/05/02	31/05/02	1/06/02	1/06/02	1/06/02
cell		HU	HM	HD	MU	MM	MD	HU	HM	HD
month		May02	May02	May02	May02	May02	May02	May02	May02	May02
night		1	1	1	2	2	2	2	2	2
code		HU/May02/n1	HM/May02/n1	HD/May02/n1	MU/May02/n2	MM/May02/n2	MD/May02/n2	HU/May02/n2	HM/May02/n2	HD/May02/n2
		HU5	HM5	HD5	MU6	MM6	MD6	HU6	HM6	HD6
Species	**Total catch**									
Tetractenos glabar (smooth toadfish)	286	0	0	0	0	0	0	0	0	0
Galaxias maculatus (galaxid)	1	0	0	0	0	0	0	0	0	0
Mugil cephalus (sea mullet)	11	0	0	0	0	0	0	0	0	0
Aldrichetta forsteri (yellow-eye mullet)	153	22	0	4	0	0	0	4	2	5
Favonigobius lateralis (goby)	9	2	0	1	0	0	0	0	1	0
Rhombosolea tapirina (greenback flounder)	14	0	0	0	0	0	0	0	0	0
Pomatomus saltatrix (tailor)	3	0	0	0	0	0	0	0	0	0
Platycephalus speculator (southern blue-spot flathead)	1	0	0	0	0	0	0	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0	0	0	0	0	0	0
Anguilla australis (eel)	3	0	0	0	0	0	0	0	0	0
Scobinichthys granulatus (Leatherjacket)	1	0	0	0	0	0	0	0	0	0
Bovichthys variegatus (thornfish)	1	0	0	0	0	0	0	0	0	0
Centropogan australis (fortesque)	2	1	0	0	0	0	0	0	0	0
Myxus elongatus	1	1	0	0	0	0	0	0	0	0
Brachaluteres jacksonianus	1	0	1	0	0	0	0	0	0	0
Mudskipper	1	0	0	0	0	1	0	0	0	0
Luderick	1	0	0	0	0	0	0	0	1	0
Unknown 1	3	0	0	0	0	0	0	0	0	0

Date		19/08/02	19/08/02	19/08/02	20/08/02	20/08/02	20/08/02	10/11/02	10/11/02	10/11/02
cell		MU	MM	MD	HU	HM	HD	MU	MM	MD
month		Aug02	Aug02	Aug02	Aug02	Aug02	Aug02	Nov02	Nov02	Nov02
night		1	1	1	1	1	1	1	1	1
code		MU/Aug02/n1	MM/Aug02/n1	MD/Aug02/n1	HU/Aug02/n1	HM/Aug02/n1	HD/Aug02/n1	MU/Nov02/n1	MM/Nov02/n1	MD/Nov02/n1
		MU7	MM7	MD7	HU7	HM7	HD7	MU8	MM8	MD8
Species	**Total catch**									
Tetractenos glabar (smooth toadfish)	286	0	0	0	0	4	1	1	0	2
Galaxias maculatus (galaxid)	1	0	0	0	0	0	0	0	0	0
Mugil cephalus (sea mullet)	11	0	0	0	0	0	0	0	0	0
Aldrichetta forsteri (yellow-eye mullet)	153	0	0	0	0	0	1	0	0	18
Favonigobius lateralis (goby)	9	0	0	0	0	0	0	0	0	0
Rhombosolea tapirina (greenback flounder)	14	0	0	0	1	0	0	1	3	0
Pomatomus saltatrix (tailor)	3	0	0	0	0	0	0	0	0	0
Platycephalus speculator (southern blue-spot flathead)	1	0	0	0	0	0	0	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0	0	0	0	0	0	0
Anguilla australis (eel)	3	0	0	0	0	0	0	0	0	0
Scobinichthys granulatus (Leatherjacket)	1	0	0	0	0	0	0	0	0	0
Bovichthys variegatus (thornfish)	1	0	0	0	0	0	0	0	0	0
Centropogan australis (fortesque)	2	0	0	0	0	0	0	0	0	0
Myxus elongatus	1	0	0	0	0	0	0	0	0	0
Brachaluteres jacksonianus	1	0	0	0	0	0	0	0	0	0
Mudskipper	1	0	0	0	0	0	0	0	0	0
Luderick	1	0	0	0	0	0	0	0	0	0
Unknown 1	3	0	0	0	0	0	0	0	0	0

Date		11/11/21	11/11/21	11/11/21
cell		HU	HM	HD
month		Nov02	Nov02	Nov02
night		1	1	1
code		HU/Nov02/n1	HM/Nov02/n1	HD/Nov02/n1
		HU8	HM8	HD8
Species	**Total catch**			
Tetractenos glabar (smooth toadfish)	286	15	12	9
Galaxias maculatus (galaxid)	1	0	0	0
Mugil cephalus (sea mullet)	11	0	0	0
Aldrichetta forsteri (yellow-eye mullet)	153	1	0	1
Favonigobius lateralis (goby)	9	0	0	0
Rhombosolea tapirina (greenback flounder)	14	4	0	0
Pomatomus saltatrix (tailor)	3	0	0	0
Platycephalus speculator (southern blue-spot flathead)	1	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0
Anguilla australis (eel)	3	0	0	0
Scobinichthys granulatus (Leatherjacket)	1	0	0	0
Bovichthys variegatus (thornfish)	1	0	0	0
Centropogan australis (fortesque)	2	0	0	0
Myxus elongatus	1	0	0	0
Brachaluteres jacksonianus	1	0	0	0
Mudskipper	1	0	0	0
Luderick	1	0	0	0
Unknown 1	3	1	1	1

	Oct-01		Feb-02		May-02		Aug-02		Nov-02	
Summary	MC	OHC	MC	OHC	MC	OHC	MC	OHC	MC	OHC
Tetractenos glabar (smooth toadfish)	24	166	11	41	0	0	0	5	3	36
Galaxias maculatus (galaxid)	1	0	0	0	0	0	0	0	0	0
Mugil cephalus (sea mullet)	1	5	3	2	0	0	0	0	0	0
Aldrichetta forsteri (yellow-eye mullet)	43	24	21	7	0	37	0	1	18	2
Favonigobius lateralis (goby)	0	1	0	3	1	4	0	0	0	0
Rhombosolea tapirina (greenback flounder)	1	0	0	4	0	0	0	1	4	4
Pomatomus saltatrix (tailor)	0	3	0	0	0	0	0	0	0	0
Platycephalus speculator (southern blue-spot flathead)	0	1	0	0	0	0	0	0	0	0
Macquaria novemaleata (Australian bass)	1	0	0	0	0	0	0	0	0	0
Anguilla australis (eel)	0	2	0	1	0	0	0	0	0	0
Scobinichthys granulatus (Leatherjacket)	0	0	1	0	0	0	0	0	0	0
Bovichthys variegatus (thornfish)	0	0	0	1	0	0	0	0	0	0
Centropogan australis (fortesque)	0	0	0	1	0	1	0	0	0	0
Myxus elongatus	0	0	0	0	0	1	0	0	0	0
Brachaluteres jacksonianus	0	0	0	0	0	1	0	0	0	0
Mudskipper	0	0	0	0	1	0	0	0	0	0
Luderick	0	0	0	0	0	1	0	0	0	0
Unknown 1	0	0	0	0	0	0	0	0	0	3

APPENDIX D: EXTERNAL REVIEWS OF FRDC PROJECT 2000/179

External review of FRDC project 2000/179

Habitat Restoration and Management: A Trial of an Investment-Based Approach.

April 2003

This project aims to examine the effectiveness of restoring fish habitat in Corner Inlet in Victoria and the likely benefits to fisheries. Delays in opening the site to the sea for re-flooding have led to this review of how useful the data already collected are for the purposes of the project. In my review I have consulted the objectives and methods sections of the original proposal and a summary of the project to date by the investigators.

My brief was to:

1. assess the survey design and possibly do statistical power analysis to determine how effective future sampling might be,
2. comment on the value of existing data to our knowledge about fish use of mangroves,
3. identify the implications of a further delay in re-flooding.

I address each of those points below. My overall impression is of a project in which the actual sampling of fish in mangrove forests was well considered and thoroughly carried out. However a lack of rigour in the design of the survey means that the results to date are of little use to the objectives of the project.

1. Survey design and methodology – ability to detect impact of flooding on fish

There are no model and hypothesis statements in the original proposal or summary report. The survey design indicates confusion amongst the investigators about what hypothesis is being tested.

Either the study is attempting to determine effects of flooding on fish within Black Swamp and/or on fish adjacent to Black Swamp, based on one of the following models.

Model 1. Flooding allows fish to use a newly available habitat (and these fish act independently of fish using adjacent coastal habitat).

Model 2. Flooding allows fish to use newly available habitat, which also affects fish use of surrounding habitat:

a) positively (there are more fish in surrounding habitat because swamp is flooded; e.g. will operate if organic matter from flooded swamp provides nutrition to fish in adjacent areas)
b) negatively (there are fewer fish in surrounding habitat because swamp is flooded; e.g. will operate if supply of recruits is limited, and same number of fish are now spread over greater area).

In methods section of original proposal, the design is stated as having before and after samples, at flooding site (one only) and controls (2 sites). The intention seems to have been a classic asymmetrical before-after control-impact design, albeit with a low number of controls. That is, it would have shown whether fish use of the flooded site changed after flooding, relative to fluctuations at other (non-flooded) sites. That is, Model 1, above. However, no (marine) fish can enter the flooding site prior to flooding, so fish there would be zero, and ANY fish caught there after flooding would be an increase on pre-flooding. Fortunately common-sense prevailed and no sampling was done there. If this is the Model being tested, then no sampling was needed prior to flooding in either the flooding site or controls, and work to date has been wasted.

If Model 2 is thought to operate, it makes sense to sample not only the flooded site but also sites at different distances from the flooded site (the design eventually employed). In this case, pre to post flooding we would look for a change in fish abundance (either increase or decrease) immediately adjacent to the flooded site compared with sites further away. I doubt the investigators had this in mind, given that the 2 non-flooded sites are called controls on their map. In any case, the design employed here could not detect such changes, given: a) there is only 1 site (Mosquito Creek) near flooded site, and 1 (Old Hat Creek) further away, so the design is unreplicated, and b) the site nearest to the flooded site is almost certainly too far away to be affected. Such a design is still possible, given that the swamp is not yet flooded. However, the level of sampling to detect effects on fish use of adjacent habitats would be substantial, and I don't recommend that it be attempted. Statistical power analysis can be done to show how many sites would be needed, but the answer will be that numerous sites will be needed. The situation is analogous to solving the conundrum over whether artificial reefs increase the total number of fish in an area or merely attract fish already in the area – this has proved very difficult to solve because of high variability in fish abundances.

RECOMMENDATION

a) Notwithstanding the above, there is sense in sampling in the future. My recommendation is that an hypothesis based on Model 1 be tested, namely that fish use the flooded area once it is flooded. This requires sampling only inside the flooded area, and only after flooding. Multiple locations within the flooded site should be sampled to properly represent fish use of the site. Given the period over which I believe saltmarsh and mangrove vegetation would develop, and knowing the supposed link between vegetation and fish, I would add a temporal component to this. It would make most sense to sample at (say) 1, 2, 5 & 10 years after flooding, predicting that the rate of change in species composition and abundance will slow with time.

b) Is there any point in comparing fish of the flooded site with that at other sites? There is no point comparing fish use of flooded site (after flooding) with existing data on adjacent sites, because fish assemblages are expected to change through time for any number of other reasons anyway. However, comparisons between the flooded site and adjacent sites after flooding would be useful. This comparison could be used to test the hypothesis that after a certain time, the flooded site will contain the same species and abundances of fish as other coastal areas of Corner Inlet. This would require sampling several adjacent sites, and comparing all sites in a one-way ANOVA model to see if the flooded site is different to all other sites. This can be done at a single time (but this should be many years after flooding, when marine vegetation is established at the flooded site). A more complex design with sampling through time would compare whether the difference between the flooded site and other sites narrowed through time. In either of these designs, sites either side of the flooded site should be used to avoid having the flooded site at one end of any potential gradients along the shore. The 2 existing non-flooded sites are both to the north of the site to be flooded. Substantial effort and resources are required for such a design; these should be spent only if the result can be applied to other drained or reclaimed areas that can potentially be re-flooded.

SKILL BASE WITHIN RESEARCH TEAM

Given the lack of explicit hypothesis testing evident to date, the existing team of investigators would seem to require substantial assistance in re-designing a sampling program capable of testing either (a) or (b) above. Programs such as this that require sampling only occasionally but over long periods might also be a challenging operating model for FRDC.

2. Value of existing data to knowledge about fish use of mangroves

Given the lack of data on fish use of these stunted mangrove forests of Victoria, the data collected thus far are interesting.

The netting technique is good. Certainly there is a problem in having the 3 replicates immediately adjacent to each other at each site; this is less than ideal, but saves huge amounts of effort and was used successfully by Halliday in Qld. Quantitative sampling is extremely difficult in mangrove habitat and this is ahead of many other attempts. The researchers are to be commended.

There is a surprising lack of species diversity and total abundance, very different to Queensland. Not a lot can be made of assemblage differences over time. With only 2 species (yellow-eye mullet and toadfish) caught in any number, and other species caught only very occasionally, even a multivariate approach would be too shallow to be useful. Any manuscript would thus be simply a description of what was caught. The importance of these data is to show that not many fish use mangroves directly in Corner Inlet. The results may be publishable as a short note in a local journal. To do this, they should be put in the context of fish use of mangroves elsewhere in world, and fish use of adjacent habitat in Victoria (e.g. seagrass).

I note that not a single individual of the target species in this study (school sharks) was caught in the mangroves, but I wonder if fishers really thought the sharks entered the mangrove forest, or were simply in the shallow waters of Corner Inlet somewhere.

3. Implications of 12 month delay between pre and post flooding data

Given my recommendations for future work and the lack of a logical link between pre and post flooding data, the delay is irrelevant. I do not consider it important to do any further pre flood sampling.

4. Other comments

The original proposal states that in a pilot phase, measurement of the degree of variability will be used to determine appropriate sample sizes for given levels of statistical power in the baseline study. This apparently was not done. If it had been, the flaws in design would have become apparent earlier.

The original proposal states that "various habitats" will be sampled in Black Swamp and adjacent control locations. This was not done; in fact only mangrove stands have been sampled. When Black Swamp is re-flooded, it is likely that saltmarsh as well as mangroves will develop, and saltmarsh should have been (and should be) included in the sampling effort.

External review of FRDC project 2000/179

Habitat Restoration and Management: A Trial of an Investment-Based Approach

March 2004

The focus of my review of the Final Report of the above project is in terms of the five stated objectives outlined below, their achievement, fish sampling activities and the conclusions.

The stated objectives of the project are:

1. Develop an appropriate monitoring methodology for assessing the progress of fisheries habitat restoration within the trial wetland area (Black Swamp);
2. Describe the nature of fish communities, sediments and benthic flora present at and adjacent to the site prior to reflooding;
3. Assess changes in fish communities, sediments and benthic flora within and adjacent to the trial area in the years following reflooding;
4. Assess the effectiveness of the restoration of fish habitat in Corner Inlet and the likely benefits to commercial and recreational fisheries.
5. Assess the effectiveness of the investment-based approach as a management tool for the restoration of fisheries habitats.

At the time of the Report, 30 January 2004, the trial wetland area known as Black Swamp had not been reflooded for a number of reasons. Consequently, as objectives 3,4 and 5 depend on the reflooding event, those objectives could not be fully achieved.

It is considered that objectives 1 and 2 were capable of being achieved.

Objective 1 – This objective has not been completed to any substantial extent, although the sampling methodology used at Mosquito Creek and Old Hat Creek may have been applicable.

Objective 2 - The Report does not describe the nature of fish communities or sediments at and adjacent to the site prior to reflooding. Although it is self evident that sampling could not proceed on the reclaimed side of the Black Swamp site, there is no explanation why no sampling or monitoring was undertaken immediately adjacent to the site on the seaward side of the sea wall.

The nature of fish communities is described at two reference sites that are claimed to be structurally similar. No information is provided on the criteria used to select these sites or of their structural similarities.

The authors refer to a separate report (not supplied for review) of vegetation mapping at and adjacent to the Black Swamp site.

Comments on fish sampling activities

Two reference areas in close proximity to Black Swamp were chosen that had similar structural features - Mosquito Creek and Old Hat Creek. There is no clear hypothesis put forward as to the connection between the sample reference sites and the Black Swamp site. Little information is provided on how representative these two sites are of Black Swamp – and consequently there remains an open question on the applicability of sampling results at these two sites to the Black Swamp area.

There also remain questions about the sampling technique and the frequency. The authors agree that quantitative fish sampling is extremely difficult in mangrove habitats. The sampling was undertaken over a very limited timeframe and spatial replication was low. The two reference sites were sampled for 2 nights each on Oct 2001, Feb 2002, May 2002, and then for one night each site in Aug 2002 and Nov 2002. The sampling was carried out in the intertidal area.

This is a total of 16 sampling events. A total of 490 fish were caught over this period. Within both locations, the number of individuals caught was highest in Oct 2001 and lowest in August 2002. Over 55 percent of the fish were caught on October 2001, compared to only 1 percent caught in August 2002.

The authors found it difficult to draw any strong conclusions from their project, apart from the (expected) conclusion of 'patchiness' of habitat usage by fish in mangroves over space and time, and the need for further investigation.

I have found that objectives 1, 3,4 and 5 of the project were not achieved. The focus was on objective 2. However, the off site sampling and the (surprisingly) small number of fish caught limits the confidence with which any conclusions can be made, especially with reference to the Black Swamp site. In conclusion, I find that the project outcome has very limited relevance and benefit for the (uncompleted) NHT funded project 'Proposed Trials for Habitat Investment Based Fisheries Management'.