FINAL REPORT

Quantitative Training Unit for Fisheries (QTUF), Phase II

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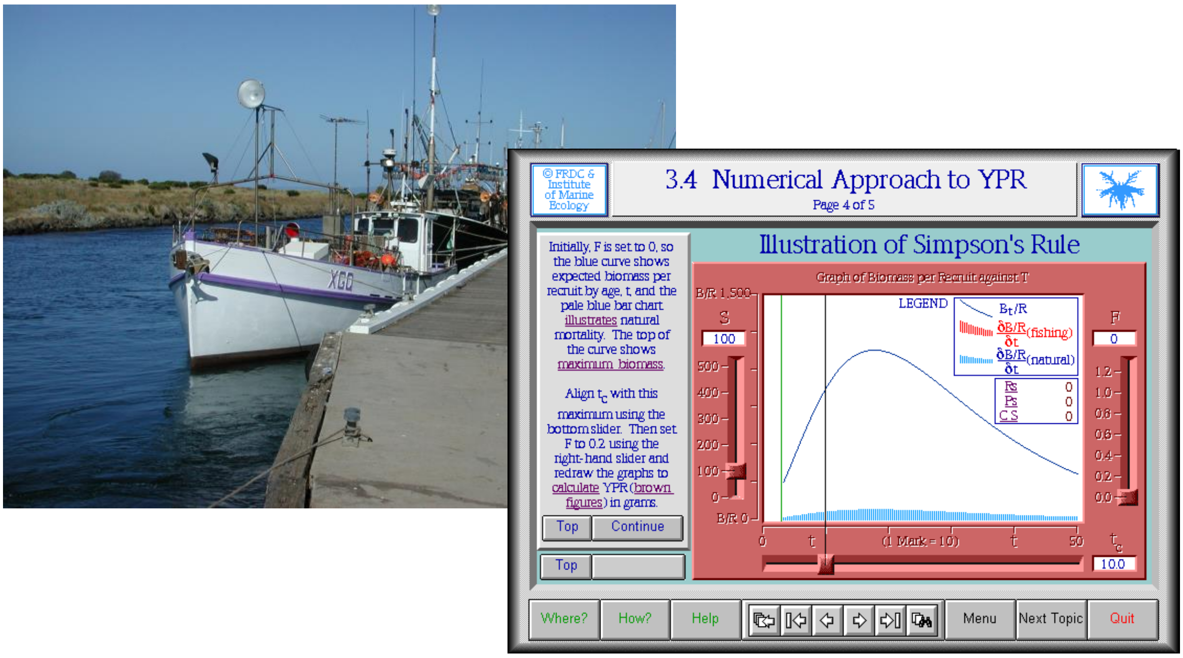

Project No. 98/348

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

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98/348 Quantitative Training Unit for Fisheries (QTUF), Phase II

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Objectives

1. Continue to provide training in the population dynamics of fish stocks.
2. Assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney.
3. Develop additional computer based modules.
4. Disseminate the products of QTUF.

Non-Technical Summary

Outcomes Achieved

From February 1998 to January 2001, Phase II of the Quantitative Training Unit for Fisheries (QTUF) convened 15 courses for fishery scientists, 6 courses for fishery managers and 6 courses for university students. We collected course evaluations from 107 scientists, 68 managers and 104 students. From these evaluations, we determined that 87.5% of all participants of the courses agreed or strongly agreed with the statement that "Overall, I was satisfied with the quality of this course" and 94% of scientific participants agreed or strongly agreed with the statement "The things I have learned in this course will be useful to me in my career". Participants in courses for fisheries managers were also positive about the outcomes of QTUF Phase II, with 90% agreeing or strongly agreeing that, "The tasks were useful learning experiences". Courses for university students generated a similar positive response, with 72% agreeing or strongly agreeing, "The teaching stimulated my interest in the course content". We cannot determine the extent to which these responses will translate into better long-term outcomes for Australian fisheries but they do reflect an improved confidence in the application and interpretation of quantitative methods.

The computer-based-instruction software *Quantitative Training in Fisheries* was distributed to 81 individuals in Australian research and managerial institutions. The software provides a medium for ongoing self-study of the quantitative methods and applications required for fisheries management. The effectiveness of the software in achieving particular objectives was measured using a questionnaire. Responses from over 211 people indicated that the content was appropriate, the help and navigational systems effectively designed and the software was an effective learning tool.

The Quantitative Training Unit for Fisheries (QTUF) operated at The University of Sydney from 1995 to 2001. There were two distinct phases to the project: Phase I (Project 93/117, from 1995 to 1997) and Phase II (Project 98/348, 1998 to 2001). The QTUF project was designed to address the need for Australian fisheries scientists and managers to have improved knowledge of and skills in quantitative methods. This need has arisen because of changes to strategies of management, particularly the use of catch quotas and the implementation of the precautionary approach. A need was also identified for a permanent medium for self-study of quantitative methods and applications. We addressed this need by the development of computer-based-instruction software entitled *Quantitative Training in Fisheries* (Montgomery and Hood 2001). An additional requirement included the development of a postgraduate award system for training in quantitative fisheries science. QTUF has met this need by helping to create new awards in Quantitative Marine Ecology at the University of Sydney.

To achieve our training objectives, the QTUF ran five different types of courses for fishery scientists, fishery managers and university students. This involved teaching courses to over 100 scientists and managers and almost 70 managers. All participants at the courses completed an anonymous questionnaire that has provided us with extensive information about outcomes of the courses. This indicated the achievement of the first project objective: “Continue to provide training in the populations dynamics of fish stocks”.

The second project objective, “assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney”, was also achieved. New awards in Quantitative Marine Ecology, to be taught by the Centre for Research on Ecological Impacts of Coastal Cities, commenced in 2001, having been approved by the University’s Academic Board. These awards include units of study in the assessment of living marine resources that are the continuation of the QTUF courses. There are also units of study in the assessment of environmental impacts. Such units will help met the need for individuals trained in identifying the impacts of fishing activities.

The third project objective, “develop additional computer based modules”, referred to the software *Quantitative Training in Fisheries*. The software is now complete and includes computer-based-instruction on the following topics:

- Simple Population Models
- Parameter Estimation
- Standardised Indices of Abundance
- Stratified Random Survey Design
- Biomass Dynamic Models
- Growth of Individuals
- Stock-Recruitment Relationships
- Yield Per Recruit
- Deterministic Age-Structured Models
- Statistical Age-Structured Models

We will be making extensive use of the training software in the Quantitative Marine Ecology Awards. Extensive evaluation of over 200 users of the software indicated that the content was pitched at the appropriate level. The software was considered to be easy to navigate and was identified as an effective learning tool. It is unlikely that there will be extensive revisions to the software at this time. The forth project objective, "disseminate the products of QTUF", was also achieved. We have direct evidence that over 80 copies of *Quantitative Training in Fisheries* were distributed to individuals in over 10 Australian institutions.

Long-term outcomes of the QTUF project are difficult to assess. The impact that our courses and software have had on individuals in the short-term (for example, directly after a course) can be documented, but this cannot give firm evidence of long-term benefit. Any training project will experience the same difficulties. We trust that the extensive outputs of the project, along with our enthusiasm and dedication to quantitative methods, will have a long-term impact on the sustainability of Australian fisheries.

Keywords
population dynamics, stock assessment, models, uncertainty, computer-based-instruction, training, quantitative, professional development

1 Acknowledgements

The staff of QTUF would like to thank members of the Advisory Committee (Prof. Howard Choat, Dr Bob Kearney, Dr Mary Peat, Dr Malcolm Haddon, Mr Steve Hinge and Mr Richard Stevens). These individuals provided strategic direction and enthusiasm for the project and contributed greatly to its success.

Responsibility for initiating and then co-ordinating courses outside The University of Sydney almost always fell to a single individual. In the approximate order of the courses these individuals were: Cathy Dichmont (QDPI), Rick Fletcher (NSW Fisheries), Nick Rayns and Rik Buckworth (NTDPIF), Peter Stevenson, Norm Hall and Lindsey Joll (Fisheries WA), Rich Little (CSIRO Marine Research), Graeme Ewing (TAFI), Steve Hall (Flinders University of South Australia), Murray MacDonald (Victorian NRE), Bruce Mapstone (CRC Reef Research Centre) and Peter Skeen (AFMA). In-house courses benefited from the timely computer support provided by Kyle Kiefer at the University of Sydney.

Most of all we would like to thank the course participants. People persevered with modelling exercises, battled with Excel and tolerated early (and imperfect) versions of the computer-based-instruction software. With very few exceptions, everybody stayed for the length of the entire course and provided the valuable feedback about this project that is reported upon here.

2 Background

The study of populations of wild fish has been a growing area of research over the last 100 years (e.g. Edser 1908, Baranov 1918). In recent decades, mounting pressures on fish stocks have encountered limits to production resulting in a growing need to manage and protect these stocks more effectively. Maximising production while preventing over-exploitation requires quantitative scientific methods to understand and forecast the dynamic processes of aquatic environments. Theoretical progress (see Megrey, 1989, Quinn and Deriso 1999) and advances in computer technology are providing sophisticated tools for modelling fisheries. Widespread adoption of modelling techniques to provide advice for the management of fisheries has lead to a shortage of people with the necessary skills.

To tackle this shortage, people with aptitude in quantitative methods should be identified and their skills developed. Novel methods of communication and training need to be explored. The role of computers in teaching fisheries modelling needs to be better understood and applied in tertiary institutions that are themselves adapting to new markets and to educational strategies and outcomes.

Management continues to require more robust analyses of stocks. Australia, like many countries, is exploring and, in many cases, implementing quota management systems. This results in additional demands for stock assessment (Walters and Pearse 1996). The shortage of individuals with the necessary knowledge and skills in Australia was recognised by the Australian Fisheries Research and Development Corporation (FRDC). It provided funds to the University of Sydney to produce training resources to help rectify this situation. Consequently, the Quantitative Training Unit for Fisheries (QTUF) was formed in 1995 (Phase I) and was refunded in 1998 for an additional 3 years (Phase II). Outcomes of Phase I of QTUF were described by Underwood and Montgomery (1998). This document reports upon Phase II.

3 Need

The original needs stated in the project application were that:

"There is a need for the continual provision of training courses in the introductory and core material. To maximise the benefits of the existing investment in computer-based material, there is a need to provide a mechanism for the distribution of the software. In addition, the value of the computer-based material can be increased by developing further modules for which a requirement has been identified by the Unit's National Advisory Committee."

We would like to take this opportunity to expand upon the needs that were (to be) met by this project. Improved knowledge of and skills in quantitative methods within the professional fisheries community is crucial. Changes to the systems and objectives of fisheries management are placing unprecedented demand on agency personnel. These changes are discussed in turn.

3.1 Quota Management Systems

As introduced in the background section, the shift towards quota management systems in Australia and overseas is now underway. Fisheries economists continue to argue (Grafton 1996) that the only way to prevent overcapitalisation of fishing fleets is by providing a "property right" to operators. This gives fishers the right to land and sell a proportion to the total allowable commercial catch (TACC). The effectiveness of quota management systems to prevent over-fishing is still under review, but their adoption in many Australian fisheries is ensured. This has placed new and exacting demands on fisheries scientists and managers because the TACC must somehow be determined. Estimating and implementing an appropriate TACC is a complex technical and political task.

The TACC should be based upon determination of the harvest to be taken to achieve specified objectives of management (for example, to rebuild the spawning stock to a particular level). The steps required to calculate this can be complex and will always involve some type of population model of the fishery, whether this model is explicit or not. Political processes further complicate the methods used to set a TACC. Most jurisdictions in Australia set the TACC via some sort of consultative process. This requires managers and industry to be able to interpret the documentation associated with stock assessments.

Simulation studies have also shown that a strategy involving constant rates of harvest, *i.e.* to catch a constant proportion of the exploitable biomass, is robust to variations in production (Walters and Parma 1996). Use of such harvest strategies require an estimate of what the exploitable biomass actually is. This is another argument why assessments of fish stocks have such an important role in the sustainability of fisheries.

This generates three interdependent needs for Australian fisheries. (1) More scientists are required with the knowledge and skills to apply stock assessment methods. Although some techniques are specialised, many are straightforward and well within the capabilities of experienced fishery scientists. It is also important to demystify these techniques and make the strengths and weaknesses of particular methods apparent. Scientists therefore need to be trained in interpreting and communicating the outcomes of quantitative approaches. (2) Fisheries managers require similar outcomes to the scientists, but with emphasis on interpretation. Managers could also benefit with some skills in the methods of qualitative modelling. (3) Commercial and recreational fishers also need to develop their understanding of the issues associated with the assessment of fish stocks.

The QTUF project directly interacted with scientists and managers to meet the needs identified above. The project did not develop training material suitable for industry for reasons outlined in the Results and Discussion section.

This need was to be met by Objective 1 ("Continue to provide training in the populations dynamics of fish stocks"), Objective 3 ("Develop additional computer based modules"), and Objective 4 ("Disseminate the products of QTUF").

3.2 Uncertainty

Uncertainty has become somewhat of a buzzword in the contemporary fisheries literature (Hilborn 1987; Ludwig et al. 1993; Frederick and Peterman 1995). This is because there is and will continue to be a huge amount unknown about complex fishery systems. Management still occurs within this indeterminate world so technical and political processes have been developed to help us cope with this uncertainty.

Quantitative analyses of errors (or the probability distributions) associated with estimated parameters or predicted outcomes are an expectation within contemporary assessments. The wide availability of high-speed computers has resulted in most of these analyses being done using numerically intensive methods[1]. Many of these methods were not taught to fisheries scientists during their under-graduate and post-graduate training so there exists a need for retraining. Courses taught within both Phases of QTUF were designed to meet this need.

The impact of uncertainty on political processes is exemplified by the widespread adoption of the precautionary approach in state and federal legislation for managing fisheries. This approach provides a mechanism for the interpretation of uncertain scientific results for decision-makers (Harding 1998). Within many managerial agencies confusion about the approach is still, however, pervasive. There was a need to provide a forum for managers and scientists to discuss and improve their understanding of critical concepts such as the precautionary principle. Courses were taught by Phase II of QTUF to meet this need.

This need was to be met by Objective 1 (“Continue to provide training in the populations dynamics of fish stocks”).

3.3 Permanent medium for self-study

Fisheries scientists and managers in Australia are geographically dispersed and a relatively[2] small community. As a result of this, teaching and research institutions that have the resources to specialise in an area such as fisheries science will be few and far between. Tasmania has become the *de facto* centre for fisheries research in Australia, but there are sizeable research institutions in Brisbane, Perth, Adelaide, Sydney, Townsville, Canberra, Queenscliff and Darwin. Personnel in these institutions need access to material to provide them with opportunities for continuous professional development in quantitative fisheries science. For trained experts, books and professional journals will be the ultimate reference resources. Intermediate-level personnel require something beyond undergraduate textbooks but simpler than journal articles (which can be dauntingly technical). Furthermore, people should be given the opportunity to use a medium that is interesting and motivational. Fisheries modelling and stock assessment are intellectually rewarding and conceptually rich subjects. Technical prose and static plots do not always manage to capture these aspects of the subject.

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[1] Examples include Monte Carlo simulation and bootstrap re-sampling.
[2] Compared to Canada, New Zealand or the USA.

To meet these needs, QTUF Phase I embarked upon the development of computer-based-instruction (CBI) software that was later entitled *Quantitative Training in Fisheries*. The CBI medium was appropriate because it:

- enabled the inclusion of text, graphics, animation and interactivity;
- allowed for a dynamic representation of the complex relationships and interactions that are typical in fishery systems;
- is straightforward to reproduce (usually on CD-ROM) and inexpensive to distribute, and;
- permitted user interaction and feedback that was aimed in engaging and motivating users.

Additional details on the design, implementation and outcomes of this approach are provided in the methods section of this report. The CBI software also required a method of distribution that respected the intellectual property of the Centre for Research on Ecological Impact of Coastal Cities and the Fisheries Research and Development Corporation. Such strategies were developed within QTUF (Phase II).

These needs were to be met by Objective 3 ("Develop additional computer based modules") and Objective 4 ("Disseminate the products of QTUF").

3.4 Skills rather than knowledge

Much of the written material for quantitative fisheries analysis is focussed upon documenting theory and providing some worked examples of calculation (for example Quinn and Deriso 1999). Some texts, particularly Hilborn and Mangel (1997) and King (1995), take a more practical approach but in general there is a lack of instruction on not "what to do" but "how to do it". This phenomenon can be described by recognising that knowledge is being given greater emphasis than are skills. The reasons for this are simple, the actual execution of a method is directly tied to the software that is used to complete the task. For example, it is possible to build a biomass dynamic model in Microsoft Excel, Insightful S-Plus, Microsoft Visual Basic, Linux gcc and many other microcomputer packages. Publishers do not want to tie textbooks to software packages that can become obsolete in an embarrassingly short time.

QTUF staff were acutely aware of this issue and decided not to create formal links in the software between *Quantitative Training in Fisheries* and other computer programs. The skills deficit was addressed by ensuring that the training courses included extensive and realistic exercises that could be solved with the support of QTUF staff. We attempted to be flexible with our use of software packages but the institutional choice for virtually all courses was Microsoft Excel. Some effort was therefore made to identify situations when this was not the best choice and alternatives discussed.

This need was to be met by Objective 1 ("Continue to provide training in the populations dynamics of fish stocks").

3.5 Postgraduate award system for training in quantitative fisheries science

Short courses on particular subjects are an effective method for professional development but they may suffer two shortfalls. First, often the course material is prepared, delivered, and then sometimes – after the relevant teaching expertise had moved on – forgotten. Second, individuals interested in a career in fisheries science will require a recognised postgraduate award to fulfil criteria for appointment to a professional position, promotions, pre-requisites for other awards, personal goals, *etc*. Short-courses may not fill these roles.

There was therefore a need to provide, within a recognised tertiary institution, an ongoing award structure for people requiring qualifications in fisheries science. Various institutions in Tasmania (Australian Maritime College and the University of Tasmania) and Western Australia (the recently funded Centre for Fish and Fisheries Research at Murdoch University) are attempting to meet this need, but none has focussed entirely upon quantitative approaches. Furthermore, there are advantages in locating such a service in a university in a major east coast city (such as Sydney or Melbourne) because these institutions have a very large intake of students.

Rather than take the approach of focussing the research and teaching on fisheries, the Centre for Research on Ecological Impacts of Coastal Cities (hereafter the Centre), has focused on quantitative methods for marine biologists, marine ecologists, fisheries scientists and environmental scientists. This ensures that our service does not directly compete or overlap with those offered by other Australian institutions.

This need is met by Objective 2 (“Assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney”).

3.6 Impacts of Fishing

There is increasing interest and pressure to understand the impacts of fishing activities on all members of aquatic assemblages - not just the target species (see Hall 1999). Scientists with appropriate quantitative skills will be required for this difficult task and expertise in multi-variate statistical methods will be in particular demand. The new Awards in Quantitative Marine Ecology included several units of study designed to teach knowledge and skills in methods for the assessment of environmental impacts.

This need is met by Objective 2 (“Assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney”).

4 Objectives

1. Continue to provide training in the populations dynamics of fish stocks.
2. Assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney.
3. Develop additional computer based modules.
4. Disseminate the products of QTUF.

5 Methods

5.1 Strategic

QTUF was given strategic advice by the Phase II Advisory Committee. This was a smaller committee than that during Phase I. Table 1 summarises members of the committee and meetings they were able to attend.

Advisory Committee meetings were held at The University of Sydney on the 31-July-1998, 18-Jun-1999 and the 28-July-2000. All members of the Committee made the greatest possible efforts to attend all the meetings. The format of the meetings was flexible but was generally structured as follows:

- Introductions
- Reports by James Scandol and Ian Montgomery
- General Discussion
- Recommendations from the Committee

The meetings were minuted and draft minutes circulated (within 48 hours) to those who attended, with a request for any corrections. Minutes were then finalised as quickly as possible and sent to all members of the Advisory Committee. Final minutes for each Advisory Committee Meeting were included as an Appendix within the FRDC Milestone Reports that required that Advisory Committee meeting (specifically Milestones 1, 4 and 7).

Table 1 Members of the QTUF (Phase II) Advisory Committee and the meetings attended.

Name	**Institution**	**Attended**
Prof. Howard Choat	James Cook University	1998
Dr Bob Kearney	University of Canberra	2000
Dr Mary Peat	University of Sydney	1998, 2000
Dr Malcolm Haddon	Australian Maritime College & Tasmanian Aquaculture and Fisheries Institute	1998, 1999, 2000
Mr Steve Hinge	Commercial Fisherman	1998, 1999, 2000
Dr Ian Montgomery	University of Sydney	1998, 2000
Dr James Scandol	University of Sydney	1998, 1999, 2000
Mr Richard Stevens	Australian Fisheries Management Authority & Primary Industry and Resources South Australia	1998, 1999, 2000
Prof Tony Underwood	University of Sydney	1998, 1999, 2000

The role of the Advisory Committee was to provide strategic direction, not comment on the day-to-day logistics of the project.

5.2 Courses

5.2.1 Types of Courses

The primary way QTUF achieved teaching objectives was by delivery of courses or workshops[3] for professionals working in fisheries. There were five types of these courses (see Table 2). The numeric codes to indicate the course types also reflect the approximate priority given to organising the courses.

Table 2 Summary of the types of courses held by QTUF.

Type	Location	Length	Primary Client
1	Held at Institution	3-5 days	Fisheries Scientist
2	University of Sydney	2-4 days	Fisheries Scientist
3	Held at Institution	1-2 days	Fisheries Manager
4	University of Sydney	3 days	EICC Honours and Postgraduate Students
5	Held at Institution	1 day	Undergraduate Student

Twenty-seven courses were convened by QTUF from June 2000 to January 2001. Twelve courses were run at the University of Sydney;15 were held at the host institution (or a location convenient for them).

Courses were held in every State and Territory in Australia, although the type and timing of the distribution of courses was rather heterogeneous. For example, The Australian Fisheries Management Authority (AFMA) organised three courses for managers in 2000, while only one course for scientists was organised for the Department of Primary Industry and Fisheries in the Northern Territory (in late 1998).

Table 3 Summary of courses/workshops taught during QTUF (Phase II).

Code (Type.Num)	Name	Date	Location	Number[4] Attended
1.1	Parameter Estimation and Biomass Modelling	3-Aug-1998	Queensland Department of Primary Industry (Deception Bay)	8
1.2	Stock Assessment Workshop	9-Nov-1998	NT Department of Primary Industry and Fisheries (Darwin)	10
1.3	Stock Assessment Workshop	31-Jan-2000	Fisheries WA (Perth)	14
1.4	Fisheries Modelling and Stock Assessment Workshop	6-Mar-2000	CRC Reef Research Centre (Townsville)	9
1.5	Stock Assessment Workshop	4-Sep-2000	CSIRO (Hobart)	10

[3] During the project both the terms "course" and "workshop" were used. This report will use the term "course" only.

[4] This number reflects the number of course questionnaires returned. People who left the course early or did not complete a questionnaire were not included in this tally.

Code (Type.Num)	Name	Date	Location	Number[4] Attended
1.6	Stock Assessment Workshop	18-Dec-2000	Tasmanian Aquaculture and Fisheries Institute (Taroona)	12
2.1	Introduction to Fisheries Modelling	20-Jul-1998	University of Sydney	7
2.2	Methods for Fisheries Modelling	17-Aug-1998	University of Sydney	2
2.3	Applications of Fisheries Modelling	5-Oct-1998	University of Sydney	4
2.4	Introduction to Fisheries Modelling	2-Aug-1999	University of Sydney	7
2.5	Methods for Fisheries Modelling	11-Oct-1999	University of Sydney	5
2.6	Applications of Fisheries Modelling	22-Nov-1999	University of Sydney	6
2.7	Introduction to Fisheries Modelling	17-Jul-2000	University of Sydney	4
2.8	Methods for Fisheries Modelling	14-Aug-2000	University of Sydney	4
2.9	Applications of Fisheries Modelling	23-Jan-2001	University of Sydney	5
3.1	Quantitative Fisheries for Managers	4-Jun-1999	NSW Fisheries (Sydney)	7
3.2	Quantitative Fisheries for Managers	4-Feb-2000	Fisheries WA (Perth)	10
3.3	Quantitative Fisheries for Managers	16-Mar-2000	Australian Fisheries Management Authority (Canberra)	12
3.4	Quantitative Fisheries for Managers	2-May-2000	Australian Fisheries Management Authority (Canberra)	12
3.5	Quantitative Approaches for the ESD of Fisheries	29-May-2000	Victorian Natural Resources and Environment (Geelong)	14
3.6	Quantitative Fisheries for Managers	7-Dec-2000	Australian Fisheries Management Authority (Canberra)	13
4.1	Introduction to Fisheries Modelling	23-Jun-1998	University of Sydney	4
4.2	Introduction to Fisheries Modelling	28-Jun-1999	University of Sydney	7
4.3	Introduction to Fisheries Modelling	4-Apr-2000	University of Sydney	5
5.1	Introduction to Fisheries Modelling	29-Sep-1998	Flinders University of South Australia (Adelaide)	20
5.2	Introduction to Fisheries Modelling	21-Sep-1999	Flinders University of South Australia (Adelaide)	44
5.3	Introduction to Fisheries Modelling	26-Sep-2000	Flinders University of South Australia (Adelaide)	28

5.2.2 Locations of Courses

There was a dichotomy between courses (for scientists) held at the University of Sydney versus those held elsewhere (*i.e.* type 2 versus type 1 courses). This was reflected in their organisation, participants and outcomes. Courses held at the University of Sydney (Type 2) were aimed at bringing a cohort of students through an entire fisheries modelling program. The program consisted of three dependent courses:

- Introduction (3 days)
- Methods for fisheries modelling (3 days)
- Applications of fisheries modelling (4-5 days)

From Table 3 it is evident that this programme was executed in 1998, 1999 and 2000. These courses were "advertised" by keeping the details of the programme on the web site of the Centre, and sending letters or broadcast emails to a list of contacts within Australian fisheries science and management. There was a small cost of participating in these courses to cover the cost of hiring a computer laboratory at the University. This cost averaged about $300 per person per course.

Most of the queries were from potential attendees keen on attending a course, but needing to get travel funding from their employers. Unfortunately, the cost of sending one person to Sydney return, paying for accommodation and their contribution to computer room hire was about the same as arranging travel and accommodation for a QTUF staff member to travel to the location of the host organisation. When this cost was tripled (three courses) and then multiplied by the number of interested persons, the economy of arranging onsite (Type 1) courses became evident.

The only exception to this cost saving was for the NSW Department of Fisheries, for whom it was cheaper to send staff to the University of Sydney. For this reason, NSW Fisheries made up the majority of participants (about 80%) of Type 2 courses. Without this support, the courses would have been very expensive. The remainder of participants at Type 2 courses were students/ researchers from the University of Sydney, two CSIRO employees and one Ph.D. student from the University of Wollongong.

Apart from reducing costs there were other advantages for organisations to operate Type 1 courses. Courses were held at a time and location suitable for the client and were customised to suit the nature of the fisheries being researched and managed. For example, the CRC Reef Research Centre requested some spatial modelling be included in their course, whilst Fisheries WA wanted greater emphasis on age-structured modelling. Where appropriate, agency personnel could also contribute to the course. The stock assessment workshop for Fisheries WA was officially run by James Scandol (QTUF), Norm Hall (Fisheries WA) and Peter Stephenson (Fisheries WA). This extended "ownership" of the onsite course was beneficial for both QTUF and the host agency alike.

5.2.3 Structure of Courses for Scientists (Type 1 and 2 Courses)

There was no single structure for the courses for scientists (either onsite or at the University of Sydney). Courses were continuously improved using the feedback to the convener and more computer-based modules became available. Some of the content was based upon Haddon and Montgomery (1995) and additional content was developed as required. The following strategy was applied to development of courses:

- identify the objectives;
- articulate the likely outcomes of the course;
- develop appropriate presentations to guide participants through the course;
- use the computer-based modules to impart knowledge;
- use spreadsheet-based exercises to develop skills;
- change the topic that is studied every day; and finally,
- obtain an evaluation from participants.

The usual strategy was to make the first day of a course an exercise in fisheries modelling and definition of problems. Participants were encouraged to work their way through the "Simple Population Models" module that include a simple simulation of a fishery (from Hilborn and Walters 1992). They then had to recreate the model in Excel. This exercise enabled us to ascertain the range of skills that participants had with spreadsheets. Their model was then extended with process and observation errors, biological reference points, indicators, input and output controls. This simple fishery model was therefore used to illustrate many of the important concepts of fisheries science and management. Day One usually included a series of slides to outline the issues and challenges facing fisheries managers and scientists.

The second day was usually focussed upon the process of estimating parameters. Participants were shown analytical, graphical and numerical methods. Both sums-of-squares and maximum likelihood approaches were taught. Many models used in stock assessment are non-linear and badly specified. The estimation of parameters can therefore be difficult and frustrating, so emphasis was given to teaching people problem-solving strategies. This included the important step of fitting models to datasets where the solution is known (Hilborn and Mangal 1997). The "Parameter Estimation" module was used to introduce and explain the fundamental concepts involved with confronting models with data.

Day Three was used to introduce or revise biomass dynamic models and give participants experience with a difficult and realistic estimation exercise of parameters. The "Biomass Dynamic Models" module was used extensively. Once a spreadsheet model for the estimation of parameters was completed, participants extended the model with stock projection for a quota-managed fishery. People with greater skills then undertook the task of bootstrapping the residuals of the model to estimate the variability of the estimated parameters. When combined with the stock projection model, this calculation was equivalent to a quantitative risk analysis of harvest options. This later exercise required reasonable skills with Visual Basic for Applications.

Days Four and Five were filled with similar exercises looking at growth curves, stock-recruitment relationships or yield-per-recruit analysis. In all cases, the CBI software, *Quantitative Training in Fisheries* provided an effective medium for communicating the concepts. In January 2000, Norm Hall and James Scandol developed a simple age-structured modelling project that provided a very effective one-day training exercise. This exercise was well received in many courses that year.

Appendix 12.3 gives an example of some of the teaching material used for the onsite course at the CSIRO in Hobart (September 2000). The effectiveness of the courses in achieving the objectives is evaluated in the Results and Discussion sections of this document. Figure 1 is a photograph of participants at Course 1.6 at the Tasmanian Aquaculture and Fisheries Institute (Taroona).

Figure 1 Participants solving modelling problems during a Type 1 course at the Tasmanian Aquaculture and Fisheries Institute (Taroona) in December 2000.

5.2.4 Structure of Courses for Managers (Type 3 Course)

The courses for fisheries managers were quite different from those developed for the scientists. Primary differences included that:

- no assumptions were made about the technical or quantitative skills of attendees;
- the course was to be presented within one day[5];
- the course was oriented towards problem description rather than solution prescription, and;
- the course was to use language and methods of relevance to managers.

[5] An exception to this was the two-day course held at NRE Geelong in March 2000.

The motivation for the courses for managers was two-fold. First, our Advisory Committee recommended that we explore options to extend some of the QTUF material to management and industry. Second, the short-course format was amenable to the large numbers of fisheries managers expected to interpret documents such as stock assessments, but who had little background or no training or direct experience in doing so. The courses for managers were designed to fill this void. James Scandol had had previous experience teaching a course in environmental management and thus we felt that QTUF had the appropriate experience for undertaking this challenging task.

The courses for managers contained three themes: decisions, forecasts and uncertainty. These themes are summarised below.

Decisions
An overview of models of decision-making from planning theory. We contrasted Lindblom's (1979) incremental decision-making model with that of rational comprehensiveness. Decision tables and multi-criteria decision analysis were examined as tools to explore outcomes of decisions over multiple dimensions, or (Chechile 1991; Chesson and Clayton 1998).

Forecasts
An outline of the general strategies used by population modellers to assess fish stocks was presented, along with a consideration of the strengths and weaknesses of these methods. The importance of age-structured data for stock assessment was also introduced. We also included extensive discussion about the issues associated with the interpretation of data from fishery-dependent sources. Role-playing exercises were completed to illustrate the interpretation of a stock assessment in an environment of negotiating stakeholders.

Uncertainty
We provided definitions of uncertainty and risk (Harding 1998) and summarised the procedures used by stock assessment scientists to calculate the probabilities of outcomes from stock projections. A forum for discussion was provided to consider interpreting uncertainty and precautionary principles. The course also explored research and managerial strategies that could improve the sustainability of Australian fisheries.

The practical exercises for this course were based upon a case study of an imaginary fishery - the tasty red jaw. We used a synthetic fishery because it enabled the simultaneous presentation of many research and management issues without criticising any real-life stakeholder group, agency officer or jurisdiction. Background documents were prepared that included: the history of the fishery, biology of the target species; a simple assessment using biomass dynamics; political agendas of the various stakeholders and the policy directives of the Government. Course participants were required to play out the role of a particular stakeholder within a committee that was attempting to set a total allowable catch quota for the fishery. The point of this exercise was to give managers exposure to the issues associated with the interpretation of technical documentation within a politicised decision-making environment. Participants were also asked to draft a decision-table and recommend research and managerial strategies that would improve biological, economic and social outcomes for the fishery.

The CBI modules were not used in the courses for managers. The criterion that the "Course [is] to use language and methods of relevance to managers" suggested that simulated meetings and small-group discussion were more appropriate than computer-based-instruction. The CBI modules were discussed and offered to course participants if they wanted to study the content at a later date.

Appendix 12.4 contains some examples of the background material, proposed outcomes and exercises that were used in the courses for managers.

5.2.5 Structure of Courses for Centre Students (Type 4 Course)

The Centre for Research on Ecological Impacts of Coastal Cities maintains very selective entry Honours (4th year) teaching programme involving coursework and research. QTUF convened three-day courses in fisheries modelling in 1999, 1999 and 2000 that all Honours students were required to complete. The course made extensive use of the introductory module within the CBI software. Students then recreated the simulation of a fishery (a set of coupled difference equations) and extended this model to include simple economic and social dimensions. Various managerial options for the fishery were then explored, including: catch quotas, input controls, taxes or subsidies and other options. The subsequent assignment was assessed and the mark was a 5% contribution to the final grade of the student.

5.2.6 Structure of Courses for Undergraduates (Type 5 Course)

Undergraduate teaching was not a particular focus for the QTUF project. When Professor Steve Hall (then of Flinders University of South Australia) invited us to teach a one-day course on an "Introduction to Fisheries Modelling" within a third-year unit on Fisheries and Aquaculture, this seemed an excellent opportunity to build links with Flinders University. We prepared a one-day course with three lectures and a three-hour practical exercise based upon CBI software *Quantitative Training in Fisheries*.

The course outlined the issues facing managers and researchers of fisheries and the potential role of modelling and stock assessment. Different types of assessments were then introduced. Students were required to build a spreadsheet of the simple fishery (using the algorithms provided in the CBI software) and examine the outcomes of various types of harvest policies. The short assignment generated by this exercise was assessed by the QTUF. Members of the South Australian Research and Development Institute (SARDI) also contributed to teaching this unit. This course was taught in 1998, 1999 and 2000.

5.3 Computer-Based-Instruction Modules

5.3.1 Implementation

Quantitative Training in Fisheries (Montgomery and Hood 2001) was created with Macromedia Authorware 4.0. This development environment was chosen following a review of candidate packages and computer languages because if offered important advantages. These include an icon-based flow-charting structure for rapid development, built-in interactive components, a powerful language with good mathematical functions, its cross-platform nature and the ability to distribute packaged solutions which require no other software or licenses. Its authoring features combine the ability to use high-level graphics and control structures with a low-level algorithmic language.

5.3.2 Format and Navigation

An early design goal was to create an intuitive and consistent user-interface. After much trial and error, a single screen format was selected and stylistic, structural and functional conventions were adopted. A navigational module, launched by double-clicking on an icon is the entry point to all the training modules and quitting a training module takes the user back to the navigational module. Figure 2 shows the opening screen of the navigational module and the common screen format.

The common elements of the screen format are the frame and the navigation buttons along the bar. The three large buttons on the bottom left form the help system, the six buttons in the centre are the page search and navigation buttons and the three buttons on the right are the section and module navigation buttons. The area within the frame is the current page and any controls that relate only to the current page appear in this area.

Figure 2 Opening screen of *Quantitative Training in Fisheries*. The navigation buttons at the bottom of the screen are a common design element to the training software. Corporate logos of the Fisheries Research and Development Corporation and the Institute of Marine Ecology (the research agency that was funded for QTUF Phase I) appear on the opening screen.

Each module or chapter of the software has a default workflow from start to end. Users can just keep “turning the page” as you would a book to cover the material in a logical sequence. Users can, however, jump to a particular location, or understand where they are within a module, by clicking the "Where" button (see the lower left hand side of Figure 2). Figure 3 is the image presented to the user if they do this.

One novel visual cue used in the modules was the metaphor of depth. Menus that were at the top level of navigation (modules) used a background image of surface waters. The main menu (choice of sections) within a module used an image of schooling pelagic fish, a section menu (choice of subsections) used a benthic image. We hoped that this metaphor would appeal to the desk-bound fisheries scientist!

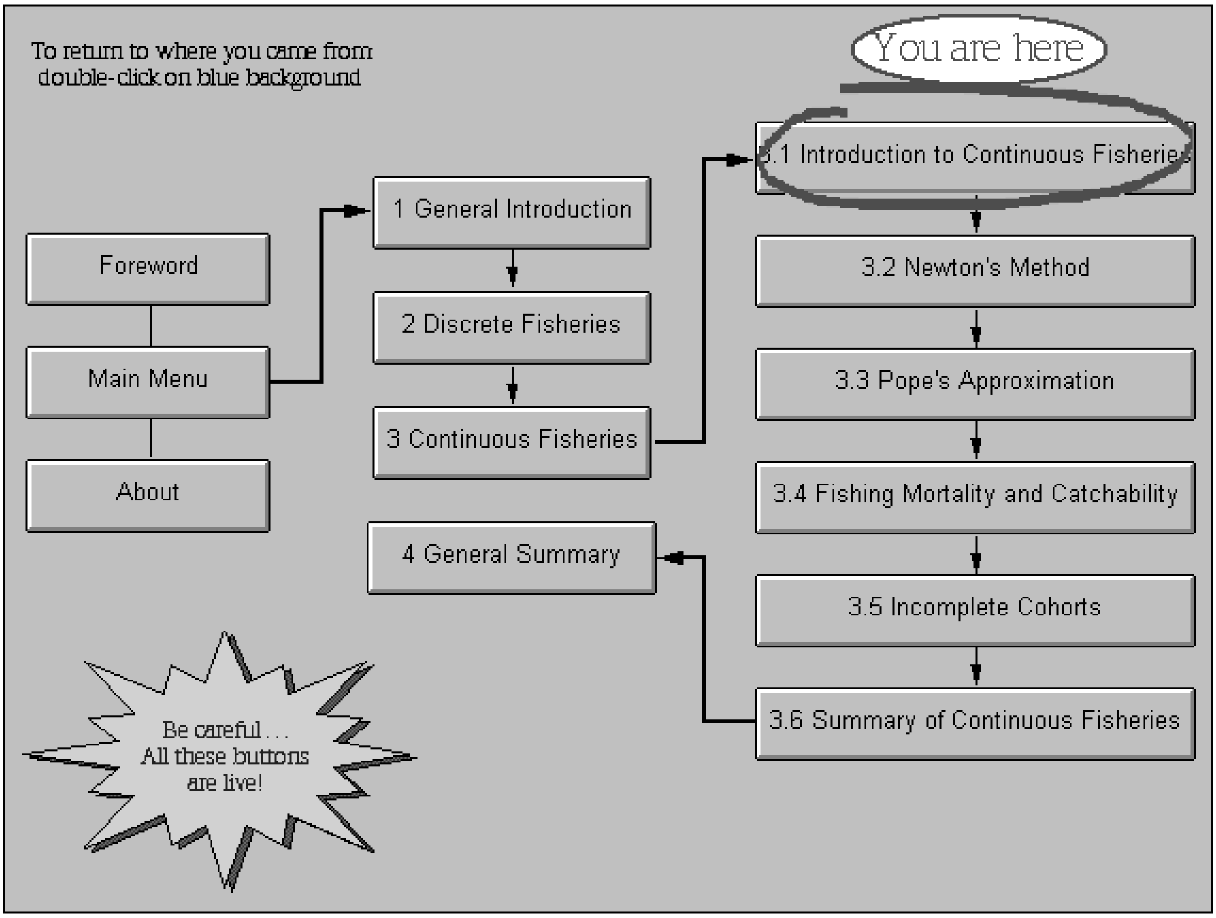

Figure 3 Screen snapshot of the Deterministic Age Structured Models Module. This illustrates the logical flow of topics within the module. Users can also use this screen to move to any particular topic.

5.3.3 Novel CBI Strategies

Computer visualisation has long been recognised as an effective strategy for communicating complex ideas in science (Nielson 1991). We made extensive use of visualisation with two and three-dimensional graphics and animation. For example, Figure 4 is a screenshot from the Parameter Estimation module illustrating a linear relationship with constant standard deviation. This plot was animated from a 3D perspective plot to a contour plot. Users could use this image to help them understand the complex role of probability density functions in the development of minimal residual and likelihood models.

Another strategy used extensively in the modules is the animation of the derivation of equations. Rather than presenting a conventional series of equations, the animation allowed parts of equations to evolve, separate and merge so that the derivation unfolded as a process. The process paused at regular intervals to let the user control it and restart or terminate it. Understanding the fundamental relationships underlying many of the final equations is important and several modules provide extensive derivation. For example, the analytical integration used by Beverton and Holt (1957) for the isometric yield-per-recruit equation is fully animated. Although the availability of computers has reduced the analytical demands upon many fisheries scientists the ability for teachers to communicate these derivations is still important.

To make the models visually appealing, the amount of text was kept to a minimum. This was done by presenting text in point format and hiding detail, such as explanations and bibliographical references, in hot text. This gave the reader control over how much information was presented.

Finally, many of the graphics are interactive. Sliders can be moved to change values of parameters, mouse clicks and buttons used to zoom in or out, redraw graphs or repeat calculations. Although people are now blasé about this sort of functionality in software, the modules go much further. Some graphs have the ability to step through layers of data, such as cohorts of a virtual population analysis. Others require the user to position points to create underlying relationships.

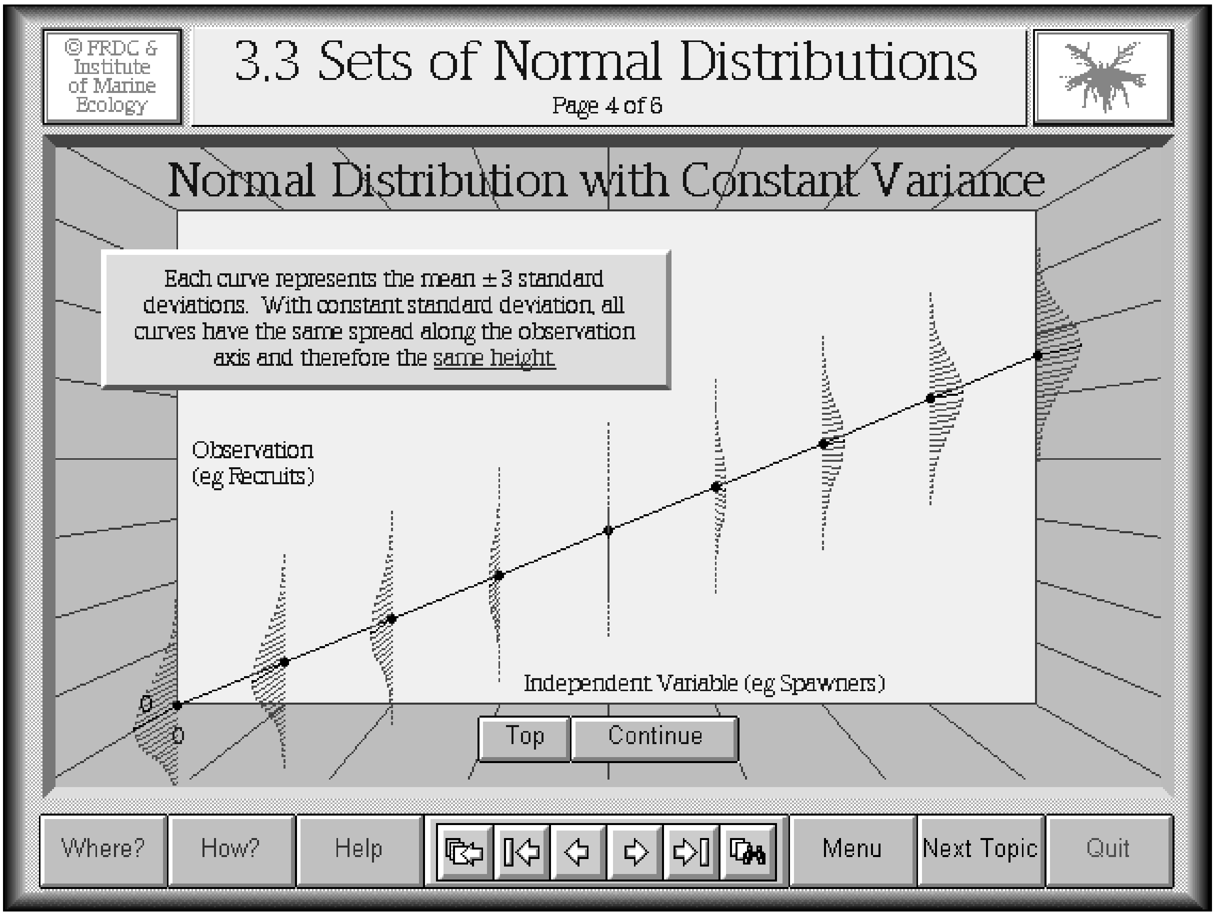

Figure 4 Screen snapshot of the parameter estimation module illustrating the use of 3D graphics. These images were also animated.

5.3.4 Distribution

With the exception of the undergraduates completing Type 5 courses and participants of the Type 3 courses (for managers), all participants were given the most up-to-date version of the software at the beginning of their course. All recipients of the software signed a letter outlining the terms of agreement for use (Appendix 12.7). Copyright of the software is owned by the FRDC and the Centre for Research on Ecological Impacts of Coastal Cities (see Appendix 12.1).

All institutions listed in Table 3 have copies of the software *Quantitative Training in Fisheries*. We expect that the software would become distributed throughout each institution as its values become evident. A condition on the terms of agreement is that the software is not to be used for teaching courses that would compete with future teaching undertaken by the Centre for Research on Ecological Impacts of Coastal Cities. This constraint caused some individuals to decline to sign the agreement until a suitable arrangement could be negotiated.

5.4 Questionnaire

In July 1998, we prepared a four-page questionnaire to be completed by all participants of QTUF courses (Appendix 12.5). The questionnaire included:

- 26 statements about the course to be responded to using a Lickert scale (i.e. did people: strongly agree; agree; neutral; disagree; or strongly disagree, with the statement). An example statement was: "The tasks were useful learning experiences";
- one page of free-form comments about the course prompted by questions such as: "Please list the two most important things about this course that helped you to learn and explain why each was important to you.";
- 20 statements (assessed using a Lickart scale) about the CBI software, to measure the users response to navigation, content and motivation;
- one page of free-form comments about the CBI software.

Statements about the teaching were taken directly from the standard University of Sydney course evaluation questionnaire (Centre for Teaching and Learning). All coursework and teaching at the University is systematically evaluated with questionnaires of this type. We removed questions that were repetitious or attempted to measure attributes that were not relevant to our teaching programme. Ian Montgomery developed statements about the CBI software in 1996 when he began to design the software. All questionnaires were anonymous (identified only by the course at which they were completed) and no attempt was ever made to associate a particular questionnaire with a person.

The convenor of a course explained to all participants the importance of completing the questionnaire. We used the results to evaluate the effectiveness of teaching and the utility of the CBI software. Although we cannot guarantee that the responses capture an unbiased sample of participants (people who really dislike courses will not spend their time filling in the associated questionnaire), we made a determined attempt to measure attitudes about and outcomes from our courses.

5.5 Quantitative Marine Ecology

5.5.1 Overview

Objective 2 ("Assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney"), was achieved with the development of new postgraduate awards in Quantitative Marine Ecology. Creating these new awards required a lengthy negotiation with the Faculty of Science and a large amount of paper work! We integrated the teaching objectives of QTUF with other material being taught at the Centre.

The following markets have been identified for this service:

- Professionals working in Australian local, State/Federal government agencies, or international professionals responsible for marine and coastal resource management.
- Recent science graduates wishing to further develop their knowledge and skills in Quantitative Marine Ecology.

From January 2001, the Centre started convening coursework programmes in Quantitative Marine Ecology and offered three new awards: a Graduate Certificate; Graduate Diploma and Masters. Candidates will initially enrol in a Graduate Certificate in Quantitative Marine Ecology and, depending on their performance, may upgrade to a Graduate Diploma or Masters in Quantitative Marine Ecology. Figure 5 is a schematic representation of these awards and how they are related.

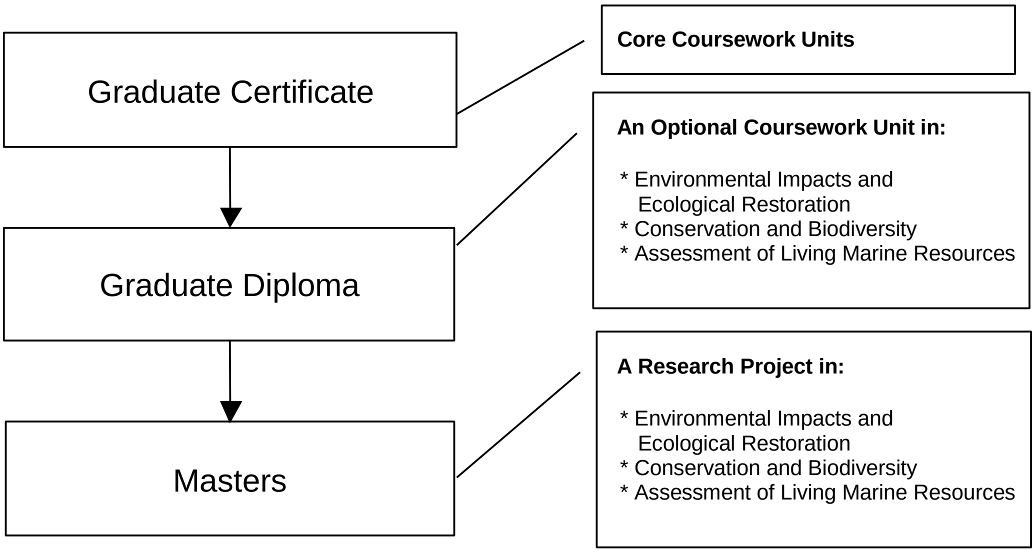

Figure 5 Flow-diagram illustrating the components of, and linkages between, the three new awards in Quantitative Marine Ecology.

The Diploma and Master's awards have been structured around three study themes that allow a consistent and integrated approach to problem-solving in these areas. The three themes are:

- environmental impacts and ecological restoration;
- conservation and biodiversity;
- assessment of living marine resources.

5.5.2 Personnel

The new awards will be administered by the Faculty of Science but managed on a day-to-day basis by the Centre. The key personnel employed by the Centre will be:

Prof. A.J. Underwood
As Director of the Centre, Professor Underwood will have final responsibility for admission and progression of an individual's candidature. Professor Underwood is an international leader in the design and implementation of experimental designs to detect environmental impacts. Prof. Underwood will teach and supervise students within the environmental impacts theme.

Dr M.G. Chapman
Dr Chapman is the Deputy Director of the Centre and has published widely in the field of marine biodiversity and ecological restoration. Dr Chapman will teach and supervise students within the marine biodiversity theme.

Dr J.P. Scandol
Dr Scandol is currently a Senior Research Fellow at the Centre and was the course convener within the Quantitative Training Unit for Fisheries project. Dr Scandol has national and international experience in fisheries and marine modelling and will teach and supervise students within the assessment of living marine resource theme.

5.5.3 Description of the Awards

Graduate Certificate in Quantitative Marine Ecology (GradCertQuantMarEcol)
This award is by coursework and requires the completion of 24 credit points from new courses to be taught by the Centre. The Graduate Certificate can be completed in one semester full-time or up to four semesters part-time.

Professionals must understand and apply the appropriate quantitative methods in applied marine ecology. The Graduate Certificate (and the concurrent Graduate Diploma and Master's in Quantitative Marine Ecology) will allow holders of relevant Bachelor's degrees to extend their knowledge and skills of the scientific methods used by researchers to underpin management of marine and coastal resources. No Certificate level awards are currently being taught in Australia to fill this niche. We expect that many of the students enrolled in the GradCertQuantMarEcol will continue to the higher awards of the GradDipQuantMarEcol or the MQuantMarEcol.

The GradCertQuantMarEcol involves the completion of 4 core units. These are summarised in Table 4.

Table 4 The four units of study required for a Graduate Certificate in Quantitative Marine Ecology.

Unit of Study Code	Unit of Study Name
QMEC5110	Structure and Management of Research Projects
QMEC5120	Introduction to Design and Analysis of Sampling
QMEC5130	Introduction to the Interpretation of Complex Data
QMEC5140	Introduction to the Assessment of Living Marine Resources

Graduate Diploma in Quantitative Marine Ecology (GradDipQuantMarEcol)

This award will be by coursework and require the completion of 36 credit points from new courses to be taught by the Centre for Research on Ecological Impacts of Coastal Cities. The Graduate Diploma can be completed in two semesters full-time or up to eight semesters part-time.

Diploma Candidates must complete a unit of study to the value of 12 credit points in addition to 24 credit points of core units of study. Table 5 lists the units available and the topics within these units that are required for a Diploma.

Table 5 The hours of face-to-face teaching for the optional topics offered to Diploma candidates. Candidates will select a particular 12 credit point unit of study and complete the topics required for that unit.

Unit of Study → / Topic ↓	Environmental Impacts and Ecological Restoration	Conservation and Biodiversity	Assessment of Living Marine Resources
Design and Analysis of Sampling	28	28	28
Marine Population Dynamics and Stock Assessment			35
Legislative and Policy Frameworks	7	7	7
Numerically Intensive Statistical Methods	14	14	14
Monte Carlo Simulation			14
Analysis of Multivariate Data	14	14	
Assessment of Environmental Impacts	14		
Analysis of Marine Biodiversity	0	14	
Ecological Restoration	21	21	

Master of Science in Quantitative Marine Ecology (MQuantMarEcol)

This award will be by coursework and research. It will require the completion of 36 credit points of new courses to be taught by the Centre, a research project to the value of 12 credit points supervised by staff of the Centre. The Master of Science can be completed in three semesters full-time or up to ten semesters part-time.

MQuantMarEcol candidates must complete a research unit to the value of 12 credit points. This project will be in one of the following themes: environmental impacts and ecological restoration (QMEC5310), conservation and biodiversity (QMEC5320) or assessment of living marine resources (QMEC5330).

5.5.4 Other Information

Up-to-date information about the units of study and the awards is available on the Centre's web-site. This enables information about costs and dates of courses to be kept current. All other information, such as enrolment processes and University policies are available through the University of Sydney and Faculty of Science web-pages. The pertinent addresses are provided in Table 6.

Table 6 Web sites with information pertinent to the units of study and awards in Quantitative Marine Ecology.

Description and Address of Site	Information Available
The Centre for Research on Ecological Impacts of Coastal Cities www.eicc.bio.usyd.edu.au	• Role of the Centre • The Centre's research • Objectives of the QMEC awards • Interests and skills of staff members • Dates of the units of study • Costs of the units of study
The Faculty of Science www.scifac.usyd.edu.au	• Policies and procedures for undergraduate and postgraduate enrolments
The University of Sydney www.usyd.edu.au	• Policies and relevant information about the University of Sydney

6 Results and Discussion

6.1 Results of Questionnaires

The Methods section provided a list (Table 3) of the courses taught within QTUF Phase II. This section provides a description of results from the questionnaires. Recall that these responses were obtained from clients at the end of a course. Results from the questionnaires have been classified into three groups: scientists (Type 1 and Type 2 courses), managers (Type 3 courses) and students (Type 4 and Type 5 courses). This classification was completed because the objectives for the three client groups were not identical and the teaching resources allocated towards the various clients also differed (for example student teaching was given a lower priority than courses held at fisheries research institutes). We would not have expected comparable responses between groups.

Of the 26 course statements, only 6 statements per group have been graphically reported on in this section. A complete table summarising all responses is given in Appendix 12.6. Responses from the scientists (Figure 6, 107 respondents), managers (Figure 7, 68 respondents) and students (Figure 8, 104 respondents) are briefly described here.

Scientists were in general more satisfied with the courses than the other groups (compare Figure 6f, Figure 7f and Figure 8f). About 10% of managers were "neutral" about the quality of the course whilst only 2% of the scientists were. Scientists affirmed that the things they learned were useful in their careers (93% agreed or strongly agreed) and that the course developed their problem-solving skills (85% agreed or strongly agreed). We received confirmation that the teaching material was appropriate with 95% of the 107 scientific respondents agreeing or strongly agreeing that the tasks were useful learning exercises. A similar response was obtained (87% agreed or strongly agreed) about the statement "The teaching stimulated my interest in the course content". Responses were more ambivalent on the important outcome "As a result of the course, I feel confident about tackling unfamiliar problems". In this case, 29% of respondents were neutral and 6% disagreed.

Figure 7 illustrates that managers were more hesitant about the outcomes from the courses. The less-focused content may have resulted in 30% of the 68 respondents agreeing or being neutral about the statement "It was often hard to discover what was expected of me in this course" (though 53% did disagree with the statement). The group exercises used in the Type 3 courses made some impact of teamwork but nothing striking. Figure 7b illustrates that 32% were neutral to the statement about developing teamwork skills. We were pleased that clients thought that we could explain concepts in simple language (78% agreed or strongly agreed that "The staff were extremely good at explaining things"), and virtually all (91%) respondents thought that we worked hard to make our subject interesting.

Type 4 and Type 5 courses were distinguished by being relatively short in duration and with a large teacher-to-student ratio. Furthermore, many of these clients may have had a limited interest in fisheries. We did not expect particularly positive responses from these students. Nevertheless, most (66%) of the 104 respondents agreed or strongly agreed that the applications of the topics covered were clear and that the teaching in the course had helped them learn (64% agreed or strongly agreed with the latter statement). Many thought that the course was overly theoretical and abstract (59% were neutral, agreed or strongly agreed) and 62% were neutral, disagreed or strongly disagreed that they were "given enough time to understand the things I had to learn". Graphical results for student responses are presented in Figure 8.

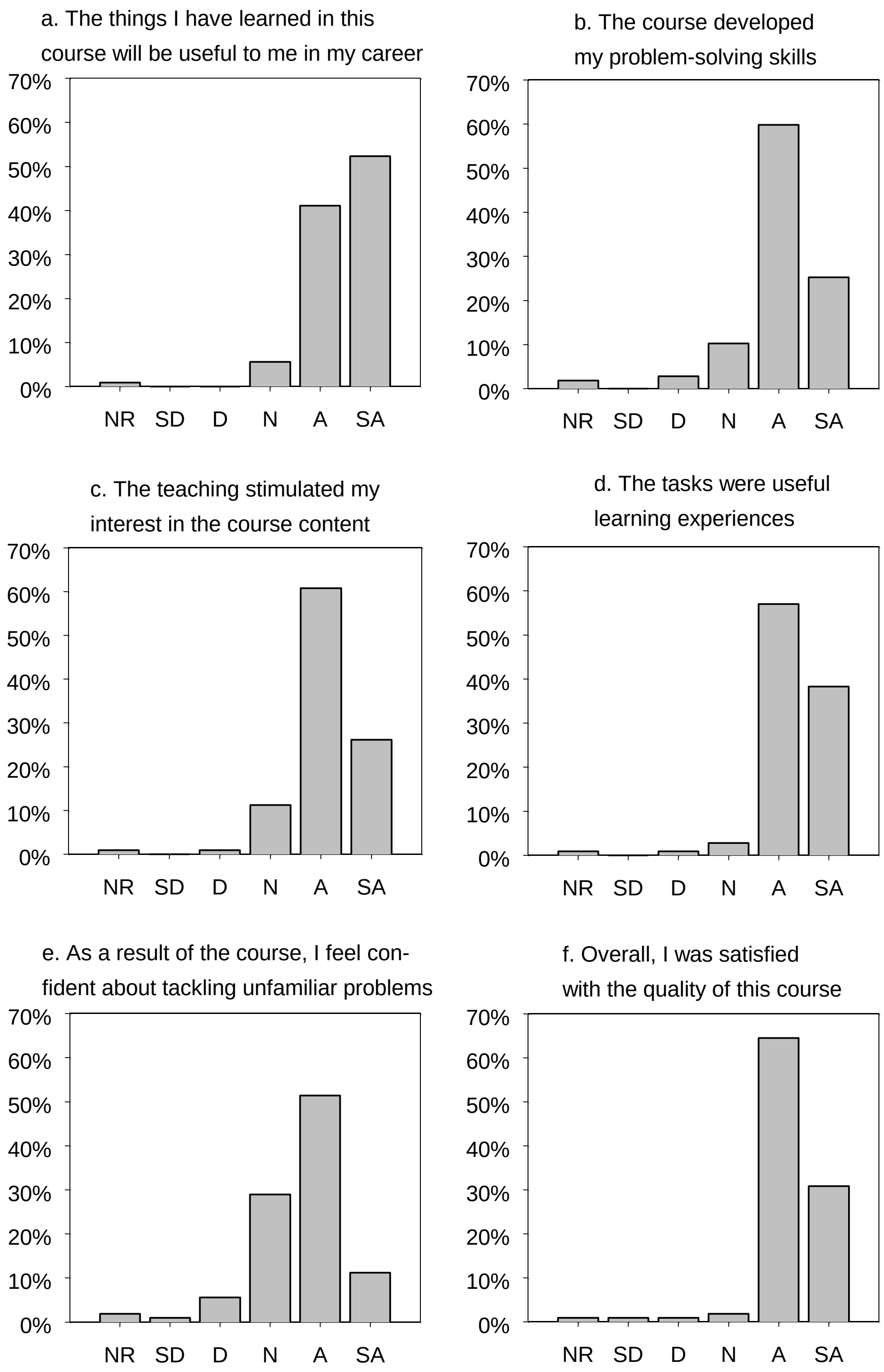

Figure 6 Frequency histograms of the responses from scientists (Type 1 and Type 2 courses). Codes: NR (No Response); SD (Strongly Disagree); D (Disagree); N (Neutral); A (Agree); SA (Strongly Agree).

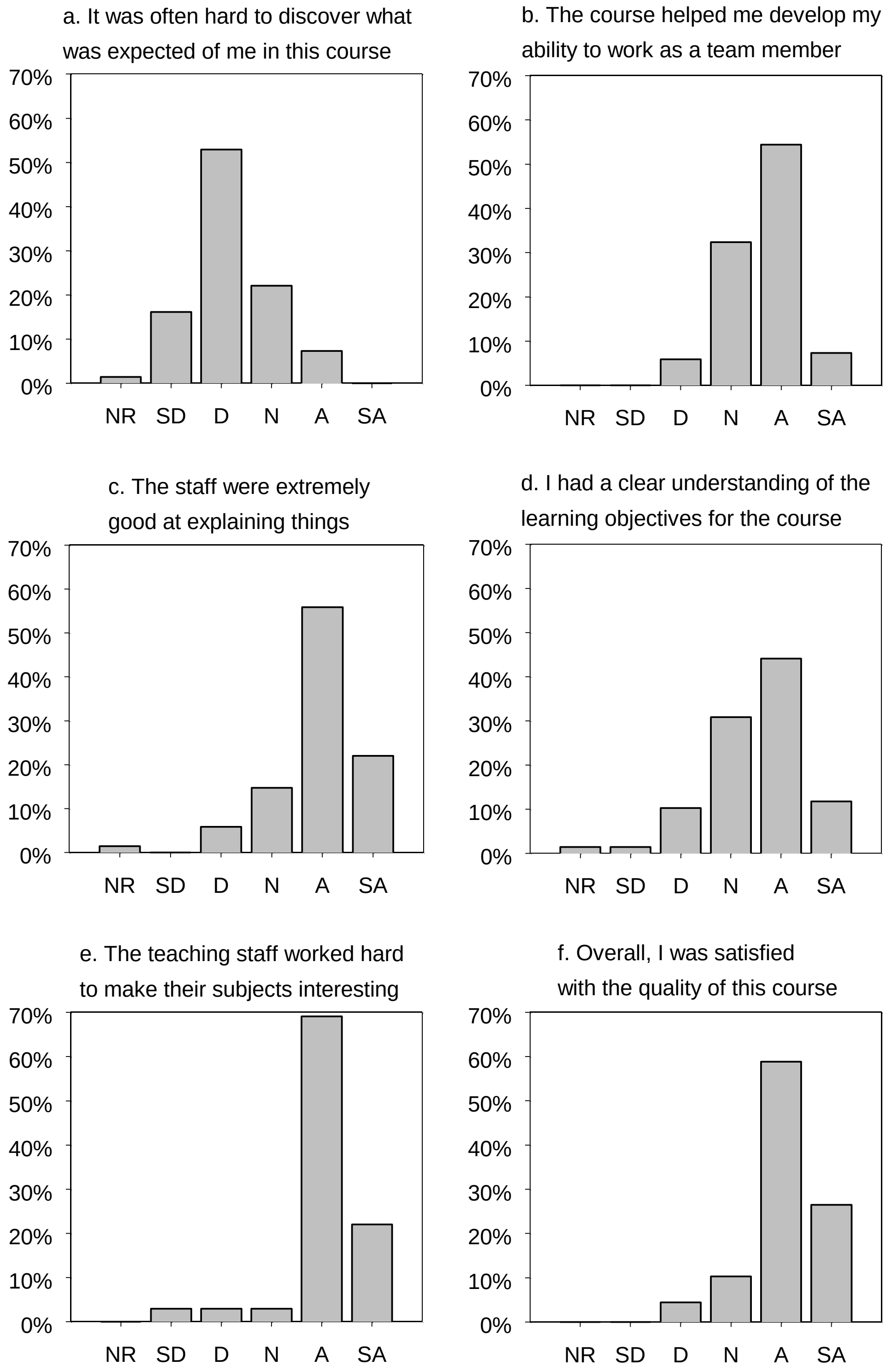

Figure 7 Frequency histograms of the responses from managers (Type 3 courses). Codes: NR (No Response); SD (Strongly Disagree); D (Disagree); N (Neutral); A (Agree); SA (Strongly Agree).

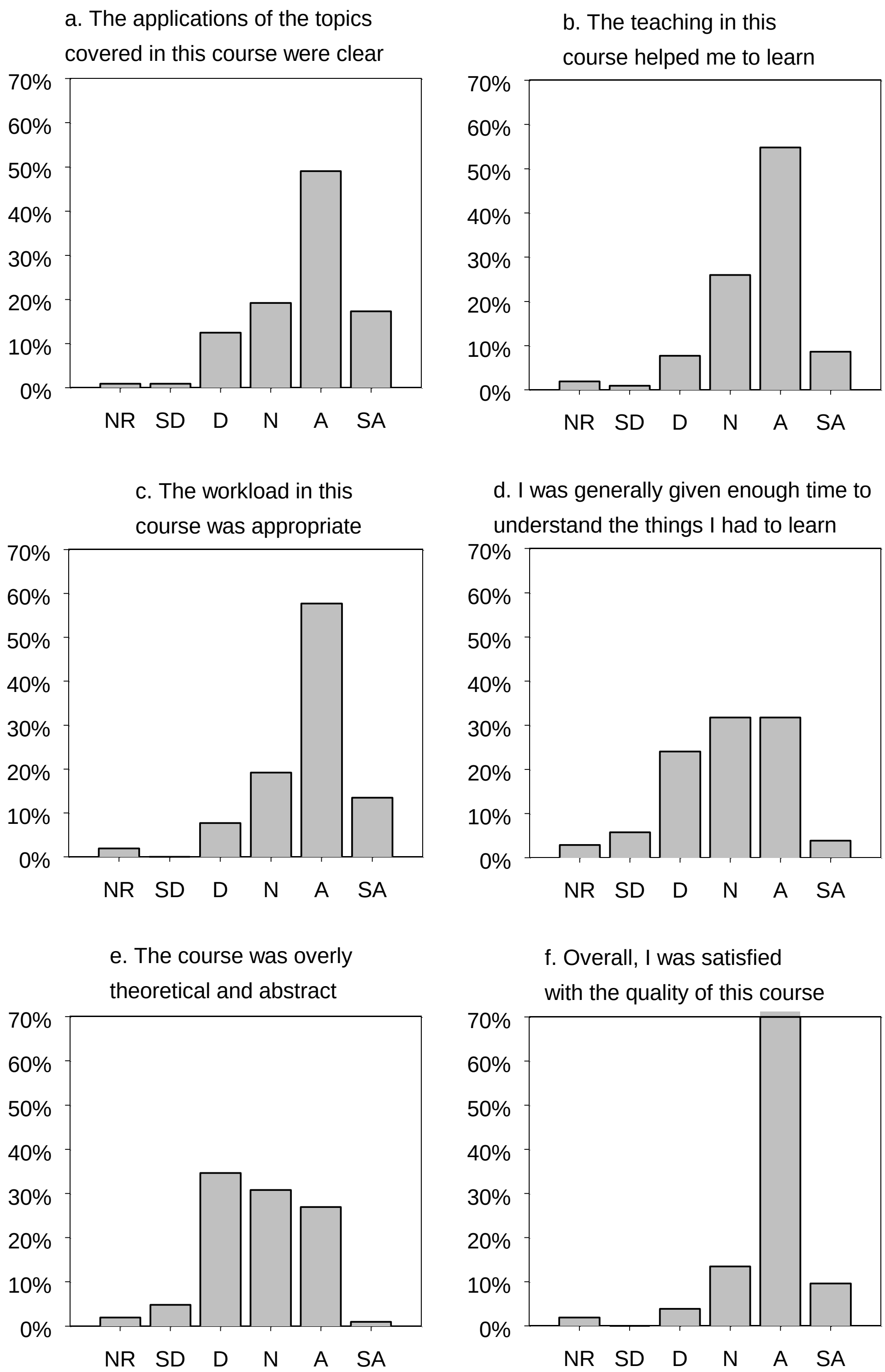

Figure 8 Frequency histograms of the responses from students (Type 4 and Type 5 courses). Codes: NR (No Response); SD (Strongly Disagree); D (Disagree); N (Neutral); A (Agree); SA (Strongly Agree).

6.2 Comments on the Courses

We also obtained written responses to the courses and acted upon them appropriately. For example, one client suggested that "Using the same equations [notation] in the modules as the ones in the exercises" would make the exercises easier to understand. We responded to this by ensuring the notation used was consistent between the modules and exercises, or any differences were clearly explained. Another example which was more difficult to accommodate was the suggestion that we "Need to run a course on using Visual Basic [for Applications] first", because "too much time is spent trying to learn VB commands rather than concentrating on the modelling exercises". We explored various strategies to teach Visual Basic. Some clients preferred to record keystrokes whilst others preferred to draft pseudo-code and then use a small subset of the language. There does not appear to be a single strategy to learn Visual Basic except lots of practise.

There were plenty of positive comments about the courses. For example "There was sufficient time on the course to solve problems and to further develop our analytical skills" and "Staff were prepared to explain problems and possible solutions (often <u>several</u> times!)"

6.3 Results of Questionnaire about the Modules

Responses to the questionnaires about the modules were not classified into the two client groups (scientists or students, recall that managers did not use the modules in Type 3 courses). Long-term outcomes of the CBI software, *Quantitative Training in Fisheries*, will be derived from its use as a student teaching tool *and* as a scientific reference tool. It will be difficult to differentiate these roles in the future, so reporting of the responses of the two client groups separately would be of limited value. Therefore, the responses have been aggregated over Type 1,2,4 and 5 courses. Readers should note that the 211 (107 scientists and 104 undergraduates) responses reported upon below include those from dedicated fisheries scientists to surly undergraduates (a realistic evaluation of any teaching tool).

The navigational system was evaluated by the statements "The Where? button is useful for finding out where I am in the module" and "I use the Where? button frequently to jump to other sections" (Figure 9a and Figure 9b). The "Where?" button was used by 18% of users but 26% responded neutrally to the second statement. Very few respondents thought that, "navigating around the modules was difficult" (only 7% agreed or strongly agreed with that statement, Figure 9c). Initial concern about the multiple levels of menus was reduced with 67% disagreeing or strongly disagreeing that "was confusing when there was more than one level of menus" (Figure 9d).

We were reassured that we had designed the material at the appropriate level when we compared Figure 9e and Figure 9f. The similar distributions of responses to the contrasting statements "The material was too elementary" and "The material was too advanced" affirmed that we got the level about right. The relatively large frequency of neutral responses reflected disinterested undergraduates, of which about 30% were neutral about both statements. This reflected lesser experience with the subject matter.

Figure 10a indicated that "the interactive exercises were helpful in gaining an understanding of the material" with 78% of respondents agreeing or strongly agreeing with the statement. Responses were mixed about the comparative value of spreadsheets with the modules for investigating models. Figure 10b illustrates a symmetric set of responses on the Lickart scale. Given that the spreadsheets would have been written by the client, there may have been a sense of ownership of the spreadsheet model compared to the one provided in the modules. The modules generated effective learning outcomes as illustrated by Figure 10c, where 74% of respondents agreed or strongly disagreed that they did not learn much from the modules. The reference value of the modules was confirmed with 77% of respondents agreeing or strongly agreeing that they found the modules a useful source of reference.

Motivated self-study was a primary reason why the CBI strategy was chosen by QTUF. The statement “I like studying on my own” (Figure 10e) was received with a mixture of enthusiasm. Very few students (6%) indicated strong (agree or disagree) responses. We were pleased to see that 52% of the clients found the modules enjoyable (Figure 10f). When examining this proportion by type of attendees it can be seen that 60% of scientists agreed or strongly agreed that “I found the modules enjoyable” whilst the corresponding figure for students was 45%.

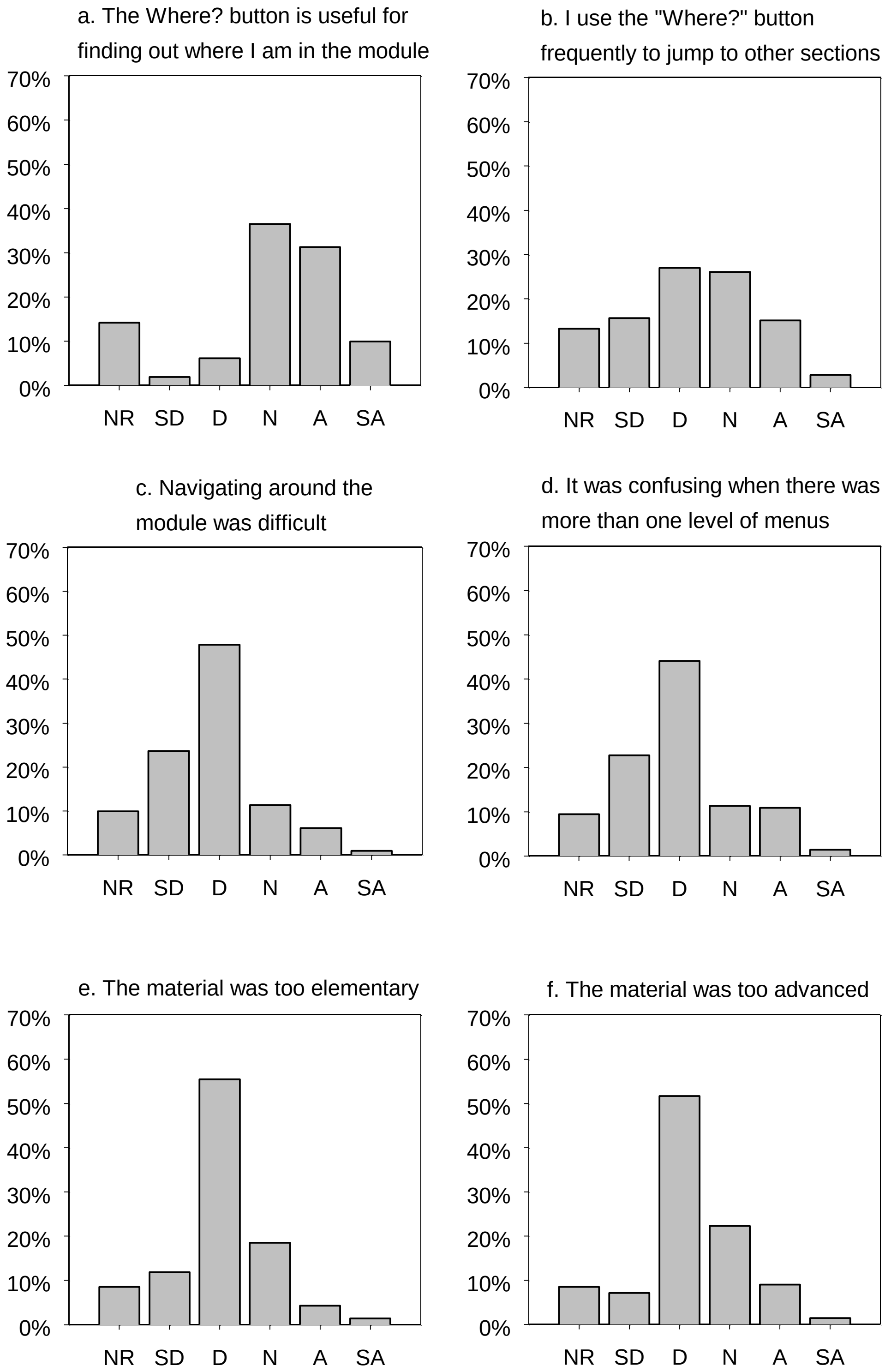

Figure 9 Frequency histograms of responses to comments about *Quantitative Training in Fisheries*.

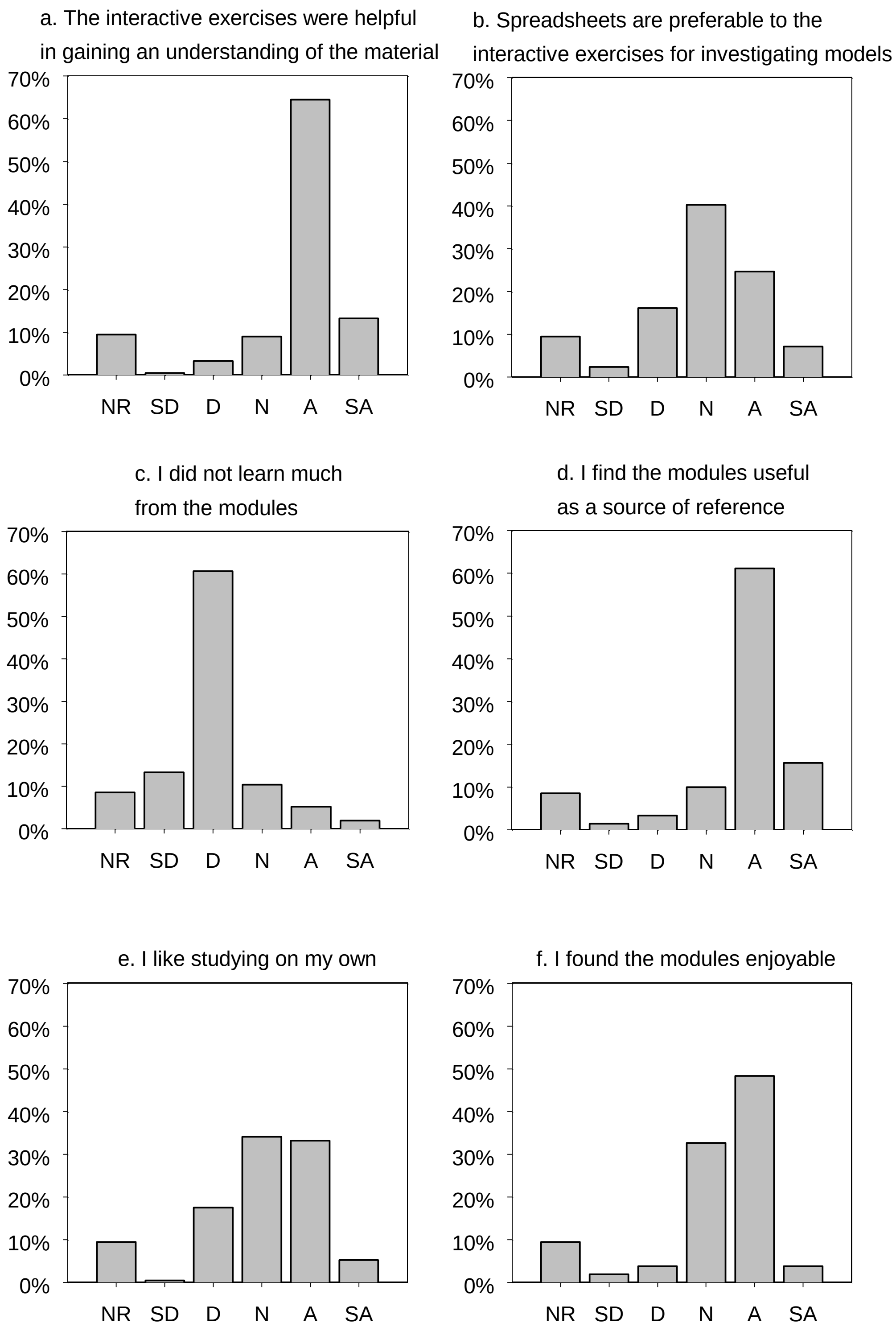

Figure 10 Frequency histograms of responses to comments about *Quantitative Training in Fisheries*.

6.4 Comments about the Modules

As with the courses, we obtained written responses to the modules, and if possible, acted upon them. Unfortunately, many of the issues raised would have required a major reprogramming effort that would have not been possible, for example "Pull down menus would have been useful" or "The scale of potential movement in the software seemed to be either large (i.e. Quit or Front) or small (i.e. forward or backward), with no scope for other moves (e.g. to the middle of another module)." One course participant suggested that "More interpretation/biology in the modules and exercises i.e. real examples, real management/ecological outcomes." Many of these issues were best dealt with by modifying the exercises rather than a major revision of the software that would have come at the expense of developing new material.

People were generally happy with the CBI software "I think it is a good resource available to formalise learning these techniques" and "The module (sic) is a valuable learning tool more motivated to use as is on screen rather than paper (easier to push to side + not read)". Finally, "Overall, a good package and one I'd encourage you to further refine and distribute."

6.5 Discussion

Direct evidence exists that the courses were well received by participants and that general educational outcomes were met in all three groups. It is also evident that we have created a permanent medium for self-study (Section 3.3). The QTIF software has been thoroughly tested and evaluated and there is every indication that the software addresses the planned outcomes.

The Centre has commenced teaching units of study for the new awards in Quantitative Marine Ecology. This confirms that we have provided a postgraduate award system for training in quantitative fisheries science (Section 3.5). The awards will also offer training in environmental impact assessment that will help address the need of understanding the impacts of fishing (Section 3.6).

There are two limitations about these conclusions. First, long-term outcomes of the project cannot yet be determined. We cannot yet determine whether course participants will remember or apply their new quantitative skills in the future. We could complete a follow-up questionnaire of ex-clients to evaluate the longer-term effects, but this would be uncontrolled and impossible to interpret. Rather than get too ambitious about attempting to measure the long-term outcomes of the QTUF projects (Phase I and Phase II) we constrained our evaluation to a descriptive summary of questionnaire results.

Second, we only have anecdotal evidence that specific outcomes have been achieved. For example, Section 3.2 implied that training in bootstrap re-sampling would be beneficial for Australian fisheries scientists. This need was translated into an educational outcome, e.g. Appendix 12.3 states "At the end of the five-day course participants will have: … Estimated the confidence intervals of the fitted parameters using bootstrapping of time-series residuals". Lack of a formal assignment and assessment process for the Type 1 to Type 3 courses weakens our ability to conclude that this specific outcome was achieved. This situation will be rectified in the formal award programme of Quantitative Marine Ecology.

We commented in Section 3.1 that quota management systems required improved understanding of the issues from industry partners. The Advisory Committee also continued to recommend that such training programmes be developed. This need was not met, nor was this recommendation followed, because: (1) the Australian Maritime College runs workshops for new members of management advisory committees (MACs). Offering a competing service would not have been efficient; (2) it was felt that such a project would distract QTUF from achieving its core objective of providing training for fisheries scientists; (3) QTUF did not have the key contacts, staff and resources to complete the task effectively. The Centre retains the teaching personnel required for meeting this need and may look at future options for doing so.

7 Benefits

The QTUF project (Phase II) has generated several tangible and intangible benefits for Australian fisheries. The courses held between 1998 and 2001 have exposed over 107 scientists, 68 fishery managers and 104 undergraduates to the quantitative methods required for the sustainable development of living marine resources. Courses of types 1, 2 and 3 gave the opportunity for agency staff to learn about and to practise working with the methods required to understand fish stocks. There were also intangible benefits of these courses: people interacted with colleagues, gathered insight into their aptitude in this area and obtained a better understanding of the role of fisheries modelling within their organisation. Some of these outcomes are difficult to measure, but written responses within the evaluation questionnaires (reported above) confirmed the positive reaction of most participants.

Courses for undergraduate and honours students (Type 3 and 4 courses) gave over 100 students an introduction to quantitative fisheries science. Although we have no direct evidence that any these students have been attracted to quantitative fisheries science as a career option, the process of introducing students to this important field has begun. The development of the new awards in Quantitative Marine Ecology at the University of Sydney provides an educational pathway for these students. Furthermore, the future presence of fisheries modelling expertise at the University provides more options for students considering this area of study.

An example of how this process might occur can be given by the case study of David Abelson[6]. David was a third year undergraduate student who enrolled in a "Talented Student Programme" because of his aptitude in mathematics. He was attracted to the Centre because of its reputation for quantitative ecological research. He undertook a project applying game theory to the NSW prawn fishery that concluded with some erudite comments about the potential use of quota management. With more work, the study would have been readily publishable. These are the sorts of individuals that have the potential to make substantial contributions to quantitative fisheries science in Australia. Universities require structures to attract and retain such people.

One outcome of the QTUF project that deserves comment is the training of staff within the project. Table 7 summarises the personnel employed within the QTUF project (both Phase 1 and Phase 2). As is evident from the Table, everybody employed by QTUF has

[6] David has give us permission to describe these events.

continued to develop their career in either fisheries modelling/assessment of stocks (Malcolm Haddon, Ian Montgomery and James Scandol), ecological modelling (Shane Richards) or development of computer-based-instruction software (Gail Hood). A very positive outcome is that both Malcolm Haddon and James Scandol continue to be employed in senior training positions at universities. This is likely to yield long-term benefits for the training of fisheries scientists with enhanced skills in quantitative methods.

Table 7 Summary of current positions held by personnel employed by the Quantitative Training Unit for Fisheries (Phase 1 and Phase 2). Staff are listed in alphabetical order by surname.

Name	**Current Occupation**
Malcolm Haddon	Associate Professor and Principal Research Scientist Resource Modelling & TAFI Wild Fisheries Program Leader Tasmanian Aquaculture and Fisheries Institute Tasmania
Gail Hood	CBI Software Developer Lesson Lab California
Ian Montgomery	Resource Assessment Modeller Marine and Freshwater Resources Institute Victoria
Shane Richards	Post-doctoral Research Fellow, National Centre for Ecological Analysis and Synthesis California
James Scandol	Senior Research Fellow Centre for Research on Ecological Impacts of Coastal Cities University of Sydney, New South Wales

The most tangible benefit from the QTUF (Phase II) project is the completion of *Quantitative Training in Fisheries*. This software is a unique and permanent contribution to the professional development of Australian fisheries scientists. Over 80 copies of the software have been distributed to Australian scientists and managers and copies are available in over 10 fisheries research and management institutions.

8 Future Development

As discussed extensively in this document, the staff and teaching materials of QTUF have been transferred to the new awards in Quantitative Marine Ecology. This provides a stable and long term-term future for the FRDCs investment. The nature of tertiary institutions in Australia mean that we cannot guarantee that fisheries modelling and stock assessment will be taught at The University of Sydney indefinitely. Demand for units of study and award programmes will be the final determinant to the long-term survival of these programmes. The Centre for Research on Ecological Impacts of Coastal Cities has made a commitment to the FRDC to maintain this teaching programme until 2005.

The new awards will be full-fee paying or non-Higher Education Contribution Scheme[7]. Such costs may require some potential candidates to obtain financial support from fisheries research and management agencies. This strategy is not unknown for

[7] This was only announced in February 2001 and the application to QMEC courses is uncertain at the time of writing.

Government agencies (for example the NSW Environment Protection Authority) and relatively common in private enterprise. We expect to negotiate with fisheries research and management agencies about financial and logistic strategies to enable the ongoing professional development of their staff within the QMEC programme.

The final version of *Quantitative Training in Fisheries* (Montgomery and Hood 2001) will be copied onto the CD-ROM included with this final report. We will screen the product carefully for small glitches, such as spelling errors, and any such errors will be corrected. Similarly, all logical or numerical faults that we can find will be rectified. We have yet to determine the most efficient method of redistributing any corrected versions of the software, but we will likely use our password protected internet server with the file-transfer-protocol (ftp).

Unless encouraged by the FRDC or a third party, the Centre does not plan to undertake major extensions to *Quantitative Training in Fisheries*. The ten topics covered reflect the common methods and applications needed by fisheries scientists in Australia. There will always be people who would like to see a particular topic covered and there will always be research developments that should be included. The software was, however, never designed to fulfil this role. *Quantitative Training in Fisheries* provides a background for the subject matter and a jumping-off point for further study. The source code will be retained and maintained by the Centre.

9 Planned Outcomes

The planned outcomes of the QTUF (Phase II) were: the delivery of courses; integration of the training material with the postgraduate programme at The University of Sydney; development of additional computer based modules; and, dissemination of the products of QTUF. The conclusion to this report contains a summary of how these outcomes were achieved.

During QTUF Phase I, Dr Malcolm Haddon prepared extensive notes (Haddon and Montgomery 1995). These notes are included (in Adobe Acrobat format) on the CD-ROM used to distribute the final version of *Quantitative Training in Fisheries*. Dr Haddon is in the final stages of rewriting these notes into a book (Haddon 2001). Since this book was not a part of the QTUF (Phase II) project it is not reported upon here. These notes, and the ensuing book, are an important alternative medium to the CBI training material generated by QTUF Phase I and Phase II.

10 Conclusion

Our concluding comments are about the QTUF (Phase II) project are made with reference to the objectives of the project. During the July 2000 Advisory Committee meeting, a consensus agreement was made that the project was expected to meet its objectives by January 2001 and was commended for its program and initiatives. We provide the following summary to confirm this.

10.1 Continue to provide training in the populations dynamics of fish stocks

In total 27 courses were run at the University of Sydney and elsewhere from June 1998 to January 2001. These courses were specifically designed to meets the needs of clients who ranged from third year undergraduates, technically skilled stock assessment scientists to fisheries managers. We completed a through assessment of the outcomes of these courses and determined that the majority of all the participants were satisfied.

10.2 Assure the future of the training material by integrating it into the postgraduate programs of the University of Sydney.

The teaching material developed by QTUF has now been integrated into the postgraduate teaching program of the University of Sydney. New coursework awards in Quantitative Marine Ecology are available to allow completion of either a Graduate Certificate, Graduate Diploma or Master's of Science in Quantitative Marine Ecology (Assessment of Living Marine Resources). These awards have been designed to facilitate part-time and distance enrolment by organising the teaching into short continuous blocks.

10.3 Develop additional computer based modules.

Dr Montgomery has now completed CBI software consisting of 10 modules. These were summarised above. Modules now cover the common methods and applications used for quantitative analyses of fisheries in Australia and overseas. The following modules are packaged within the final version of *Quantitative Training in Fisheries* (Montgomery and Hood 2001).

- Simple Population Models
- Parameter Estimation
- Standardised Indices of Abundance
- Stratified Random Survey Design
- Biomass Dynamic Models
- Growth of Individuals
- Stock-Recruitment Relationships
- Yield Per Recruit
- Deterministic Age-Structured Models
- Statistical Age-Structured Models

A paper summarising the modules is to be published in the Proceedings of the 3rd World Fisheries Congress (Beijing, China, 2000), (Montgomery and Scandol *in press*).

10.4 Disseminate the products of QTUF.

A CD-ROM was provided to all people who completed either Type 1, 2 or 4 courses. Institutions where Type 3 or 5 courses were held were provided a copy of the software for their use. We have received 81 copies of the distribution agreement (see Appendix 12.7).

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12 Appendices

12.1 Appendix: Intellectual Property

As agreed in the contract for this project, the FRDC's proportion of the ownership of intellectual property of this project (primarily the computer software, *Quantitative Training in Fisheries*) is 60.02%. The remainder (39.98%), is held by The Centre for Research on Ecological Impacts of Coastal Cities.

12.2 Appendix: Staff

The following staff were engaged within the project:

Professor Tony Underwood (Principal Investigator)

Dr Ian Montgomery (Software Developer)
Part-time (0.5) from Feb 1998 to Jun 2000
Part-time (0.2) from Jul 2000 to Mar 2001

Dr James Scandol (Course Convener)
Part-time (0.6) from May 1998 to Mar 2001

12.3 Appendix: Example Material from a Type 1 Course

Fisheries Modelling and Stock Assessment Workshop

A five-day workshop prepared for CSIRO Marine Research by the Quantitative Training Unit for Fisheries (The Centre for Research on Ecological Impacts of Coastal Cities & the Fisheries Research and Development Corporation).

Date	4-Sep-2000 to 8-Sep-2000
Location	Hobart
Number of Participants	~10

Outcomes

At the end of the five-day course participants will have:

- Revised their understanding of ecologically sustainable development (ESD) of fisheries in Australia
- Heard about models of decisions that can be used to understand the complex role of quantitative methods in fisheries management
- Developed a simulation model of a fishery that includes biological, economic and social dimensions
- Used decision tables and multi-criteria decision analysis to represent the management options and the outcomes with respect to the principles of ESD

- Revised their understanding of parameter estimation using sums-of-squares and maximum likelihood.
- Fitted a biomass-dynamic model to catch and effort data using non-linear numerical optimisation
- Estimated the confidence intervals of the fitted parameters using bootstrapping of time-series residuals
- Completed a risk analysis of the harvesting options for the fishery

- Fitted growth curves to length-at-age and tagging data
- Developed an age-structured model of a fishery that includes individual growth and a stock-recruitment relationship
- Calibrated this model to catch, catch-rate and catch-at-age data
- (if time permits, completed length structured extensions to this model)

Course Convener
James Scandol (University of Sydney)
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Quantitative Training Unit for Fisheries
A project funded by the Fisheries Research and Development Corporation

Quantitative Training Unit for Fisheries 3/05/2001

Fisheries Modelling & Stock Assessment Workshop

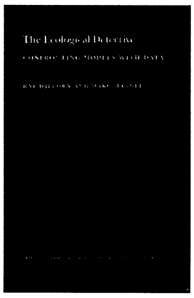
CSIRO Marine Research
(4-Sep-2000 to 8-Sep-2000)

Tuesday

- Parameter Estimation
  - Confronting models with data
  - Parameter estimation & bias-variance trade-off
  - The QTUF Module
- Skills in Parameter Estimation
  - Excel Solver
  - Confidence intervals with bootstrapping
  - Tricks and traps

Confronting Models with Data

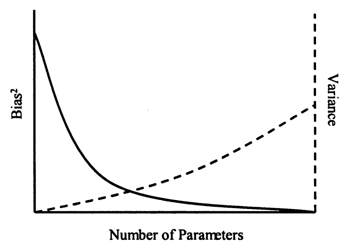
- Parameter estimation
  - Difficult and frustrating but completely necessary
  - Two approaches: minimise sums-of-squares or maximise likelihood L(M|D)
  - SSQ is "easier"but makes more hidden assumptions
  - There are no general solutions to many non-linear optimisation problems. This is better outcome than using a linear model and getting the wrong answer.



Parameter Bias-Variance Tradeoff

- Adding more parameters will always give you a better fit (reduce bias) but the precision of the parameters is compromised
- Knowing what model to use requires experience ("art of model selection")
- Do different models give different representations of the stock?
- Would these models lead to contrasting harvesting recommendations?

Parameter Bias-Variance Tradeoff



1

Quantitative Training Unit for Fisheries

Exercises for Fisheries Modelling and Stock Assessment Workshop
CSIRO Marine Research (4-Sep-2000 to 8-Sep-2000)
James Scandol (Quantitative Training Unit for Fisheries)

Monday 4-Sep-2000

Introduction to Fisheries Modelling

- Develop the model of the simulated fishery outlined in the modules and in the talk. Use either Excel, Visual Basic or C.
- When developing the model keep the parameters stored in separate cells/file so that they can be easily altered.
- Plot a graph with a spreadsheet so that you can see the population change in time.
- Identify possible management actions that could be imposed upon the fishery and suggest how they might be able to be interpreted as changes to parameters *s*, *q* or U^* (or other parameters that you define, see below).
- Extend the model to capture some simple economic and social characteristics of the fishery.
- Define and calculate appropriate reference points or indicators for the model. Make sure you include reference points or indicators that span the principles of ecologically sustainable development.
- Use the table function in Excel to perform a sensitivity analysis of one or more of the above "management" parameters on the model.
- Represent a management decision by extending the model for 10 years and imposing that decision for the additional years.

- Vary a single management parameter (the decision) and plot the value of that parameter against the value of the reference point.

Tuesday 5-Sep-2000

Parameter Estimation

- Plot the stock-recruitment data provided (page ParEstData, file csiroDataFiles.xls). Which sort of model is the likely to be the fit best for this data?
- Assume the data can be fitted with the line R=bS. Set up a spreadsheet with the observed and predicted values of R for a given S. Calculate the sum-of-squares of deviations between the observed and predicted values. Plot b versus SSQ (graphical search). What approximate value of b gives you the best fit between the model and the data?
- Use the Excel Solver or the simplex algorithm in C or Basic to calculate the value of b that minimises the SSQ. Use the analytic equations given in the module or the regression procedure in Excel to check your answer. What are the advantages and disadvantages of using these methods to calculate the slope of the line.
- Set up a maximum likelihood estimation algorithm for the stock-recruitment data using the three error structures outlined in the modules:
    - Constant variance
    - Constant coefficient of variation
    - Log-normal
- Check your results agree with those obtained with the modules.
- Bootstrap the data to estimate the 5% and 95% confidence intervals of the estimated parameter values.

- 1 -

Quantitative Training Unit for Fisheries

Wednesday 6-Sep-2000

Biomass Dynamic Modelling

- Create a new spreadsheet or Basic/C project that you will use to fit a biomass dynamic model to "observed" catch rates. Use solver or the simplex algorithm to fit this model to data. Use either your own catch and effort dataset, the hake dataset provided or a simulated one from Monday's work. Which is the better strategy?
- Restructure your spreadsheet or project for bootstrapping. This is quite a difficult exercise and very easy to get wrong. Think about what you want to do before you actually make the changes. You will need:
  - cells or code that correctly optimise the model to "observed" cpue data;
  - cells or code that generate bootstrapped cpue data from the fit of the actual data to the model;
  - code that loops over the desired number of bootstraps and writes the results to a suitable location;
  - code that copies the relevant information around your spreadsheet for each simulation;
  - to think about recalculation and screen updating issues.
- Extend your modelling of a management decision (see above) to use your bootstrap results in a full risk analysis. Do this by re-sampling your estimated parameters and applying these parameter values to a simulation. Estimate the probability of a particular proposition about a reference point being true (e.g. $B(now+10)/B(now) \geq 1.0$) for each level of the management parameter (the decision). Plot your results.

Thursday 7-Sep-2000

Individual Growth & Stock Recruitment

- Use the AgeLenData data provided in file "csiroDataFiles.xls" and fit a Von Bertalanffy growth curve using least-squares and maximum likelihood approaches.
- Fit Schunte versions of the model to this data (equations given on handout). Which is the best model?
- Bootstrap one or more of the above model fits to estimate the uncertainty of the parameter estimates.
- Use the tagging dataset on Sheet (TagData) to calculate the VB parameters. Bootstrap the data to estimate the confidence intervals of the parameters and the parameter correlation.
- Check your results with the command line program growthFit.exe (a Win32 command line program). What are the advantages and disadvantages of a command line program?
- Using the dataset on sheet "Halibut" fit Beverton-Holt, Ricker and Deriso stock-recruitment relationships using least squares. Plot the residuals from this curve fitting exercise. What alternative strategies might you use. Which model gives the best fit to the data?

- 2 -

12.4 Appendix: Example Material from a Type 3 Course

Quantitative Fisheries for Managers: Decisions, Forecasts and Uncertainty

One: Modelling Decisions

Introduction

Background

This exercise has been designed to assist your understanding of quantitative methods in fisheries management. The objective of this process is not to teach you how to do stock assessments, or even what the technical details are, but rather, illustrate some of the issues associated with the interpretation of stock assessments within the complex environment of management. To do this we will work with a fictitious case study. This case study includes aspects of which you will be familiar, but no particular fishery has been used as the basis. The underlying dynamics of the fishery are represented with a computer model that generates synthetic catch and effort information.

I have chosen to keep the modelling frame-work simple for this case study. This was deliberate. As you will see, there are many complications to even the simplest assessment.

There is no right answer to the exercises that I've provided you with. Rather the material simply provides you with a framework to develop and discuss ideas with your colleagues. As you will be aware, fisheries management involves facilitating complex negotiation processes, not solving technical problems. The raison d'état of this course is to illustrate the issues associated with the integration of technical information into a management environment. Participants will hopefully leave this course with a greater empathy for the challenges facing both fisheries scientists and the managers.

Objectives

- Introduce the case study and allow participants to develop their understanding of the fishery.
- Develop simple decision tables for certain decision about the fishery.
- Identify the strengths and weaknesses of these tools.

Material Provided

- This information sheet.

The Case Study

The Fish

The tasty red jaw (*Trickius countfishi*) is an imaginary species. Never-the-less this is a medium lived species (maximum recorded age of 15 years) and grows to a maximum length of about 60 cm. It inhabits temperate rocky reefs usually at depths below 40m. The species is found on the east-coast of Australia between the latitudes of 25°S and 30°S.

The fish is can be identified by a bright red lower jaw (lower mandible or dentary bone). The biological significance of this feature is unknown but some scientists suspect that it is a sexually selected character. Individuals prefer to live in small shoals of about 10 fish but will aggregate during the spawning season into large schools of several thousand. This is clearly a strategy to maximise external fertilisation success rates. The larval fish spent about 6 months as ichthyoplankton then settle onto the rocky reefs as juveniles. Nobody really knows where the larval fish are dispersed. Most scientists suspect they are advected southwards. Tagging studies have suggested that the fish migrate northwards for about a month before the spawning season of late November and December.

History

For some bizarre reason the commercial fishery for the tasty red jaw didn't develop until the early 1970s. A small hook and line fishery has been operating since and the catch history will be provided to you later. The fishery involved some learning on behalf of the commercial fishers and many people suspect the first few years of effort data are a bit dubious. Within five years the fishery became restricted to entry by new fishers.

An early fishery operating in the early 1980s tested some new gear (multiple baited hooks with lures). These had the unfortunate consequence of being irresistible to the local dolphins. Thirty-five dolphins were killed when things went wrong one day. This caused public outrage and the conservation group, The Marine Life Protectors, has had a role in the management processes ever since. There have been strict input controls on gear types ever since.

Decisions: Page 1 of 3

When the spawning aggregations were first discovered there was a rapid decision to close the fishery during November and December to protect the stock. This decision was met with support from all stakeholders though the recreational fishers were unimpressed. They argued that their catch was so small that it was not causing a significant impact on the stock.

The Marine Life Protectors have been lobbying for a very large marine protected area over about 10% of the area in which the tasty red jaw fishery operates. This will have a proportional impact (10% reduction) on catches and will increase the costs of travel to the industry. A valuable whale watching industry has developed since the early 1990s that has made some of the commercial fishermen really wonder if fishing for the tasty red jaw is the way to go. People operating the whale watching boats are making about 50% more money and work far fewer hours.

The Commercial Fishery

The commercial catch history is presented in the stock assessment reports. The commercial catch data is considered good quality but nobody really trusts the commercial effort data. The use of GPS has bought some benefits to the fishers, but perhaps not caused the increase in fishing power observed in many other fisheries. In the non-GPS days fishermen would explore a bit more and discover new grounds, but now they tend to just go back to the reliable ones. Perhaps this has created some natural refuges for the fish.

In the mid 1990s, discussions were initiated by the management agency about shifting the fishery to quota management. This caused a fair bit of discussion in the commercial industry about how to add the most value to your allocated share. There were rumours that some fishermen were over-declaring their catch. Other sources suggested that the entire fishery was under-reporting effort to give the impression that the stock was in better health than it actually was. The decision to introduce quota management was taken in 1999 and catch quotas will be applied from this year (2000). Allocation of catch will be in proportion to the individual fisher catches averaged between 1992 and 1997.

The Recreational Fishery

The recreational fishery started about 1990. This has developed quickly because the tasty red jaw is a good fighting fish and tastes great. The recreational fishers have started their own lobby group called the Tasty Red Jaw Recreational Fishing Association (TRJRFA). For some unusual reason lawyers have really taken to tasty red jaw fishing. This means that the TRJFRA has more legal clout than the management agency could ever muster. The lobbying skills of the recreational fishers do not impress the commercial fishers who tend to have working class backgrounds.

Nobody really knows what the recreational catch is. It could be as low as 5t or it could be as high as 60t. There is no information on recreational effort.

Sources of Data Available

There are relatively good catch records for the commercial fishery. As indicated above, discussion about quotas may have corrupted the catch records from the mid 1990s. The effort data was questionable at the beginning but was probably consistent during the 1980s. Nobody really knows what impact the discussions of quota management had upon the effort data.

Fish biologists have good information on fish growth but most of the fish have come from the fishery and have therefore been size selected. There is very little data on the growth rates of the smaller size classes. Recruitment appears to be highly variable though there appears to be some speculation that recruitment is especially weak when there is an ENSO event.

The fish are relatively easy to age, but there has been no systematic aging study completed. Aging will cost about $15 per fish.

The Research and Management Environment

Like the fishery itself, the management of this fishery has had a rich history. The principle manager has been involved with the fishery since 1985. Managers have a good working relationship with the commercial fishers but most people find the recreational fishers difficult to deal with. There are two junior managers who provide support for the principle manager.

The decision to move to quota management was somewhat controversial. The commercial fishers were supportive but were unimpressed that there was not being any effort to put a ceiling on the recreational catch. The scientists were a bit miffed that an academic economist seems to be getting contract money that should be being used for "real science".

Stock Assessment for the Tasty Red Jaw (*Trickius countfishi*)

Assumptions of Assessment

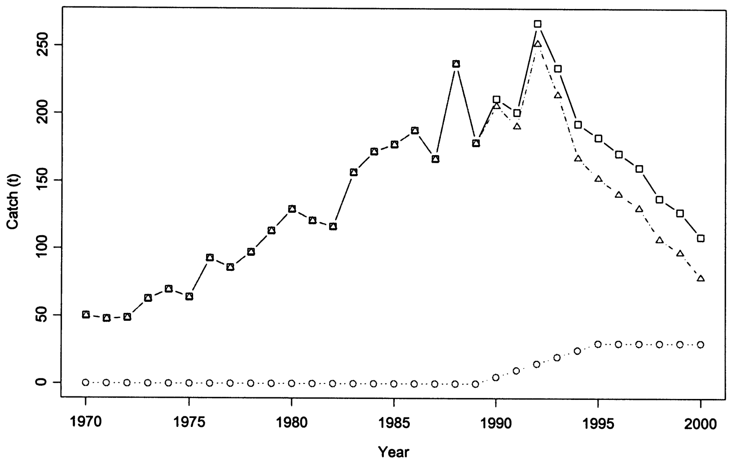
- That the commercial catch per unit effort (CPUE) data is a good indicator of abundance for the species.
- An observation error biomass dynamic model is an appropriate representation of the fishery.
- Recreational catch is represented by the time series in the table.
- Commercial catch data is reliable.

Historical Catch Records and Assumed Recreational Catch Used in the Assessment

Year	Commercial Catch (tonnes)	Assumed Recreational Catch (tonnes)	Total Catch (tonnes)	Commercial CPUE (tonnes/boat year)
1970	50.27	0.00	50.27	11.84
1971	47.82	0.00	47.82	6.68
1972	48.73	0.00	48.73	5.83
1973	62.71	0.00	62.71	12.41
1974	69.57	0.00	69.57	12.24
1975	63.94	0.00	63.94	9.90
1976	92.99	0.00	92.99	13.56
1977	85.94	0.00	85.94	8.95
1978	97.38	0.00	97.38	8.70
1979	113.17	0.00	113.17	10.79
1980	129.19	0.00	129.19	8.94
1981	120.81	0.00	120.81	8.37
1982	116.40	0.00	116.40	10.35
1983	156.68	0.00	156.68	8.76
1984	171.97	0.00	171.97	8.53
1985	177.39	0.00	177.39	12.79
1986	187.67	0.00	187.67	9.25
1987	166.79	0.00	166.79	6.59
1988	237.29	0.00	237.29	12.32
1989	178.60	0.00	178.60	5.49
1990	205.93	5.00	210.93	7.37
1991	190.91	10.00	200.91	8.55
1992	252.11	15.00	267.11	5.86
1993	214.10	20.00	234.10	7.53
1994	167.54	25.00	192.54	6.41
1995	152.48	30.00	182.48	5.01
1996	140.68	30.00	170.68	3.72
1997	130.22	30.00	160.22	5.02
1998	107.24	30.00	137.24	5.40
1999	97.32	30.00	127.32	3.51
2000	78.92	30.00	108.92	3.21

Quantitative Fisheries for Managers

History of all Catches



Results of a Biomass Dynamic Model Fitted to the Catch Rate Data

Parameter	Value	Comment
B0	2 845 t	Pre-exploitation biomass of the stock
K	8 662 t	Carrying capacity of the environment
R	0.05	Growth rate of stock (individual growth + recruitment)
log(q)	-2.48	The catchability or efficiency of the fleet
Confidence Intervals (10%, 50%, 90% quantiles)		
B0	(1 051, 2 203, 4 681) tonnes	
K	(1 741, 38 460, 434 024 382) tonnes	
R	(0.014, 0.059, 0.362)	
log(q)	(-2.66, -2.40, -2.11)	

Page 2 of 5

12.5 Appendix: Questionnaire

QTUF Survey

QTUF Course and Computer-Based Training Module Survey

Title of Course:

Dates:

Modules Used:

Location:

The Course

The following statements are based upon those developed by University of Sydney's "Centre for Teaching and Learning". We have adapted these standard course surveys to suit QTUF. Your opinions on the QTUF courses are critical for our quality assurance procedures so please respond honestly. These surveys are anonymous.

To respond, please circle the number beside each statement that most accurately reflects the extent to which you agree or disagree with the statement. You may chose from a scale where (1) means that you strongly disagree with the statement and (5) means you strongly agree.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

		SD	D	N	A	SA
1	It was often hard to discover what was expected of me in this course	1	2	3	4	5
2	The things I have learned in this course will be useful to me in my career	1	2	3	4	5
3	The time allocated to teaching specific topics was appropriate	1	2	3	4	5
4	I was satisfied with the amount of choice in this course	1	2	3	4	5
5	The applications of the topics covered in this course were clear	1	2	3	4	5
6	The course developed my problem-solving skills	1	2	3	4	5
7	The course helped me develop my ability to work as a team member	1	2	3	4	5
8	The staff were extremely good at explaining things	1	2	3	4	5
9	The teaching in this course helped me to learn	1	2	3	4	5
10	The teaching stimulated my interest in the course content	1	2	3	4	5
11	The staff were concerned that participants learnt in this course	1	2	3	4	5
12	I was encouraged to take an active role in classes	1	2	3	4	5
13	I had a clear understanding of the learning objectives for the course	1	2	3	4	5
14	I knew what was expected of me as a learner in this course	1	2	3	4	5
15	Participants were respected and their needs were accommodated where possible	1	2	3	4	5
16	Participants were treated fairly and impartially in this course	1	2	3	4	5
17	The workload in this course was appropriate	1	2	3	4	5
18	The tasks were useful learning experiences	1	2	3	4	5
19	The course sharpened my analytic skills	1	2	3	4	5
20	Feedback about the tasks was useful to me	1	2	3	4	5
21	As a result of the course, I feel confident about tackling unfamiliar problems	1	2	3	4	5
22	I was generally given enough time to understand the things I had to learn	1	2	3	4	5
23	The course was overly theoretical and abstract	1	2	3	4	5
24	The teaching staff worked hard to make their subjects interesting	1	2	3	4	5
25	The sheer volume of work to be got through in this course meant it couldn't all be thoroughly comprehended	1	2	3	4	5
26	Overall, I was satisfied with the quality of this course	1	2	3	4	5

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QTUF Survey

27 Please list the two most important things about this course that helped you to learn and explain why each was important to you.

(i) . . . .

Why was this important?

(ii) . . . .

Why was this important?

28 Please list two things about this course that could be improved and explain why these changes would help you to learn.

(i) . . . .

Why would this help?

(ii) . . . .

Why would this help?

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QTUF Survey

The Modules

The computer-based training modules have been developed by the QTUF to assist learning in quantitative fisheries modelling. We would value any feedback that would help us improve the modules.

To respond, please circle the number beside each statement that most accurately reflects the extent to which you agree or disagree with the statement. You may chose from a scale where (1) means that you strongly disagree with the statement and (5) means you strongly agree.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

		SD	D	N	A	SA
	The Help System.					
1	The Where? button is useful for finding out where I am in the module	1	2	3	4	5
2	I use the Where? button frequently to jump to other sections	1	2	3	4	5
3	The Navigation Tutorial helped me to understand the navigation conventions used in the modules	1	2	3	4	5
4	The Help button was useful whenever I needed to find out about a particular page	1	2	3	4	5
	Navigation					
5	Navigating around the module was difficult	1	2	3	4	5
6	It was confusing when there was more than one level of menus	1	2	3	4	5
7	The difference between the next page button and the next section button was clear	1	2	3	4	5
	Level and Content					
8	The material was too elementary	1	2	3	4	5
9	The material was too advanced	1	2	3	4	5
10	Too much knowledge was assumed	1	2	3	4	5
	Interaction and Exercises					
11	The interactive exercises were helpful in gaining an understanding of the material	1	2	3	4	5
12	The interactive exercises encouraged me to investigate the behaviour of different type of models	1	2	3	4	5
13	Spreadsheets are preferable to the interactive exercises for investigating models	1	2	3	4	5
	Usefulness					
14	I did not learn much from the modules	1	2	3	4	5
15	I find the modules useful as a source of reference	1	2	3	4	5
16	I find it easier to learn from printed matter than from the modules	1	2	3	4	5
	Motivation					
17	I found it difficult to get around to using the modules	1	2	3	4	5
18	I like studying on my own	1	2	3	4	5
19	I found the modules enjoyable	1	2	3	4	5
20	I find learning easier in a classroom environment	1	2	3	4	5

21 Any additional comments about the help system

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QTUF Survey

22 Any comments about navigation

23 Any comments about level or content

24 Any comments about exercises or interaction

25 Any comments about motivation

26 Any other comments

Your time and cooperation is greatly appreciated.

Please return this form to:

QTUF	Fax:	(02) 9351 6713
EICC	Phone:	(02) 9351 4786
Marine Ecology Laboratories A11,	Email:	qtuf@bio.usyd.edu.au
University of Sydney, NSW 2006.		

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12.6 Appendix: Questionnaire Results

12.6.1 Responses to statements about courses from scientists

Code	Statement	n	NR	SD	D	N	A	SA
C1	It was often hard to discover what was expected of me in this course	107	2	13	59	21	9	3
C2	The things I have learned in this course will be useful to me in my career	107	1			6	44	56
C3	The time allocated to teaching specific topics was appropriate	107	1	1	16	28	54	7
C4	I was satisfied with the amount of choice in this course	107	3		3	22	66	13
C5	The applications of the topics covered in this course were clear	107	1		5	14	66	21
C6	The course developed my problem-solving skills	107	2		3	11	64	27
C7	The course helped me develop my ability to work as a team member	107	1	6	23	48	27	2
C8	The staff were extremely good at explaining things	107	2		3	14	70	18
C9	The teaching in this course helped me to learn	107	1	1	2	11	72	20
C10	The teaching stimulated my interest in the course content	107	1		1	12	65	28
C11	The staff were concerned that participants learnt in this course	107	1		3	9	60	34
C12	I was encouraged to take an active role in classes	107	1			17	61	28
C13	I had a clear understanding of the learning objectives for the course	107	2	2	9	16	63	15
C14	I knew what was expected of me as a learner in this course	107	1		10	24	62	10
C15	Participants were respected and their needs were accommodated where possible	107	1		2	6	60	38
C16	Participants were treated fairly and impartially in this course	107	1			4	56	46
C17	The workload in this course was appropriate	107	1		19	14	57	16
C18	The tasks were useful learning experiences	107	1		1	3	61	41
C19	The course sharpened my analytic skills	107	1		2	15	55	34
C20	Feedback about the tasks was useful to me	107	3		4	24	58	18
C21	As a result of the course, I feel confident about tackling unfamiliar problems	107	2	1	6	31	55	12
C22	I was generally given enough time to understand the things I had to learn	107	2	2	25	28	40	10
C23	The course was overly theoretical and abstract	107	1	25	63	9	5	4
C24	The teaching staff worked hard to make their subjects interesting	107	1		1	11	79	15
C25	The sheer volume of work to be got through in this course meant it couldn't all be thoroughly comprehended	107	1	8	26	26	32	14
C26	Overall, I was satisfied with the quality of this course	107	1	1	1	2	69	33

12.6.2 Responses to statements about courses from managers

Code	Statement	n	NR	SD	D	N	A	SA
C1	It was often hard to discover what was expected of me in this course	68	1	11	36	15	5	
C2	The things I have learned in this course will be useful to me in my career	68			3	6	42	17
C3	The time allocated to teaching specific topics was appropriate	68			13	9	41	5
C4	I was satisfied with the amount of choice in this course	68	1		3	30	33	1
C5	The applications of the topics covered in this course were clear	68			4	10	45	9
C6	The course developed my problem-solving skills	68			3	14	40	11
C7	The course helped me develop my ability to work as a team member	68			4	22	37	5
C8	The staff were extremely good at explaining things	68	1		4	10	38	15
C9	The teaching in this course helped me to learn	68			2	15	40	11
C10	The teaching stimulated my interest in the course content	68	1		1	11	40	15
C11	The staff were concerned that participants learnt in this course	68		1	1	15	32	19
C12	I was encouraged to take an active role in classes	68				9	33	26
C13	I had a clear understanding of the learning objectives for the course	68	1	1	7	21	30	8
C14	I knew what was expected of me as a learner in this course	68		1	8	21	32	6
C15	Participants were respected and their needs were accommodated where possible	68			1	10	35	22
C16	Participants were treated fairly and impartially in this course	68	1			2	39	26
C17	The workload in this course was appropriate	68			5	14	38	11
C18	The tasks were useful learning experiences	68				7	43	18
C19	The course sharpened my analytic skills	68			2	21	38	7
C20	Feedback about the tasks was useful to me	68			2	22	33	11
C21	As a result of the course, I feel confident about tackling unfamiliar problems	68		2	3	27	33	3
C22	I was generally given enough time to understand the things I had to learn	68	1	1	12	14	35	5
C23	The course was overly theoretical and abstract	68	1	12	34	12	7	2
C24	The teaching staff worked hard to make their subjects interesting	68		2	2	2	47	15
C25	The sheer volume of work to be got through in this course meant it couldn't all be thoroughly comprehended	68		6	30	10	18	4
C26	Overall, I was satisfied with the quality of this course	68			3	7	40	18

12.6.3 Responses to statements about courses from students

Code	Statement	n	NR	SD	D	N	A	SA
C1	It was often hard to discover what was expected of me in this course	104	2	4	44	21	29	4
C2	The things I have learned in this course will be useful to me in my career	104	1	1	8	27	50	17
C3	The time allocated to teaching specific topics was appropriate	104	1	4	21	15	55	8
C4	I was satisfied with the amount of choice in this course	104	4	1	11	49	36	3
C5	The applications of the topics covered in this course were clear	104	1	1	13	20	51	18
C6	The course developed my problem-solving skills	104	1	1	8	29	58	7
C7	The course helped me develop my ability to work as a team member	104	1	6	37	26	32	2
C8	The staff were extremely good at explaining things	104	2		16	27	44	15
C9	The teaching in this course helped me to learn	104	2	1	8	27	57	9
C10	The teaching stimulated my interest in the course content	104	1	4	3	21	58	17
C11	The staff were concerned that participants learnt in this course	104	1		4	16	57	26
C12	I was encouraged to take an active role in classes	104	4	1	9	25	55	10
C13	I had a clear understanding of the learning objectives for the course	104	2	2	18	38	37	7
C14	I knew what was expected of me as a learner in this course	104	2	2	21	32	43	4
C15	Participants were respected and their needs were accommodated where possible	104	2		2	23	59	18
C16	Participants were treated fairly and impartially in this course	104	2	1		13	56	32
C17	The workload in this course was appropriate	104	2		8	20	60	14
C18	The tasks were useful learning experiences	104	3	1	3	18	61	18
C19	The course sharpened my analytic skills	104	2	1	12	25	52	12
C20	Feedback about the tasks was useful to me	104	4	1	7	47	43	2
C21	As a result of the course, I feel confident about tackling unfamiliar problems	104	3	1	16	53	28	3
C22	I was generally given enough time to understand the things I had to learn	104	3	6	25	33	33	4
C23	The course was overly theoretical and abstract	104	2	5	36	32	28	1
C24	The teaching staff worked hard to make their subjects interesting	104	3		4	12	65	20
C25	The sheer volume of work to be got through in this course meant it couldn't all be thoroughly comprehended	104	2	2	26	30	32	12
C26	Overall, I was satisfied with the quality of this course	104	2		4	14	74	10

12.6.4 Responses to statements about modules from all groups

Code		Total	NR	SD	D	N	A	SA
M1	Help:The Where? button is useful for finding out where I am in the module	211	30	4	13	77	66	21
M2	Help: I use the Where? button frequently to jump to other sections	211	28	33	57	55	32	6
M3	Help: The Navigation Tutorial helped me to understand the navigation conventions used in the modules	211	33	4	14	73	74	13
M4	Help: The Help button was useful whenever I needed to find out about a particular page	211	34	8	10	88	63	8
M5	Navigation: Navigating around the module was difficult	211	21	50	101	24	13	2
M6	Navigation: It was confusing when there was more than one level of menus	211	20	48	93	24	23	3
M7	Navigation: The difference between the next page button and the next section button was clear	211	20	11	23	23	89	45
M8	Level & Content: The material was too elementary	211	18	25	117	39	9	3
M9	Level & Content: The material was too advanced	211	18	15	109	47	19	3
M10	Level & Content: Too much knowledge was assumed	211	18	16	97	43	32	5
M11	Interaction & Exercises: The interactive exercises were helpful in gaining an understanding of the material	211	20	1	7	19	136	28
M12	Interaction & Exercises: The interactive exercises encouraged me to investigate the behaviour of different type of models	211	20	1	7	29	121	33
M13	Interaction & Exercises: Spreadsheets are preferable to the interactive exercises for investigating models	211	20	5	34	85	52	15
M14	Usefulness: I did not learn much from the modules	211	18	28	128	22	11	4
M15	Usefulness: I find the modules useful as a source of reference	211	18	3	7	21	129	33
M16	Usefulness: I find it easier to learn from printed matter than from the modules	211	18	11	78	66	30	8
M17	Motivation: I found it difficult to get around to using the modules	211	22	26	106	38	17	2
M18	Motivation: I like studying on my own	211	20	1	37	72	70	11
M19	Motivation: I found the modules enjoyable	211	20	4	8	69	102	8
M20	Motivation: I find learning easier in a classroom environment	211	20	5	32	81	65	8

12.7 Appendix: Distribution Agreement

ECOLOGICAL IMPACTS OF COASTAL CITIES

A COMMONWEALTH SPECIAL RESEARCH CENTRE

Established and supported under the Australian Research Council's Research Centres Program

MARINE ECOLOGY LABORATORIES A11, UNIVERSITY OF SYDNEY, NSW 2006
DIRECTOR: Professor A.J. Underwood DSc, PhD, FAA, FLS, FIBiol, FABiol
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