

# Guide to the assessment of sediment condition at marine finfish farms in Tasmania

*Edited by  
Catriona Macleod & Susan Forbes*





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SEAbase developed by Susan Forbes



Aquafin CRC Project 4.1 (Extension): Development of a field guide and associated training to facilitate rapid transfer of the outcomes of CRC Project 4.1 to marine finfish farms in Tasmania.

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### **Minimum Hardware / Software Requirements for SEAbase CD**

#### **Hardware**

To use the CD that accompanies this manual, the user will need a computer with the following features:

- IBM compatible computer with 300 MHz processor
- CD\_ROM drive

OR the Macintosh equivalent

#### **Software**

Users will also need the following software/plugin-ins installed on their computer:

- Microsoft Access, Word and Excel 2000 or later, to open and use the database, worksheets and forms.
- Windows Media Player (or equivalent) to open and play the demonstration video.

(Incorrect versions of these applications could result in information being shown in an unreadable form, or not shown at all).

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## 1 Introduction

This guide has been developed to enable farmers to readily incorporate the findings of CRC project 4.1 (The development of novel methods for the assessment of sediment condition and determination of management protocols for sustainable finfish cage aquaculture operations) into their farm management protocols. This project had 2 main objectives; to develop a training package (field guide and multimedia cd) for the aquaculture industry to simply explain the techniques proposed in CRC project 4.1, and to conduct a series of workshops to instruct farm personnel in the field sampling requirements, analysis and interpretation of the techniques recommended in CRC project 4.1. This guide summarises the rationale behind the original project, explains the project findings and includes detailed descriptions of the recommended techniques.

### 1.1 Background To Original Study

This study was undertaken at the instigation and with the collaboration of the Tasmanian Salmonid Aquaculture industry, the Department of Primary Industry, Water and Environment (DPIWE) and the Fisheries Research and Development Corporation (FRDC). The salmonid aquaculture industry recognised that to be economically sustainable it needed to be environmentally sustainable, and that to do this it needed to have a clearer understanding of the relationship between farming practices and environmental conditions. It is well recognised that one of the most significant impacts from caged fish farming is organic enrichment of the sediments (Iwama, 1991, Black *et al.*, 2001). What was less clearly understood was the effect that differing farming practices, such as rotational farming/fallowing, had on the level of impact or the effect that different background environmental conditions may have on overall impact. Consequently, this project was initiated to assess the rate of recovery associated with fallowing practices, to determine if current farming practices were sustainable and to develop novel approaches for farm based monitoring of environmental condition.

### 1.2 Previous Research on Sediment Recovery

There is a considerable body of research examining environmental impacts but much of this has focussed on the degradation response rather than recovery. One of the most significant studies to date is that of Pearson & Rosenberg (1978). Pearson & Rosenberg identified a series of macrobenthic successional stages in relation to an increasing organic enrichment gradient that have subsequently been supported by many studies of the benthic impacts of aquaculture (eg. Brown *et al.*, 1987; Ritz *et al.*, 1989; Weston, 1990; Holmer & Kristensen, 1992; Findlay *et al.*, 1995; Cheshire *et al.*, 1996; Hargrave, *et al.*, 1997, Wildish *et al.*, 1999, Macleod *et al.* 2002, Brooks *et al.*, 2003). Several of these have compared the infaunal categories defined by Pearson and Rosenberg to other physical-chemical and biological parameters (Brown *et al.*, 1987, Weston, 1990, Holmer & Kristensen, 1992, Findlay *et al.*, 1995, Cheshire *et al.*, 1996, Hargrave *et al.* 1997, Wildish *et al.*, 1999, Macleod *et al.* 2002) and have suggested a direct relationship between the chemical status of the sediment and the infaunal community structure. However, more recent research in Tasmania has suggested that the correlation levels indicated in the northern hemisphere studies may not be applicable to temperate Australian waters (Macleod, 2000; Macleod *et al.*, 2002, Macleod *et al.*, 2004).

Relatively few studies have been undertaken to evaluate recovery of sediments at marine finfish farms, but several of these have suggested that recovery is relatively rapid (6-12 months) compared with other sources of organic pollution (Johannessen *et al.*, 1994, Brooks *et al.*, 2003). However, the

rate of recovery will be strongly influenced by the prevailing environmental conditions. Many environmental studies have shown that site characteristics, such as water depth, particle size, current velocities and tidal effects play an important role in determining the rate and extent of both degradation and recovery of sediments. In the aquaculture context, farm management criteria (i.e. cage size, stocking density/biomass, feed input and timing/duration of stocked/fallow period) will also be critical factors in determining impact/recovery level. What is measured is also extremely important in obtaining a realistic evaluation of recovery. Some measures are much more sensitive to sediment impact/recovery than others. For example, at fish farms in British Columbia, Canada, physical-chemical parameters at cage sites returned to reference conditions within a few weeks, whilst the macrofauna took more than 6 months to recover (Brooks *et al.*, 2003). In Tasmania, the physical and chemical properties of sediments showed that fish farm-derived organic matter levels (identified through fatty acid profiles) remained elevated at cage sites 12 months after the cages were emptied, despite redox potential indicating a return to reference conditions (McGhie *et al.*, 2000). In another Tasmanian study, sulphide concentration returned to reference conditions within 6 months of the lease being vacated, whilst the infaunal community structure was still significantly different after 36 months (Macleod *et al.*, 2002). In this study, recovery was evaluated for several key criteria (physical, chemical and biological) at two farm sites with very different environmental conditions and the results compared to determine the effect of location on overall recovery performance. It is well recognised that benthic infaunal evaluation is one of the most sensitive approaches for evaluation of sediment condition. Consequently, full community assessment was the benchmark against which all other evaluations of recovery were judged. It was also recognised that for sustainable management of sediments within marine farm leases it may not be necessary for the system to recover to pristine condition. Therefore the project aimed to evaluate the level of recovery necessary for sustainable operation, and which does not result in progressive deterioration of the sediments.

## **2 Aims & Scope of the Original Study**

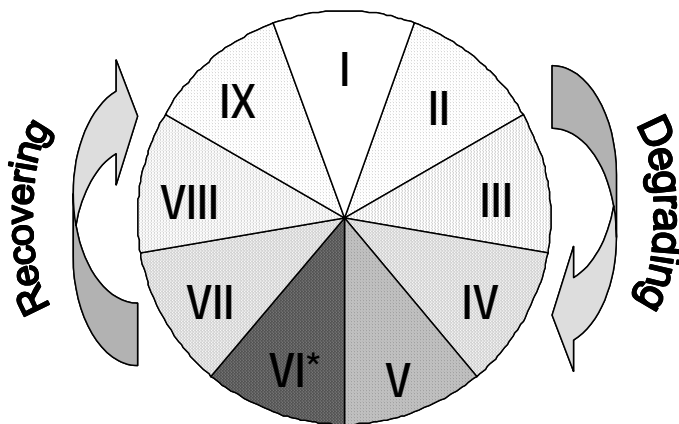
CRC project 4.1 was developed as an integrated multidisciplinary investigation of the changes in sedimentary processes associated with current salmonid farming practices in Tasmania. The project involved assessment of the chemical, microbiological and biological responses of sediments under Atlantic salmon (*Salmo salar*) cages at two locations in southern Tasmania over two complete farming cycles. One site was relatively exposed and subject to greater water flows and wave action than the other, which was more sheltered.

The project had three principal objectives

1. To assess the potential for progressive degeneration of sediments in association with cage aquaculture operations.
2. To adapt and develop novel combinations of monitoring techniques to facilitate evaluation of sediment degradation associated with ongoing marine cage aquaculture operations.
3. To incorporate these techniques into farm management protocols as tools for the evaluation and management of sediment condition in order to maximise sustainable aquaculture production.

### 3 Findings & Recommendations

The results indicate that at both sites there were clear spatial and temporal impact gradients. Initially, unimpacted conditions at each of the sites were biologically and chemically distinct, but as organic enrichment of the sediment increased the chemistry and ecology of the two systems became more similar. Although there was significant recovery at the end of the study, neither site recovered completely to pre-farming/reference conditions (i.e. some measures always differed). However, at both sites it was found that the sediment recovery was likely to be sufficient to enable re-use of the site. Although the potential for progressive deterioration of sediments to occur was identified at both sites, the duration of the project was insufficient to establish this conclusively. The rate of recovery differed both between sites and with differing stocking intensities, but clear impact levels were discernible and comparable between the sites. Benthic infaunal evaluation was the most useful indicator of both degradation and recovery and impact was classified for the sediment conditions at each of the study sites according to the benthic infaunal community changes. Nine stages were defined, encompassing both degradation and, importantly, recovery phases (Fig. 1). Potential monitoring techniques and differing farming intensities were subsequently related to this scale.



\* Indicates conditions not observed in this study  
Suggest stage IX is sufficiently recovered for restocking

STAGE – Category	STAGE – Description
I - Unimpacted	I - No evidence of farm impact
II - Minor Effects	II - Slight infaunal & community change observed
III - Moderate Effects	III - Clear change in infauna & chemistry
IV - Major Effects (1)	IV - Major change in infauna & chemistry
V - Major Effects (2)	V - Bacterial mats evident, outgassing on disturbance
VI* - Severe Effects	VI* - Anoxic/ abiotic, spontaneous outgassing
VII - Major Effects	VII - Monospecific fauna, major chemistry effects
VIII - Moderate Effects	VIII - Fauna recovering, chemistry still clearly effected
IX - Minor Effects	IX - Largely recovered, although slight faunal/ chemical effects still apparent

Fig. 1. Impact and recovery stages.

### 3.1 Benthic Community Assessment

The analysis of the combined benthic infaunal data from the two study sites indicated significant differences between the benthic infaunal communities characterising unimpacted and impacted (farmed) sediments (Fig. 2). These differences were consistent with successional community patterns previously described in association with organic enrichment from fish farms (Brown *et al.*, 1987, Weston, 1990, Wildish & Cranston, 1997). Although many of the species involved were clearly specific to the Tasmanian environment, the functional changes were largely equivalent. Interestingly, there were significant differences between the baseline communities at the two study sites. This is important as an understanding of the community composition prior to farming is essential for determining recovery and may provide an indication of the potential resilience of the system.

This study also assessed the benthic community information from both sites to determine whether any simplification of the data was possible or whether any generalisations could be made in regard to the infaunal results and the level of impact. Several simple approaches for evaluation of the faunal community, such as total number of species, total abundance and the presence of key indicator species, all provided useful information on the sediment condition, even distinguishing particular impact stages (Fig. 2). Some of these features were equally applicable at both study sites, were easy to define and were clearly linked to particular impact stages, whilst others characterised a broader change or were site specific.

Many of the site-specific features are likely to have resulted from the prevailing environmental conditions at the study sites. The sheltered site is highly depositional, characterised by mud sediments, whereas the more exposed site was characterised by fine sand sediments. Consequently, in the following sections site specific differences have been categorised according to the background sediment conditions ie. mud or sand. However, it should be noted that these categories are based on samples from only two locations in Tasmania and therefore may not be generally applicable to all sand or mud environments.

The benthic community results also clearly showed that when sediment conditions were degraded polychaete worms were the dominant faunal group, both in terms of abundance and diversity. In organically enriched sediments capitellid polychaetes (distinctive, red, opportunistic worms) can occur in huge numbers and in this study these worms were strongly indicative of the moderate and major impact stages, III-VIII (Fig. 2). Since in impacted sediments the worms represent the greatest proportion of the fauna, evaluation of total abundance reflected these changes.

Where there was a major impact the number of species was generally reduced (Fig. 2); a 50% or greater reduction in the number of species compared to the reference site suggested a significant impact (stage V). However, number of species by itself was a poor indicator of impact. For example if a farm sample contained the same number or more species than an equivalent reference it did not necessarily mean that the sediment had recovered, since the mix of species might be quite different. In the initial stages of impact (or in recovery) diversity can be increased, as the conditions have not yet deteriorated sufficiently to eliminate the stable species but there are enough resources to encourage the establishment of opportunistic species (sometimes referred to as a "zone of enhancement").

There were also changes in some general faunal groups that could be related to the level of apparent impact (Fig. 2). Although most of these were site specific (discussed in section 3.4) the following observations were made:

- Where crustaceans dominate the reference community, a significant drop in numbers should be considered carefully, especially if associated with an increase in the abundance of worms;
- Change in the abundance of molluscs as a group was on the whole a fairly poor indicator of sediment condition; *and*
- Echinoderm abundance appeared to be relatively sensitive to organic enrichment, particularly when this was associated with a decline in the oxic status of the sediments.

Stage		
DEGRADING (Active)	I	General - No evidence of farm impact; unimpacted indicator species present Indicators - Site specific Function - Range of functions
	II	General - Larger, long lived species & unimpacted indicators absent. Diversity may be greater than pristine (zone of enhancement) Indicators - Site specific Function - Site specific
	III	General - Rapid change in community mix; deposit feeding polychaetes / opportunists dominate. Filter / suspension feeders absent; Polychaetes dominant (Annelid abundance x20 ref); Number of Species >50% of ref Indicators - <i>Capitella</i> , <i>Nebalia</i> Function - Deposit feeders
IMPACTED	IV	General - Opportunists (esp. Capitellids) characterise community Indicators - <i>Capitella</i> , <i>Nebalia</i> Function - Deposit feeders
	V	General - Infaunal opportunists (esp. Capitellids) dominate - Annelid abundance x50 ref; Patchy Beggiaetia/ outgassing on disturbance; Number of Species <50% ref Indicators - Polychaetes highly dominant; <i>Capitella</i> , <i>Nebalia</i> Function - Deposit feeders
	VI	<b>No Fauna - Sediments &amp; bottom waters anoxic</b>
RECOVERING (Passive)	VII	General - Opportunists (Capitellids) still dominate but no.s dropping & other species colonising Indicators - <i>Capitella</i> , <i>Nebalia</i> Function - Deposit feeders
	VIII	General - Transitional species prevalent – notable increase in epibenthic opportunists Indicator - <i>Capitella</i> Function - Site specific
	IX	General - Diversification of community but absence of climax / long lived species Indicators - Site specific Function - Range of functions
	I	General - No evidence of farm impact; unimpacted indicator species present Indicators - Site specific Function - Range of functions

Fig. 2. General characterisation of impact/recovery stages based on main infaunal community, key faunal indicators and functional changes. Shaded area indicates period when cage was stocked.

### 3.2 Comparison of Other Techniques

A range of techniques was evaluated to assess their suitability for industry based management of sediment condition. Several established environmental monitoring approaches were found to be poor indicators of sediment recovery, although useful measures of sediment degradation. However, other techniques such as video assessment were found to be very reliable (Fig. 3). Quantitative video assessment was determined to be the most effective approach for simple farm-based assessment of sediment condition. This approach was capable of discerning the broadest range of impact stages and was particularly useful in evaluating recovery over time.

The video scores associated with particular impact stages and the key visual features, are shown in Fig. 3. The proposed quantitative video technique is simple, rapid, cost-effective and provides an immediate evaluation of sediment condition. When linked with farm data, the condition of a lease can be reviewed in a management context and informed management actions undertaken.

Another simple technique tested was the evaluation of benthic photos (still photos taken of benthic community samples prior to sorting). This technique also identified generally applicable criteria indicative of levels of impact (Fig. 3).

Both these simple visual assessment techniques could apply to assessments of other sources of organic enrichment or contamination. However, when used in a finfish aquaculture context and combined with farm production information it is possible to categorise the sediment condition to a particular stage and also predict the likely future classification on the basis of the proposed farming schedule. Differentiation between degrading and recovering sediments is most easily accomplished when the information is reviewed as a time series.

Several techniques, including geochemical biomarkers and microbial community assessments, were found to be powerful tools to help in elucidating the processes governing the sediments of inshore marine environments. However, due to the complexity of carrying out these techniques, they are unlikely to be useful in the context of routine farm-based monitoring.

Of the geochemical measures evaluated estimation of redox potential and sulphide concentration were the most useful for distinguishing between impacted and unimpacted sediments (Fig. 4). Measurement of physico-chemical parameters, such as redox and sulphide, has been applied as an indicator of sediment condition in many monitoring programmes worldwide (e.g. Scotland - SEPA, 1998, Canada - Levings *et al.*, 2002,). Redox has been included in the regulatory standards required for fish farm monitoring in Scotland, Canada, the U.S. and in Tasmania. However, this study determined that both approaches were poor indicators of recovery, generally greatly overestimating the extent of recovery. Wildish *et al.* (2001) produced a model that defined four stages of impact in relation to redox potential and sulphide concentration. Comparison of the present data with the organic enrichment model proposed by Wildish *et al.* (2001) suggests that although redox levels defining the impact stages in the current study were comparable to those of the Canadian study, the local sulphide concentrations were greatly reduced. In the current study a major impact was suggested by sulphide levels more than 10 times lower than that indicated by Wildish *et al.* (2001). In New Brunswick, Canada the requirements for environmental monitoring of salmon farms require that redox and sulphide be evaluated in combination (Wildish *et al.*, 1999) and certainly the results from this study indicate that measurement of both redox and sulphide concurrently would increase the reliability of the result. Redox appeared to be influenced by seasonal changes and both redox potential and sulphide concentration were variable in recovering

sediments. Consequently it is recommended that redox and sulphide only be considered either as part of a reliable and frequent time series data set or in conjunction with other measures of sediment condition (e.g. faunal information or video assessment).

Stage		
Minor	I	Photo score +ve; Video score >5 <i>Mud – Brittlestars</i> <i>Sand –Algae / Echiurans / Sipunculans</i>
	II	Photo score 0 to –2.5; Video score 2.5-5; Prevalence of burrows / faunal tracks / tubes <i>Mud– Squat lobster / dog whelk (Nassarius)</i> <i>Sand– Echiurans / Sipunculans</i>
	III	Photo score –2.5 to -4 Video score <2.5 <i>Mud– Squat lobsters/ dog whelk (Nassarius), Pellets/Faeces</i> <i>Sand–Sea slugs, Pellets/Faeces</i>
Major	IV	Photo score <-4 Video Score -ve ; <i>Beggiatoa</i> ; Gas bubbles; Obviously blackened sediments, Pellets/Faeces <i>Mud– Continuous patches / mats of Beggiatoa</i> <i>Sand–Any evidence of Beggiatoa</i>
	V	<b>Not encountered in this study - However, photo score &lt;-6 &amp; video score &lt;-10 would apply</b>
Major	VII	Photo score <-4 Video Score -ve ; <i>Beggiatoa</i> ; Gas bubbles; Obviously blackened sediments <i>Mud– Continuous patches / mats of Beggiatoa</i> <i>Sand–Any evidence of Beggiatoa</i>
Moderate	VIII	Photo score –2.5 to -4 Video score <2.5 <i>Mud - Squat lobsters &amp; dog whelk (Nassarius)</i> <i>Sand–Sea slugs</i>
Minor	IX	Photo score 0 to –2.5 Video score 2.5-5; stabilisation of cumulative scores within this range; prevalence of burrows / faunal tracks / tubes <i>Mud– Brittlestars very strong indicator of recovery; Squat lobster/ dog whelk (Nassarius)</i> <i>Sand–Point at which sea slugs are displaced (temporal)</i>
	I	Photo score +ve Video score >5 <i>Mud– Brittlestars</i> <i>Sand–Algae / Echiurans / Sipunculans</i>

Fig. 3. Characterisation of impact/recovery stages based on visual assessment scores and main indicator features at both mud and sand sites. Shaded area indicates period when cage was stocked.

UNIMPACTED		DEGRADING (Active)		IMPACTED	
Geochemical Measures: Eh >100mV S <sup>=</sup> below detection	Unimpacted	Shaded area		Eh = -ve S <sup>=</sup> >100uM Major	Not encountered in this study Severe
		Minor	Moderate		
STAGE I Normal		II Transitory		IV Polluted	
STAGE I Normal		III Transitory		V Polluted	
STAGE I Normal		VI Grossly Polluted		VI Grossly Polluted	
Wildish et al. Geochemical Measures: Eh = >100mV S <sup>=</sup> = <300uM Microbial: Normal	Eh = 0-100mV S <sup>=</sup> = 300-1300uM Oxic		Eh = -100-0mV S <sup>=</sup> = 1300-6000uM Hypoxic		Eh = <-100mV S <sup>=</sup> >6000uM Anoxic

Fig. 4. Redox potential and sulphide concentration associated with impact stage and compared with organic enrichment model as defined by Wildish *et al.* (2001). Shaded area indicates period when cage was stocked.

### 3.3 Site Specific Conclusions (Regional variability)

Substrate type is a critical determinant of infaunal community structure (Snelgrove & Butman, 1994, Morrissey *et al.*, 1998). The unimpacted communities at each of the two sites were very different. The exposed site had many features typical of a sandy sediment community, although functionally relatively diverse there was a high proportion of suspension feeding crustaceans. In contrast the sheltered site community was characteristic of soft mud sediments which are polychaete dominated with few suspension feeders but many surface and infaunal deposit feeders. With the onset of farming the communities at the two sites changed and over time became more similar. Each impact stage can be characterised by specific genera or community changes (Fig. 5). At the sheltered (mud) site the key genera defining the various stages were very similar to those proposed by Pearson & Rosenberg (1978). However, there were some notable differences in the exposed (sand) site, particularly in the early stages of impact.

All of the monitoring approaches examined in this study identified differences between the two study locations. For the most part these differences refined the sensitivity of the more generally applicable criteria. To facilitate comparison between the two sites these differences are detailed below.

P&R ZONE	STAGE	
<p><i>Nucula, Amphiuira, Terebellides, Rhodine, Echinocardium, Nephrops</i> Sediments aerobic to 2cm or more</p>	Normal I	Mud - <i>Amphiura, Lysilla, Mediomastus, Nucula, Thyasira</i> Sand - <i>Apseudes, Ampelisca</i>
<p><i>Labidoplax Chaetozone</i> <i>Corbula Anaitides</i> <i>Goniada Pectinaria</i> <i>Thyasira Myriochele</i> <i>Pholoe Ophiodromus</i></p> <p>Sediments become anaerobic between 1–2cm</p>	Transitory II	Mud – <i>Nassarius, Corbula, Echinocardium, Phoxocephalidae, Nemertea</i> Sand - <i>Lyssianassidae, Eupilomedes, Spionidae (Polydora cf. socialis), Phoxocephalidae</i>
		III
<p><i>Capitella</i> <i>Scolelepis</i></p> <p>Sediments become anaerobic between 0-1cm</p>	Polluted IV	Mud – <i>Capitella, Nebalia</i> (dominant) <i>Corbula, Nassarius, (Neanthes)</i> Sand – <i>Capitella</i> (dominant) ( <i>Neanthes, Phoxocephalidae, Dimorphostylis</i> )
		V
<p>NO MACROFAUNA</p> <p>Sediments anoxic at surface</p>	Grossly Polluted VI	<p>Not encountered in this study</p>
		VII
	VIII	Mud – <i>Capitella, Nebalia</i> – decreasing abundance <i>Nassarius, Echinocardium, Phoxocephalidae</i> Sand – <i>Capitella</i> (lower no.s), <i>Euphilomedes, Polydora cf socialis, Sabellidae (cf Euchone)</i>
	IX	Mud - <i>Nassarius, Corbula, Neanthes, Echinocardium, Phoxocephalidae, Nemertea</i> Sand – Mix of species with increased crustacea & decreased annelids. <i>Spionidae, Polydora cf socialis, Euphilomedes, Nephtys, Apseudes</i>
		<p>UNIMPACTED</p> <p>DEGRADING (Active)</p> <p>IMPACTED</p> <p>RECOVERING (Passive)</p>

Fig. 5. Comparison of main indicator organisms with P&R model (1978). Combinations of key indicator organisms should be assessed. Shaded area indicates period when cage was stocked.

*Exposed / Sandy Environment:*

The background faunal community at the exposed site was characterised by crustaceans, in particular *Ampelisca* sp. and *Apseudes* sp. These species were present at both recovered and reference sites however they were considerably more abundant at reference sites than at recovered sites (Table 1). Unimpacted sediments generally contained more than 450 m<sup>-2</sup> and 700 m<sup>-2</sup> individuals per sample (0.01m<sup>2</sup>) of *Ampelisca* sp. and *Apseudes* sp. respectively. When the sediment was impacted *Ampelisca* sp. was entirely absent and only 15-30 individuals m<sup>-2</sup> of *Apseudes* sp. were noted. Consequently, the presence of between 150-300 individuals m<sup>-2</sup> of *Apseudes* sp. might be considered indicative of a reasonable level of recovery. The presence of more than just one or two *Ampelisca* sp. would be a good indicator of quite a high level of recovery. These species are quite large and distinctive and would be relatively easy to distinguish even by a non-skilled ecologist, particularly when present in abundance. Another crustacean group (Phoxocephalids), were also notably more abundant in the samples from recovered positions than at either the impacted or reference positions.

Several simple approaches, including number of species and total abundance, were examined in the analysis of the benthic infaunal community at the sand site and the following conclusions were drawn:

- There was a slight increase in species recorded at the references of the sand site than at the references of the mud site (35-50 species per site (sand), 20-30 species per site (mud));
- Where a major impact was evident the number of species at both sand and mud sites were reduced and were similar (10-15 species per site (sand), 10 species per site (mud));
- Total abundance at the references of the sand site was also slightly higher than at the mud site. However, where there was impact, the increase in total abundance was not as marked at the sand site as at the mud site (in both cases this increase was mostly due to capitellid worms);
- At the sand site an increase in total abundance 3x that at the reference could be considered to reflect a moderate impact, whilst an increase 6-9x the reference would suggest a major impact.

The findings and scoring for the visual assessment techniques were very similar for both study sites. The main differences were in the key fauna underpinning the scores, which for the most part reflected the species differences indicated above. Several features, including algae, echinurans and large annelids, appeared to be good indicators of unimpacted / recovered conditions at the sand site. Sea slugs were only present when there was a moderate impact, they were not observed in unimpacted conditions or when a major impact had occurred. At the sand site evidence of bacterial (*Beggiatoa*) mats were less evident at impacted sites than at the mud site (Tables 1 and 2).

*Sheltered / Mud Environment:*

In contrast to the crustacean dominated community at the exposed/sand site, the unimpacted community at the sheltered/mud site was characterised by a diverse range of polychaete worms including several surface deposit feeders (Table 2). Impacted conditions were distinguished by a significant increase in abundance of opportunistic capitellid worms and a scavenging epibenthic

crustacean (*Nebalia longicornis*). This latter species is very distinctive and in combination with increased Capitellid abundance would be a very good indicator that sediments were markedly impacted (stages III-VIII). However, as a swarming epibenthic deposit feeder, *N. longicornis* is both highly clumped in its distribution and very susceptible to sampling technique, so can be missed easily. Consequently its absence from samples is not as significant as its presence.

Table 1. Summary of features characterising impact/recovery stages at the exposed/sand site based on key features for each of the techniques deemed suitable for farm based assessment. (NB. Key Biotic Indicators row: organisms identified with \* are indicative in combination rather than individually).

Impact Stage	I	II	III	IV	V	VII	VIII	IX
Effect Category	No evidence of impact	Minor effects (Degrading)	Moderate effects (Degrading)	Major effects 1. (Degrading)	Major effects 2. (Degrading)	Major effects (Recovering)	Moderate effects (Recovering)	Minor effects (Recovering)
Description		Small scale community change; Sediment chemistry unaffected or with only very minor effects	Significant community change; Sediment chemistry affected	Major community change; Monospecific dominance; major sediment chemistry changes	As in Stage IV; Beggiatoa/ outgassing on disturbance	Fauna returns to monospecific dominance; major sediment chemistry effects	Fauna re-establishing (zone of enhancement); Sediment chemistry still affected	Community largely recovered; Sediment chemistry recovered
Generalised Benthic Categories	Unimpacted indicator species present	Larger, long lived species & pristine indicators absent. Diversity may be greater than pristine (zone of enhancement)	Rapid change in community mix; deposit feeding polychaetes/ opportunists dominate. Filter/suspension feeders absent.	Opportunists (esp. Capitellids) characterise community	Infaunal opportunists (esp Capitellids) dominate. Patchy beggiatoa/ outgassing may be evident.	Opportunists (Capitellids) still dominate but no.s dropping & other species colonising.	Transitional species prevalent - notable increase in epibenthic opportunists.	Diversification of community but absence of climax/long lived species.
Key Biotic Indicators	<i>Apeudes</i> , <i>Ampelisca</i>	* <i>Lyssianassidae</i> , * <i>Euphilomedes</i> , * <i>Polydora cf socialis</i> , *Phoxocephalidae	<i>Capitella</i> (dominant); <i>Neanthes</i> , * <i>Corophium</i> , * <i>Polydora cf socialis</i> , * <i>Tethygenia</i> , * <i>Cumacea</i> , *Phoxocephalidae	<i>Capitella</i> (dominant); * <i>Neanthes</i> , *Phoxocephalidae, * <i>Dimorphostylis</i>	<i>Capitella</i> (greatly dominant); * <i>Neanthes</i> , *Phoxocephalidae	<i>Capitella</i> (dominant), * <i>Neanthes</i> , * <i>Corophium</i> , * <i>Nebalia</i> , *Phoxocephalidae	<i>Capitella</i> (lower no's), * <i>Euphilomedes</i> , * <i>Polydora cf socialis</i> , * <i>Euchone</i>	Mix of species with increasing crustacea and decreasing annelids. * <i>Apeudes</i> , * <i>Polydora cf socialis</i> , * <i>Euphilomedes</i> , * <i>Nephtys</i>
Shannon Index	>2	>2	>1<2; No. spp. >50% of ref	<1; No. spp. <50% of ref		<1; No. spp. <50% of ref	>1<2; No. spp. >50% of ref	>2
Total Abundance	Same as ref		x3 ref	x6-9 ref		x6-9 ref	x3 ref	
Redox Potential (mV)	>100mV	0-100mV (or >50% ref)	0-100mV (or >50% ref)	<0mV		<0mV	0-100mV (or >50% ref)	0-100mV (or >50% ref)
Sulphide Conc. (uM)	Below detection	Below detection	>50uM	>100uM		>100uM	>50uM	Below detection
Benthic Photo Score	Pos've	0 to -3	-4 to -3	<-4		<-4	-4 to -3	0 to -3
Video Score	>5	2.5-5	<2.5	Neg've		Neg've	<2.5	2.5-5
Video Features	Algae, Echiurans/ Sipunculans	Prevalence of burrow/ faunal track/ tubes; Echiurans/ Sipunculans	Sea slugs (Pleurobranchia)	Any evidence of Beggiatoa, Gas bubbles, Black sediments;		Any evidence of Beggiatoa, Gas bubbles, Black sediments;	Sea slugs (Pleurobranchia)	Point at which sea slugs are displaced (temporal)

**Table 2.** Summary of features characterising impact/recovery stages at the sheltered/mud site based on key features for each of the techniques deemed suitable for farm based assessment. (NB. Key Biotic Indicators row: organisms identified with \* are indicative in combination rather than individually).

Impact Stage	I	II	III	IV	V	VII	VIII	IX
<b>Effect Category</b>	No evidence of impact	Minor effects	Moderate effects	Major effects	Major effects	Major effects	Moderate effects	Minor effects
<b>Description</b>		Small scale community change; Sediment chemistry unaffected or with only very minor effects	Significant community change; Sediment chemistry affected	Major community change; Monospecific dominance; major sediment chemistry changes	As in Stage IV; Beggiatoa/ outgassing on disturbance	Fauna returns to monospecific dominance; major sediment chemistry effects	Fauna re-establishing (zone of enhancement); Sediment chemistry still affected	Community largely recovered; Sediment chemistry still slightly affected
<b>Generalised Benthic Categories</b>	Unimpacted indicator species present	Larger, long lived species & unimpacted indicators absent. Diversity may increase (zone of enhancement)	Rapid change in community mix; deposit feeding polychaetes/ opportunists dominate. Filter/suspension feeders absent.	Opportunists (esp. Capitellids) characterise community	Infaunal opportunists (esp Capitellids) dominate. Patchy beggiatoa/ outgassing may be evident.	Opportunists (Capitellids) still dominate but no.s dropping & other species colonising.	Transitional species prevalent in epibenthic opportunists.	Diversification of community but absence of climax/long lived species.
<b>Key Biotic Indicators</b>	<i>Amphiura</i> , <i>Lysilla</i> , <i>*Mediomastus</i> , <i>*Nucula</i> , <i>*Thyasira</i>	<i>*Nassarius</i> , <i>*Corbula</i> , <i>*Echinocardium</i> , <i>*Phoxocephalidae</i> , <i>*Nemertea</i>	<i>Capitella</i> , <i>Nebalia</i> (dominant); <i>*Corbula</i> , <i>*Nassarius</i> , <i>*Neanthes</i>	<i>Capitella</i> , <i>Nebalia</i> (dominant); <i>*Corbula</i> , <i>*Nassarius</i> , <i>*Neanthes</i>	<i>Capitella</i> , <i>Nebalia</i> (extremely dominant)	<i>Capitella</i> , <i>Nebalia</i> (abundant); <i>*Nassarius</i> , <i>*Neanthes</i> , <i>*Corbula</i> , <i>*Phoxocephalidae</i>	<i>Capitella</i> , <i>Nebalia</i> (decreasing abundance); <i>*Nassarius</i> , <i>*Echinocardium</i> , <i>*Phoxocephalidae</i>	<i>Nassarius</i> , <i>Corbula</i> , <i>*Neanthes</i> , <i>*Echinocardium</i> , <i>*Phoxocephalidae</i> , <i>*Nemertea</i>
<b>Shannon Index</b>	>2	>2	>1<2; No. spp >50% of ref	<1; No. spp. <50% of ref	<1; No. spp. <50% of ref	<1; No. spp. <50% of ref	>1<2; No. spp >50% of ref	>2
<b>Total Abundance</b>	Same as ref		x10 ref	x20 ref		x20 ref	x10 ref	
<b>Redox Potential (mV)</b>	>100mV	0-100mV (or >50% ref)	0-100mV (or >50% ref)	<0mV		<0mV	0-100mV (or >50% ref)	0-100mV (or >50% ref)
<b>Sulphide Conc. (uM)</b>	Below detection	Below detection	>50uM	>100uM		>100uM	>50uM	Below detection
<b>Photo Score</b>	Pos've	0 to -2.5	-2.5 to -4	<-4		-2.5 to -4	0 to -2.5	Pos've
<b>Video Score</b>	>5	2.5-5	<2.5	Neg've		Neg've	<2.5	2.5-5
<b>Video Features</b>	Brittlestars	Prevalence of burrow/faunal track/tubes; Brittlestars, squat lobsters, dog whelk	Squat lobsters, dog whelk	Continuous patches/mats of Beggiatoa, Gas bubbles, Black sediments;		Continuous patches/mats of Beggiatoa, Gas bubbles, Black sediments;	Squat lobsters, dog whelk	Prevalence of burrow/faunal track/tubes; Brittlestars, squat lobsters, dog whelk

The data from the mud site showed some interesting changes in the local molluscan communities that appear to be associated with farming operations and level of impact (Table 2). In this instance, changes were species specific and were correlated over time. Two introduced bivalves (*Corbula gibba* & *Theora lubrica*) appeared to be indicative of minor/moderate impact (stage II-III, VII-VIII). Over time and with increasing enrichment of the sediments these species seemed to become more abundant, although numbers diminished rapidly after a certain level of impact. In contrast the

abundance of two native bivalves (*Nucula pusilla* & *Thyasira adelaideana*) declined rapidly with impact, re-establishment of these species suggesting that conditions had greatly improved.

The heart urchin *Echinocardium cordatum* was occasionally found at the reference positions in the mud site but was absent where there was any significant impact, although at low levels of enrichment it appeared to thrive. In contrast the local brittlestar (*Amphiura elandiformis*) was never found where there was any organic enrichment but was frequently abundant at the references. Consequently its presence represented a very reliable indicator of good sediment conditions.

There were two very important site specific differences in the video assessment features at the mud site. Squat lobsters (*Munida haswelli*) and the little local dog whelk (*Nassarius* sp.) were extremely good indicators of intermediate impact. Consequently when monitoring the progress of fallowing, the presence of these two species would suggest that the sediments are well on the way to recovery. Both species are very easy to identify in video footage. Also as identified in the benthic community analysis, brittle stars were strong indicators of unimpacted environmental conditions, they too are very easy to recognize and the presence of these on video footage would suggest that conditions are close to reference.

### **3.4 Integrated Management Model**

The results suggest that at both sites there was a very close relationship between sediment condition and farm production levels (Fig. 6.a,b). Changes in management practices resulted in quite significant alterations in sediment condition.

In the first production cycle, at the sand site, one cage was fallowed for 6 weeks longer than planned. This not only resulted in a marked improvement in the sediment condition but also produced continued benefits in the subsequent production cycle. The sediments appeared less impacted at the end of the second production cycle at this position than they were at the position which had not had this extra fallow period. Additionally, in the second production cycle, there was a general reduction in both biomass of fish stocked and in feed input which resulted in a further improvement in overall sediment condition. This was observed in both biotic and visual assessment features which indicated better conditions at the completion of the second cycle than at the end of the first stocked phase (Fig. 6a).

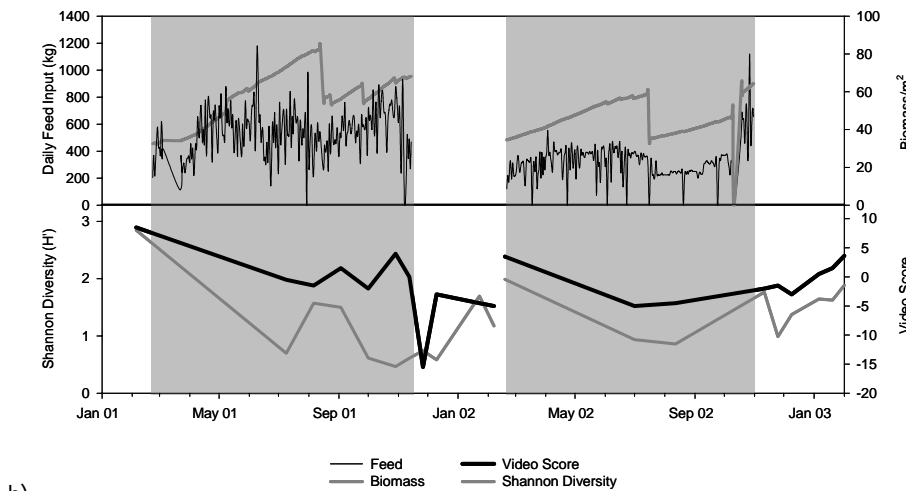
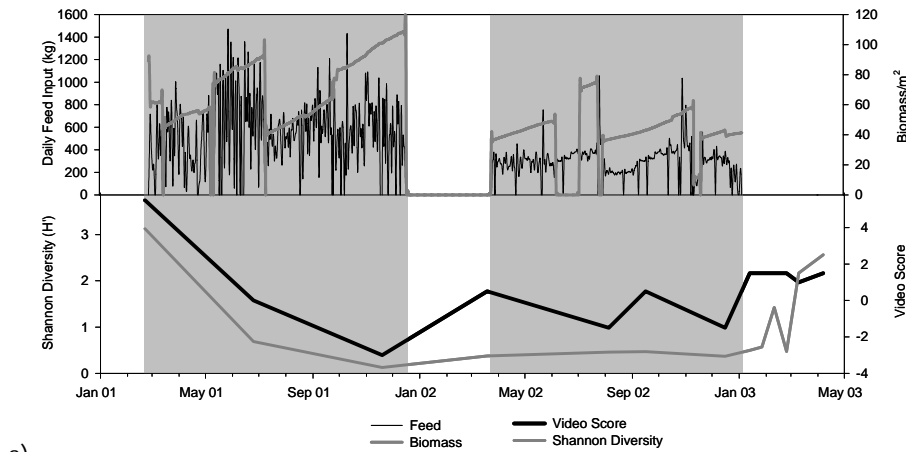
Although the biomass of fish stocked at the mud site was relatively stable over the two production cycles, there was an appreciable reduction in feed input over the second cycle (Fig. 6b). Once again environmental conditions reflected this, showing a substantial reduction in overall impact over the second production cycle.

Relating the production information to the impact stages defined earlier suggests that at the sand site the impact stages were associated with slightly lower levels of stocking and feed input than at the mud site (Fig. 7). This supports the suggestion that the benthic community at the mud site was better adapted to cope with organic enrichment.

The study also established that farm operations produce a generalised residual impact throughout the farm lease. Consequently, any evaluation of recovery at "fallowed" positions within the lease should take into account the likely effects of adjacent operational cages. It is not appropriate to determine the effectiveness of fallowing just by the time that an area has been without a cage.

Clearly environmental condition reflects farm production level and consequently farm production can be managed to produce desirable environmental outcomes. Our results demonstrate that reliable information on sediment condition, used in conjunction with feed rate and stocking density, can assist farmers to manage their lease areas to obtain the best economic and environmental outcomes. These findings also suggest that it is possible for farmers not just to compensate for environmental impacts sustained in any given production year but that it would be possible to manage their production strategies in order to forward plan and adjust for likely episodes of increased or prolonged stocking in particular areas.

It should be noted however that there is no adjustment for the duration of impact in this model, and although in this particular study the stocking cycles were broadly equivalent this would not always be the case, and this would have to be taken into account in any other comparisons.



**Fig. 6.** Representative data from one study pen showing the relationship between farm production (feed input and fish biomass), Shannon diversity index and visual assessment of sediment condition for a) exposed (sand) site & b) sheltered (mud) site. Shaded area indicates period when cage was stocked.

Stage		
Minor	I	No Feed/Fish Input (Present or Historic) Mud – No Farm Effects Sand – No Farm Effects
	II	Pre-Farming/End of Fallow Period Mud – Residual Farm Effects Sand – Residual Farm Effects
	III	Cage Stocked/ Continuous Feed Input Mud – Fish=30-60kg/m <sup>2</sup> ; Feed=200-400kg/day Sand – Fish=30-50kg/m <sup>2</sup> ; Feed=250-500kg/day
Major	IV	Cage Stocked / Continuous Feed Input Mud – Fish=40-60kg/m <sup>2</sup> ; Feed=300-500kg/day Sand – Fish=50-75kg/m <sup>2</sup> ; Feed=400-750kg/day
	V	Cage Stocked / Continuous Feed Input Mud – Fish=60-80kg/m <sup>2</sup> ; Feed=500-750kg/day Sand – Fish=75-100kg/m <sup>2</sup> ; Feed=750-1000kg/day
	VI	<b>Not encountered in this study</b>
Major	VII	Cage Empty Mud – Residual Farm Effects Sand – Residual Farm Effects
	VIII	Cage Empty Mud – Residual Farm Effects Sand – Residual Farm Effects
Minor	IX	Cage Empty Mud – Residual Farm Effects Sand – Residual Farm Effects
	I	No Feed/Fish Input (Present or Historic) Mud – No Farm Effects Sand – No Farm Effects

Fig. 7. Characterisation of impact/recovery stages based on generalised farm production information at both mud and sand sites. Shaded area indicates period when cage was stocked.

## 4 Summary of Key Findings and Recommendations

This study had three principal objectives.

### 1. To assess the potential for progressive degeneration of sediments in association with cage aquaculture operations.

The results from the first cycle suggested that at the end of the initial fallow period conditions at both farms, but particularly at the sheltered/mud site, had deteriorated compared to those pre-farming. Whilst this did not conclusively indicate that progressive deterioration had occurred, it was of some concern as it suggested that there was the potential for degeneration and certainly warranted further study. Unfortunately we were unable to evaluate whether progressive deterioration would have occurred under the defined production scenario as the stocking and feed regimes at both sites were markedly reduced in the second cycle, so that it was no longer appropriate to compare the two cycles.

The changes to the stocking/feed input in the second cycle did provide some useful information, suggesting that reduction in the farming intensity could result in marked improvement in both the rate and degree of recovery. This in turn suggests that relatively minor farm management adjustments can produce substantial environmental improvements.

To effectively evaluate whether progressive deterioration is occurring it is necessary to determine whether the conditions post-farming differ from what existed pre-farming. In this study the two farm sites had very different pre-farming community structures. Consequently, in order to be able to determine the potential for progressive deterioration it is essential to establish baseline environmental conditions.

**2. To adapt and develop novel combinations of monitoring techniques to facilitate evaluation of sediment degradation associated with ongoing marine cage aquaculture operations.**

Many approaches for farm-based monitoring have been assessed as part of this project. Benthic infaunal assessment was used as the standard by which the sensitivity, reliability and suitability of techniques was evaluated. Our findings suggest that visual assessment techniques are probably the most useful approach for farm-based monitoring.

We have made the visual assessment more objective by defining indices, based on easily identifiable visual criteria, which relate to specific stages of impact (Fig. 3). The proposed visual approaches can determine different levels of impact and therefore can be used to monitor both degradation and recovery. Discussions with industry stakeholders, environmental consultants and government regulators suggest that these indices would apply equally well in environments other than those included in the study. Consequently we are confident that with only minor and relatively simple modifications they would be applicable to the broader farming community.

Key faunal indicators have also been identified, and these complement the visual techniques. The indicator organisms are easy to distinguish and provide additional reliable ecological information on the sediment condition. In conjunction with the quantitative visual analysis information, this ecological information will enable farmers to obtain an understanding of their sediment condition that they could only previously have achieved with the assistance of highly trained scientific professionals.

**3. To incorporate these techniques into farm management protocols as tools for the evaluation and management of sediment condition in order to maximise sustainable aquaculture production.**

Although the methods described in this study could be used for a variety of monitoring purposes, the proposed protocol was developed specifically in relation to on-farm monitoring, and was not intended for regulatory or compliance purposes. The purpose of the proposed monitoring programme is to provide farmers with sufficient information to enable them to incorporate an environmental condition factor into their current farm management strategies. To this end this study has defined a range of impact stages (Fig. 1) that categorise the sediment condition, which are applicable to a range of environments, and which can be easily established by farmers using the proposed techniques.

Accordingly, it is recommended that video assessment be adopted as the main approach for farm based monitoring. Video footage should be obtained relatively frequently (at least monthly but

preferably fortnightly) from cages within the farm, towards the end of the stocking cycle and over the fallow period, and this should be compared with footage from reference positions taken at the same times. Only a short (1-2 minute) video drop is necessary. Assessment can be done in the field or post-processed. If there is any uncertainty as to the classification resulting from the visual assessment the findings could be validated with infaunal grabs and subsequent evaluation of key species. Other approaches (eg. redox/sulphide, lipid analysis, microbial status) can be undertaken if a greater sensitivity or understanding of the system processes is required.

In order to ensure that the characterising features for the video assessment are relevant to a particular site it is essential to have baseline information on the benthic community structure and sediment conditions for that site. It is also recommended that infaunal grab samples be collected from representative reference and farm locations at regular intervals (every 2-3 years) to calibrate key indicators and identify any significant community changes. These samples would be quick to obtain, would not require any complex processing, their principal function being to identify and validate the key/dominant species. Photographic records should be taken of these samples to establish a baseline environmental archive, providing a pictorial record of the community structure. This can then be compared with subsequent evaluations (i.e. to identify any major community shifts, to validate indicator identifications and to validate categorisation of impact levels).

## 5 Recommended Techniques

### 5.1 Overview of Techniques

The recommended techniques cover a variety of differing levels of complexity related to the collection, processing and analysis of samples, but also have different levels of sensitivity of results (Fig. 8). Some of the techniques are very easy to undertake, but these tend to give only a fairly broad indication of sediment condition. Other techniques involve more complex procedures, but give a much more detailed indication of sediment condition. These techniques can be used in isolation or in combination.

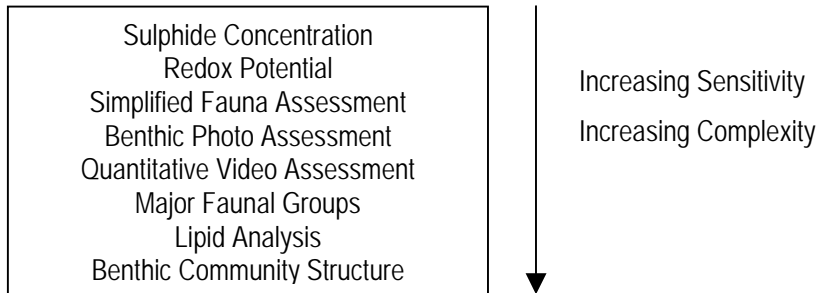


Fig. 8. Relative sensitivity and complexity of techniques tested in Aquafin CRC Project 4.1.

Of all the techniques tested, analysis of the full benthic community structure provided the clearest picture of sediment condition and also the most information into the extent of degradation and recovery, and the processes occurring within the sediment during each. Analysis of full benthic community structure is a relatively time consuming and potentially expensive exercise, however several other techniques were identified that can provide useful results but require less resources and expertise, such as simplified analysis of the benthic community using faunal groupings and key species, and analysis of benthic photographs and video footage. The methods and application of these techniques are described in detail in the following sections. However, other more complex techniques are also described here, including analysis of the microbial community, lipid and sterol levels in sediments, stable isotopes and sediment geochemical measures (in particular redox potential and sulphide concentration).

### 5.2 Methods and Application

#### 5.2.1 Field Sampling

Although the specific requirements for each technique differ slightly, the field requirements have several generalities. Sampling requires a minimum of two personnel, and a vessel with sufficient deckspace to store and process the samples. As some of the equipment is heavy it is advisable, for occupational health and safety reasons, that hauling be done using an appropriate winch.

When sampling predetermined stations, positioning equipment is required. This can be any form of Global Positioning System (GPS), however differential GPS units tend to give greater accuracy

(approximately 12m) than standard GPS units. The GPS should be set to Australian Grid Datum (AGD) 66 prior to recording easting and northing coordinates.

*i) Benthic Sediment Sample Collection*

Grab samples can be collected either from a boat or by diver. There are many different grabs available but for the broad range of conditions encountered in Tasmania we have found that a Van Veen Grab (with sampling area between 0.05 – 0.1m<sup>2</sup>) is most appropriate (Fig. 9a). On the first sampling occasion, evaluate the volume of sediment collected in each grab and ensure that replicates and subsequent sampling collect similar sediment volumes. For diver sampling, a hand held 150mm diameter PVC pipe corer should be used (sediment depth 100mm; sample area 0.0177m<sup>2</sup>) (Fig. 9b).

For faunal analysis and benthic photo assessment a minimum of three replicate grabs/cores should be collected at each station. Sediment grab samples may also be used to characterise key fauna and to obtain subsamples for analysis of lipids/sterols.

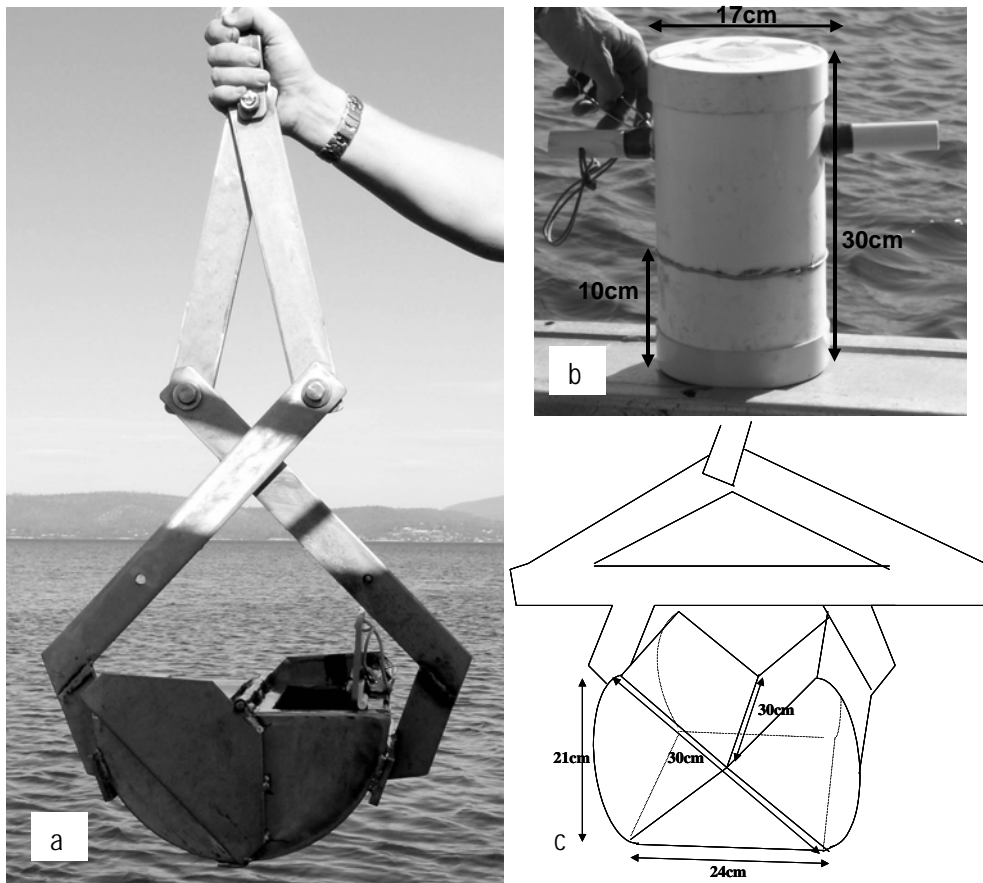


Fig. 9. a) Van Veen grab in closed position, b) Diver core showing dimensions, c) Diagram of grab in open position showing dimensions.

If the grab/diver sample is for faunal analysis it should be washed through a 1mm mesh sieve using a low pressure seawater supply or rinsed in mesh bags (0.875mm mesh aperture) (Fig. 10). If using a sieve it is easiest to wash the sample through with an external water supply i.e. using a bilge pump. However, it is important that the water pressure is kept low otherwise fauna may be forced through the mesh. The material retained on the sieve should be transferred to plastic or glass storage containers and completely covered with a solution of 10% formalin (4% formaldehyde) buffered in seawater i.e. 100ml formalin to 900mls seawater. If using mesh bags, they should be placed into drums containing a pre-mixed solution of 10% formalin in buffered seawater. Samples must remain in the 10% formalin solution for a minimum of 48 hours to ensure complete fixation.

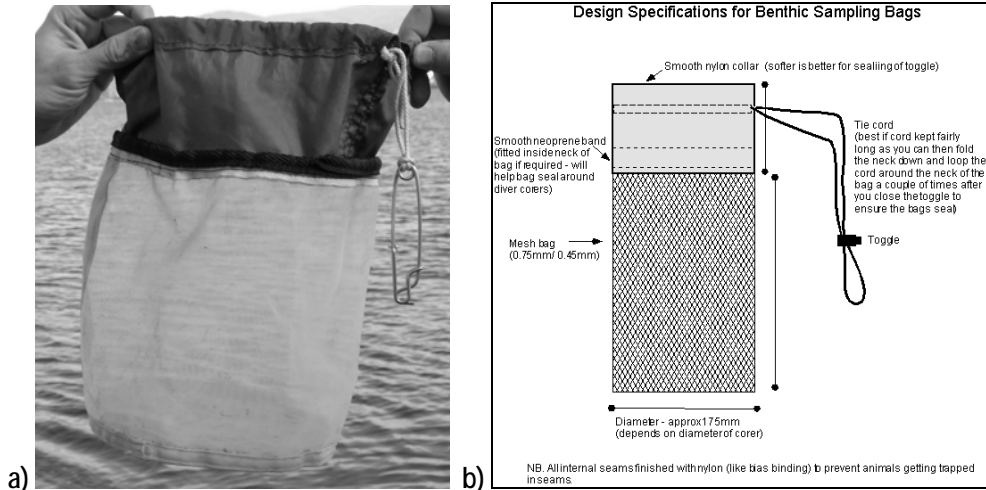


Fig. 10. a) Mesh bag, b) Diagram of mesh bag showing dimensions.

### ii) Video Assessment

Video footage can be obtained either remotely or by diver. For remote sampling, a remotely operated vehicle (ROV) can be used (Fig. 11) or it is possible to use a digital underwater camera system linked by an umbilical to a digital recorder on the surface vessel (Fig. 12.a,b). In order to appropriately assess some of the key assessment features colour footage taken with a camera with an independent light source is preferable. For diver videos, a colour digital video camera in an underwater housing with an independent light source is the best option (Fig. 12.c). There should be sufficient light to clearly distinguish all the assessment features (i.e. sediment colour) and consequently the light intensity required may vary between sites/regions. The distance between the sediment surface and the camera is very important and to standardise this it is advisable to house the camera in a frame (Fig. 12.a,b) The distance between the camera and the seabed should be between 30 – 50cm. The video footage is recorded either in the underwater housing or on the surface. Using digital technology will ensure that video quality is maintained with any subsequent reproduction or copy of the video, however it is possible to use a Hi8 camera if that is all that is available. At each sampling station, a minimum of 2 minutes footage should be taken on and around each sample location.

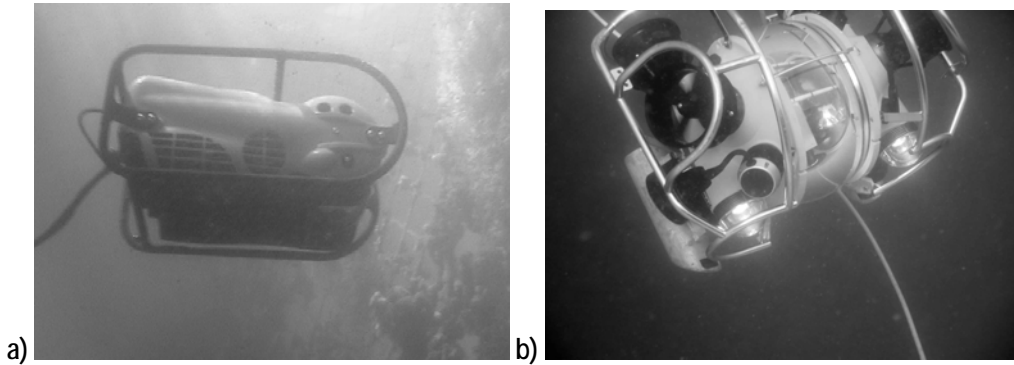


Fig. 11. a) ROV (Photo courtesy of DPIWE, sourced from Seabotix), b) ROV (Photo courtesy of Aquenal).

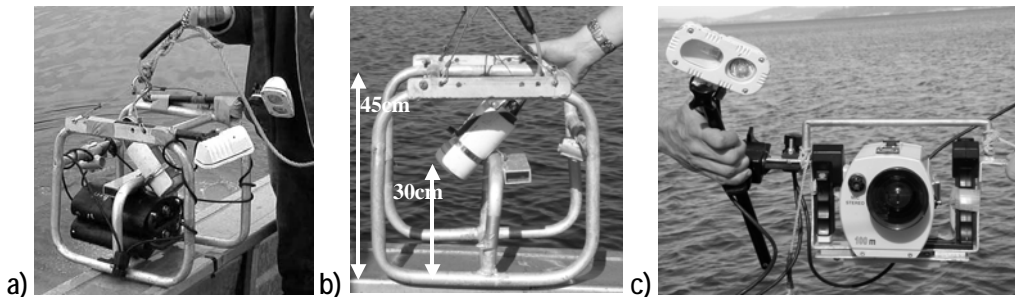


Fig. 12. a) Umbilical digital camera in frame with external lights attached b) Photo of camera indicating position above sediment surface, c) Diagram of camera setup, d) Underwater digital camera housing with external light.

### iii) Sediment Core Collection

Core samples are used for analysis of redox potential, sulphide concentration and evaluation of microbial communities. There are many different types of corer available but the two recommended in this study are either a Craib corer (Fig. 13a) or Multicorer (Fig. 13b,c). Core tubes should be approximately 250mm length x 45mm internal diameter, and preferably clear Perspex (Fig. 14). Cores for analysis of redox potential and sulphide concentration need to have side access sample ports (Fig. 14b). These holes are sealed with duct tape during deployment. A locking pin can also be attached to the core so they can be secured in the corer (Fig. 14b).

Cores can also be collected by divers. In this situation, the core is inserted into the sediment to a depth of approximately 15cm. This depth can be ensured by establishing a mark or lip on the outside of the core that the divers can use as a guide. A bung is placed in the top of the core, the core is then carefully removed from the sediment and a second bung placed in the bottom. The bung in the top causes a vacuum within the core that holds the sediment in position while it is removed. This works very well in fine sediments but can be less successful in sandy conditions. In sandy sites the diver may have to excavate around the core to insert the bottom bung.

It is important that the cores are kept upright at all times. A simple carrying box can be used to ensure that the cores are kept vertical both whilst sampling and when being hauled to the surface (Fig. 13c). If measurements or analyses are not to be performed immediately then the cores should be transferred to suitable container (e.g. an esky) filled with water at ambient temperature for transfer.

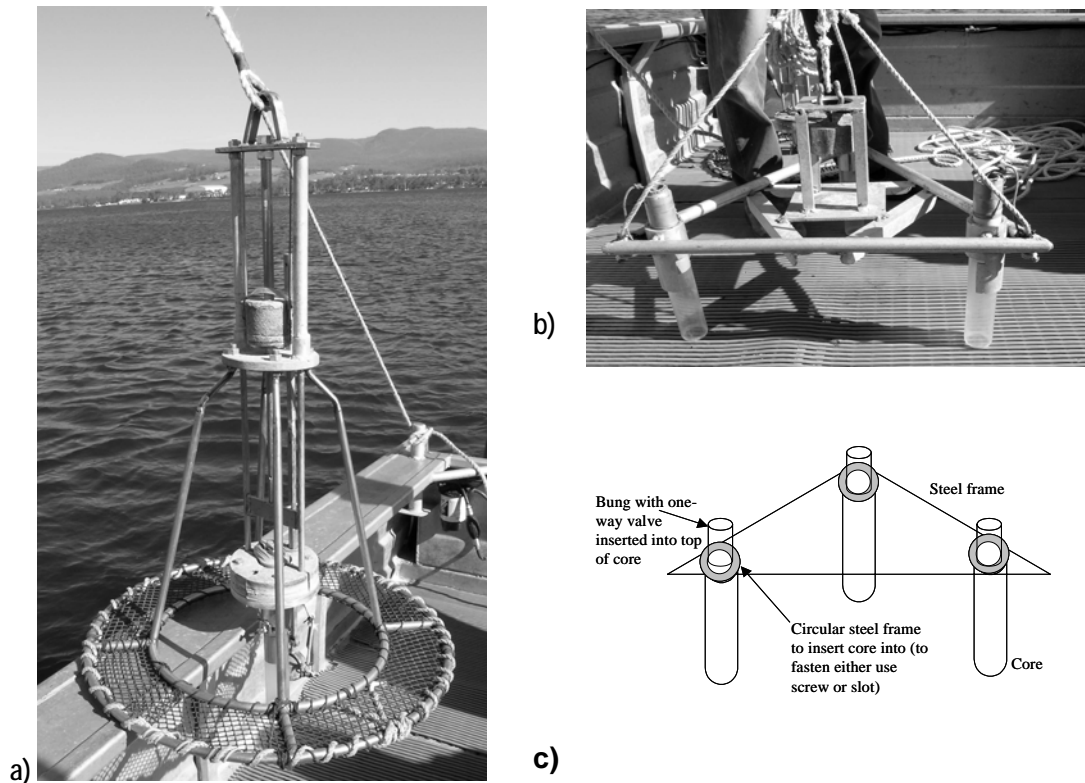


Fig. 13. a) Craib corer, b) Multicorer, c) Diagram of core setup in Multicorer.

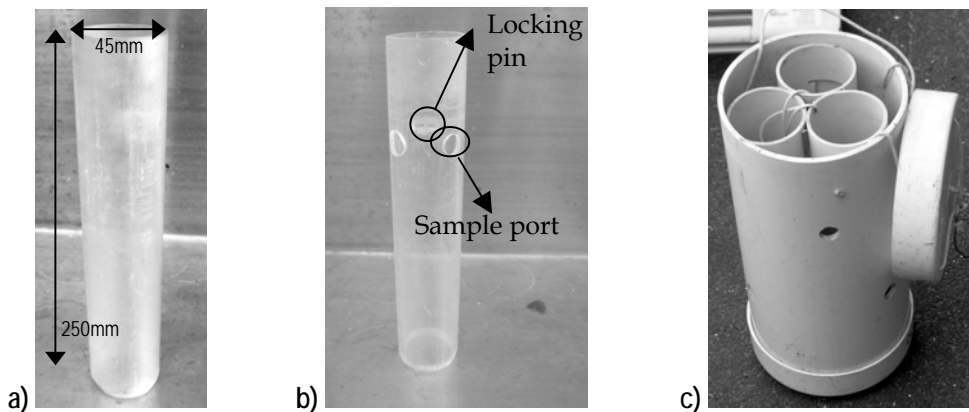


Fig. 14. a) Standard cores, b) Redox/sulphide cores, c) Core holder / carrier.

## 5.2.2 Laboratory/Shore Based Processing of Samples

### *i) Faunal Assessments*

The sieved samples (mesh bags or jars) should be rinsed thoroughly in freshwater before being transferred to shallow white trays for sorting. Samples should subsequently be stored in a solution of 70% ethanol. If the samples have been well preserved in formalin the ethanol solution can be made up using freshwater.

*a) Full Faunal Evaluation*

The fauna are removed from any remaining sediment and the species present identified to the lowest possible taxonomic level and each taxa counted. Full identification of all the infaunal species requires highly skilled and well-trained biologists/taxonomists and therefore is not dealt with any further in this guide. If this type of assessment is required contact the DPIWE Marine Resources division (phone (03) 6233 3370) to gain a list of suitably trained professionals to undertake the identifications.

*b) Simplified Faunal Assessment*

Samples are rinsed and transferred to sorting trays as per the full faunal assessment. The samples are then examined and the following criteria assessed (Table 3).

**Key/Indicator Organisms:**

There are several general indicators (Fig. 2) that appear to be indicative of sand or mud sediments, but there may also be site specific indicators that will need to be identified (site baseline information may be useful). General indicators include:

- Unimpacted conditions – Brittle stars present / key amphipods present (*Ampelisca* sp / *Apeudes* sp.) (Appendix 7.1).
- Impacted conditions – samples dominated by capitellid polychaetes / abundant *Nebalia longicornis* (Appendix 7.1)

**Number of Species:**

Unimpacted – Comparable to reference;

Moderate Impact – Number of species may be reduced (>50% of reference);

Major Impact – Considerable reduction in species diversity (<50% of reference).

**Annelid Abundance:**

Unimpacted – Comparable to reference;

Moderate Impact – More than 20x increase compared to reference abundance;

Major Impact – More than 50x increase compared to reference abundance;

**Table 3.** Summary of levels for a) major faunal characteristics and b) key faunal species.

a) Description	Stage	Number of Species	Annelid Abundance
Unimpacted	I/II or IX	Same as ref	Same as ref
Moderate Impact	III/IV or VII/VIII	>50% of ref	20x ref
Major Impact	V	<50% of ref	50x ref
Severe Impact	VI	Defaunate or Azoic	
b) Description	Stage	Key Indicator Organisms	
Unimpacted	I	<i>Apeudes</i> &/or <i>Ampelisca</i> &/or Brittle stars present in abundance	
Minor Impact	I/II or IX	Heart urchins present in abundance	
Moderate Impact	II/III or VII/VIII	<i>Corbula</i> &/or <i>Theora</i> present in abundance	
Severe Impact	III - VIII	Capitellids &/or <i>Nebalia</i> present in abundance	

**ii) Quantitative Visual Assessment**

**a) Benthic Photos**

The sieved sample material should be rinsed thoroughly in freshwater before being transferred to a white sorting tray. A digital photograph is then taken of each sample. Where possible the same tray should be used for all photographs to ensure consistency. Where large shell fragments are present, it may be useful to remove these prior to taking the photograph. The photographs are then assessed by evaluating the presence/absence and relative abundance of key features (Table 4a, Appendix 7.2.2). A scoring system based on parameters indicative of impacted or unimpacted sediments (identified through the full analysis of these samples) is applied (Table 4a). Parameters are either positive or negative depending on whether the parameter indicates a positive or negative effect. Scores are weighted depending on the severity of impact indicated by each parameter. When cumulatively added they provide a total sample score which corresponds to the level of impact for that sample (Fig. 15a). Some features may not be relevant at all sites. An initial baseline study (full benthic faunal analysis and video survey) will indicate the key indicator species and visual assessment features specific to each farm.

**b) Quantitative Video Assessment**

Video footage for each sample position is scored according to key features that are determined to be indicative of impacted or unimpacted conditions (Fig. 3, Appendix 7.2.1). These features are weighted according to their ability to discriminate impact. Features indicating little or no impact add to the score, whilst those indicating a detrimental affect subtract from the score (Table 4b). Therefore the higher the score, the better the sediment condition (Fig. 15b). The resulting scores for all variables can be set up as a multivariate matrix or they can be summed to give a single video score for each station/time. The video data can be analysed using univariate or multivariate techniques. Univariate analysis provides a single score for each site and time and these can be compared over time or for all positions within a lease at any given time. Multivariate analysis makes it easier to compare the differences between the sites in relation to particular assessment features/criteria. However, for farm assessment purposes calculation of the cumulative score will be sufficient to assign impact level.

Table 4. a) Key features and scoring levels for benthic photographs.

Photo Feature	Scoring Levels				Weighting	Category
Introduced Bivalve ( <i>Corbula gibba</i> )	0-Absent	1-Few	2-Many			1 -1
Capitellid Worms	0-Absent	1-Few	2-Many	3-Whole sample		2 -1
Other Worms	0-Absent	1-Few	2-Many			1.5 1
Suspension Feeders (Brittlestars)	0-Absent	1-Present				2 1
Heart Urchins	0-Absent	1-Few	2-Many			1 1
Sea Slugs	0-Absent	1-Few	2-Many			1 -1
Mussell Shells	0-Absent	1-Few	2-Many			1 -1
Nassarid Gastropods (dog whelk)	0-Absent	1-Few	2-Many			1 -1
Other Invertebrates	0-Absent	1-Few	2-Many			1 1

b) Key features and scoring levels for video assessment.

Video Feature	Scoring Levels				Weighting	Category
Gas bubbles	0-Absent	1-On disturbance	2-Spontaneous outgassing		10	-ve
Black/grey sediment	0-Normal	1-Not normal (compared to reference)			1	-ve
Beggiata	0-Absent	1-Patchy	2-Thin mat	3-Thick mat	1.5	-ve
Pellets and faeces	0-Absent	1-Few	2-Many	3-Feed spill	1	-ve
Farm-derived debris	0-Absent	1-Present			1	-ve
Burrow density	0-Absent	1-Few	2-Many	3-Dense	1.5	+ve
Worm tubes/casts	0-Absent	1-Present			1	+ve
Faunal tracks	0-Absent	1-Present			1	+ve
Algal Cover	0-Absent	1-Sparse	2-Moderate	3-Dense	1.5	+ve
Brittle star	0-Absent	1-Present			1.5	+ve
NZ screw shell	0-Absent	1-Few	2-Many		1	+ve
Nassarid gastropod	0-Absent	1-Few	2-Many		1	-ve
Side gilled seaslug	0-Absent	1-Few	2-Many		1	-ve
Heart urchin	0-Absent	1-Few	2-Many		1	+ve
Squat Lobster	0-Absent	1-Few	2-Many		1	-ve
Swarming epibenthic crustaceans	0-Absent	1-Few	2-Many		1	+ve
Echiurans & Annelids	0-Absent	1-Few	2-Many		1.5	+ve
Fish / Other Vertebrates	0-Absent	1-Few	2-Many		1	+ve
Other Crustaceans	0-Absent	1-Few	2-Many		1	+ve
Sea Stars	0-Absent	1-Few	2-Many		1	+ve
Other Fauna	0-Absent	1-Few	2-Many		1	+ve

(Refer to Appendix 7.2.1 / 7.2.2 for clarification of terminology (i.e. sparse / moderate / dense & few / many)).

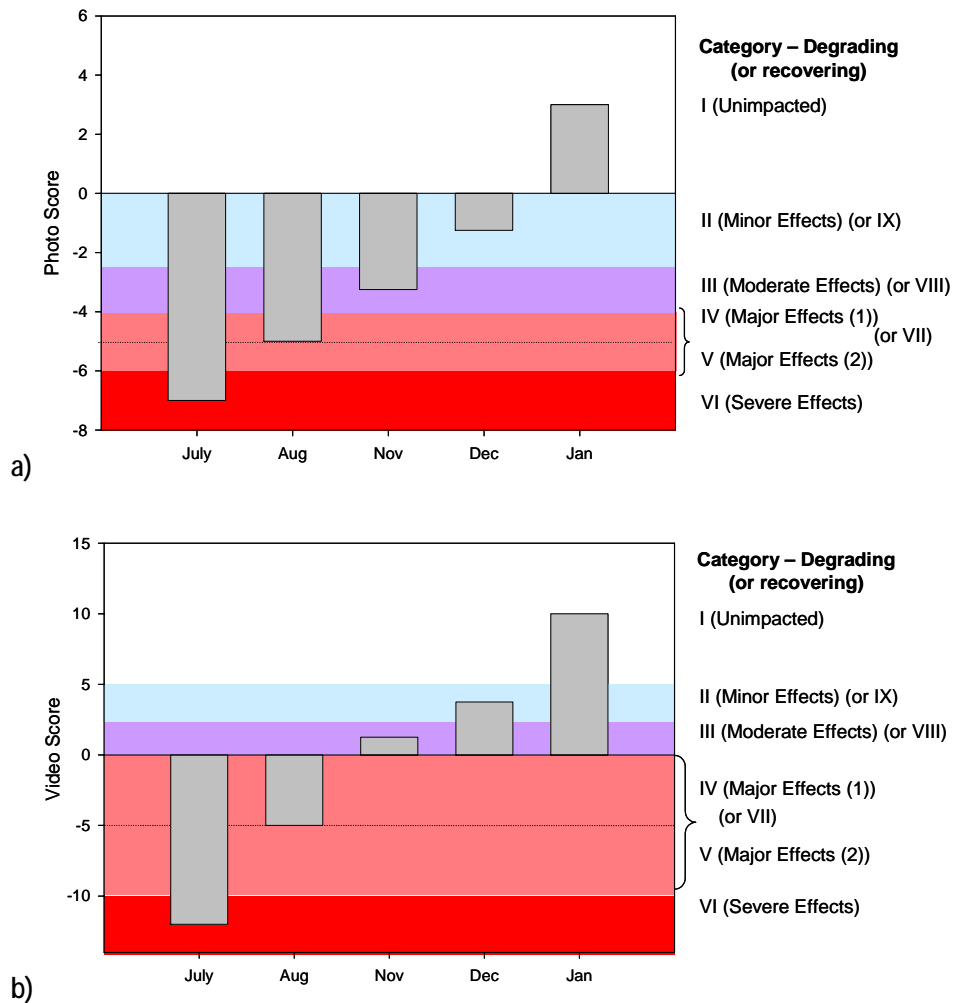


Fig. 15. Representation of relationship between a) photo scores and impact levels (example data used) and b) video scores and impact levels (example data used).

*iii) Redox Potential and Sulphide Concentration*

Redox potential and sulphide concentration measurements are taken from sediment cores (collected as previously described – 5.2.1.iii). Both redox and sulphide should be measured at 3cm depth. There are a variety of redox probes available; single cell and combination electrodes. For ease of sampling the combination electrodes are recommended. In CRC Project 4.1 a WTW Combination Redox Probe was used. Prior to each set of measurements being taken the probe should be calibrated. Pre-packaged calibration solutions can be purchased. As calibration is sensitive to temperature it is important to note the temperature of both the calibration solution and the sample at the time of sampling. It is best if these temperatures are comparable. To obtain a measurement the probe is inserted into the hole in the side of the core tube (Fig. 13b).

Redox potential values should be allowed to stabilise prior to recording. Depending on the sediment condition the measurement may settle quickly or it may take a few minutes. Redox measures the oxidation/reduction potential of the sediments by determining the availability of free hydroxyl ions. Measurement will itself affect this level and therefore the reading on the meter will continue to decline (albeit slowly) whilst the measurement is being made. Consequently it is not necessary for the probe to stabilise completely before taking a reading, simply ensure that the rate of decline has steadied. Note that an error level of +/- 10-20mV in the final reading is acceptable.

Sulphide concentration is measured using a silver/sulphide combination electrode. Once again there are a variety of different probes available but a combination electrode is recommended. Each manufacturer will have slightly different specifications regarding use, sensitivity and calibration and these should be followed carefully. In Project 4.1 a Cole-Parmer 27502-40 silver/sulphide electrode was used. Prior to each sampling occasion, a Sulphide Anti-Oxidant Buffer (SAOB) must be prepared (see technique below & Appendix 7.4.3) and standard curves should be established for calibration (technique described below & Appendix 7.4.3).

A sediment sub-sample (2ml) is extracted from the port in the side of the core tube (Fig. 13b) using a 5ml syringe, and placed in a glass vial. SAOB (2ml) is added to each jar and sulphide concentration measured (mV) by placing the probe into the jar, and slowly stirring the sediment/buffer mix until the reading stabilises. The mV readings can be converted to sulphide concentration using the calibration curve described earlier. The procedure for this is included in the attached data analysis package (CD).

***Preparation of Sulphide Anti-Oxidant Buffer Solution (SAOB) for Cole Parmer Electrode:***

The SAOB solution can be purchased ready made or it can be prepared by adding 20.0g of NaOH (Sodium Hydroxide pellets) and 17.9g of EDTA (Ethylenediaminetetra-acetic acid) in a 250ml volumetric flask and diluting to volume with distilled water. This solution should be refrigerated (4°C) until required. Just prior to use add 8.75g of ascorbic acid for every 250ml of solution required. Once ascorbic acid has been added, the solution will only remain viable for approximately 3 hours.

***Calibration of Cole Parmer 27502-40 Sulphide Probe:***

The accuracy of the probe is established by checking the calibration with known standards.

To make up the primary standard (C1), weigh approximately 0.2402g of sodium sulphide ( $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ ) into a 100ml volumetric flask and fill to the mark with deionised water. Record the exact weight of sodium sulphide used (refer recording sheet, Appendix 7.4.3). Extreme care should be taken when handling and weighing sodium sulphide (gloves and safety glasses should be worn and all procedures carried out in or adjacent to a fume cabinet).

To make additional standards, dilute the primary standard using 50ml volumetric flasks.

C2 = 5mls of C1 in 50ml (make up to volume using  $\text{DH}_2\text{O}$ )

C3 = 5mls of C2 in 50ml (make up to volume using  $\text{DH}_2\text{O}$ )

Step 1 - Conduct a slope check.

Add 20ml SAOB to a small plastic beaker, and stir the solution with a magnetic stirrer. To this add 1ml of C1 and record the mV reading (A), then add 10ml of C1 and record the mV reading (B). The difference between A and B should be  $26 \pm 2$  mV.

Step 2 - Determine the standard curve.

Add 15ml of standard (C3) to the same volume of SAOB solution (1:1 ratio). Stir the solution using a

magnetic stirrer and record the mV reading. Repeat the procedure for the other standards, C2 and C1, in that order. Once again, the difference in mV readings between C1 & C2, and C2 & C3, should be  $26 \pm 2$  mV.

NB. The calibration requirements may vary depending on the type and make of the probe employed. Please refer to manufacturers guidelines for specific details.

**iv) Other Techniques**

**a) Lipid/ Fatty Acid / Sterol Assessment:**

Fatty acids, lipids and sterol samples are collected from grab samples. A subsample from the grab (approximately 50ml) is placed in a sterile glass jar and frozen for analysis. If any of these assessments are required then samples should be sent to the CSIRO Marine Laboratories, Hobart. Contact Dr J.Volkman, CSIRO Marine Laboratories for any further information (Phone (03) 6232 5222).

**b) Microbiology (Bacterial enumeration):**

Core samples are necessary for bacterial enumeration. The top 1-2cm of sediment are sliced into three sections (0-2 mm, 2-5 mm and 5-10 mm) and these samples fixed in 4% formalin buffered in 0.2µm filtered seawater. Samples should be stored at 4°C. Enumeration of bacteria is a complex process, and will require specialised assistance.

For more information regarding this process, please contact Dr C. Burke, School of Aquaculture, University of Tasmania (Phone (03) 6324 3801).

**v) Data Management (SEAbase)**

As part of this project a Sediment Environmental Assessment database (SEAbase) has been developed to facilitate environmental data management and analysis. SEAbase provides a user-friendly interface for data entry, storage and analysis, and for production of reports. When used correctly, the system can provide useful insights into the relationship between the sediment condition and farm production. Data can be input directly into SEAbase or extracted from existing spreadsheets/databases. A full guide to using SEAbase can be found in Appendix 7.3.

**a) Data Entry**

Records can be entered directly or imported from Microsoft Excel or another database package (eg. Access or Oracle). When importing data to SEAbase it is important that the data format matches. Once data is entered into SEAbase, it is automatically saved. However, it is advisable to back up the database regularly, particularly if using the system for primary data storage. Ensure that SEAbase is backed up after entering any large amounts of data.

**b) Data Analysis and Reports**

With some techniques, i.e. redox potential, sulphide concentration, video assessment and visual assessment, the raw data must be converted into meaningful units before the results can be interpreted. There are specifically designed functions within SEAbase to both convert the relevant raw data into meaningful measurements and to extract certain combinations of data. Once the data has been entered, there is a command button on each of the relevant data entry forms that will automatically convert your data. The data must be converted before undertaking any other functions/ analyses.

A variety of reporting options are currently available in SEAbase. These can produce summaries of the data and combinations of different results to give an overall picture of sediment condition.

However, it is possible to tailor reports for particular needs. It is also possible to extract data for use in further analysis, (e.g. univariate analyses (such as ANOVA's) or multivariate analyses) and SEABase contains several functions specifically for this purpose.

*c) Data Interpretation*

Aquafin CRC Project 4.1 indicated a strong relationship between farm management and the condition of sediments. It was evident that changes to the farm production schedule, and in particular changes to feed input and biomass, can influence the sediment condition, and hence the time required to recover prior to restocking. SEABase makes it possible to easily view sediment condition data in combination with production data, by producing reports that combine production data, farm environmental data (dissolved oxygen and temperature collected on farm) and sediment condition data.

For any further information on SEABase or data interpretation, please contact Ms S. Forbes or Ms C. Macleod, TAFI, University of Tasmania (Phone (03) 6227 7277).

## **6 Important Notes**

This field manual and SEABase have been developed using a restricted dataset. In interpreting sediment condition at farms where baseline environmental conditions differ markedly from those of the original study sites (CRC project 4.1) it is important that the data and associated impact stages be validated. Baseline benthic information is necessary to characterise the fauna of the system and to determine key faunal and visual assessment indicators. Even where baselines have already been established indicators should be revalidated regularly (i.e. biannually) to ensure that they continue to be representative.

Although video assessment may appear to be very reliable, any assessment of environmental condition based on a single factor/technique should be viewed with caution. Evaluation of sediment condition is always more reliable when multiple approaches are employed or where the findings can be tracked over time. For example assessment of video in combination with key benthic indicators and measurement of redox potential will give a clearer picture than video assessment alone and the assessment may be further enhanced if a data series is available over time and is able to be considered in conjunction with farm production information.

## 7 Appendices

### 7.1 Photo guide to key indicator organisms.

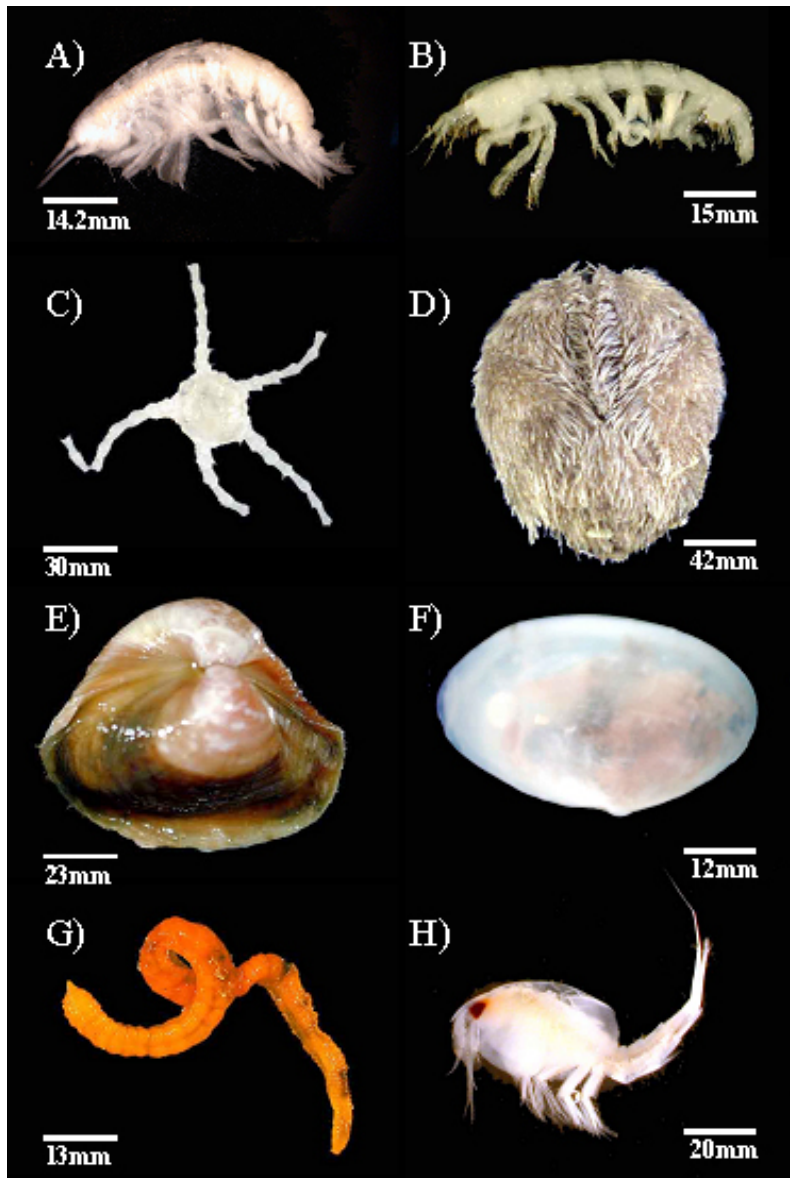


Fig. 7.1. Key Indicator Organisms a) *Ampelisca* sp., b) *Aapseudes* sp., c) *Amphiura elandiformis* (Brittle Star), d) *Echinocardium cordatum* (Heart Urchin), e) *Corbula gibba*, f) *Theora lubrica*, g) *Capitella capitata*, h) *Nereis longicornis*.

## 7.2 Visual characterisation criteria for Visual Assessments

### 7.2.1 Guide to Video Assessment Features

The video assessment features are detailed below, with scoring options and associated photographs. When scoring groups of fauna, 'few' usually refers to one to five individuals, whilst 'many' refers to more than five individuals.



#### 1. Gas Bubbles

*Scoring:* 0=Absent

1=Present on disturbance (pictured)

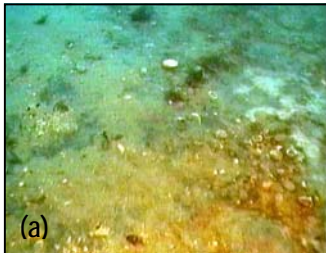
2=Spontaneous bubbling



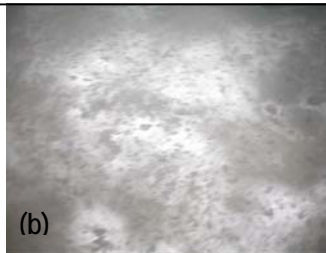
#### 2. Sediment Colour

*Scoring:* 0=Normal

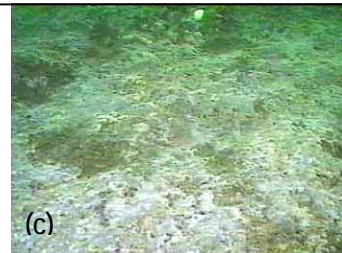
1=Not normal (pictured – grey/black as compared to reference)



(a)



(b)



(c)

3. Beggiatoa

*Scoring:*

0=Absent; 1=Patchy (a); 2=Thin Mat (b); 3=Thick Mat (c)



#### 4. Pellets / Faeces

*Scoring:* 0=Absent

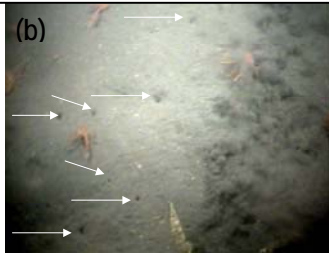
1=Few

2=Many (pictured)

3=Feed Spill



**5. Farm Debris**  
*Scoring:* 0=Absent  
1=Present (pictured)



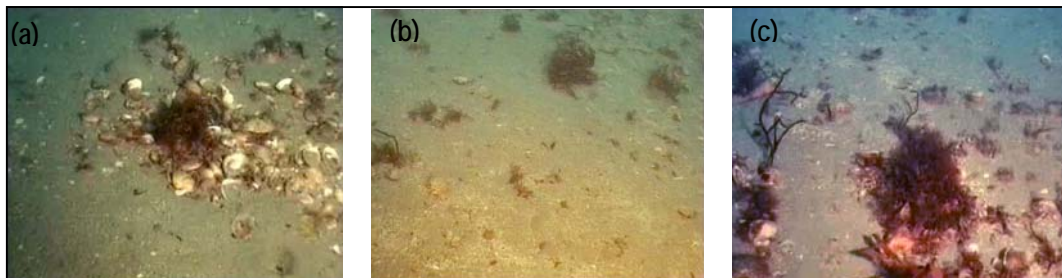
**6. Burrow Density**  
*Scoring:* 0=Absent; 1=Few (a); 2=Many (b); 3=Dense (c)



**7. Worm Tubes**  
*Scoring:* 0=Absent  
1=Present (pictured)



**8. Faunal Tracks**  
*Scoring:* 0=Absent  
1=Present (pictured)



**9. Algal Cover**

*Scoring:* 0=Absent; 1=Sparse (a -few isolated patches); 2=Moderate (b -many isolated patches); 3=Dense (c -continuous patches)



**10. Brittle Stars**

*Scoring:* 0=Absent  
1=Present (pictured)



**11. New Zealand Screw Shells**

*Scoring:* 0=Absent  
1=Few (<10 individuals)  
2=Many (pictured)



**12. Dog Whelks**

*Scoring:* 0=Absent  
1=Few (<10 individuals)  
2=Many (pictured)



**13. Sea Slugs**

*Scoring:* 0=Absent

1=Few (1-2 individuals)(pictured)

2=Many



**14. Heart Urchins**

*Scoring:* 0=Absent

1=Few (1-2 individuals)

2=Many (pictured)



**15. Squat Lobsters**

*Scoring:* 0=Absent

1=Few (1-2 individuals)

2=Many (pictured)



**16. Swarming epibenthic crustaceans**

*Scoring:* 0=Absent

1=Few (1-2 individuals) (pictured)

2=Many



**17. Echiurans / Large Annelids**  
(e.g. Echiuran proboscis (pictured)).

*Scoring:* 0=Absent  
1=Few (1-2 individuals)  
2=Many



**18. Fish / Other Vertebrates**  
(e.g. Banded Stingaree (pictured)).

*Scoring:* 0=Absent  
1=Few (1-2 individuals)  
2=Many



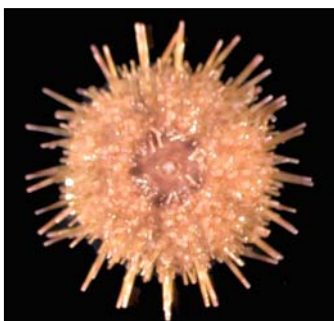
**19. Other Crustaceans**  
(e.g. Pebble Crab (pictured)).

*Scoring:* 0=Absent  
1=Few (1-2 individuals)  
2=Many



**20. Sea Stars**

*Scoring:* 0=Absent  
1=Few (1-2 individuals) (pictured)  
2=Many

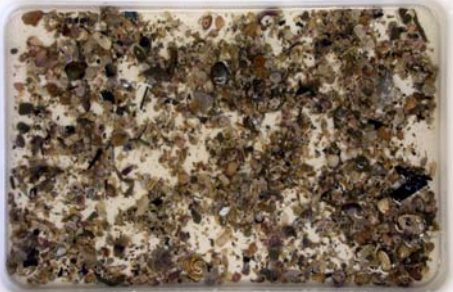



**21. Other Fauna**  
(e.g. Sea Urchin (pictured)).



*Scoring:* 0=Absent  
1=Few (1-2 individuals)  
2=Many


### 7.2.2 Guide to Photo Assessment Features

The photo assessment features are detailed below, with scoring options and associated photographs.

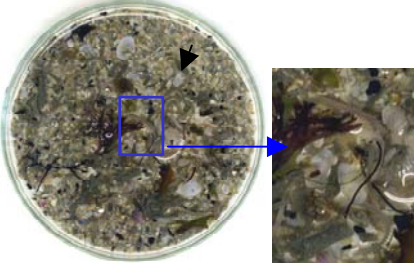

a)  b) 

**1. Introduced Bivalve (*Corbula* – individual photo shown in Fig. 7.1E)**  
Scoring: 0=Absent; 1=Few (a – 1-2 individuals); 2=Many (b)

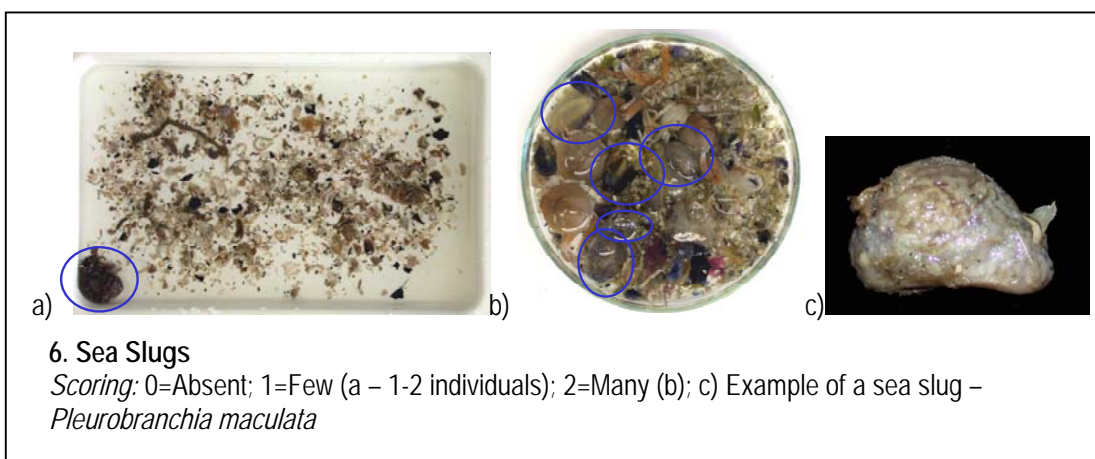
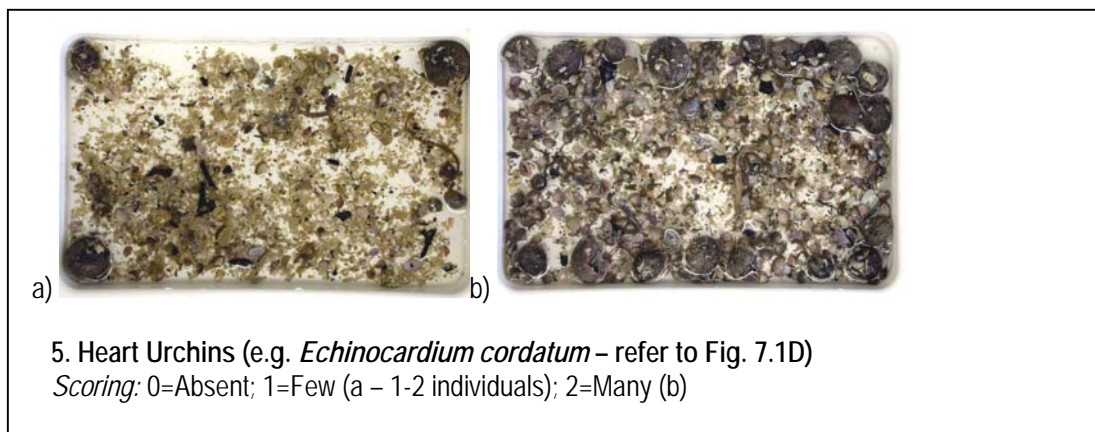
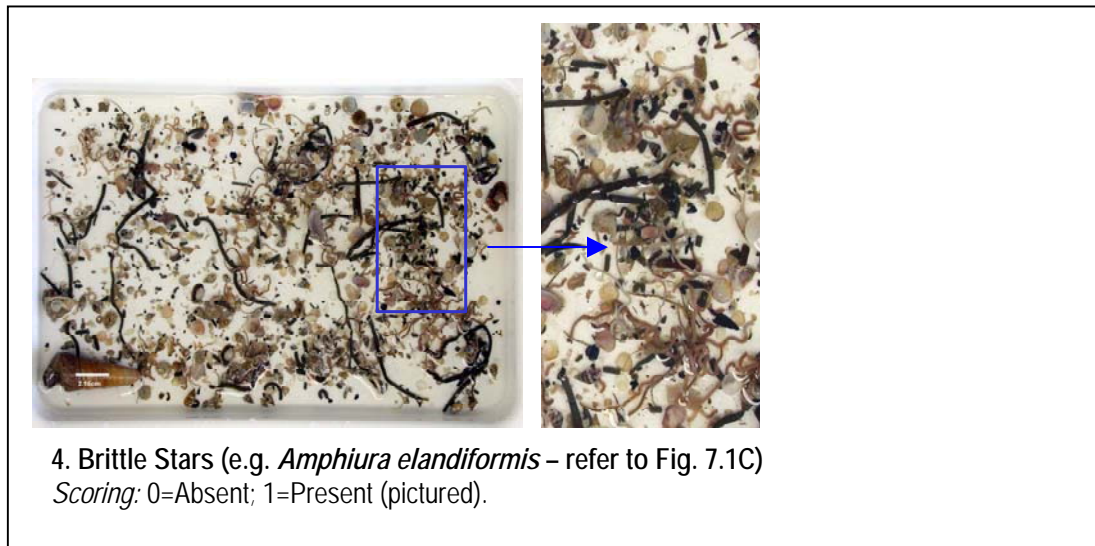
a)  b) 


c) 

**2. Capitellid Worms (*Capitella capitata* – individual photo shown in Fig. 7.1G)**  
Scoring: 0=Absent;  
1=Few (a – 1-2 individuals);  
2=Many (b);  
3=Whole Sample (c)

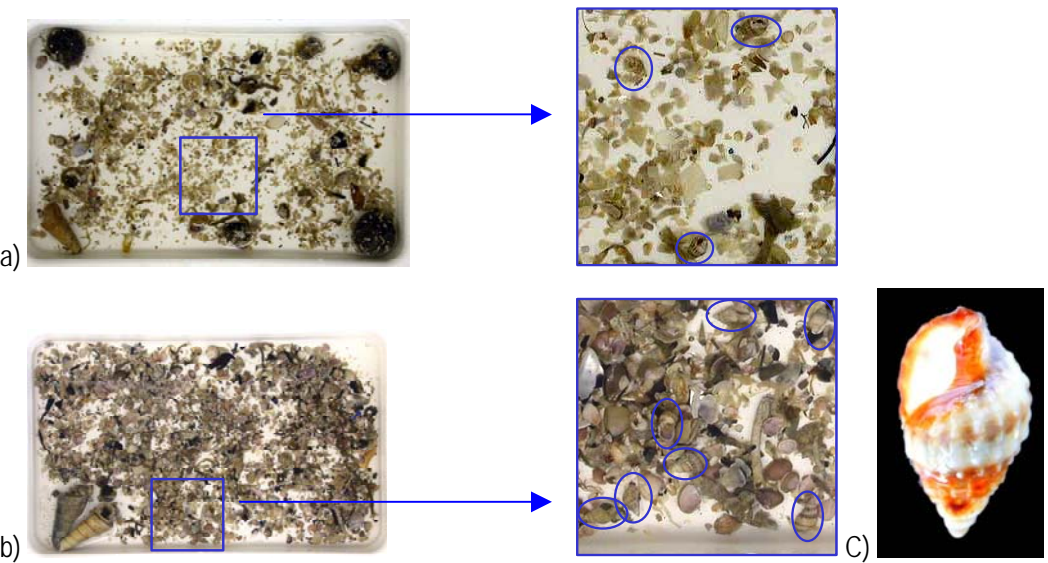
a)  b) 

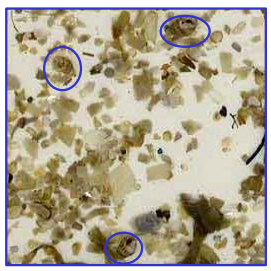
**3. Other Worms (scoring based on number of different types of other worms)**  
Scoring: 0=Absent; 1=Few (a – 1-2 individuals); 2=Many (b)







**7. Mussel Shells**  
Scoring: 0=Absent;  
1=Few (1-2 individuals) (pictured);  
2=Many.



a) 

b)  c) 

**8. Dog Whelks (circled in insets – a & b)**  
Scoring: 0=Absent; 1=Few (a – 1-2 individuals); 2=Many (b); c) Example of a dog whelk – *Nassarius nigellus*.

**9. Other Fauna**  
(e.g. crabs, urchins, seastars)

Scoring: 0=Absent;  
1=Few (1-2 individuals);  
2=Many.



E.g. New Zealand Screw Shell (*Maoricolpus roseus*).

## 7.3 Guide to using SEABase

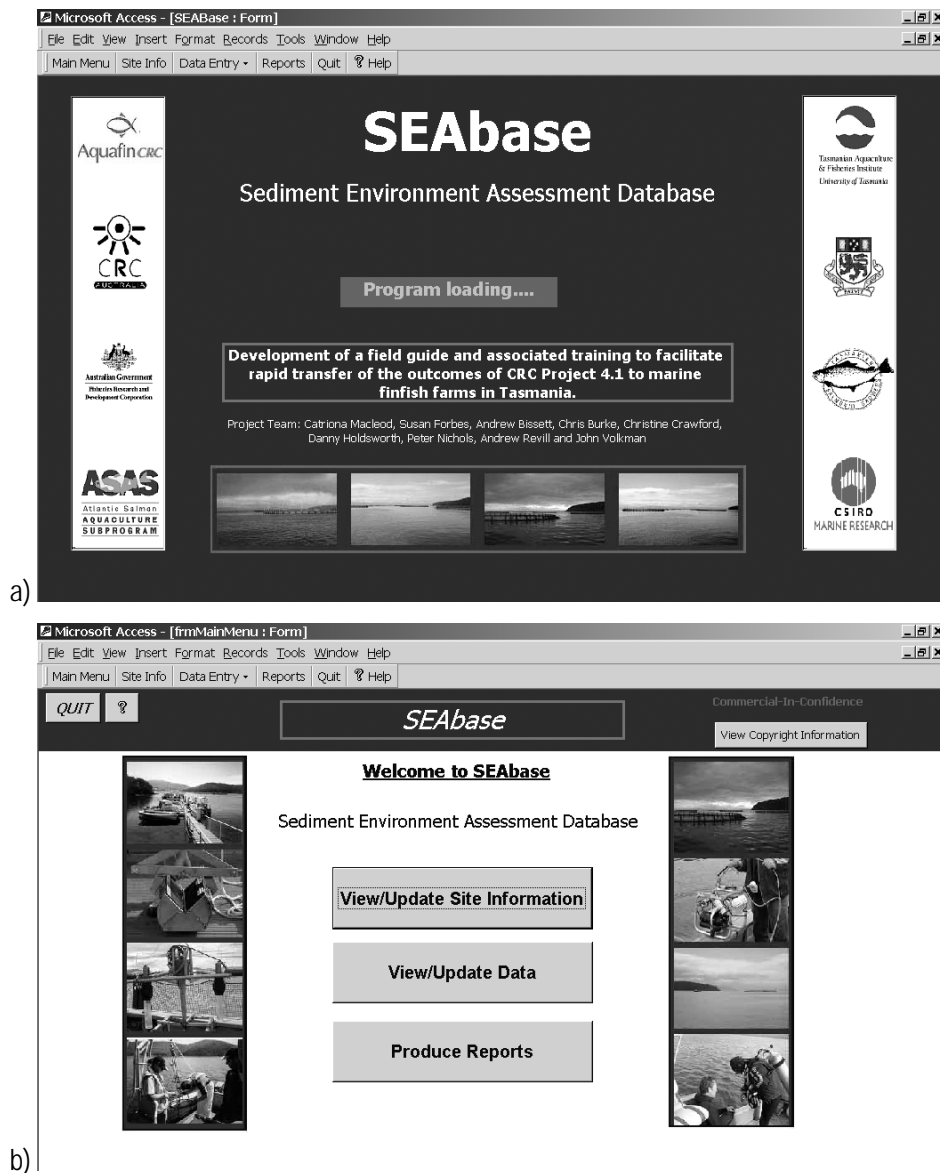


Fig. 7.3 a) SEABase Start up form; b) SEABase Main Menu form.

### 7.3.1 Introduction

SEABase is a form-based Access database designed for the Tasmanian Salmonid Finfish Aquaculture Industry. The database can be used for data storage, manipulation, analysis and reporting. The following information goes through the various forms within SEABase, providing a guide to how to use each form, the type of data required / produced and all possible analyses.

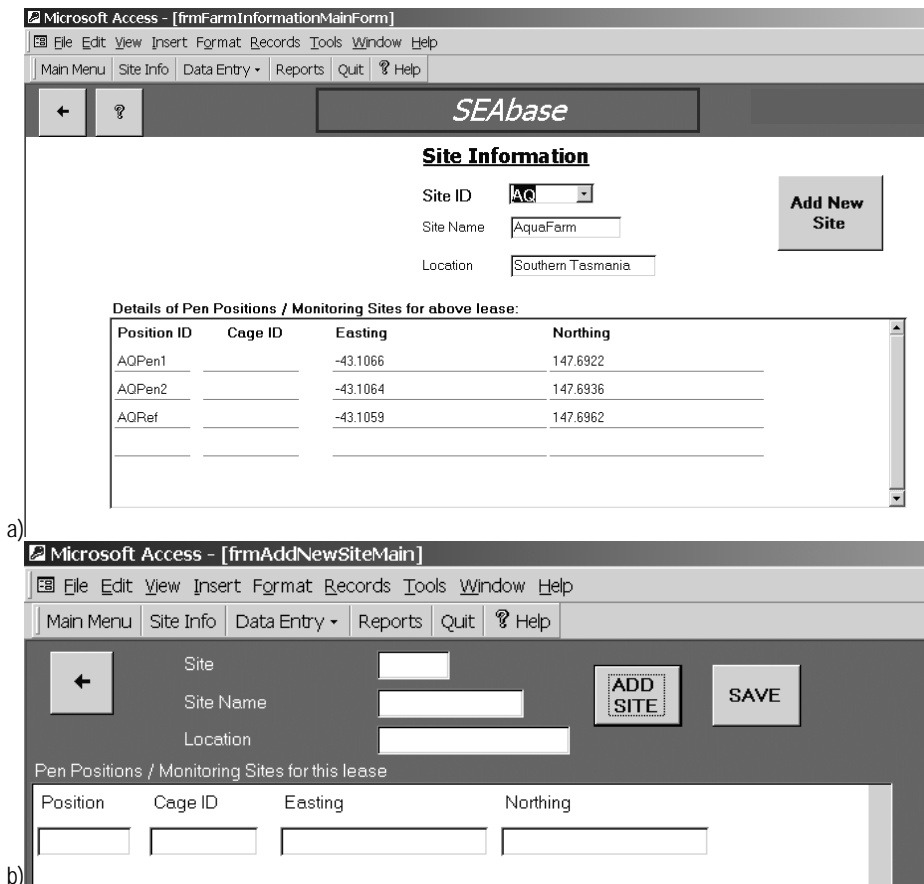


Fig. 7.3.1 a) SEABase Site Information form; b) SEABase Site Information, Add New Site form.

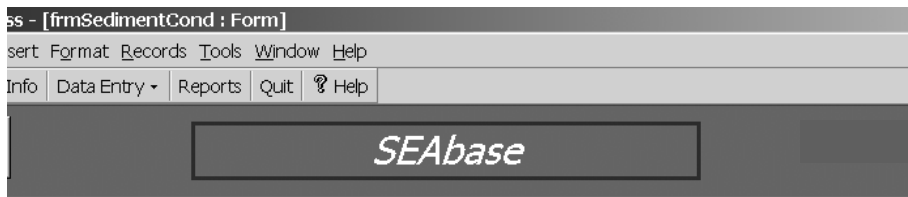
### 7.3.2 Site Information

The site information form can be used to view data on leases/sites and positions within sites. The first step when entering data for a new site is to add the site to the database. All positions have a unique ID/name, and there is the option to include easting/northing coordinates. Some farms have differing position and cage ID's. In SEABase the position ID relates to the actual position where the sediment was collected. A Cage ID, relating to the identification of the fish stocked at a position can be added. To view data on different sites, select the required site from the drop down menu. To enter data on a new site, click on 'Add New Site' command button. To enter data for a new position within an existing site/lease, simply click on the row below the last entry for that site, and enter the unique position identifier, and if desired, the coordinates for that position.

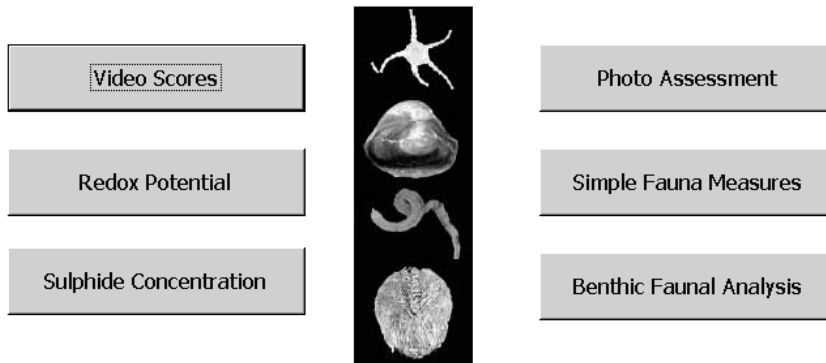
#### Site Information (add new site)

Use this page to enter an entirely new site/lease by clicking on the 'Add Site' command button. You can then enter a unique identifier for the site, the site's full name and location. Positions and cage ID's can be entered simply by clicking on the first row under 'position' and typing in the unique

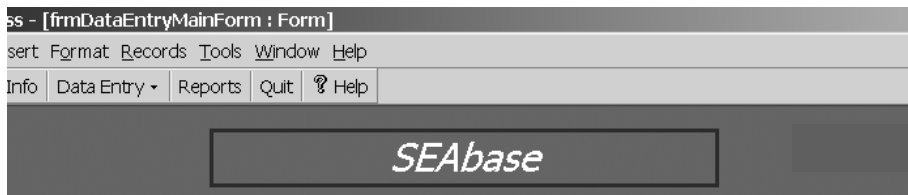
position identifier. Easting and Northing coordinates can also be added. Once added, click the 'Save' command button.



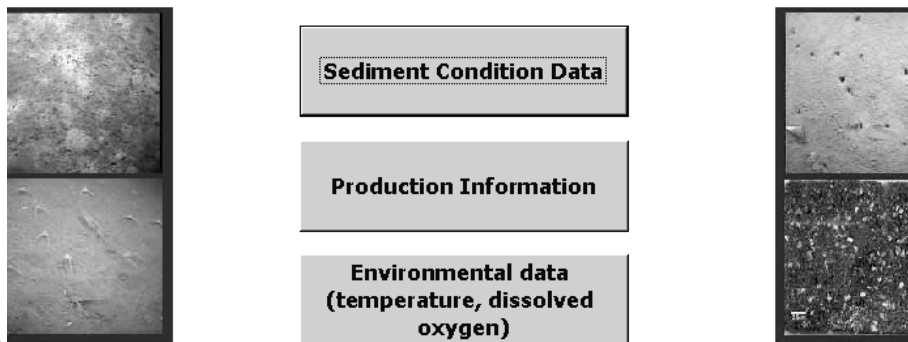
**Analysis of Sediment Condition: Choose from the following techniques**



a)



**Data Entry Main Form**



b)

Fig. 7.3.2. a) SEAbase Data Entry Main form; b) SEAbase Sediment Condition Data Entry form.

### 7.3.3 Data Entry

From the main data entry form you can navigate to all other data entry forms (you can also use the customised toolbar at the top of the page to navigate). The main data entry form is separated into

three categories – sediment condition data (for techniques recommended in the field manual), production information (site stocking and feeding information) and water quality data (such as temperature, dissolved oxygen and phytoplankton).

Sediment Condition Data

Six techniques for assessment of sediment condition are included in SEAbase. These are all described in the field manual. Data entry forms for each of these can be accessed by clicking on the relevant command button, or using the customised toolbar at the top of the page.

i) **Video Assessment Data Entry**

**SEAbase**  
Video Data Entry

Position: [ ] Date: 30-Jun-04 Position Status: [ ]

NB. To view examples of each criteria, click on the criteria heading

<b>1. Gas Bubbles</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Bubbling on disturbance <input type="radio"/> 2-Free bubbling	<b>4. Pellets/Faeces</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Few <input type="radio"/> 2-Many <input type="radio"/> 3-Feed Spill	<b>7. Worm Tubes</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Present	<b>Visible Fauna</b>
<b>2. Sediment Colour</b> <input checked="" type="radio"/> 0-Normal <input type="radio"/> 1-Black/Grey	<b>5. Farm Debris</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Present	<b>8. Faunal Tracks</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Present	
<b>3. Beggiatoid</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Patchy <input type="radio"/> 2-Thin Mat <input type="radio"/> 3-Thick Mat	<b>6. Burrow Density</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Few <input type="radio"/> 2-Many <input type="radio"/> 3-Dense	<b>9. Algal Cover</b> <input checked="" type="radio"/> 0-Absent <input type="radio"/> 1-Sparse <input type="radio"/> 2-Moderate <input type="radio"/> 3-Dense	

	0-Absent	1-Present/ Few	2-Many
10. Brittle Stars	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. NZ Screw Shell	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. Dog Whelks	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. Sea Slugs	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. Heart Urchins	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. Squat Lobsters	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. Swarming crustaceans	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
17. Echiurans	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
18. Fish	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
19. Other Crustaceans	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
20. Seasters	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. Other Fauna	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comments: [ ]

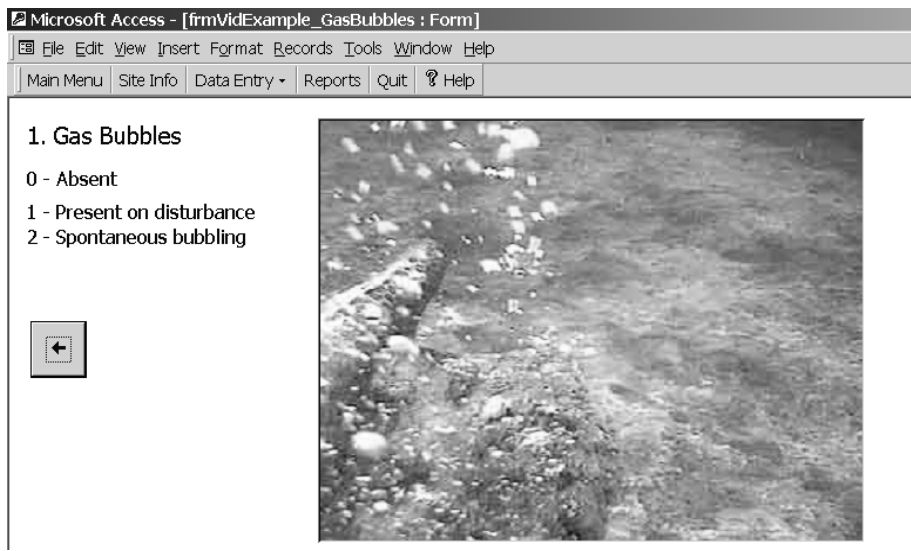
**Convert and view video score**

a)

**SEAbase**  
Converted Video Scores

Position ID	Date	Video Score	Stage	Position Status
FMPen1	18-Feb-02	-8	IV/V or VII	
FMPen1	11-Nov-02	-1.5	IV/V or VII	
FMPen1	09-Dec-02	-2.5	IV/V or VII	
FMPen1	06-Jan-03	-0.5	IV/V or VII	
FMPen1	03-Feb-03	0.5	III or VIII	

b)



c)

Fig. 7.3.3.i. a) SEAbase Video Data Entry form; b) SEAbase Converted Video Data form; c) Example of Video Feature form (Gas Bubbles).

The video features listed on the video data entry form are explained in full in the field manual, and can be viewed in the 'Video Cheat\_Sheet.ppt' on the attached CD. However, examples of the features can be accessed simply by clicking on the blue title attached to each specific feature. To enter new video data, first select the position ID from the drop down list. Today's date will appear as the default, change if necessary. The position status can be added as stocked, empty or reference. Simply click on the relevant score for each feature (these are just check boxes) to complete the scoring form. Enter comments if required. To calculate the video score click on the 'Calculate and view video scores' command button. This automatically applies the weightings and calculates the video score. It then opens the Video Converted form (Fig. 7.3.3.i.b) which shows the video scores for each date that this position has been assessed, and applies the impact stages, as explained in the field manual.

ii) **Photo Assessment Data Entry**

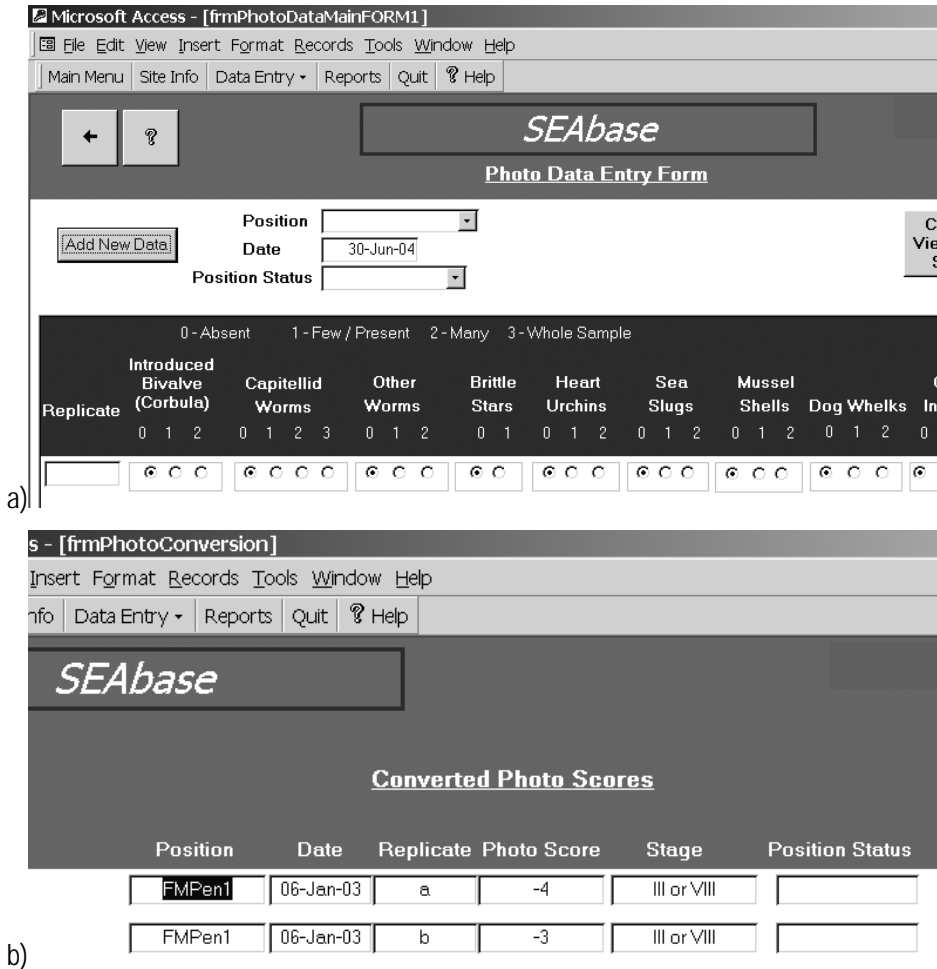


Fig. 7.3.3.ii. a) SEABase Photo Assessment Data Entry form; b) SEABase Converted Photo Data form.

Data for photo assessments is added in a similar manner. Select a position ID from the drop down menu, insert the date and position status. Feature scores can be entered. As photo's are based on single grab samples covering relatively small surface areas, there is the option to add more than one replicate, to get a broader representation of the sediment condition. Replicates are usually 'a', 'b', 'c' etc. For each replicate, the feature scores are added by clicking on the appropriate check box. Comments can be added for each replicate. Any number of replicates can be included, the overall photo score for that position on that day will be calculated as the average of all replicates. To view examples of the features, click on the 'View Example Photos' command button. To convert the data to a photo score, click on the 'Convert/View Photo Scores' command button. This runs a similar query to that described for the video assessment, where weightings are applied to the feature scores and the overall photo score calculated. The Converted Photo Score form opens automatically, showing photo scores and impact stage for all replicates at that position on that date. To view the photo scores for that position over all dates, go to reports.

iii) **Simple Fauna Assessment Data Entry**

a)

b)

Fig. 7.3.3.iii. a) SEABase Simple Fauna Assessment Data Entry form; b) SEABase Converted Simple Fauna Data form.

To enter simple faunal assessment data, select the position from the drop down list, enter the date and position status. Not all options within the simple fauna assessment need to be completed. If only the number of species has been recorded, simply add this data and leave the rest blank. Similarly for the number of individuals, or key indicator species. For both the number of species or number of individuals, there are two options; total number can be entered abundance and number of species can be categorised. Key indicator organisms can be assessed and selected from a drop down list. Comments can also be added. Pictures of key indicator organisms can be viewed by clicking the 'View Pictures of Key Organisms' command button. 'View data converted to stage' command button opens the Simple Fauna Converted Data form Fig. 7.3.3.iii b), showing the recorded data for that position on that date and the related impact stage.

iv) **Benthic Fauna Assessment Data Entry**

Fig. 7.3.3.iv. SEAbase Benthic Fauna Data Entry form.

The option to enter data from analysis of the full benthic community structure has been included. Many company's either already have this information from previous assessments or may wish to store subsequent assessments. To enter benthic fauna data, select the position from the drop down list, enter the date and position status. Select the sample technique – at present the options available are van veen grab or diver core. Defining the sampling technique enables the database to calculate the number of individuals per square metre for reporting purposes. Enter the Species identification (either the scientific name and/or a species identification code), replicate and number caught. As with the assessment of benthic photos any number of replicates can be added. The results presented in reports are an average of all replicates for a position on any given date.

v) **Redox Potential Data Entry**

a)

Position ID	Date	Replicate	RedoxConverted	Stage	Position Status
AQPen1	04-Feb-03	a	140	I	
AQPen1	04-Feb-03	b	190	I	
AQPen1	04-Feb-03	c	172	I	

b)

Fig. 7.3.3.v. a) SEABase Redox Data Entry form; b) SEABase Converted Redox Data form.

To enter redox potential data, select the position from the drop down list, enter the date and the position status (stocked, empty or reference). Redox potential can be measured for one or more replicate cores at any given time. For each replicate a unique identification (typically 'a', 'b' etc.) is entered, followed by the calibration value (mV) and the uncorrected redox value (mV). Two other values are also required – the correction for the 'H' Electrode reference and temperature. Information command buttons ('i') above each of these fields describe how to determine these values. In most instances, the default values will apply, these will only change if the temperature at which sampling is undertaken changes markedly (for further information see the field manual). To convert the uncorrected redox value to a meaningful measure, use the 'Convert data' command button. This runs a query that applies the calibration and opens the Redox Converted form, showing the converted redox (mV) and impact stage for all replicates at a given position on any specified time.

vi) **Sulphide Concentration Data Entry**

Before entering sulphide data, you must first create a calibration ID, by entering the calibration data for those replicates. To enter new data, click on >\* on the scroll bar on the left. The calibration ID number will automatically be generated when you enter data. Note the note of your calibration ID, you will need to enter this when you enter your sulphide data.

**Sulphide Calibration Data**

Calibration ID	<input type="text" value="AutoNumber"/>	<input type="button" value="Add/View Sulphide Data"/>
Wt Na2S used (g)	<input type="text"/>	
C1	<input type="text"/>	
C2	<input type="text"/>	

a)

ft Access - [frmSulphideDataMainForm]

File View Insert Format Records Tools Window Help

Site Info Data Entry Reports Quit Help

**SEAbase**

**Sulphide Data Entry Form**

Position ID

Date

Position Status

Sulphide Data

Calibration ID	Replicate	Sulphide (mV)
<input type="text"/>	<input type="text"/>	<input type="text"/>

Record: 1 of 1

b)

ft Access - [frmSulphideConverted]

File View Insert Format Records Tools Window Help

Site Info Data Entry Reports Quit Help

**SEAbase**

**Converted Sulphide Data**

PositionID:	Date:	Replicate:	Sulphide Concentration (S2(uM))	Stage
AQPen2	5-Feb-03	a	1.05	I/II or IX
AQPen2	5-Feb-03	b	1.58	I/II or IX
AQPen2	5-Feb-03	c	0.75	I/II or IX

c)

**Fig. 7.3.3.vi.** a) SEAbase Sulphide Calibration Data Entry form; b) SEAbase Sulphide Data Entry form; c) SEAbase Converted Sulphide Data form.

Sulphide is also recorded from cores and usually more than one replicate will be taken. When determining sulphide concentration, calibration of the probe is necessary and this should be done prior to each sampling event. Calibration values need to be recorded on the first of the sulphide data entry forms. Calibration ID is an automatically generated number. This number is a reference and is needed when entering the sulphide data. To add sulphide concentration values, click the 'add/view sulphide data' command button. Select the required position from the drop down list, enter the date and position status. Then select the appropriate calibration ID from the drop down list, add the replicate (typically 'a', 'b' etc) and the raw sulphide value (mV). Any number of replicates can be added. To convert the field sulphide values to meaningful measures, click the 'convert data' command button. This runs a query (SUQuery), linked to an excel spreadsheet. For this reason, the table SUQuery must be linked to the database. If it is not an error message will appear.

To link the table, simply follow these steps:

1. Open SEABase
2. Go to File: Get External Data: Link Tables
3. Find the location of the Sulphide Excel File (make sure you have the 'Files of Type' set to Microsoft Excel)
4. Select FieldGuide\_Sulphide.xls and click on 'Link'
5. Select the worksheet SUQuery – click Next
6. Check that the 'First Row Contains Column Headings' is selected – click Next
7. Accept default name – click Finish

After clicking the “convert data” command button, the converted sulphide form should open. This will show the converted sulphide values for all replicates on any given position on the date entered, and the associated impact stage. To view the average of the replicate sulphide values for this position over time, go to the reports.

**vii) Production Information**

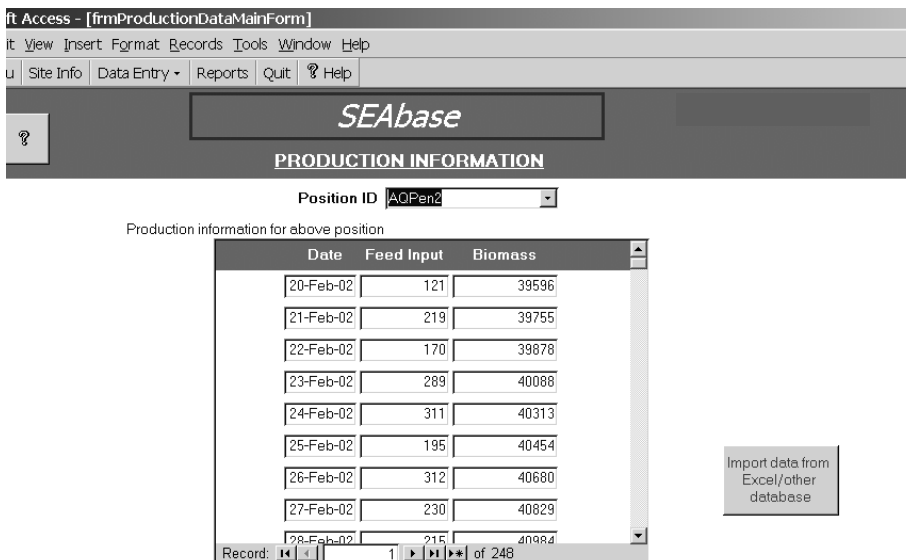


Fig. 7.3.3.vii. SEABase Production Information Data form.

The second option in the data entry main form is production information. This option has been included as it enables the viewing of production information in conjunction with sediment condition data. Data can be entered in one of two ways, either directly using SEABase or by importing the data from another database or spreadsheet. To enter data directly select the appropriate position then enter the date, feed input and biomass. To import data, the command button 'import data' needs to be linked to a macro, which will import data from the specified source. The only requirement is that the table in the specified data source needs to match that identified in SEABase. Consequently this linkage should be set up by someone experienced in the operation of Access. If you have any difficulty with this please contact Susan Forbes or Catriona Macleod (TAFI) (ph: (03) 6227 7277).

viii) **Water Quality Information**

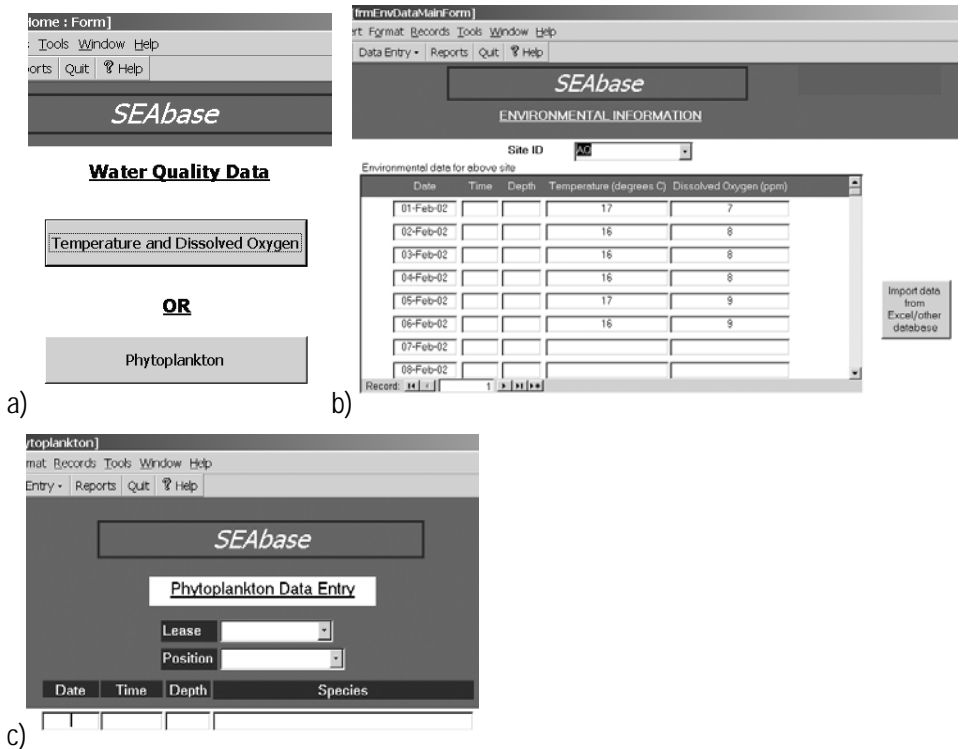


Fig. 7.3.3.viii. a) SEABase Water Quality Data Main form; b) SEABase Temperature and Dissolved Oxygen Data Entry form; c) SEABase Phytoplankton Data Entry form.

Currently SEABase is set up to record and store temperature, dissolved oxygen and phytoplankton information.

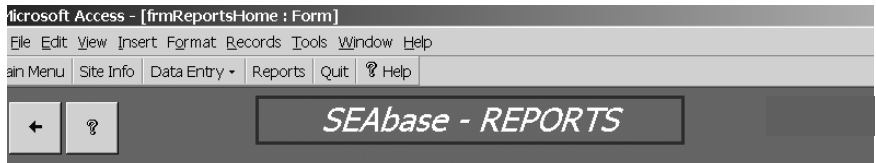
Temperature / Dissolved Oxygen Data Entry

The procedure for entering temperature and dissolved oxygen data in SEABase is similar to that for production data. Data can be entered by scrolling down to the next available line (once the site is selected) (Note: individual positions are not available as this data is generally collected only for entire sites/leases). Enter the specific time and depth on any given date. It is also possible to import this data from an external data storage system, by linking the 'import data' command button to a macro to import the data, in the same way that the production information can be imported.

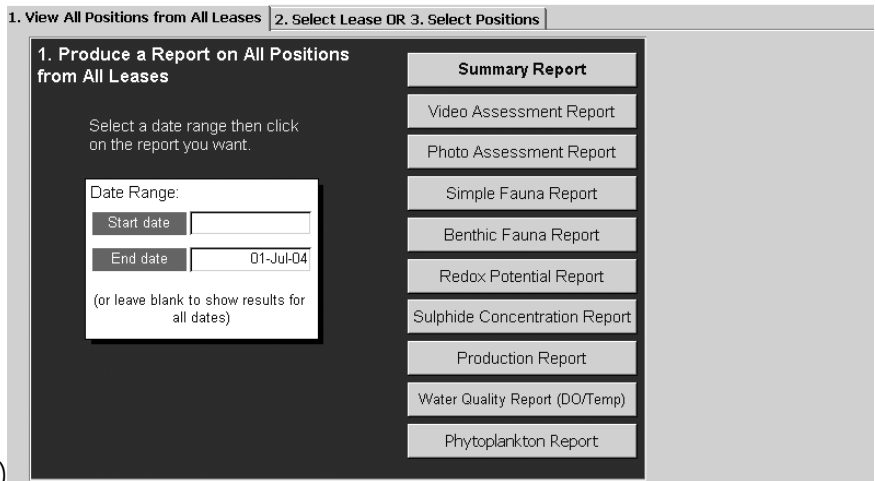
Phytoplankton Data Entry

To enter phytoplankton data, select the lease and/or position from the drop down lists. Then enter the date, time, depth and plankton species recorded.

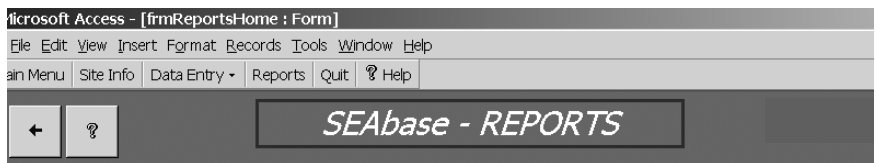
### 7.3.4 Producing Reports



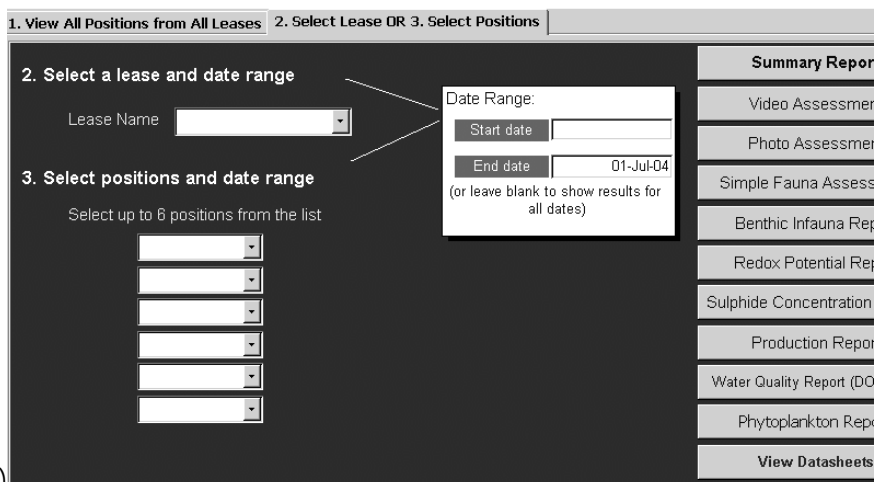
You have three options for producing reports...



a)



You have three options for producing reports...



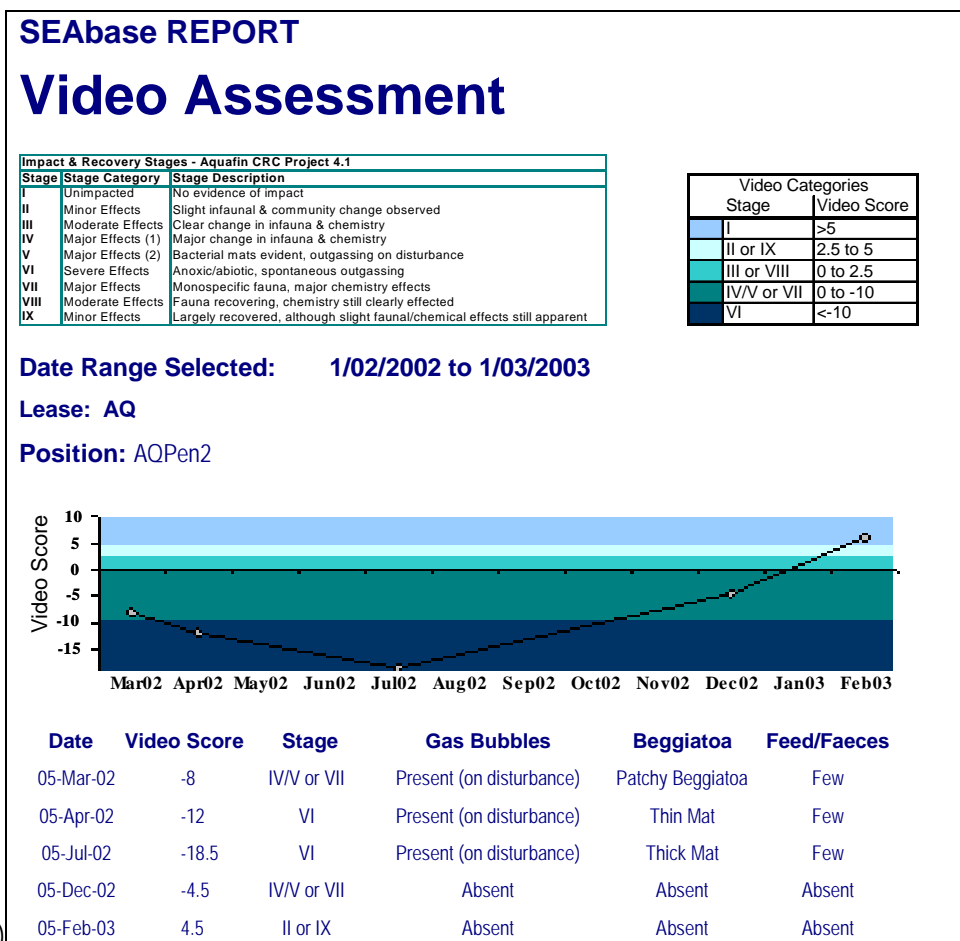
b)

Fig. 7.3.4.i. a) SEAbase Report Form – produce a report on all positions from all leases; b) SEAbase Report Form – produce a report on selected lease/positions.

There are several options for producing reports. Reports can be produced for any of the available data entry options, or for a combination or summary reports (e.g. combination of production information and video scores).

Option 1. Reports for all positions in all leases. Any date range can be selected (the end date of the range will be the current date by default). To view all available data, leave the start date blank and use the command buttons to the right of the screen to produce the selected report.

Option 2. Report for all positions in a selected lease, or up to 6 selected positions from any lease (or a combination of both). Click on the tab labelled '2. Select lease OR 3. Select Position'. A lease can then be selected from the drop down list, or up to 6 positions can be selected using drop down lists. If all positions in one lease are required, plus several positions from other leases, a combination of the two can be used (e.g. Select lease ID and other position ID's). It is also possible to enter a date range. To view all data from all dates, leave the start date blank. Then use the command buttons to select the required report. It is also possible to view the raw datasheets, by clicking on the 'view datasheets' command button.



b)

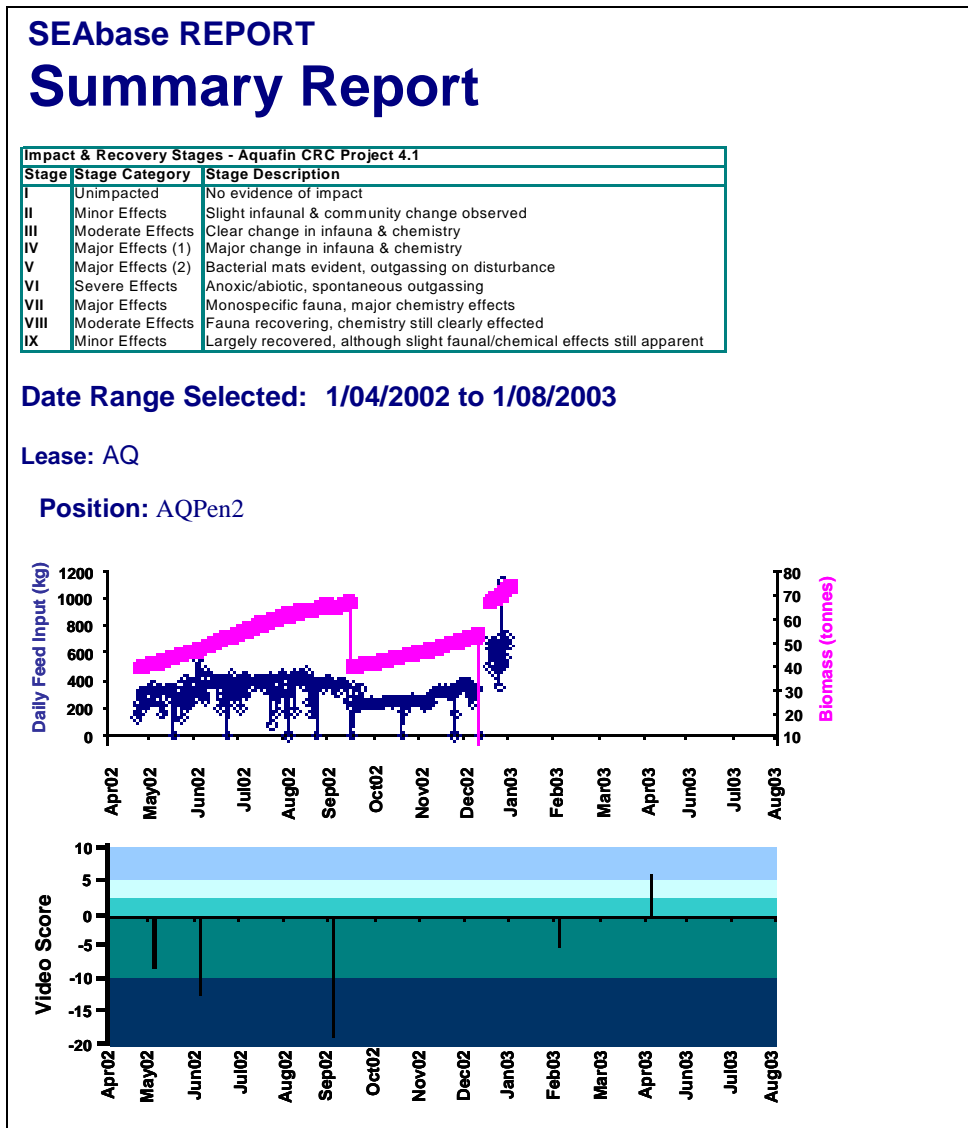


Fig. 7.3.4.ii. Example Reports from SEAbase. a) Video Assessment Report; b) Summary Report, showing production, video scores and photo scores.

### 7.3.5 View Data Sheets

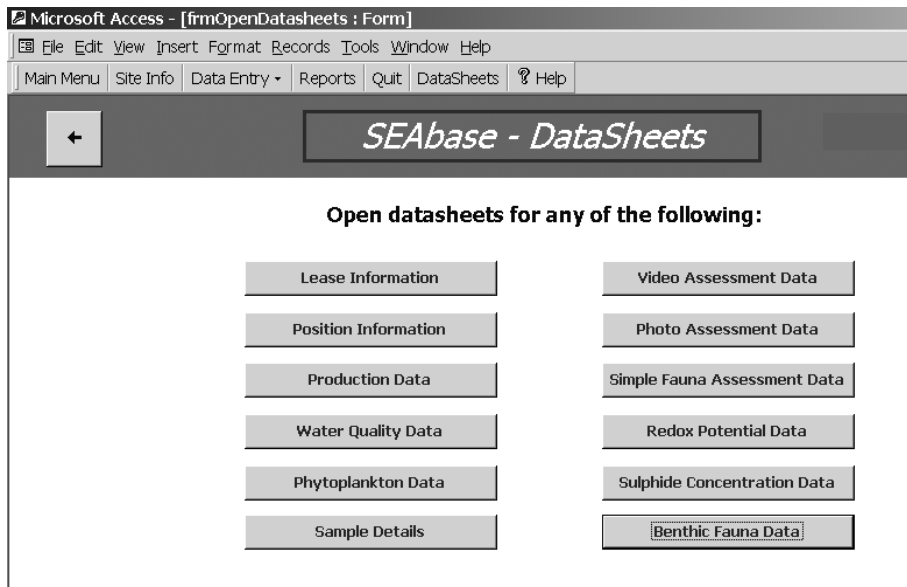


Fig. 7.3.5. SEABase View Datasheet Main form.

Datasheets can be accessed either through the reports home or using the customised toolbar at the top of the page. You can then access almost all the datasheets that make up SEABase BUT be careful as you can actually change data here.



7.4.2 Video Assessment Data Recording Sheet

Date						
Lease						
Position						
1. Gas bubbles						
2. Sediment Colour						
3. Beggiatoa						
4. Pellet/sFaeces						
5. Debris						
6. Burrows						
7. Worm Tubes						
8. Faunal Tracks						
9. Algal Cover						
10. Brittlestars						
11. NZ Screw Shell						
12. Dog Whelks						
13. Sea Slugs						
14. Heart Urchins						
15. Squat Lobsters						
16. Epibenthic Crusts.						
17. Echiurans						
18. Fish						
19. Other Crustaceans						
20. Seastars						
21. Other Fauna						

1. **Gas Bubbles** – Scoring: 0-Absent; 1-On disturbance; 2-Spontaneous outgassing.
2. **Black/Grey Sediment** – Scoring: 0-Normal; 1-Not normal (grey/black as compared to ref).
3. **Beggiatoa** – Scoring: 0-Absent; 1-Patchy; 2-Thin mat; 3-Thick mat.
4. **Pellets/Faeces** – Scoring: 0-Absent; 1-Few; 2-Many; 3-Feed spill.
5. **Debris** – Scoring: 0-Absent; 1-Present.
6. **Burrow Density** - Scoring: 0-Absent; 1-Few; 2-Many; 3-Dense.
7. **Worm Tubes** / 8. **Faunal Tracks** – Scoring: 0-Absent; 1-Present.
9. **Algal Cover** - Scoring: 0-Absent; 1-Sparse; 2-Moderate; 3-Dense.
10. **Brittlestars** – Scoring: 0-Absent, 1-Present.
- 11 – 21 (all other faunal categories) – Scoring: 0-Absent, 1-Few; 2-Many.











## **8 Glossary**

CRC	Centre for Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPIWE	Department of Primary Industries, Water and Environment
EDTA	Ethylene diamine tetra - acetic acid
Eh	Redox Potential
FRDC	Fisheries Research and Development Corporation
GPS	Global Positioning System
ROV	Remotely Operated Vehicle
S=	Sulphide Concentration
SAOB	Sulphide Anti-Oxidant Buffer
TAFI	Tasmanian Aquaculture and Fisheries Institute

## **9 Contact Details**

For help, please contact the following:

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- Copies of Final Report (Project 4.1):  
Aquafin CRC (Ph: +61 8 82902303);
- Additional copies of field manual / IP and Database application:  
Aquafin CRC (Ph: +61 8 82902303).

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