Fish Resource Assessment Survey Project of Abu Dhabi and UAE Waters

PROJECT REPORT

Presented to the Environmental Research and Wildlife Development Agency Abu Dhabi March 2003

Fish Resource Assessment Survey Project of Abu Dhabi and UAE Waters

Project Report
by
Bruce Shallard & Associates

CONTENTS

1 EXECUTIVE SUMMARY

1.1 General

A survey was undertaken during the period February 2002 to January 2003 with the objectives of assessing the current status of the demersal and small pelagic fish stocks of UAE waters. This survey was undertaken using the Research Vessel 'Flinders' and incorporated a combination of acoustic recording, trawl surveys and fish trapping.

The survey was the first such survey in the area since 1978 and the first ever that provided a full year picture of these resources.

Twelve cruises were undertaken with alternate months being dedicated to demersal fish resources surveys and to small pelagic fish surveys. All of UAE waters were sampled, including the East Coast Emirates bordering the Arabian Sea. A total of 279 demersal trawl stations were sampled during the period in each of 17 pre-determined strata while approximately 18,000km of acoustic transects were recorded using the vessel's Simrad EK-60 sounder. Fish trapping was undertaken between August and December 2002 to gain further information on the relative distribution and abundance of key demersal species between trawlable and non-trawlable areas. Oceanographic data were also collected during all cruises.

The work was carried out by the contractor, Bruce Shallard and Associates of New Zealand, on behalf of the Environmental Research and Wildlife Development Agency (ERWDA) of Abu Dhabi and included participation from ERWDA as well as other Government Ministries. On-job and formal training was provided to counterpart staff. A report of the activities and the conclusions of the project were presented to ERWDA in February 2003.

1.2 Survey results

1.2.1 Demersal resources.

Demersal fish biomass, particularly of the 20 selected 'key' species (which represented the major demersal commercial species of the UAE) was measured using a combination of trawl surveys, fish trapping and acoustic techniques. The main characteristics of the biomass changes were the large seasonal variations. The biomass of many of the major commercial species increased significantly during the cooler winter months (presumably as a result of movement into UAE waters) and decreased during the extreme summer months. The increase in biomass in winter coincided with spawning activity for many species.

A few species, most notably the hamoor (*Epinephelus coioides*) did not show significant seasonal changes in biomass and appeared to remain in UAE waters throughout the year.

Fish trapping demonstrated that, overall demersal biomass was approximately 30% higher in trawlable areas than in non-trawlable (often reef) areas. In addition, some species (such as *E. coioides*) showed a size-specific distribution with larger individuals being present in non-trawlable areas than in trawlable areas. However, for many demersal species, no such size-specific distribution was apparent.

Acoustic data recorded during demersal trawl and fish trapping surveys showed that this acoustic backscatter (recorded for an area 1 meter above the seabed) was well correlated with measured estimates of biomass. Acoustic data were therefore also used to provide more comprehensive estimates of total demersal biomass in areas and at times when direct sampling was not carried out.

By combining the data from trawl sampling, fish trapping and acoustics, overall biomass estimates of demersal species for all of UAE waters were made. These seasonal ranges of estimates were as follows:

	Biomass (Arabian Gulf area)	**Biomass (East Coast)**
Commercial demersal species (1)	10800 – 26300t	140 – 610t
Total commercial plus non-commercial demersal species (2)	24900 – 41500t	590 – 4350t
Total non-commercial demersal species (2 – 1)	14100 – 15200t	450 – 3740t

Biomass estimates of demersal species were low in the East Coast, an observation that was supported by acoustic data.

1.2.2 Small pelagic resources

Acoustic records, supplemented by mid-water trawl sampling and underwater video recording for species identification, were used to provide a comprehensive seasonal picture of the distribution and abundance of small pelagic species within UAE waters. Estimates of biomass for the various identified species were as follows:

Species/Species Group	**Seasonal Biomass range**
Baitfish (anchovy/small sardine species)	11,000 – 126,000t
Decapterus spp.	4,500 – 52,000t
Species 2 (small unidentified sardine-like species)	2,000 – 60,000t
Alepes spp.	3,000 – 8,000t
Ctenophores	32,000 – 2,040,000t
Barracuda	700 – 3700t
Jellyfish	80,000 – 2,600,000t

Seven identifiable species or species groups were recorded during the survey, with 2 of these being non-commercial jellyfish and ctenophores. Of the remaining fish species, baitfish (which consisted of small sardine and anchovy species of the genera *Dussumieria* and *Encrasicholina*) were the most abundant with estimates of biomass up to 120,000t.

Other identified species included *Decapterus spp* (principally *D. russelli*), *Alepes spp* (principally *A. melanoptera*) and barracuda (*Sphyraena qenie*). All species showed highly seasonal changes in biomass with peak biomass occurring during the cooler winter months. Biomass was closely related to measured zooplankton abundance.

1.3 Modeling and stock assessment

Aging studies (using otoliths) were conducted on 8 of the most important demersal species and growth parameters established for these species. Using these growth parameters, together with collected biological information, a stochastic mathematical model of the populations of these species was constructed. This model enabled management scenarios to be investigated and also to assess the current state of exploitation of these resources.

Conclusions from the modeling were that current rates of exploitation were moderate although the size at which fish were being captured was sub-optimal. The modeling indicated that, for all species studied, an increase in size of capture for these species would result in significant increases in the biomass of the spawning stock without adversely impacting commercial catches.

Stock assessment and estimates of potential yields were made based on the population modeling for the demersal species and on direct stock assessment for small pelagic species. These results showed that, for the currently exploited species, there is minimal scope for increased sustainable yields for the demersal resources although there may be some opportunities for exploiting some species that are currently not fished.

For the small pelagic species, stock assessment indicated that up to 70,000t of small pelagic species might be available annually. However, realizing that potential yield may be difficult and probably not desirable. Commercial exploitation of these small pelagic species would be difficult because of the small school size of the species and because of the lack of established markets. Exploitation may also be undesirable given that nothing is known of how and to what extent other species (particularly large pelagics such as kingfish (*Scomberomorus spp*) depend on these small pelagic species as a food source.

With these reservations as to the ability and desirability of increasing exploitation on some of these small pelagic species, the study concluded that potential sustainable yields from the demersal and small pelagic resources are as follows:

	Current Yield (all areas)	**Potential Sustainable Yield (Arabian Gulf Area)**	**Potential SustainableYield (East Coast)**
Demersal species (currently exploited)	Not known	4% increase from 2002 level (1)	4% increase from 2002 level (1)
Demersal species (not exploited)	0	Est. 800t of *Saurida* spp. (2)	Est. 500t of *Saurida* spp & *Nemipteridae*(2)
Small pelagic species	8,950t (4)	61,000t (3)	9,300t (3)

(1) Assumes management measures introduced to (a) increase size at capture by 25% and (b) limit fishing effort to 2002 levels.

(2) Would probably involve introduction of trawling as a fishing method.

(3) Assumes constraints of small school size and lack of identified markets can be overcome.

(4) FAO Yearbook of Fisheries Statistics for 2000.

1.4 Comparisons with previous surveys

The results of the survey of demersal and small pelagic resources were compared with a previous, similar study undertaken by the Food and Agriculture Organization of the United Nations (FAO) in 1978.

This comparison showed that the abundance of demersal fish species had declined significantly since 1978, particularly in the East Coast areas where measured abundance of all species was approximately 7% of the 1978 level. The Arabian Gulf region had also shown reductions in abundance with the abundance recorded by the project being approximately 19% of 1978 levels. Most importantly, this reduction in abundance in both the Arabian Gulf and East Coast regions was apparent for both commercial and non-commercial species, indicating that commercial exploitation may not be the only factor involved.

By contrast, the estimated biomass of small pelagic species in UAE waters of approximately 200,000t was about the same as that recorded in 1978, although the 1978 survey did not include an entire year’s sampling. Although the overall abundance of small pelagic species was about the same, the project did not record any significant quantities of some species, such as *Sardinella spp*. which were a major part of the biomass in 1978.

1.5 Recommendations for future management

The project has provided comprehensive information on the demersal and small pelagic resources of the UAE that can be used for effective management of those resources. The key issues for management are (a) the high degree of seasonality of biomass of many of the major demersal species. This implies that these stocks are moving over a wider area of the Gulf than just the UAE and are probably shared with neighboring countries; (b) the apparent major declines in abundance of both commercial and non-commercial demersal species since 1978; (c) the biomass of small pelagic species within UAE waters, which appears to be at approximately the same level as in 1978.

Based on the results of the project, and particularly the stock assessment and modeling of the stocks, it was recommended that:

1. That the UAE investigate mechanisms for better regional co-ordination of fisheries management, perhaps under the umbrella of the UN Convention on the Law of the Sea (UNCLOS).

2. That management plans are prepared for the UAE’s major fisheries based on the resource information collected by the project.

Management plans for the demersal and small pelagic resources need to address two very different situations.

For demersal resources, the emphasis of the management plan should be on stock-rebuilding since all the evidence suggests that not only has the abundance of demersal species declined significantly since 1978 but also that current management arrangements are inappropriate in that fish are being caught at too small a size.

This stock rebuilding strategy needs to include plans for increasing the abundance of the spawning stock by (a) better protection of juvenile fish and (b) a closer examination of the reasons for the decline in demersal resources, including the issue of coastal habitat loss and its influence on demersal stock abundance.

By contrast, the emphasis of the management plan for small pelagic resources could be on developing the fishery rather than rebuilding or constraining it since all the evidence points to the stock levels being more or less the same as in 1978.

Successful commercial exploitation of these small pelagic resources, however, may be difficult and perhaps not desirable.

It is not known to what extent the stocks of large pelagic species in the UAE depend on these small pelagic resources as a food source. Without such information, any significant exploitation of the small pelagic resources may have unknown impacts on these important large pelagic fisheries, such as kingfish (S*comberomorus commerson*)

In addition, any commercial exploitation will need to overcome the constraints of small school size (making commercial exploitation difficult) and lack of identifiable markets.

2 INTRODUCTION

2.1 Project objectives

(a) **Obtaining improved estimates** of stock size for the major demersal and small pelagic species and their seasonal distributions.

(b) **Establishing catch rates** of major species and other species of potential commercial importance by area, depth and season.

(c) **Undertaking biological studies** of selected species for the purpose of estimating sustainable yield levels for major species.

(d) **Establishing estimates of safe harvest levels** for the major species.

(e) **Providing basic oceanographic and ecological data** relevant to fish resources.

(f) **Upgrading the technical skills of national research personnel** in fisheries research survey methods and stock assessment techniques

2.2 Scope

A comprehensive, one year survey of the demersal and small pelagic fish resources of the UAE was undertaken between February 2002 and January 2003. During the survey, comprehensive data were collected on the seasonal changes in biomass of major species, the biological characteristics of key demersal species (including aging studies) and the oceanographic environment of UAE waters.

The study was undertaken using the research vessel ‘Flinders’ and covered all UAE waters, including Abu Dhabi Emirate, the Northern Emirates and the East Coast. In addition, a review of past data was carried out so that the results could be put in an historical context.

Because of the sampling design and sampling protocols, relative and absolute abundance estimates (as well as present/absence data) were measured for all major species captured during the one year survey. This provided data on some 240 demersal and small pelagic species, thereby providing an unprecedented set of data on the demersal marine fauna of the UAE. Very few other comprehensive studies of the demersal resources have been undertaken in the region.

The design of the study involved sampling the demersal resources in a total of 17 strata (Figure 1), in UAE waters (14 in the Arabian Gulf area and 3 in East Coast areas). Small pelagic resources were measured using echoacoustic equipment within 6 strata (Figure 2). The two sets of strata were related in such a way that the strata used for demersal surveys matched, either singly or in combination, the strata used for acoustic surveys. The connections between the two sets of strata are shown in Table 1. After August 2002 Strata 1 and 2 and 8 and 9 were combined and analysed as two strata.

Figure 1: Chart showing the 17 trawl strata used in the trawl survey study.

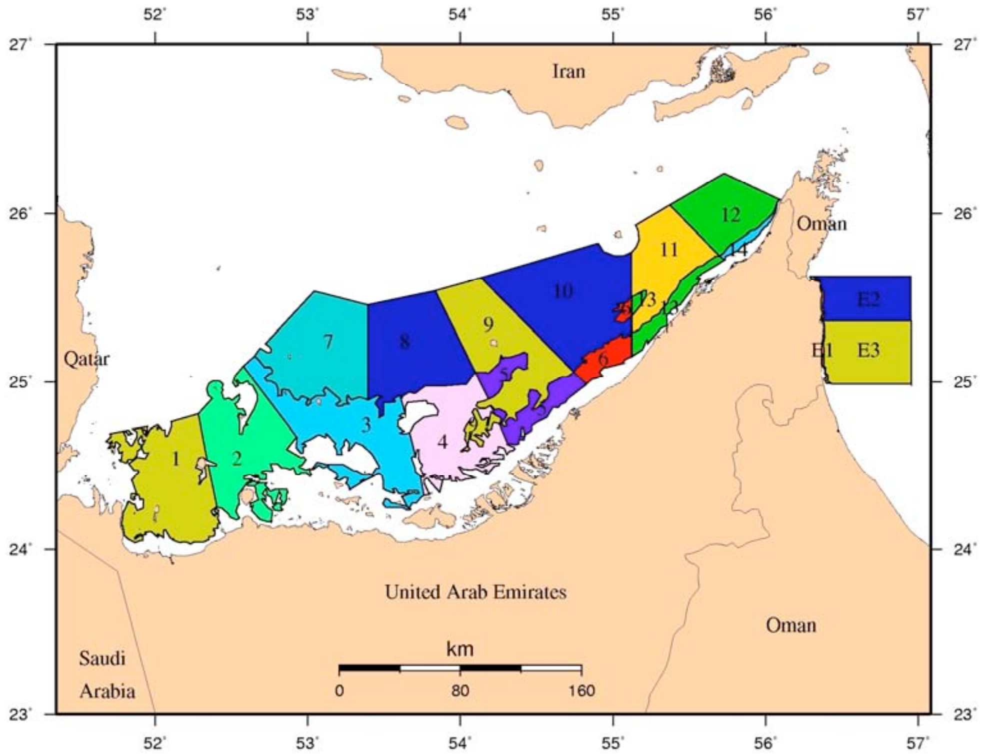


Figure 2: Chart showing the 6 strata that were used for collection and analysis of acoustic data.

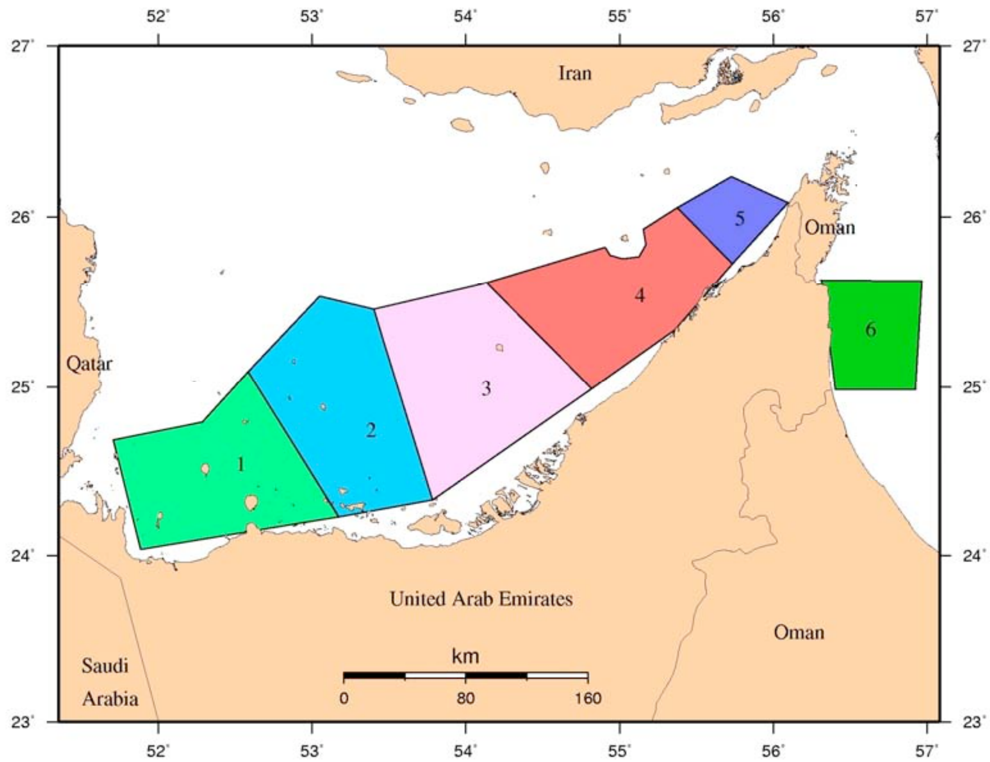


Table 1: Acoustic strata and their relationship to trawl survey strata

Acoustic Stratum	Equivalent trawl survey data:
1	1, 2
2	7, 3
3	4, 8, 9, 5
4	10, 11, 6, 13
5	12,14
6	E1, E2, E3

Demersal resources were surveyed using a combination of trawling, fish trapping and acoustic recording while small pelagic resources were surveyed using acoustic recording supplemented by mid-water trawl sampling and underwater video recording. The details of the methods used are elaborated below.

The results of the study provided a detailed assessment of the current status of the demersal and small pelagic fish stocks in the UAE, which can be used to guide future management and development of these fish resources. Management guidelines were also included as part of the project outputs.

2.3 Review of past studies/surveys

Very little information is available in the scientific literature specifically on the fisheries of the UAE. Brief reviews (e.g. Ali, 1987) concentrate on suggestions for development while broader, Arabian Gulf-wide surveys (e.g. Anon, 1974, FAO, 1981a and b) sometimes included the UAE in regional research programs. Early studies (e.g. Anon, 1974) concentrated on taxonomic work and provided little data on distribution and abundance of the major commercial fish species.

Previous surveys were undertaken by FAO in 1977 and 1978, utilizing a number of vessels from GCC countries and were part of a more general survey of the entire Arabian Gulf region. For the demersal stocks, this more general survey began in November 1976 and concluded in January 1979 using four vessels provided by Bahrain, Iran, Kuwait and Oman (FAO, 1981a). In the first phase of that survey, 695 stations were sampled over the entire Arabian Gulf with only about 34 stations being sampled in UAE waters. In the second phase, another 159 stations were sampled in the same area where previously planned stations could not be sampled. Waters shallower than 10 meters were not sampled.

Two vessels fitted with early forms of echosounders were used for the pelagic survey. In addition, the pelagic survey covered only about 6 months of the year in 1977 and therefore there is no complete annual record of changes in abundance and distribution of the pelagic resources of the UAE. The results of these previous surveys have been reviewed as part of this project and a report prepared on that review.

An outcome of the present project was the location of the original data records from the FAO demersal survey in the archives of FAO in Rome. These records were copied onto CDs and delivered to ERWDA as part of the review of the previous survey work.

3 METHODS

The methodology adopted for this project for assessing the abundance and distribution of the demersal and small pelagic resources involved monthly surveys of all UAE waters, with demersal surveys being undertaken in February, April, June, August, October and December 2002 and surveys of small pelagic resources being undertaken in March, May, July, September, November 2002 and January 2003. Demersal surveys of East Coast areas were undertaken during the small pelagic surveys.

Demersal surveys used a combination of trawling, fish trapping and acoustic recording while small pelagic surveys used acoustic recording supplemented by trawling and underwater video techniques for species identification.

3.1 Personnel and equipment

All surveys were undertaken using the research vessel 'Flinders' which was specifically commissioned for work on the project. Flinders is a 21 meter fisheries research vessel powered by a Gardner 8 cylinder main engine with a draught of 2 meters. Fishing capabilities of the vessel include twin-rig trawling, and trap fishing, both of which were used on the project. The trawl nets used were 4 seam, 7 fathom 45 mesh wing trawls with a headline height of 1 meter and a doorspread of 19 meters for both nets. The vessel was manned by an experienced research vessel crew during all cruises, under the command of Capt. Neil McCulloch for the majority of cruises.

For this project the vessel was specifically fitted with a state-of-the-art Simrad EK-60 scientific echosounder on the hull of the vessel, operating at a frequency of 120khz for this project along with associated analytical software. During each acoustic sampling cruise, the EK-60 sounder was calibrated to ensure that it was optimally configured for recording under the environmental conditions prevailing at the time. Location data was recorded directly onto the acoustic files by linking the ship's differential GPS (accurate to within 5 meters) to the EK-60 sounder This calibration was performed in accordance with Simrad procedures and involved suspending a target (a Simrad copper ball) of known target strength of –40.40 dB below the vessel. Recording of acoustic data was done at a vessel speed of approximately 7 knots so as to minimize noise interference with the recordings. The primary analytical tool used was the Echoview acoustic analysis software.

The Research Manager, Dr Gary Morgan, assisted from time to time by specialists Neil Bagley, Gavin Macaulay and Peter Horn from the New Zealand National Institute for Water and Atmospherics (NIWA), led scientific work during the survey cruises. Data analysis was performed primarily by NIWA specialists in New Zealand assisted by Dr Morgan, with scientific quality assurance provided by Dr John McKoy also of NIWA.

3.2 Survey procedures

3.2.1 Demersal survey procedures

3.2.1.1 The key demersal study species

As part of the project planning 8 key commercial species were targeted for the collection of biological and length frequency data. In addition, otoliths were removed from a stratified sample of these species for aging studies in support of stock assessments. The list of key species agreed at the commencement of the project was as follows:

Acanthopagrus bifasciatus	*Gerres acinaces*
Argyrops spinifer	*Gnathodon speciosus*
Carangoides bajad	*Lethrinus lentjan*
Epinephelus coioides	*Lethrinus nebulosus*

In addition, the following species were added to the 8 key species for the collection of biological, age and length data.

Plectorhincus pictus	*Siganus canaliculatus*
Plectorhincus sordidus	

As a result of a review of sampling strategy in April 2002, the following 8 key species were addressed after April 2002:

Acanthopagrus bifasciatus	*Lethrinus lentjan*
Acanthopagrus latus	*Lethrinus nebulosus*
Argyrops spinifer	*Plectorhinchus pictus*
Epinephelus coioides	*Plectorhinchus sordidus*

In addition, after April 2002 the following 12 species were targeted for the collection of biological and size frequency data since they represent either potential commercial species or are already of some significant interest from a commercial point of view:

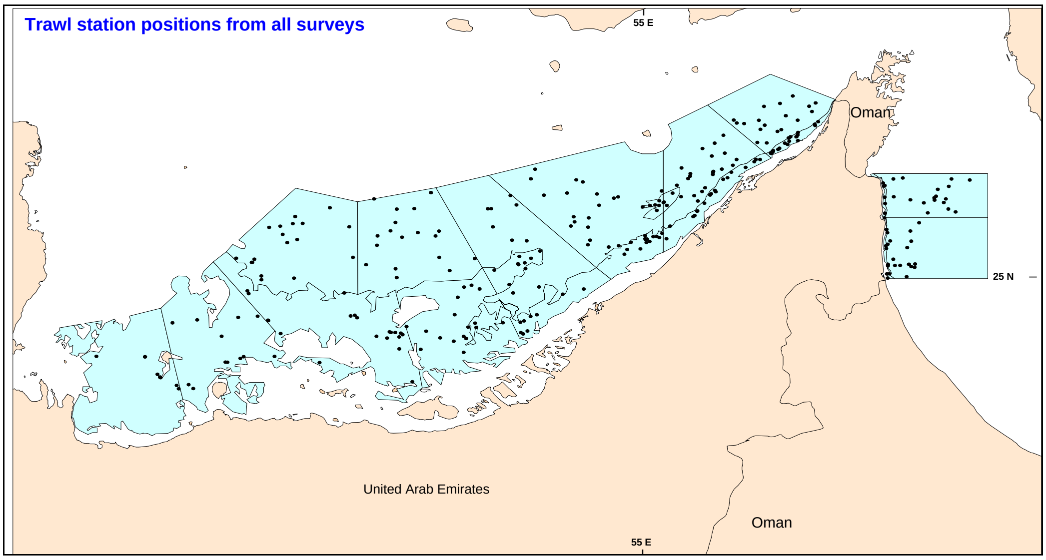
Carangoides bajad	*Rhabdosargus sarba*
Epinephelus aerolatus	*Saurida tumbil*
Gerres acinaces	*Saurida undosquamosus*
Gnathodon speciosus	*Scolopsis taeniatus*
Lethrinus borbonicus	*Siganus canaliculatus*
Lutjanus lutjanus	*Sphyraena qenie*

Not all of these species were caught in every month and, in fact, many of the species were found to be highly seasonal in their abundance and distribution.

3.2.1.2 Trawl survey methodology for demersal species

Trawl surveys were undertaken at each of 51 stations within UAE waters every two months, beginning in February 2002 and ending in January 2003. The 51 stations were randomly selected within each of 17 strata (see Figure 1) with three trawl shots being undertaken within each strata during each sampling period. The sampling stations are shown in Figure 3.

Figure 3: Location of demersal fish trawl stations.



Biomass was estimated by the swept area method described by Francis (1981, 1989) using the doorspread x distance towed as the effective area swept. Biomass was estimated by the standard stratified random survey estimator of:

$$\text{Abundance} = \sum_{\text{strata}} (\text{mean catch rate (kg/area swept)} \times \text{stratum area}).$$

The coefficients of variation *(c.v.)* of the biomass was calculated using the relationship:

$$c.v.\ (\%) = S_B / B \times 100$$

where S_B is the standard error of the biomass, B from trawl replications in each stratum.

The catchability coefficient (an estimate of the proportion of fish in the path of the net that are caught) is the product of vulnerability, vertical availability, and areal availability. These factors were set at 1 for the purpose of analysis, the assumptions being that fish were randomly distributed over the bottom, that no fish were present above the height of the headline, and that all fish within the path of the doors were caught.

Scaled length frequencies were calculated for the main species with the Trawl Survey Analysis Program, version 3.2, as documented by Vignaux (1994), using length-weight data from the first 5 surveys.

In August 2002, following a review of the stratification, Strata 1 and 2 and Strata 8 and 9 were combined for trawling purposes, thereby reducing the number of strata for the demersal survey from 17 to 15. It was determined that it was statistically appropriate in terms of the sampling design to combine these strata. Three stations were sampled in each stratum during the sampling periods of August, October and December 2002. This change of stratification took into account information gathered during the first 6 months of the sampling.

A detailed protocol and procedures manual for undertaking the trawl surveys was developed prior to the commencement of the first trawl survey. This ensured consistency in the sampling methodology. Details on the catches and catch rates of each species taken by each trawl shot during the survey were recorded, using species codes to record these data.

3.2.1.3 Acoustic survey methodology for demersal species

During all demersal surveys, acoustic data were collected for each trawl shot using the Simrad EK-60 echosounder on board the research vessel. The resulting echograms were analyzed using the EchoView software to determine the Acoustic Backscattering Coefficients (ABC) for the area covered by the trawl shot and within 1 meter of the sounder-detected bottom. This 1 meter height coincided with the mean height of the headrope of the trawl fishing gear. Therefore, the ABC values calculated could be directly related to the area swept by the trawl gear for each tow.

The relationship between the ABC values and the observed biomass density from the trawl (in kg/ sq. km) was then investigated using all data for which biomass density and ABC values were available. In addition to the acoustic data recorded during trawling operations, acoustic data were also collected during fish trapping operations (see below) and the relationship between fish trapping data and ABC values also investigated.

Throughout the acoustic surveys undertaken by the project in March, May, July, September, November 2002 and January 2003 (i.e. in months when trawl surveys were not undertaken in the Arabian Gulf waters), acoustic data were collected not only on small pelagic resources but also on demersal resources. Again, these data were analyzed using the EchoView software by calculating ABC values for each acoustic transect.

3.2.1.4 Trap fishing methodology

Trap fishing was used to calibrate acoustic data for demersal species and to investigate differences in biomass and/or size composition of the major study species between trawlable and non-trawlable areas. This was a particular issue in areas north and west of Abu Dhabi where extensive areas of coral reefs reduce the amount of trawlable bottom available. A specific survey was carried out to determine whether the relationship between acoustic data and biomass estimates was the same in trawlable and non-trawlable areas. This involved undertaking a trap-fishing survey.

The calibration of acoustic data using trapping could not be done directly because fish trapping cannot provide a direct measure of biomass of demersal species. This is a different situation to trawling activities where direct measures of biomass can be obtained using the swept area technique. As a result, the calibration of acoustic data using fish trapping was done as a three-stage process:

1. The relationship was established between (a) catch rates for the major demersal species from fish trapping and (b) biomass estimates from trawling in the same area;

2. Fish trapping was undertaken in areas not suitable for trawling and the relationship established in (1) was then used to convert fish trap catch rates to equivalent biomass estimates;

3. These biomass estimates were then used to calibrate the acoustic data from non-trawlable areas.

Three separate experiments were undertaken to establish the relationship in (1) and also to collect data on trap catch rates in non-trawlable areas. These were undertaken in August, October and December 2002 in Strata 3, 4, 5, 6, 10, 11, 13 (Figure 1) and involved the following:

- Establishing the relationship between trawl catch rates and trap catch rates by comparing 36 trawl shots of 30 minutes each and 60 trap lifts. This resulted in sufficient comparisons to establish a statistically robust relationship.

- Undertaking the fish trap survey in non-trawlable areas in August, October and December 2002 using a total of 120 trap lifts

The data from trap fishing were then used in conjunction with trawl and, particularly, acoustic data to estimate demersal biomass across all areas, including trawlable, non-trawlable, restricted oil-field areas etc.

3.2.2 Small pelagic survey procedures

3.2.2.1 Survey methodology for small pelagic species

Six cruises were undertaken, in March, May, July, September, November 2002 and in January 2003 that were designed to collect acoustic data on small pelagic resources both within the Arabian Gulf region and on the East Coast of the UAE. These surveys also collected acoustic data on demersal species (see above). The area to be surveyed was divided into 6 acoustic strata (Figure 2) and 2-6 random transects were undertaken in each stratum during each sampling cruise. The number of transects undertaken within each stratum was modified as sampling proceeded with additional transects being undertaken in areas that showed a high concentration of fish. Recording of acoustic data was done at a vessel speed of approximately 7 knots to minimize noise interference after noise tests were carried out on several occasions.

To fully document the procedures of the acoustic surveys and to ensure consistency in data collection, a manual of acoustic survey procedures was prepared for use by the project. This manual, which was adapted from the standardized NIWA manual, was then used to guide all acoustic survey procedures.

Transects were selected, in accordance with the acoustics procedures manual, by generating random transects for each stratum using the NIWA random transect generator ‘rtrans’. Transects were generally in an offshore/onshore orientation and, so far as practicable, parallel to the boundaries of the stratum. Approximately 3,500-4,000km of transects were recorded during each cruise within the 6 strata. Location data were recorded directly onto the acoustic files by linking the ship’s differential GPS (accurate to within 5 meters) to the EK-60 sounder. All of the acoustic files were deposited with ERWDA at the completion of each cruise. During each acoustic sampling cruise, the EK-60 sounder was calibrated to ensure that it was optimally configured for recording under the environmental conditions prevailing at the time.

3.2.2.2 Target identification of small pelagic species

Targets of small pelagic species seen on the sounder were identified during the project using a variety of methods, including mid-water trawling and underwater video techniques. Several different configurations of mid-water trawl were tested and used during the project.

During sampling after November 2002, JW Fisher underwater video equipment was deployed and used to directly observe schools of small pelagic species. This equipment had been installed on the ship for the project because of the difficulties experienced in sampling some of the small pelagic species with the conventional pelagic trawl net used in earlier sampling. The video equipment enabled the identification of species so that these data could be related to the acoustic signature of schools seen on the Simrad EK-60 sounder. The equipment was successful in identifying a number of species and confirming the identity of recorded acoustic marks of small pelagic species.

3.2.2.3 Acoustic data storage and analysis for small pelagic species

Recorded acoustic data were saved directly to files (of maximum size 100Mb) on the hard disk drive of the EK-60 computer. Analysis of each file recorded during each cruise was done for each of the identified species or species groups of small pelagic resources.

Analysis of echograms was carried out using the SonarData Echoview Base module (SonarData Pty Ltd, Hobart, Tasmania, Australia).. Mean weighted Acoustic Backscattering Coefficients (ABC) were calculated by weighting the ABC value for each species for each transect by the length of the transect. Where no recordings of a species were made during a transect, the ABC value for that species was set at zero and included in the weighted ABC value.

Using either recorded or other values of Target Strength (TS), these mean weighted ABC values were then converted to biomass estimates for each stratum for each sampling cruise. TS values were both measured *in situ* using the echoacoustic equipment’s advanced TS measuring capability and obtained from the scientific literature for each of the identified species or species groups. The procedures for estimating biomass were as follows:

- For each species, for each stratum, the weighted mean ABC value (Sa) was calculated with the values being weighted by the length of each transect. Transects in which none of the species being considered were recorded were included, with the ABC value for that species and transect being set at zero.

- The TS (sigma bs) value was calculated from a knowledge of the Target Strength of the species in question from the relationship TS (sigma bs)=10^(TS/10).

- The number of fish per square meter of sampled area (Nt) was calculated from the relationship Nt = Sa/TS (sigma bs).

- The total number of fish for the species and stratum under consideration was calculated by multiplying the Nt value by the area of the stratum. The stratum area was calculated from hydrographic charts.

- Mean weight of the species under consideration was calculated from data on mean length together with the length/weight parameters. The same value of mean length was used for each month (based on all specimens captured during the project) since there is no data on how mean length of the various species change seasonally.

- Biomass estimates were calculated by multiplying the number of fish for the species and stratum under consideration (Nt) by the average weight.

- Coefficients of variation of the biomass estimates were calculated from data on variation in ABC values for each species for individual transects, with each file (maximum of 100 Mb) being treated separately for the calculation of ABC values. This resulted in up to 8 separate ABC values for each species for each transect, depending on the length of the transect.

- The above sequence of analysis was then repeated for each species for each stratum to give biomass estimates and standard errors.

3.2.3 Oceanographic and plankton survey procedures

Data on oceanographic parameters and productivity of the survey area were collected both from direct sampling and from satellite imagery. Water temperature and salinity information throughout the water column was collected using a Seabird SBE37 CTD. At each station the CTD was deployed and lowered from the surface to the seabed so that a complete profile of oceanographic data was collected throughout the water column. In areas deeper than 80 meters (only the deeper strata on the east coast emirates), recording was only made to 80 meters depth, which was the limit of the CTD tethering equipment. Recording rates of the CTD were set at one record each 5 seconds, thus enabling a recording rate of approximately one record for each meter of water depth in both ascending and descending modes.

The data were downloaded to the ship’s onboard computer system and files were converted to calculate salinity values from conductivity measurements. During the recording, the measured values of salinity, temperature and sound velocity were also used for calibration of the Simrad EK-60 echosounder.

Field collection of plankton data was undertaken during each acoustic survey in July, September, November 2002 and January 2003. Nets used 60cm diameter plankton nets of 20 micron and 120 micron mesh size, mounted as a twin net configuration on ‘bongo’ frames. Each net was fitted with a removable ‘cod end’. At each sampling station, the nets were towed for a fixed time of 5 minutes. The quantity of water filtered was calculated using the tow distance (from GPS data) and the net diameter and by current meters. The wet-weight biomass of plankton taken in each net was measured.

Remotely-sensed data from the SeaWiFS oceanographic satellite was used to provide a comprehensive and geographically extensive view of oceanic conditions in the Arabian Gulf and the East Coast Emirates during the time of the survey. In particular, chlorophyll-a concentrations from this satellite data were used to provide estimates of productivity with these data being supported and calibrated against field-collected plankton and oceanographic data.

3.3 Data analysis, stock assessment and modeling

3.3.1 Demersal species

The development of an assessment model for UAE’s demersal fish stocks was undertaken as part of a major activity of the project. The model was developed in Visual Basic and implemented in MS Excel version 5.0, build 2195 running on Windows 2000 Professional.

The model was developed with the following modules:

Introduction module

This provides the introduction screens and links to other analytical screens described below.

Data input module

This module provides options for specifying the species to be assessed, whether growth parameters are to be input or whether stored values are to be used and whether input values of natural mortality are to be input or stored values used. The stored values of growth parameters are those that have been determined as part of this project. The stored values of natural mortality are the values calculated from Pauly (1980) based on these growth parameters and an average water temperature value of 25°C.

Growth parameter module

This module either (a) accepts input values of the growth parameters (either seasonal or non-seasonal growth) from the data input screen or (b) uses internally stored values of growth parameters based on the age and growth analysis carried out as part of the project.

Natural mortality module

This module either (a) accepts input values of instantaneous natural mortality, M or (b) uses derived values, which are stored internally, based on growth parameters in the growth module and environmental temperatures.

Length and weight module

This module calculates and stores the length/weight parameters for all 8 species as determined as part of the project. There is no provision for manual input of alternative length/weight relationships.

Calculation module

This module is the heart of the assessment model and performs all the calculations for output to the output module (see below). The way in which the analytical aspects of this module function are as follows:

- The module is stochastic in nature and accepts both mean and standard errors of the input parameters. All analytical functions of the model therefore include variation around the mean values of parameters, whether input or derived. The standard errors are stored internally, based on the standard errors of the parameters calculated as part of the work of the project. There is no provision for manually inputting standard errors and, when growth and mortality parameters are input manually, standard errors for all parameters are assumed to be 0.1 times the mean values (i.e. a coefficient of variation of 10%).

- The model models 6 annual cohorts of the chosen species simultaneously. Recruitment to each cohort is assumed to occur at age 1 month and be the same although there is provision to change this internally if data ever becomes available on recruitment variation to any commercial species. Alternatively, a function linking, for example, changes in the area of nursery habitat to recruitment (presumably a simple linear relationship) can easily be incorporated to examine issues such as the impact of habitat degradation.

- Growth of each cohort was modeled by using the inverse of the seasonally adjusted Von Bertalanffy growth curve of :

  $$L_t=L_\infty*(1-Exp(-(K*(t-t(zero))+(C*K*Sin(2*\pi*(t-Wp+0.5)))/(2*\pi))))$$

  (Where K and L_∞ are the Von Bertalanffy growth parameters, C is the oscillation index for seasonal growth and WP is the winter point at which seasonal growth is slowest) to calculate the average age t and standard error of t at length L_t for each 1cm size class for each cohort. The mid-point of each size class was used as the value of L_t in calculating this mean age.

- The abundance of each 1cm size group of each cohort of each species for each 1 month time period in the absence of fishing was calculated using the relationship:

$N_{t+1} = N_t exp(-M\delta t)$ where M is the instantaneous rates of natural mortality and δt was the difference between the average age at length t and the average age at length t+1.

- The total numbers in each 1cm size group was then calculated by summing across all 6 cohorts.

- The effects of fishing were examined by introducing two new parameters, F, the instantaneous rate of fishing mortality and Lc, the size at first capture. For the modeling exercise, and in the absence of any explicit fishing effort information, the value of fishing mortality was calculated internally from Z values from the age-related catch curves and values of M. Values of fishing effort, f, were set at 1 (i.e. the present situation) and values of catchability, q, therefore set at F through the relationship F=qf. This enabled the impact of the variations in relative fishing effort to be examined.

- The relative commercial catch (relative to the present catch) of each cohort for each 1cm length class was determined by first calculating the probability of retention by the fishing gear for any given input value of Lc. This probability of retention (S(L)) for any length L was given by:

  $S(L)=1/(1+exp(-Sm(L-L50)))$,

  where Sm is the steepness parameter of the logistic selection curve and L50 is the mean size at first capture (i.e. the length at which 50% of the fish are retained by the fishing gear). In the absence of any information on selection coefficients for the fishing gear used in the UAE, a value of 1 was used for Sm.

- Using the function $N_{t+1} = S(L)*N_t*exp(-(F+M)*\delta t)$, the numbers within each cohort for each 1cm size group are calculated for the input values of L50 and relative fishing effort f.

- The total numbers in each 1cm size group are then calculated by summing across all cohorts for the given combination of fishing effort, f and size at first capture L50.

- Biomass within each 1cm size class was then calculated from the numbers in each size class and their mean weight, using the length/weight relationship for the species under consideration. The mean length within each size class was used in calculating the mean weight of the fish.

- Biomass calculations were made for the situation of exploitation and no exploitation.

- The size at first maturity Lm for each species was taken from information collected by the project and the biomass of fish of mature size only, calculated using the above procedures but applying a logistic maturity function of $S(L)=1/(1+exp(-Sm(L-Lm)))$, with Sm again being set at 1. The biomass of all size classes was then summed to calculate a total biomass of fish of mature size.

- By comparing the total biomass of mature fish with and without exploitation, the proportion of spawning stock (as a percentage of the spawning stock with no exploitation) was calculated for each input combination of size at first capture and relative fishing effort.

- Finally, the anticipated size structure of the catch was calculated for each input combination of size at first capture and relative fishing effort.

Output module

The output module provided a summary of the outputs of the modeling for each input combination of L50 and fishing effort. Outputs include the anticipated size structure of the catch, the total catch (relative to the current situation), exploitation rate and the proportion of spawning stock in comparison with the virgin spawning biomass.

In applying the model to assessing the various 8 key demersal species, runs of the model were made using relative fishing effort (i.e. relative to the present levels of effort) of 0.5, 0.75, 1.0 (current fishing effort), 1.25, 1.5, 1.75 and 2.0. Size at first capture was varied by approximately ± 20% of the current size at first capture of the various species.

3.3.2 Small pelagic species

Stock assessment and modeling of the small pelagic resources identified during the project was also investigated. Many of the small pelagic fish species identified appear to be relatively short lived. A search of the literature of FishBase (Froese and Pauly, 2003) for population parameters of these species showed that some data exist on growth and other parameters from other regions, but little from the immediate vicinity of the UAE. The available population parameters were used to provide calculated values of natural mortality (M) based on the empirical equation of Pauly (1980) and using a mean environmental temperature of 25°C. From these values of M, estimated life spans were estimated.

These life span values (commonly less than 1 year) showed the generally short-lived nature of the small pelagic species found during the survey. This makes modeling of these populations impractical. With such short life spans, the biomass of these species will primarily be driven by recruitment and spawning success. Because of this, the species typically show a great deal of variation in abundance from year to year.

Factors which could have a major influence on spawning success and recruitment include available food, predator abundance, competitors and oceanographic conditions. The available information is not adequate to determine which of these factors are the determinants of recruitment and spawning success in the small pelagic species found in the UAE. Therefore, forecasting changes in abundance (whether in the presence or absence of fishing) of these species is not possible. ‘Modeling’ of the population of these species, likewise, was not possible without such information.

4 RESULTS

4.1 Oceanographic environment

Water temperature and salinity measurements taken during each sampling cruise provided an overall picture of the oceanographic environment of UAE waters during the survey. The oceanographic environment differed markedly between the western areas of the Arabian Gulf coast (Abu Dhabi Emirate), the Northern Emirates area to the north and east of the Arabian Gulf coast and the East Coast Emirates that border the Gulf of Oman.

The surface and bottom temperature recordings made during each month in each of these major areas are summarized in Figures 4, 5 and 6.

Figure 4: Surface and bottom temperatures recorded in Strata 1, 2 and 3 (Abu Dhabi Emirate) of Figure 2 during February 2002 to January 2003

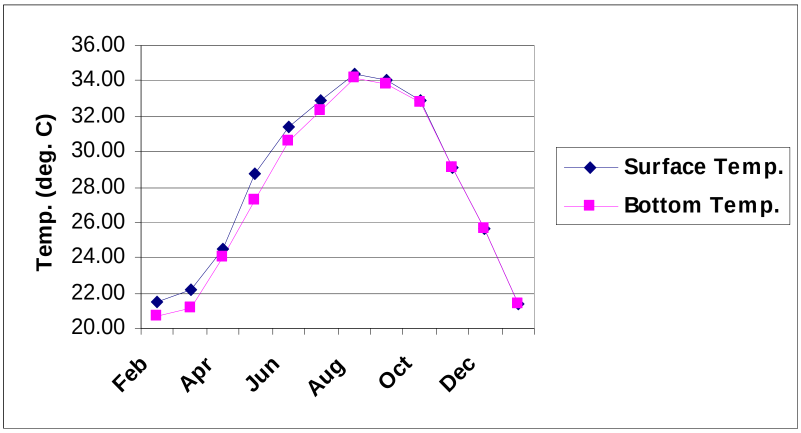


Figure 5: Surface and bottom temperatures recorded in Strata 4 and 5 (Northern Emirates) of Figure 2 during February 2002 to January 2003

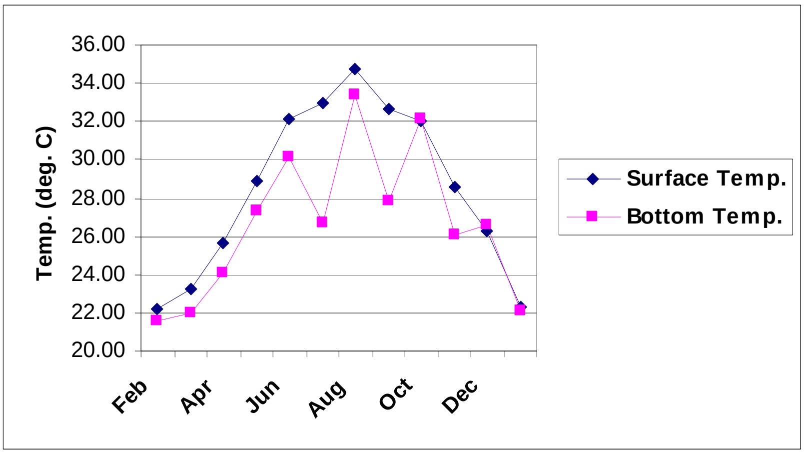
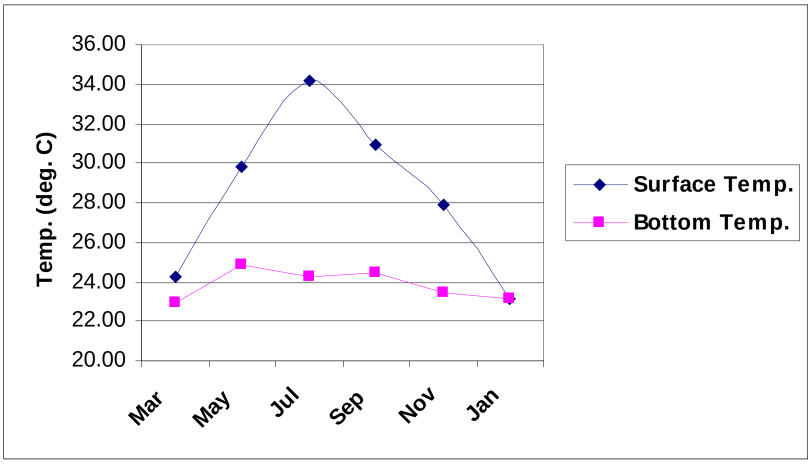


Figure 6: Surface and bottom temperatures recorded in Stratum 6 (East Coast Emirates) during February 2002 to January 2003



The patterns of seasonal change in water temperatures, (Figures 4, 5 and 6), show differences between the three areas. The East Coast area (Stratum 6) shows bottom water temperatures only changing slightly throughout the year (Figure 6). In contrast, surface temperatures undergo a seasonal pattern of rising water temperatures to highs of 35°C during July and reach lows of around 23°C during the cooler months of January and February in the Arabian Gulf areas of Abu Dhabi and the Northern Emirates (Figures 4 and 5). In these areas both surface and bottom temperatures show seasonal cycles of high water temperatures in summer and low temperatures during the winter period.

Salinity values in Arabian Gulf Strata 1-5 (Figure 2) were high and ranged from 37.0 to 43.0 parts per thousand (ppt) with bottom water salinities higher than surface salinities. The East Coast area (Stratum 6) showed water salinities ranging from 35.1 to 37.2 ppt with bottom salinities again being higher than surface salinities. The lower values of salinities measured in the East Coast areas are more in keeping with oceanic conditions than the high values recorded within the Arabian Gulf area of the UAE.

Chlorophyll-a concentrations, as measured from satellite data, were shown to vary seasonally within UAE waters. Figure 7 shows the seasonal pattern (covering 4 of the 12 monthly images available) of chlorophyll-a concentrations in both the Arabian Gulf and the East Coast areas of the UAE during the study period. These satellite imagery data show a number of interesting seasonal variations in the chlorophyll-a concentration. Among these are:

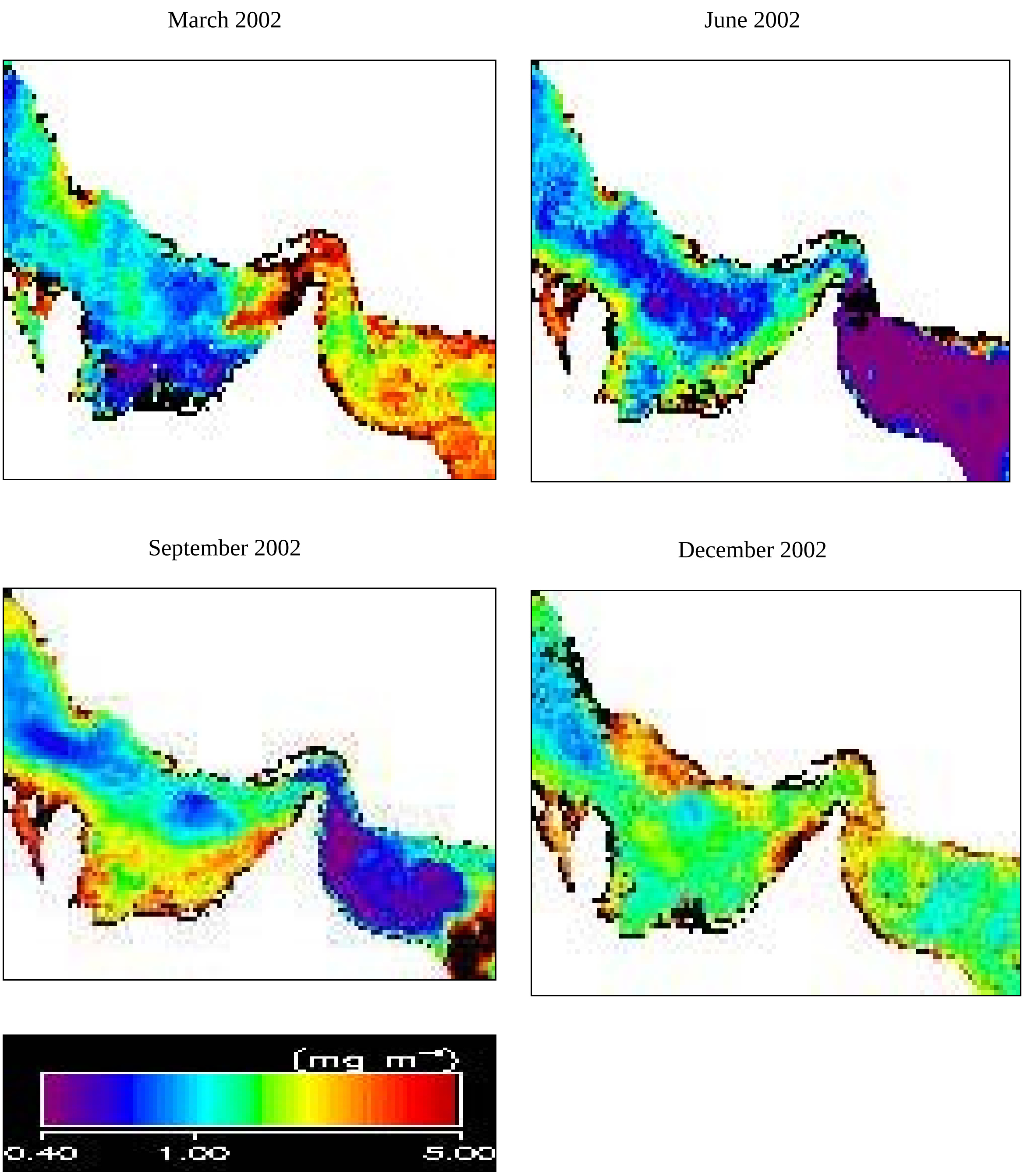
- A reduction in chlorophyll-a concentration from about March onwards in near coastal waters of the UAE. This reduction appears to begin in the western part of Abu Dhabi Emirate and move eastwards over the months following February.

- The area near Ras al-Khaimah (Stratum 5 of Figure 2) remains an area of relatively high chlorophyll-a concentration throughout the year, even as concentrations in other areas within the UAE are decreasing.

- The East Coast area follows a similar trend in reducing chlorophyll-a concentration and reaches very low levels by May/June.

- Chlorophyll-a concentrations begin increasing first on the East coast in July/August, followed in the next few months by the Arabian Gulf coast areas including Abu Dhabi Emirate, reaching a maximum in all areas in about December, following which the seasonal pattern of declining concentrations begins again in March.

Figure 7: Seasonal changes in chlorophyll-a concentrations in UAE waters during March-December 2002



The recorded plankton biomass concentrations followed the same trend as the satellite imagery data, with biomass increasing during the latter part of the year and reaching a peak during winter. As a result, the satellite imagery data can be used with some confidence as an effective and cost-efficient means of monitoring changes in plankton biomass in UAE.

4.2 Demersal fish biomass

Demersal fish biomass was measured using a combination of trawl survey, fish trapping and acoustic techniques. Encouragingly, the results from the three methods were consistent in their trends although, as expected, acoustic data provided higher biomass estimates than trawl survey data because acoustic data is measuring all demersal species whereas trawl catches are taking only a selection (both size and species) of the available resources.

Direct estimates of biomass using a combination of trawling and fish trapping were made, with the main characteristic of the data exhibiting very large seasonal trends in biomass recorded for the various species. This was most evident in Abu Dhabi Emirate where seasonal climatic fluctuations are more pronounced than in the northern emirates or on the East Coast.

The characteristics of the changes in abundance within UAE waters of the 20 key study species are as follows:

Species that have pronounced peaks in abundance during the winter period (November-February)

Acanthopagrus bifasciatus
Acanthopagrus latus
Carangoides bajad
Epinephelus aerolatus
Lethrinus borbonicus
Plectorhinchus pictus
Rhabdosargus sarba
Saurida tumbil
Saurida undosquamosus
Sphyraena qenie

Within this group of species that have pronounced peaks of abundance in winter, *Carangoides bajad* has an early winter peak in abundance although the species is present all year, while *Saurida tumbil* shows a late winter/early summer peak in abundance.

Species that show a peak in abundance during the summer period (May-September)

Argyrops spinifer
Lutjanus lutjanus
Scolopsis taeniatus
Siganus cananiculatus

Within this group of species that show a peak in abundance in summer, *Argyrops spinifer* has an early summer peak in abundance, while *Scolopsis* taeniatus is common all year with a peak in abundance during summer.

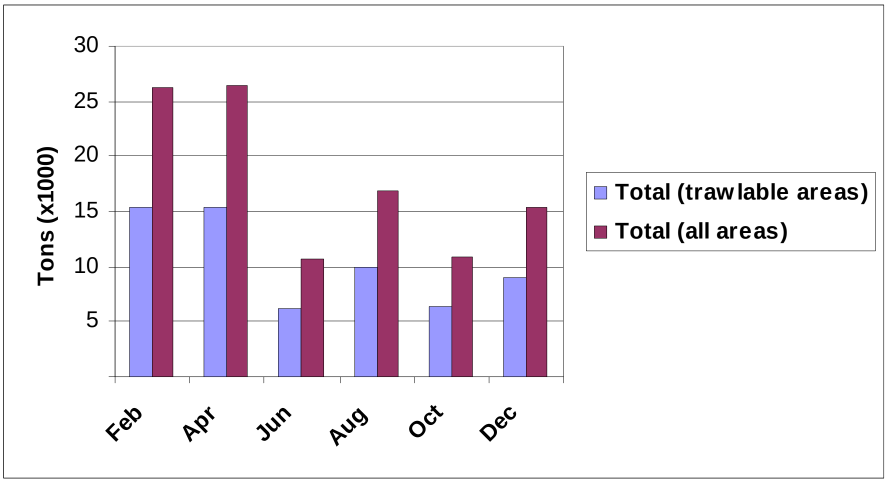
Species that are present all year in UAE waters without showing pronounced peaks in abundance

Epinephelus coioides
Gerres acinaces
Gnathodon speciosus
Lethrinus lentjan
Lethrinus nebulosus
Plectorhinchus sordidus

Within this group of species that are present in UAE waters all year, *Gnathodon speciosus* and *Plectorhinchus sordidus* show a low level of abundance all year.

Given that the majority of the species studied have peaks in abundance during the cooler winter months, it is not surprising that overall demersal biomass (i.e. for all species) is at a maximum during winter and a minimum during summer in the Arabian Gulf region of the UAE (Figure 8).

Figure 8: Seasonal changes in mean biomass for all 20 key study species for the Arabian Gulf Area (Strata 1-14 of Figure 1) estimated from trawling data



A comparison between fish trapping data, trawl data and acoustic data was undertaken for those months in which fish trapping experiments were undertaken.

The data showed:

- Overall trap catch rates (measured as catch per trap lift) are higher in trawlable areas than in non-trawlable areas. This is due to the greater abundance of semi-pelagic species taken in traps in trawlable areas.

- Hamoor (*Epinephelus coioides*) comprise over 40% of the catch by weight from non-trawlable (reef) areas, whereas the catch from non-trawlable areas is a significantly lower proportion (<10%).

- Demersal species dominate the non-trawlable areas while pelagic species dominate the trawlable areas.

- Gargoor catch rates (measured as catch/trap lift) are closely related to both trawl catch rates and to acoustic data in the same area.

- Acoustic data (measured as Nautical Area Scattering Co-efficient, NASC) provide a consistent measure of demersal biomass across both trawlable and non-trawlable areas.

- Most of the major demersal species occur over both trawlable and non-trawlable areas. The major exception to this is *Epinephelus coioides* which is more abundant in non-trawlable areas (Figure 9). However, this increased abundance (i.e. greater biomass) of *E. coioides* in non-trawlable areas is primarily due to the larger sizes being present in non-trawlable areas when compared with trawlable areas.

- The size composition of most major demersal species is similar across trawlable and non-trawlable areas. The major exception to this is *Epinephelus coioides* where larger individuals are more abundant in non-trawlable areas.

- Pelagic and semi-pelagic species comprise a significant proportion of the overall catch of gargoor. Some of these species (e.g. *Carangoides bajad*) occur across both trawlable and non-trawlable areas (Figure 10), while others (e.g. *Caranx ignoblis* and *Carangoides chrysophrys*) occur only in more open, trawlable areas.

Species composition of catches by fish traps was significantly different from the species composition of trawls with fewer species being taken in the traps. In addition the species composition in trawlable and in non-trawlable areas (on the basis of trapping) was also different with a greater abundance of semi-pelagic species such as *Carangidae* being taken in trawlable areas. Table 2 shows the species composition comparisons between trawlable and non-trawlable areas.

Size composition of major species was examined between trap and trawl catches from the same area and in trap catches in trawlable and non-trawlable areas. The size composition in trap catches and trawl catches was similar for species for which there were sufficient data. This indicated that the two fishing methods were sampling the population in the same way. However, in the size composition in trawlable and non-trawlable areas (from fish trap catches), there was evidence for some species that larger individuals were more common in non-trawlable areas.

Table 2: Percentage species composition of gargoor catches on trawlable and non-trawlable (reef) areas for the three months of fish trapping surveys.

Species	August '02		October '02		December '02		Total	
	Trawlable	Non-trawlable	Trawlable	Non-trawlable	Trawlable	Non-trawlable	Trawlable	Non-trawlable
Acanthopagrus bifasciatus	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.20
Argyrops spinifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arothron stellatus	0.00	0.00	0.00	0.00	9.67	6.73	2.83	2.85
Carangoides bajad	1.27	1.30	24.72	8.96	2.76	4.33	3.40	5.19
Carangoides chrysophrys	54.65	0.00	11.24	0.00	4.42	0.00	36.81	0.00
Caranx ignoblis	17.96	0.00	6.74	0.00	39.78	0.00	23.54	0.00
Diagramma pictum	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.51
Echineus naucrates	4.71	0.00	2.25	7.46	8.29	3.61	5.58	4.07
Epinephelus coioides	6.62	74.46	17.98	39.70	18.51	31.97	10.92	44.60
Gerres acinaces	1.40	0.43	0.00	0.00	0.00	0.00	0.89	0.10
Gnathodon speciosus	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.31
Lethrinus borbonicus	0.00	0.00	2.25	5.37	1.10	1.44	0.49	2.44
Lethrinus lentjan	0.00	0.00	0.00	1.49	0.83	2.16	0.24	1.43
Lethrinus microdon	0.76	0.87	4.49	0.00	4.42	4.57	2.10	2.14
Lethrinus nebulosus	0.13	0.87	11.24	7.16	0.28	1.92	0.97	3.46
Lutjanus fulviflamma	0.89	3.90	13.48	7.76	1.10	3.13	1.86	4.89
Lutjanus lutjanus	0.00	0.43	0.00	0.00	0.28	0.00	0.08	0.10
Plectorhinchus pictus	0.00	0.00	2.25	0.00	0.00	0.96	0.16	0.41
Plectorhinchus sordidus	0.00	0.00	0.00	2.39	1.66	0.72	0.49	1.12
Pomacanthus maculosus	0.00	3.46	0.00	2.99	2.76	0.00	0.81	1.83
Portunus spp	0.13	1.30	0.00	0.90	1.38	1.68	0.49	1.32
Rhabdosargus sarba	0.00	0.00	0.00	0.00	0.55	1.44	0.16	0.61
Scolopsis taeniatus	1.27	6.93	0.00	3.58	0.28	12.02	0.89	7.94
Sepia Sp	0.00	1.30	0.00	0.00	0.00	13.46	0.00	6.01
Seriolina nigrofasciata	8.54	0.00	0.00	0.00	0.00	3.61	5.42	1.53
Siganus canaliculatus	0.00	3.90	0.00	2.39	0.00	0.00	0.00	1.73
Sphyraena qenie	0.00	0.00	0.00	5.67	0.00	0.00	0.00	1.93
Other	1.66	0.00	3.37	3.28	1.93	5.05	1.86	3.26
Catch(kg)/trap lift*	1.33±0.51	0.49±0.25	0.24±0.20	0.51±0.14	2.13±0.53	0.76±0.14	1.09±0.16	0.58±0.09
Catch/trap lift (demersal species)*	0.15±0.08	0.46±0.22	0.12±0.11	0.36±0.09	0.91±0.27	0.53±0.10	0.26±0.08	0.44±0.07
Catch/trap lift ('pelagic' species)*	1.18±0.43	0.03±0.03	0.12±0.09	0.15±0.05	1.22±0.26	0.23±0.04	0.84±0.08	0.14±0.02

* Mean and standard error

Figure 9: Size composition of *Epinephelus coioides* taken by traps in trawlable and non-trawlable areas during sampling in August, October and December 2002.

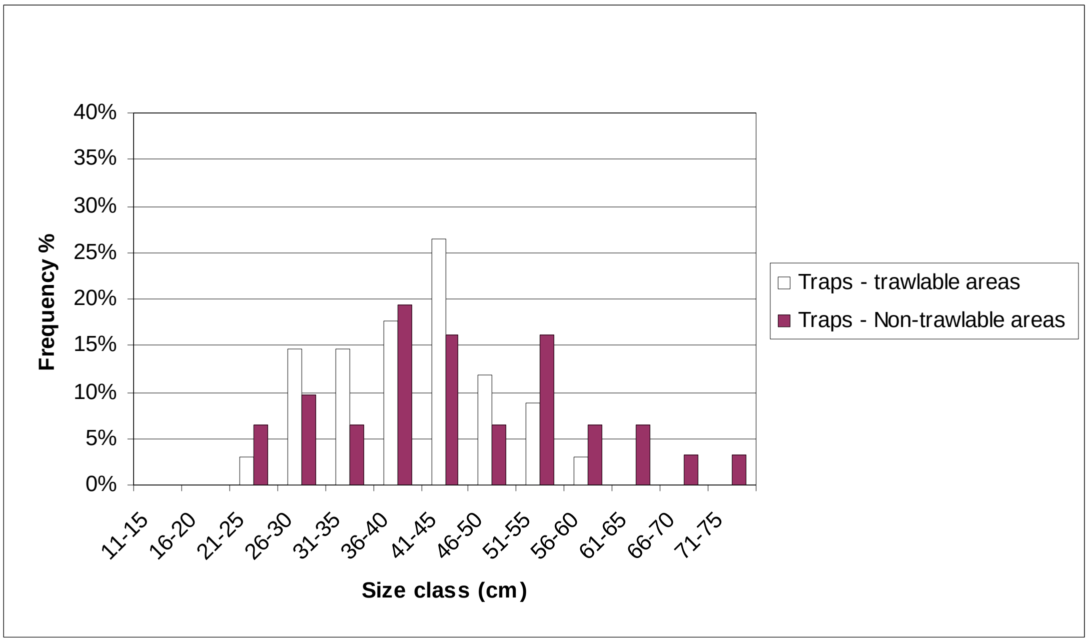
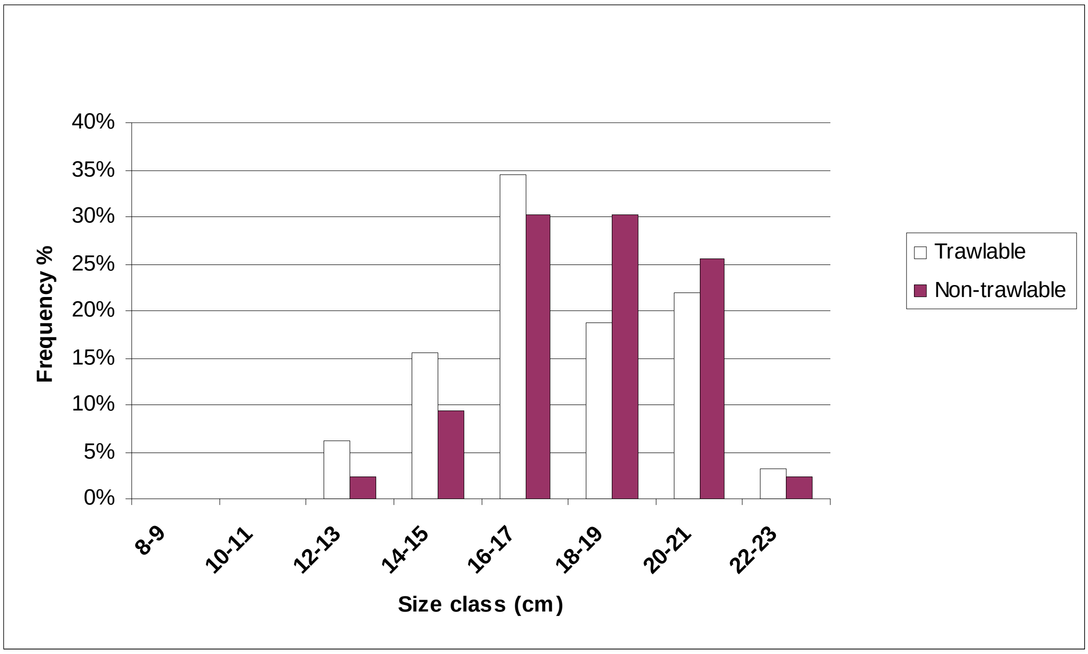
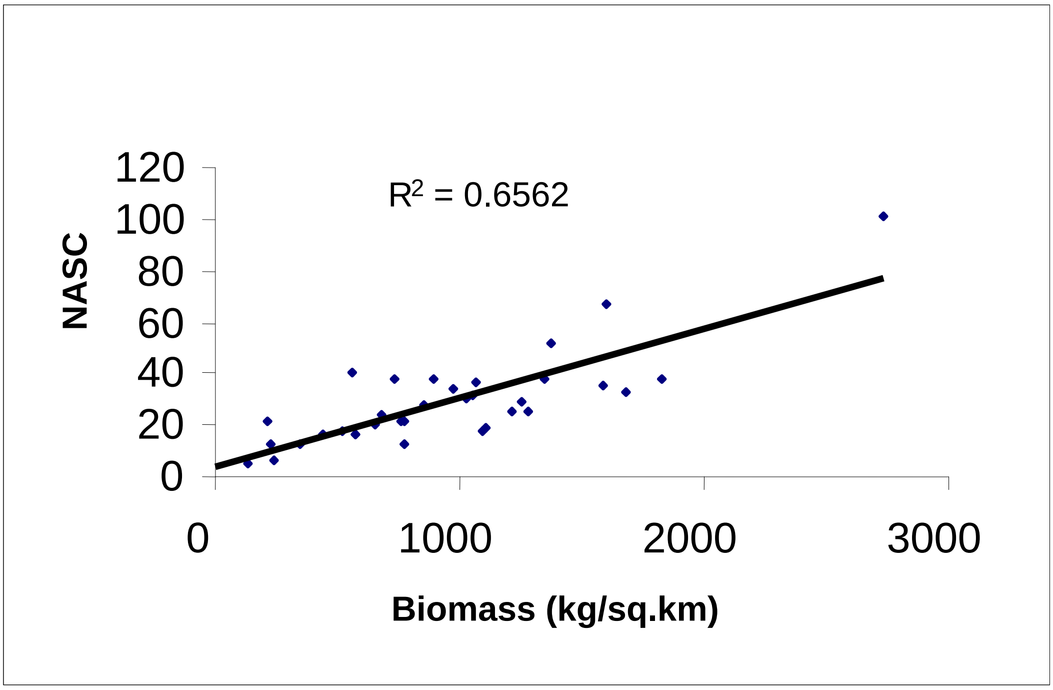


Figure 10: Size composition of *Carangoides bajad* taken by traps in trawlable and non-trawlable areas during August, October and December 2002.



By comparing the biomass density (tons/sq. km), measured by the trawl survey with acoustic recordings made at the same time, a significant relationship was found between the Nautical Area Scattering Co-efficient (NASC) and the measured biomass density. This relationship is shown in Figure 11.

Figure 11: The relationship between the Nautical Area Scattering Coefficient (NASC) and measured biomass (kg/sq. km) of all demersal species taken during trawling operations.

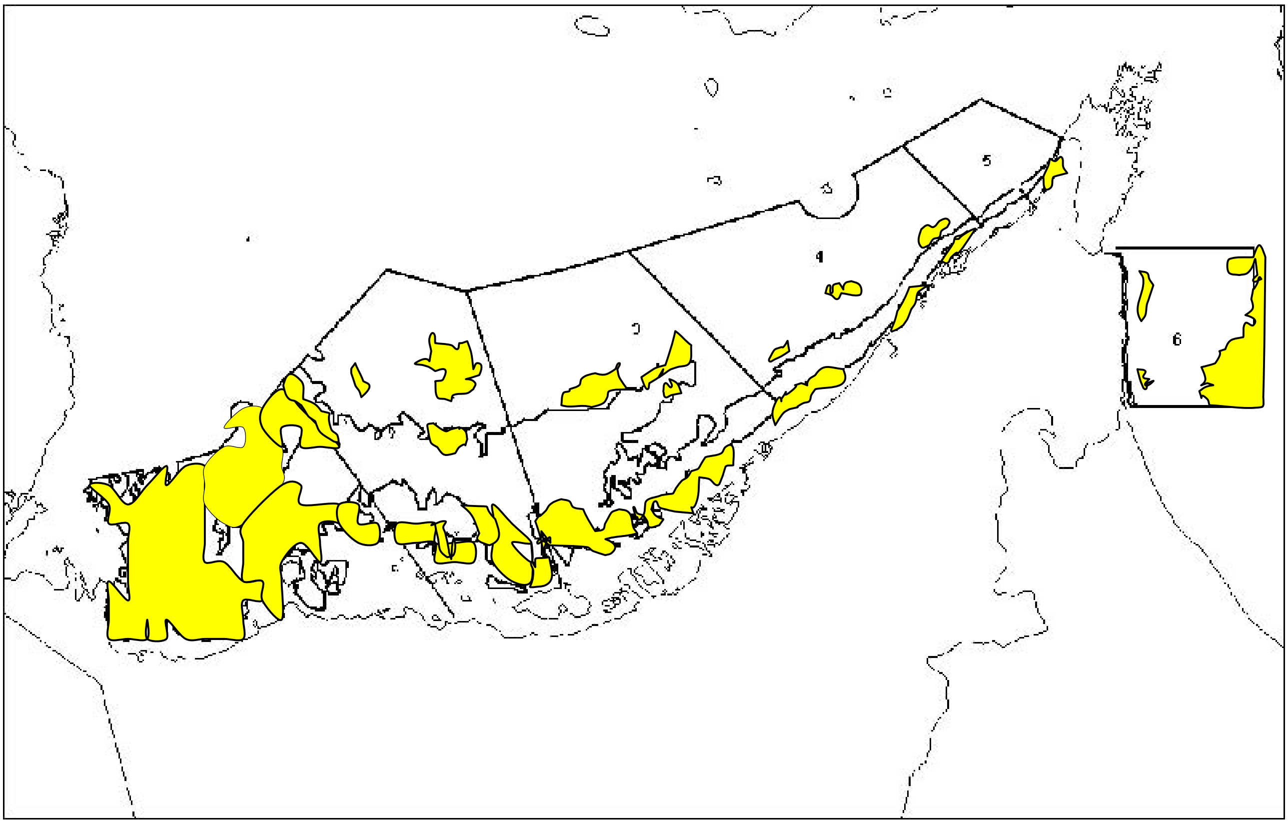


This relationship was an important one and enabled acoustic data collected during acoustic survey cruises to be used to provide estimates of total demersal biomass over the whole of UAE waters during months when trawl surveys were not conducted.

A knowledge of the extent of trawlable areas was important to allow integration of the data collected from trawl surveys (which cover only trawlable areas), fish trapping (which covered both trawlable and non-trawlable areas) and acoustics (which covered all UAE waters up to the 10 meter depth contour), This was measured using the research vessel's MaxSea electronic charting system and was based on the bottom types that could be sampled by the vessel using the trawl gear that was operated during the project.

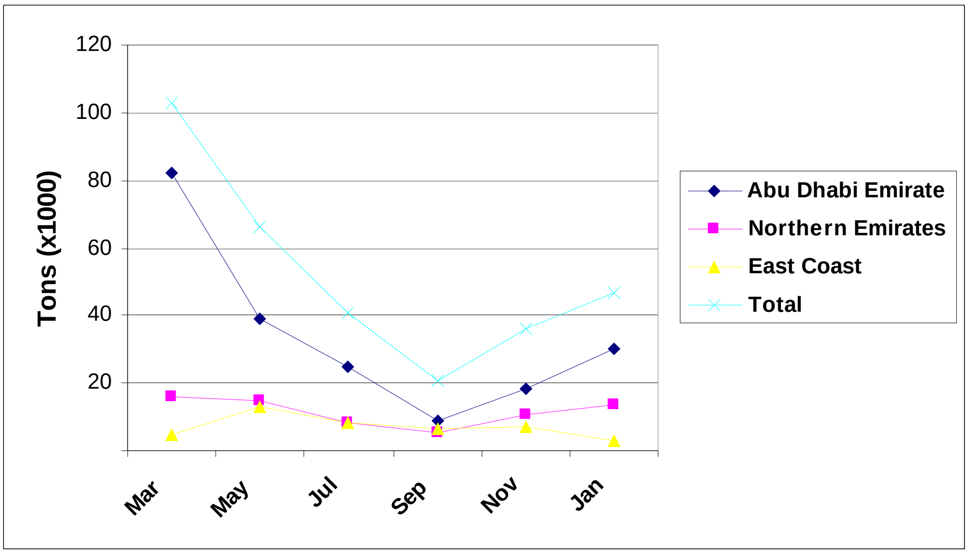
The extent of trawlable and non-trawlable areas within UAE waters is shown in Figure 12, with trawlable areas comprising a total of 58.2% of the total marine area deeper than 10 meters within the Arabian Gulf and 70.8% of the total marine area deeper than 10 meters on the East Coast. The area in the west of UAE waters contained a significant amount of non-trawlable areas, due mainly to the presence of coral reefs in the area.

Figure 12: Chart showing the location of areas (indicated in yellow) that were considered unsuitable for trawling by the research vessel with the fishing gear used.



Using acoustic data together with the relationship shown in Figure 11, estimates of the total demersal biomass (i.e. all areas, all species) in various areas of the UAE during the study period were made.

Figure 13: Changes in total demersal biomass (estimated from acoustic data) for the three major regions of the UAE.



The patterns shown in Figure 13 represent changes in the total biomass within 1 meter of the bottom throughout UAE waters, based on an analysis of acoustic transects. As such, they include not only commercial and non-commercial demersal species but also any organisms that may have been within 1 meter of the bottom (pelagic species, plankton etc). As such the values do not reflect the potential quantity of fish available for harvest.

The trends in abundance shown in Figure 13 indicate that Abu Dhabi Emirate shows the greatest seasonal fluctuation in abundance of demersal organisms. The East Coast areas, being more oceanic in nature, did not show such seasonal changes in abundance. The northern emirates area showed only small seasonal fluctuations. Accordingly, the Abu Dhabi Emirate, having the largest sea surface area, not only contains the largest biomass of demersal species but also shows the greatest seasonal biomass fluctuations. These seasonal fluctuations dominate the demersal biomass data for the UAE as a whole.

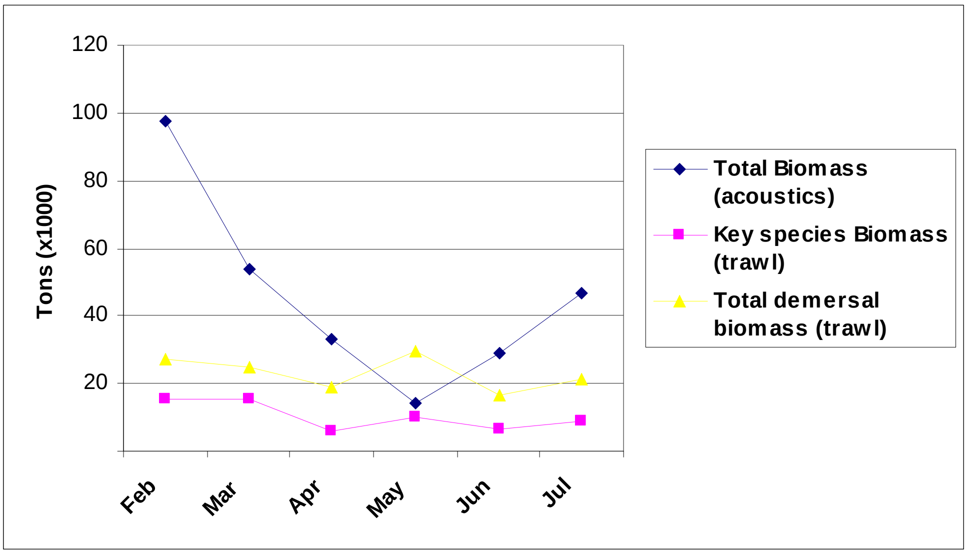
By combining the data collected on (a) biomass from trawling data (b) the differences in demersal biomass between trawlable and non-trawlable from trapping data, (c) the surface area of trawlable and non-trawlable areas and (d) acoustic data on demersal species, estimates of overall biomass of demersal species were able to be estimated. These estimates of demersal biomass (Figure 14) include:

(a) estimates of biomass of the 20 key study species. (These species comprise the majority of commercial species that are currently taken in the UAE),

(b) estimates of biomass of the total fish fauna. (This fish fauna includes commercial and non-commercial fish species and is essentially the total biomass of all fish species that were taken by trawling operations), and

(c) all organisms recorded within 1 meter of the sea bed by the acoustic equipment.

Figure 14: Biomass estimates for the Arabian Gulf regions of the UAE for all demersal species (from acoustic data) and for both total demersal species and for the 20 key study species (from trawl data)



In summary, the various measures of biomass that were made by the project, using trawling, trapping and acoustic methods, has enabled a comprehensive picture of the demersal resources of the UAE to be gained. These methods have all shown the highly seasonal changes in biomass of the demersal resources in general with many species moving into the area during the cooler winter months and leaving again during the hotter summer months. However, there are at least some species (e.g. the rabbit fish, *Siganus canaliculatus*) that exhibit a different behavior and migrate into UAE waters during summer and leave during the winter months. Some species, most importantly the hamoor (*Epinephelus coioides*), remain in UAE waters throughout the year.

Overall, the biomass of demersal species in UAE waters (particularly those of commercial importance) is not high.

Table 3 shows the estimated seasonal biomass range of the various demersal components for all UAE waters deeper than 10 meters measured during the project. Of the biomass estimates shown in Table 3, commercial species (i.e. the 20 key study species) ranged from approximately 10,800t in October 2002 to 26,300t in February 2002 (Figure 14) while all demersal fish species (commercial plus non-commercial) ranged from 24,900t in October 2002 to 41,500t in February 2002. Total demersal organisms recorded by acoustic data ranged from 18,000t to 98,000t.

In the East Coast areas (i.e. Stratum 6 of Figure 2) the biomass of commercial species was low, ranging from 140t in March 2002 to 610t in November 2002 whereas the biomass of all demersal fish species (commercial plus non-commercial) ranged from 590t in March 2002 to 4350t in November 2002.

Table 3: Comparisons of biomass estimates for demersal species for all areas of UAE waters deeper than 10meters, based on a combination of trawl and fish trapping data.

	Biomass (Arabian Gulf area), t	**Biomass (East Coast), t**
Commercial demersal species (1)	10800 – 26300	140 – 610
Total commercial plus non-commercial demersal species (2)	24900 – 41500	590 – 4350
Total non-commercial demersal species (2 – 1)	14100 – 15200	450 – 3740

4.3 Small pelagic biomass

The abundance and distribution of small pelagic species in UAE waters was measured using acoustic techniques between March 2002 and January 2003. The techniques involved in the data collection and analysis have been described above.

4.3.1 Identification of species

The identification of small pelagic species and relating individual acoustic marks to specific species or species groups required two conditions to be met:

1. Marks seen must be identifiable and distinguishable from other marks. This ‘acoustic signature’ of marks is a combination of the shape, location, configuration and general physical attributes of the marks as well as the acoustic characteristics such as the mean volume backscattering strength (Mean Sv), and target strength (TS).

2. Identifiable marks must be able to be related to species (including sizes) by either capturing samples of the fish from recorded marks or in other ways observing the species and size characteristics.

Based on the acoustic and physical characteristics of marks recorded during the survey, analysis of acoustic data collected by the project resulted in the identification of 7 distinct and consistently identifiable marks.

These 7 species or species groups were as follows:

“Baitfish”. This group produced a mark which occurred in the upper half of the water column and at the surface and was usually dense and ball or ellipsoid-shaped. Although the school size was generally small, larger schools were observed, particularly in Strata 4 and 5 (Figure 2) during the spring months. Based on both midwater trawl catches and also on underwater video recording, this species group was characterized as ‘baitfish’ consisting of small sardine and anchovy-like species of the genus *Dussumieria* and *Encrasicholina*, less than about 5cm in length.

“*Decapterus spp*.” was similar in school characteristics to baitfish and exhibited a balling, dense structure. However, it was characterized by occurring most often in the lower half of the water column and also by very different acoustic characteristics. Sampling of this species was undertaken using the pelagic net on the vessel with catches of Indian scad (*Decapterus russelli*) being taken. Direct observations using the underwater video equipment confirmed this identification. However, other species of *Decapterus* (which occur in the market) may be associated with this acoustic mark. During the project, this species was rarely seen in depths greater than 100 meters and, when it did occur, the schools were small and isolated.

“Species 2” had a much looser and open school structure than baitfish or *Decapterus* although the school shape was often rounded. In the majority of observations, this species was located in the lower part of the water column and was associated with schools of *Decapterus*. Underwater video recordings of this species in January 2003 confirmed the identity of this species as a very small (1-4cm), sardine-like species although the species could not be determined from the recordings.

“*Alepes spp*.**”** forms a characteristic dense, vertical school shape in mid-water and was rarely seen near either the surface or the bottom. A number of individual schools were often seen together. Underwater video was used to identify this species as attempts to capture the species using midwater trawling proved unsuccessful because the schools dispersed very easily. Using the underwater video equipment on the vessel, this species was identified during the cruise in January 2003 as *Alepes melanoptera* or the blackfin scad.

“Ctenophores”, or comb jellies, was a disaggregated species, forming only a weak school structure and was often found scattered over large areas, particularly in Strata 1 and 2 (Figure 2). It was only rarely observed in Strata 4 and 5 in the Northern Emirates and never in Stratum 6 on the East Coast. The ‘schools’ were mostly in mid-water and, characteristically, rose during the day and descend in the water column during darkness. Underwater video equipment was deployed into schools of this species in Stratum 1 and the ‘schools’ identified as concentrations of ctenophores. This observation coincided with previous attempts to capture this species using the pelagic net with resulting catches of ctenophores and salps only.

“Barracuda” forms characteristic vertical schools, often very dense, rising from the seabed. The height of the schools can be up to 15 meters although 5 meters was an average height. This species was identified from trawl catches as schools of barracuda, *Sphyraena qenie* with the identification having been confirmed on approximately 30 occasions during the project.

“Jellyfish**”** was only noted on the East Coast in deeper waters (greater than 100 meters) and forms characteristic, dense bands in the lower part of the water column, near the bottom. The bands often extended over tens of kilometers. Trawl catches in these deeper waters where such bands occur took quantities of a dense black jellyfish, species unknown.

4.3.2 Target strength of identified species

Target strength (TS) values for the 7 identified species or groups were measured and estimated in two ways. First, values of TS were obtained from the literature. Secondly, as part of the acoustic survey procedures, measurements of TS were made during cruises using the capabilities of the Simrad EK-60 sounder.

A literature search for the relevant species was carried out, and for species where no published estimates were found, the target strength was estimated based on the fish size, shape, swimbladder and target strength of similar species. Published estimates were found for numerous fish under the generic names of sardine, anchovy, and mackerel, but how relevant these are to the sardine-like and mackerel-like fish of interest is unknown. No estimates were found for barracuda.

In the absence of any information to the contrary, the slope of the length to target strength relationship was taken to be 20, as this has some basis in the physics of acoustic scattering from fish, and most species for which data are available have a relationship with a slope close to 20. A value for the intercept was obtained by reference to the data presented in Nakken & Olsen (1977), where target strength data from 17 species are presented, and regressions provided for five of these species. The mean intercept at 120 kHz was –61 (from their Table 14), and applying the 6 dB adjustment postulated in the paper to allow for the difference between maximal and tilt-averaged target strength one obtains a value of –67. This value is an estimate only and to reflect this, a subjective bound of ±6 dB is applied. Hence the length to target strength relationship for all species at 120 kHz was estimated to be:

$$TS = 20\log_{10} l - 67 \pm 6,$$

where l is the fish length in cm, and TS the fish target strength in dB.

Published estimates at 120 kHz were found for one of the species of interest – *Decapterus russelli*, but were reported for only a single length (Cotel & Petit 1995). The measurements were from fish in a cage and yielded a TS of –47.7 dB for a length of 16cm. It was not clear whether this was fork or total length. This data point is consistent with the generic relationship presented above.

Several measurements of echosounder integrator output to fish weight relationships for the species of interest were found in the literature. However, these are in a form (dB per kg of fish, specific to the echosounder used) that cannot be converted into the length/TS form that modern acoustic analysis techniques require.

Table 4 summarizes these results from both the literature and from measurements made during the course of the project. The values of TS in Table 4 have been used in subsequent analysis for the estimation of seasonal changes in biomass (see above).

Table 4: Mean Values of target strength (TS) used to estimate biomass of the seven identified small pelagic species and species groups.

Species/Species Group	Mean TS (dB)
Baitfish (anchovy/small sardine species)	-88.0
Decapterus spp.	-70.5
Species 2	-90.0
Alepes spp.	-65.1
Ctenophores	-85.3
Barracuda	-50.0
Jellyfish	-95.1

Note: These values were primarily based on *in situ* TS measurements.

4.3.3 Biological characteristics of identified species

Samples of the 7 identified species and species groups were captured whenever possible and the size composition and length/weight relationships calculated for each species. These data were subsequently used to convert Acoustic Backscattering Coefficient (ABC) data to biomass estimates for each stratum. Length/weight and size composition data for jellyfish or ctenophores were not collected.

Table 5 summarizes these data which were then subsequently used to estimate biomass by stratum for each of the identified species (see below).

Table 5: Length/weight and mean size information used to estimate biomass of small pelagic species from acoustic data.

	L/weight parameter 'a'	L/weight parameter 'b'	Mean size (cm)
Baitfish	0.0195	2.804	7.0
Decapterus spp	0.0126	2.963	16.5
Species 2	Assumed same as baitfish	Assumed same as baitfish	3.0
Alepes spp.	.0139	3.055	12.5
Ctenophores	Not estimated	Not estimated	4.0
Barracuda	0.0138	2.765	25.5
Jellyfish	Not estimated	Not estimated	10.0

4.3.4 Biomass estimates of small pelagic species

Using the acoustic data recorded from each transect for each stratum and the TS and biological data from Tables 4 and 5, biomass estimates by stratum have been calculated for each sampling month as detailed in the methodology.

The mean values of these biomass estimates within each of the major areas of UAE Arabian Gulf and East Coast waters are shown in Figures 15-21 while Figure 22 shows the total biomass of small pelagic fish species, calculated using the data from Figures 15-21 but excluding jellyfish and ctenophores.

In these Figures, Abu Dhabi Emirate refers to Strata 1, 2 and 3 of Figure 2, Northern Emirates refers to Strata 4 and 5 and the East Coast refers to Stratum 6.

Figure 15: Biomass changes of Baitfish (small sardine and anchovy species), March 2002 – January 2003.

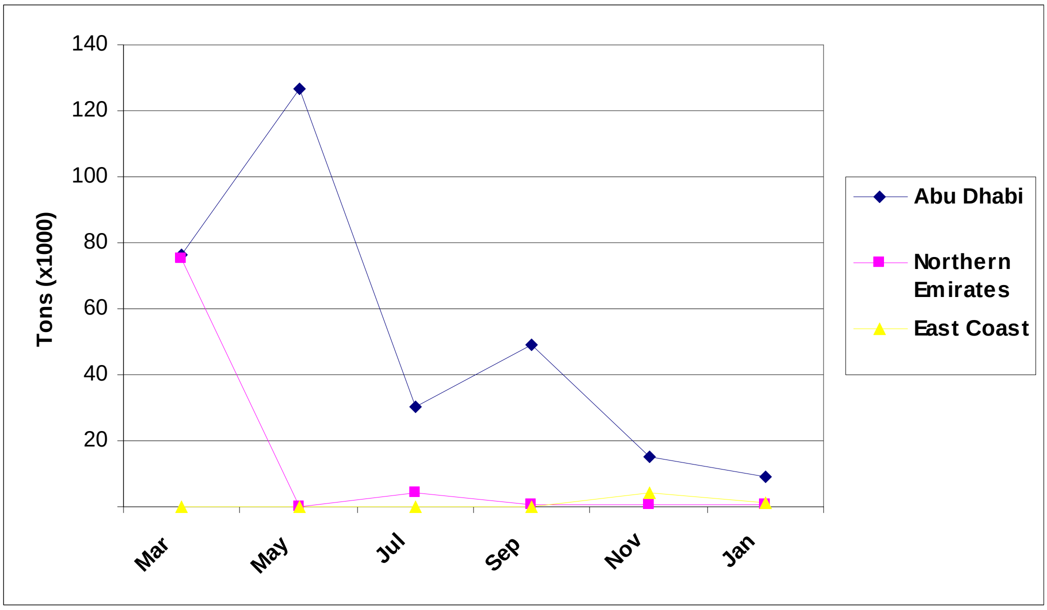


Figure 16: Biomass changes of *Decapterus spp*., March 2002 – January 2003.

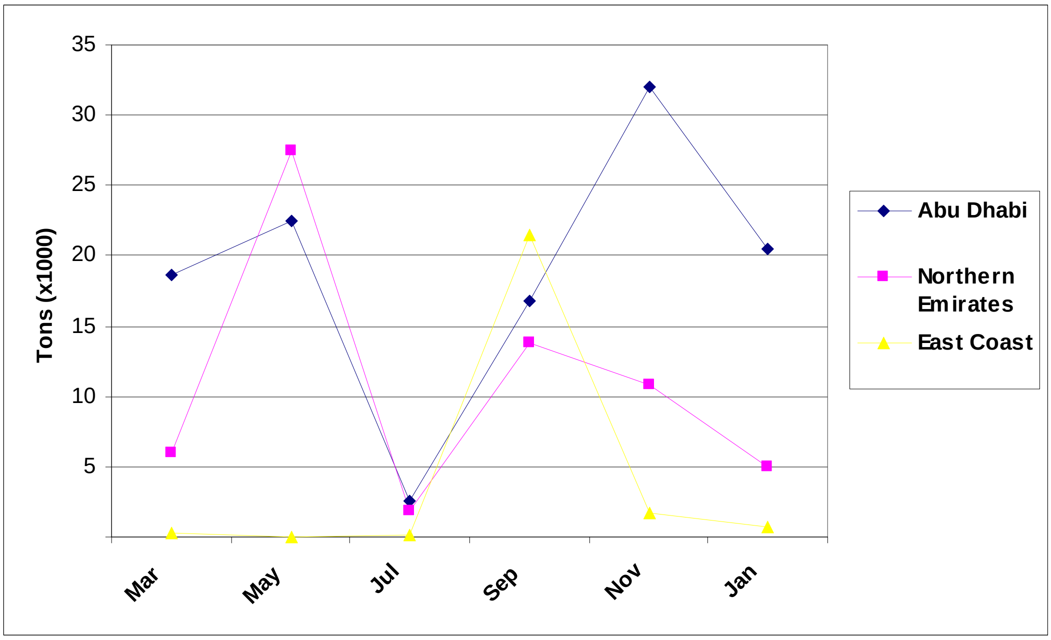


Figure 17: Biomass changes of Species 2, March 2002 – January 2003.

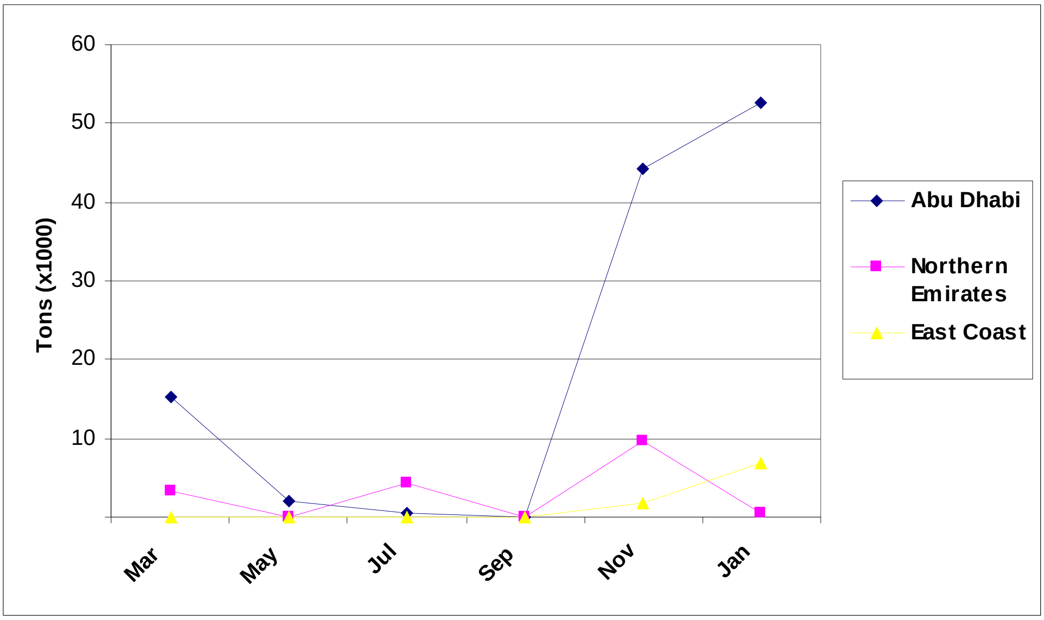


Figure 18: Biomass changes of *Alepes spp.*, March 2002 – January 2003.

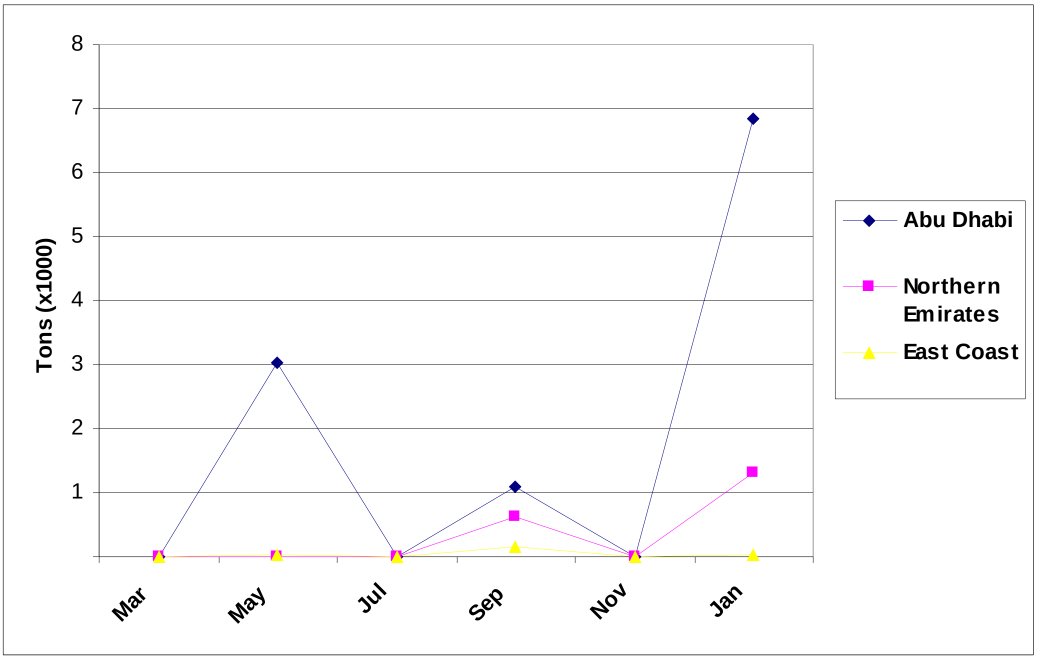


Figure 19: Biomass changes of ctenophores, March 2002 – January 2003.

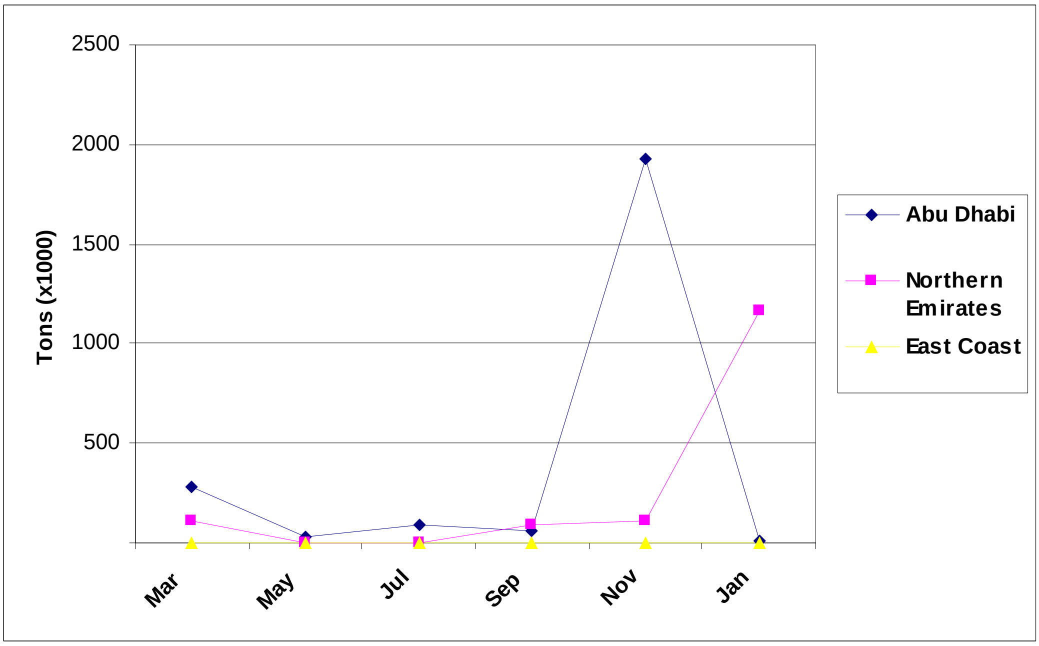


Figure 20: Biomass changes of barracuda, March 2002 – January 2003.

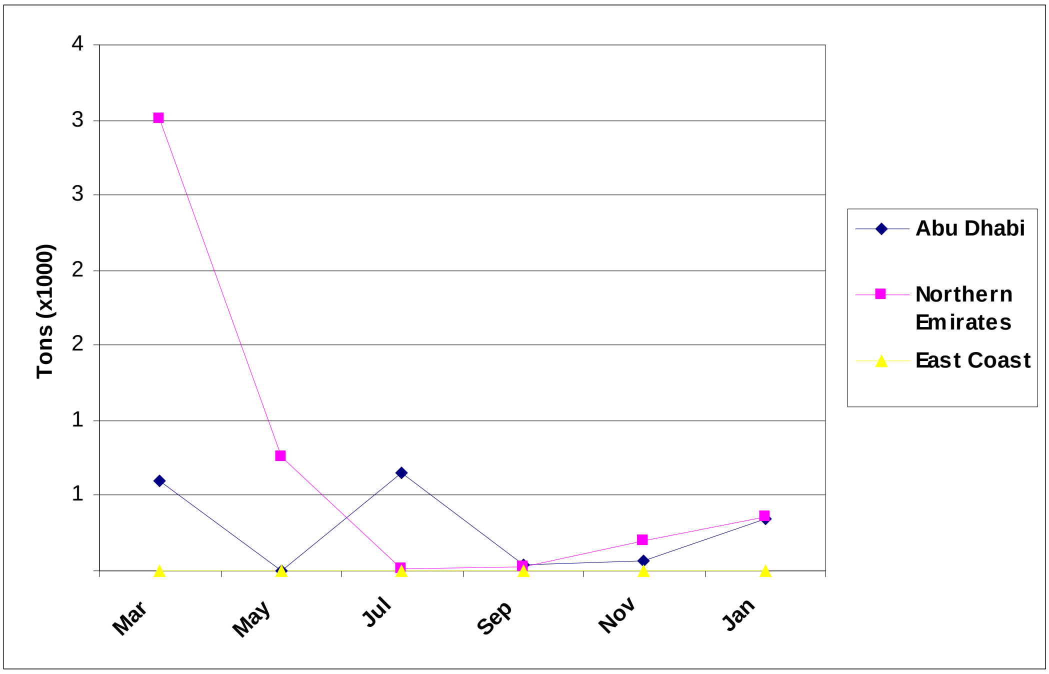


Figure 21: Biomass changes of jellyfish, March 2002 – January 2003.

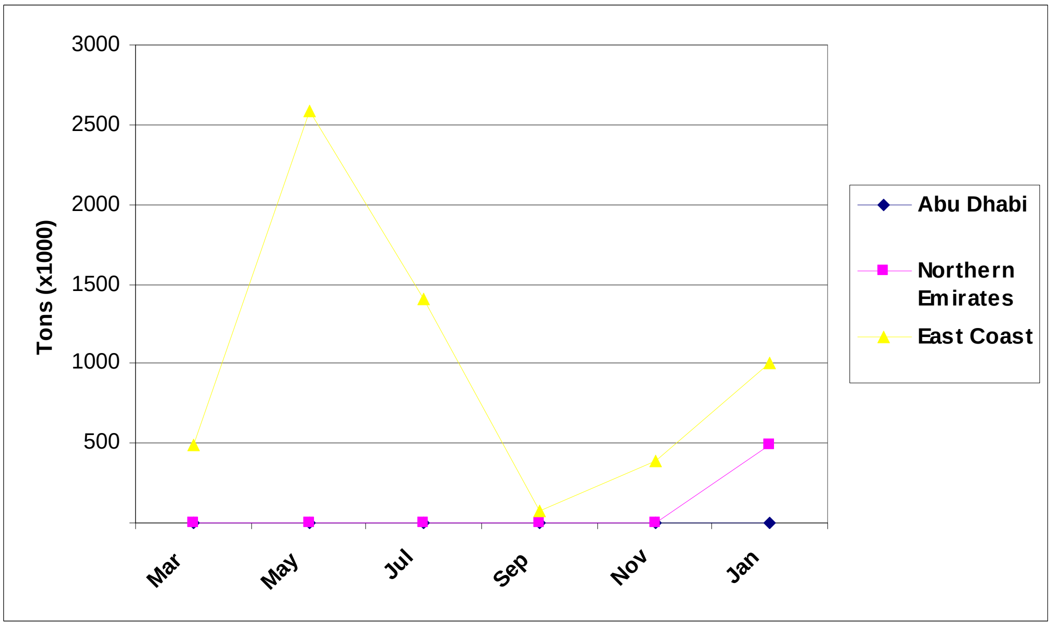
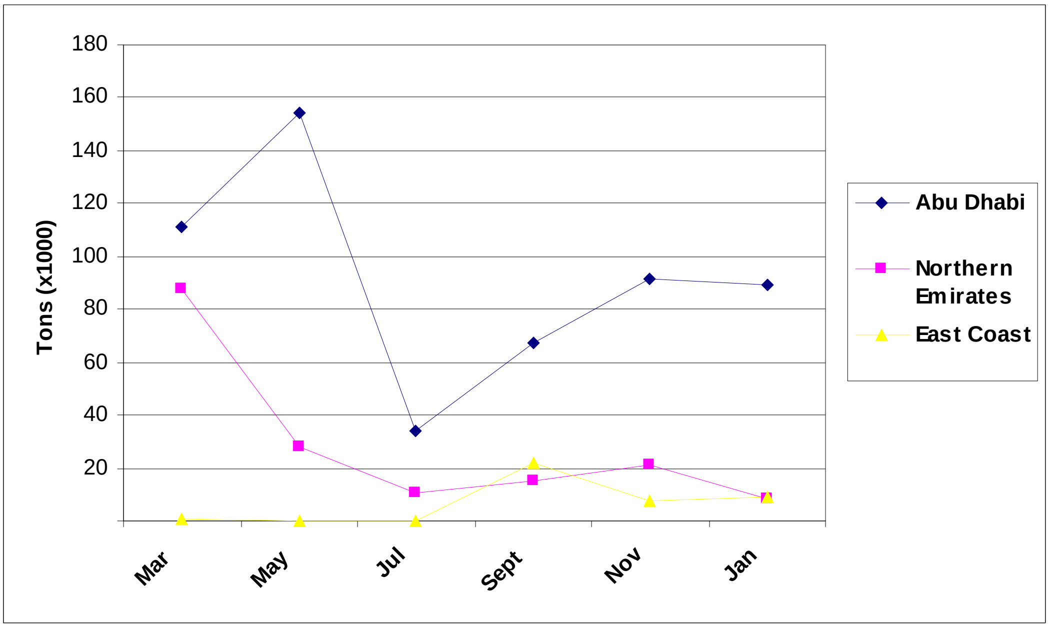


Figure 22: Biomass changes for all small pelagic species (excluding jellyfish and ctenophores), March 2002 – January 2003.



Figures 15-21 clearly show the strong seasonal patterns of abundance of these small pelagic species with peak biomass occurring for most species during the winter months in most areas.

Total biomass for all small pelagic species (excluding jellyfish and ctenophores) for the Arabian Gulf and East Coast areas of the UAE shown in Figure 22 again shows strong seasonality with biomass of small pelagic species peaking in the winter months and reaching a minimum during the summer months.

Overall, total biomass of these small pelagic species (the majority of which are non-commercial) peaks during March at around 200,000t and then declines significantly to 43,000t by July.

4.4 Stock assessment and modeling

4.4.1 Input parameters for modeling

4.4.1.1 Growth parameters

Using the results of the age and growth study, the Von Bertalanffy growth parameters used in the modeling of demersal species are shown in Table 6.

Table 6: Growth parameters estimated from age and growth studies used in the modeling of UAE demersal fish species. In all cases, non-seasonal growth was assumed.

Species	L (infinity)	K	t_0
Acanthopagrus latus	39.6	0.200	0.12
Acanthopagrus bifasciatus	33.9	0.212	-1.94
Argyrops spinifer	53.9	0.247	-0.36
Epinephelus coioides	166.6	0.238	-0.43
Lethrinus lentjan	36.5	0.361	-0.56
Lethrinus nebulosus	56.2	0.201	-0.99
Plectorhinchus pictus	60.1	0.352	-0.36
Plectorhinchus sordidus	Not assessed		

The growth parameters established for *A. bifasciatus*, *A. spinifer*, *L. lentjan*, *L. nebulosus* and *P. pictus* as part of this study were used since it was considered that reasonable growth parameters have been established for these species. Growth parameters for *A. latus* were taken from Morgan (1985) while *P. sordidus* was not assessed because neither this study nor any previous studies have established reliable growth parameters for this species. Growth parameters for *E. coioides* was taken as the mean of this study, Abdessalaam (2001), Mathews and Samuel (1987) and Edwards et al (1985) since the growth parameters for this species calculated from the current study relate to younger fish only.

4.4.1.2 Length/weight, size at first capture and size at first maturity data

Data on length/weight relationships from this study are shown in Table 7.

Table 7: Values of the length/weight parameters, a and b, the size at first maturity and the size at first capture (cm, FL) measured as part of the project and used in the modeling of UAE demersal fish resources. The length/weight relationship for all species is of the form W=a*L^b

	A. spinifer	*A. latus*	*A.bifasciatus*	*E.coioides*	*L.nebulosus*	*L. lentjan*	*P. pictus*	*P.sordidus*
A	0.032836	0.01362	0.015004	0.00971	0.02273	0.01555	0.011878	0.0318
B	2.912	3.145	3.157	3.0827	2.9333	3.0538	3.0463	2.766
Size at First Capture Lc	16	19	19	32	19	19	26	26
Size at First Maturity Lm	21.1	30.2	23.2	38.3	24.9	21.2	38.0	20.0

There is currently little information available on size at first capture by the commercial fishery for the species examined. (Grandcourt pers com) This gap in the knowledge of the interaction between the resources and the fishing industry should be a high priority for further investigation. Where information was not available, the data on the size composition of the commercial catch (where available) were used to estimate size at first capture from the approximate mid-point of the left-hand limb of the catch curve. These values are also shown in Table 7.

The size at first maturity for the species assessed was based on the information collected as part of the project. A logistical curve was fitted to the data for each species on percentage of mature animals within each 1cm size group and the size at 50% maturity calculated. These values for size at first maturity are also shown in Table 7.

4.4.1.3 Natural mortality

Natural mortality values have been estimated using the method of Pauly (1980) using a mean environmental temperature of 25°C and the growth parameters of Table 6. These values are shown in Table 8. The value of mean environmental temperature is lower than the 29.5°C used by Abdessalaam (2001) in recognition that most fish are present in UAE waters during the cooler winter months.

Table 8: Values of natural mortality rate, M, used in modeling of UAE fish stocks

Species	M
Argyrops spinifer	0.594
Acanthopagrus latus	0.564
Acanthopagrus bifasciatus	0.612
Epinephelus coioides	0.423
Lethrinus nebulosus	0.513
Lethrinus lentjan	0.849
Plectorhinchus pictus	0.726
Plectorhinchus sordidus	0.463

4.4.1.4 Calculation of total mortality values

The estimation of total mortality values (Z) for the species in question remains an extremely important and problematic issue.

The principle tool for estimating Z was an examination of the catch curve (either age-related or length-related) and the calculation of Z from the shape of the right hand limb of that catch curve. The important assumption in this analysis is that the population is being sampled representatively so that the age or length samples represent the actual structure of the population. This assumption can break down for a number of reasons including (a) aggregation of fish by age or size groups (shown for example, for *L. nebulosus* by Ibrahim et al 1988) (b) Selective sampling by the fishing gear (c) size or age-specific migration into UAE waters.

It is clear from the results of the study that many of the species (*A. latus*, *A. bifasciatus*, *P. pictus*, *A. spinifer*) show highly seasonal peaks in abundance with these peaks in abundance being probably related to spawning activity. For these species, the use of data from the right hand limb of the catch curve will very likely result in an under-estimate of Z because mature (spawning) fish will be over-represented in the sample. For more mobile fish, even if Z can be estimated accurately, the values will reflect the mortality of the fish over the whole of their range, not just in the UAE.

The analysis of catch curves to estimate Z based on commercial or trawled samples from the UAE (and taking into account the mobile behaviour of some species for spawning) may therefore result in an underestimation of Z for those species that are migrating into UAE to spawn and an over estimation of Z for at least some the more resident populations.

The results of biological studies undertaken as part of the project have shown that the issue of representative sampling of the population of demersal species remains a significant problem in the UAE. The reasons for this are the mobile nature of many of the species and the apparent separation of at least some species by size and/or age classes (e.g. *E.coioides*, this study, *L. nebulosus*, Ibrahim 1988b). However, by using the estimated values based on the age-related catch curve, a recognition of the probable under- and over-estimation of Z for mobile and non-mobile species (see above) and previous studies within the region, composite estimates of the values of Z for most species have been arrived at. These are shown in Table 9.

Table 9: Estimates of current values of Z for the 8 key study species. These values are based on the age-related catch curve of this study, together with previous studies of these species within the region.

Species	Estimated Z	Comments
Argyrops spinifer	0.76	This study, recognizing probable underestimation from catch curve; also similar to estimates by Edwards et al, (1985).
Acanthopagrus latus	0.70	Morgan (1985) and Mathews and Samuel, (1991)
Acanthopagrus bifasciatus	0.70	This study, recognizing probable underestimation from catch curve
Epinephelus coioides	0.66	This study, recognizing probable overestimation from catch curve
Lethrinus nebulosus	0.79	This study plus Ibrahim et al (1988) and Al-Sayes et al (1988)
Lethrinus lentjan	0.95	This study, recognizing probable underestimation of Z from catch curve
Plectorhinchus pictus	0.90	This study, recognizing probable underestimation of Z from catch curves.
Plectorhinchus sordidus	Not assessed	

It should be stressed however, that these are estimates only, based on a compilation of studies (including this one) but nevertheless they provide the most comprehensive available estimates of likely values of Z for the population of the key study species in the UAE waters.

4.4.2 Modeling results for demersal species

Given the uncertainty of estimates of total mortality, modeling of the populations of the key species is done with caution. Modeling results are only as good as the input parameters and, since the input parameters (including Z and size at first capture) are uncertain, the modeling results should be used with caution. However, the results of the modeling indicate general directions for management.

The modeling results are shown in Tables 10-12, with Table 11 showing the impacts of changes in fishing effort and Table 12 showing the impacts of changes in size at first capture.

Table 10: Modeling results for each of the key study species showing the present state of exploitation, the estimated sex ratio of the catch and the percentage of the maximum spawning biomass present.

Species	% Exploitation rate	% of males in catch	% of maximum spawning stock.
Argyrops spinifer	21.8	43	80.14
Acanthopagrus latus	19.4	42	83.70
Acanthopagrus bifasciatus	12.6	43	89.22
Epinephelus coioides	28.4	51	73.19
Lethrinus nebulosus	35.1	43	68.67
Lethrinus lentjan	10.6	49	88.20
Plectorhinchus pictus	19.3	41	79.42
Plectorhinchus sordidus	Not assessed		
Mean (mobile species)	18.3		
Mean (resident species)	24.7		

Table 11: Modeling results showing the impact on catches and spawning stock levels of changes in relative fishing effort, leaving the size at first capture at the present levels.

Argyrops spinifer

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.30	1.14
0.50	0.56	1.08
0.75	0.79	1.04
1.00	1.00	1.00
1.25	1.19	0.95
1.50	1.35	0.88
2.00	1.64	0.74

Acanthopagrus latus

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.30	1.17
0.50	0.57	1.09
0.75	0.81	1.05
1.00	1.00	1.00
1.25	1.22	0.94
1.50	1.40	0.87
2.00	1.72	0.72

Acanthopagrus bifasciatus

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.28	1.09
0.50	0.53	1.06
0.75	0.77	1.03
1.00	1.00	1.00
1.25	1.21	0.96
1.50	1.41	0.90
2.00	1.78	0.80

Epinephelus coioides

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.35	1.22
0.50	0.61	1.15
0.75	0.82	1.07
1.00	1.00	1.00
1.25	1.16	0.93
1.50	1.30	0.85
2.00	1.53	0.66

Lethrinus nebulosus

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.34	1.29
0.50	0.61	1.18
0.75	0.82	1.08
1.00	1.00	1.00
1.25	1.15	0.92
1.50	1.28	0.83
2.00	1.48	0.61

Lethrinus lentjan

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.28	1.08
0.50	0.54	1.05
0.75	0.79	1.03
1.00	1.00	1.00
1.25	1.24	0.96
1.50	1.46	0.91
2.00	1.85	0.81

Plectorhinchus pictus

New spawning stock abundance (present level = 1.0)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
1.16	0.29	1.16
0.50	0.55	1.09
0.75	0.79	1.05
1.00	1.00	1.00
1.25	1.19	0.94
1.50	1.37	0.87
2.00	1.68	0.73

All species combined

Relative Fishing Effort (present level = 1.00)	New catch (present catch = 1.00)	New spawning stock abundance (present level = 1.00)
0.25	0.28	1.15
0.50	0.55	1.09
0.75	0.78	1.05
1.00	1.00	1.00
1.25	1.17	0.93
1.50	1.39	0.85
2.00	1.74	0.72

Table 12: Modeling results showing the impact of a 20% increase in the size of first capture (LC50) and a 20% decrease in the size of first capture for each of the key study species.

Species	**20% increase in L_{C50}**		**20% decrease in L_{C50}**	
	Catch change	**Spawning stock change**	**Catch change**	**Spawning stock change**
Argyrops spinifer	+3.6	+19.9	+0.4	-1.1
Acanthopagrus latus	+1.0	+17.4	-1.6	-0.6
Acanthopagrus bifasciatus	+0.4	+7.6	-2.9	-0.4
Epinephelus coioides	+5.2	+21.1	+0.8	-1.1
Lethrinus nebulosus	+6.0	+23.0	+1.0	-1.3
Lethrinus lentjan	+4.0	+13.2	+1.0	-0.6
Plectorhinchus pictus	+1.0	+15.3	-2.0	-0.8
Plectorhinchus sordidus	Not assessed			

4.4.3 Stock assessment of demersal species

The modeling results shown in Tables 10-12 were used to assess the stocks of the major demersal species and are of significant interest for a number of reasons:

Firstly, there is a clear difference in estimated exploitation rates (Table 10) between the more mobile species and the resident species with the resident species (such as hamoor, *Epinephelus coioides*) showing a significantly higher exploitation rate than the mobile species. This may be a real difference (it is not known whether the mobile species are exploited in other parts of their range) or it may be due to an underestimate of the value of Z for the mobile species and an over-estimate of Z for the resident species (see above). At the moment, it is not possible to separate these two alternatives.

Secondly, overall exploitation rates are moderate and significant but are not estimated to be at the extremely high levels reported by Abdessalaam (2001). These moderate rates of exploitation (and the resulting total mortality values) are more in keeping with the observed age composition of the catches with significant numbers of fish older than 7-8 years of age present in the population.

Thirdly, given that the size at first capture is very small for most species Abdessalaam, (2001), it is not surprising that an increase in the size at first capture would have significant benefits (Table 12). Abdessalaam, (2001) has reported that a large proportion of all commercial species landed in Abu Dhabi are immature fish with the situation being particularly critical for *Argyrops spinifer,* where more than 80% of the catch is immature fish.

One of the most important assumptions surrounding the modeling exercise is the issue of constant recruitment. There is no information available for any of the species as to how and if spawning stock biomass influences subsequent recruitment and therefore the only alternative has been to assume constant recruitment. This is clearly unrealistic since many studies on both finfish and crustacean stocks have shown the importance of spawning stock biomass and environmental variation on subsequent recruitment (e.g. Gulland, 1969, Pauly, 1996).

Potential yields of demersal species were estimated based on the modeling results. The maximum yield that could be taken from the 8 species modeled is approximately 35% higher than current (2002) levels. This yield could be achieved with a doubling of fishing effort and a 20% increase in the size at first capture from the 2002 level. However, such a strategy also reduces the spawning biomass by approximately 43% from current 2002 levels and is therefore a very high-risk strategy if future recruitment to the stocks is to be maintained.

Although a full stock assessment and modeling was carried out on 8 of the 20 key commercial species, it is likely that the broad directions for management for all commercial demersal species will be the same as for the 8 species studied in detail. In essence, these directions involve increasing the size of first capture of these commercial species which should result in the twin benefits of increased spawning stock biomass as well as slightly higher commercial catches.

Adoption of the high-risk strategy of increasing fishing effort to increase catches is not recommended since this would result in reduced spawning stock biomass, thereby threatening future recruitment.

Given the above, the potential sustainable yield that could be taken from the currently exploited species is probably not significantly higher than the current catch. There may be some scope for targeting presently unexploited resources (such as lizard fish, *Saurida spp*. and the *Nemipteridae*) although the exploitation of these resources would require changes to current fishing practices and perhaps the introduction of techniques such as trawling. The benefits gained from the introduction of such techniques to exploit additional resources should, however, be carefully weighed against the potential environmental damage that may result.

4.4.4 Stock assessment of small pelagic species

Modeling of the small pelagic resources to the same level as for demersals was impractical due primarily to the short life spans of the species identified during the survey However a stock assessment was carried out to provide insight into the potential yields from these resources.

Using the method of Gulland (1969) and of Beddington and Cooke (1983), together with values of the instantaneous rate of natural mortality calculated from Pauly (1980), estimates of the potential sustainable yield of the various species have been made. These estimates are shown in Table 13. . Where a group consists of a number of species, the arithmetic mean of the values of M has been used. Estimated biomass is the maximum biomass observed for each species. Because of the strong seasonality in abundance in UAE waters, the time of this maximum biomass varied between species. Therefore, the total value of 263,000t does not represent the abundance available in any one month. Species 2 is a small sardine-like species. Values of M for small *Stolephorus* and *Encrasicholina* species have therefore been used.

Table 13: Estimates of the potential sustainable yield of small pelagic species in UAE waters

Species/Species Group	**Estimated 2002 Biomass (t)**	**Estimated M (from literature)**	**Estimated Potential yield (t)**
Baitfish	150,000	2.80	42,000
Decapterus spp	50,000	1.55	8,000
'Species 2'	60,000	3.30	19,800
Alepes spp	3,000	1.65	500
Total	263,000		70,300

5 TRAINING AND CAPACITY BUILDING

Training and capacity building activities of the project revolved around two separate activities. First, formal training seminars were conducted on various aspects of the project's work and, secondly, counterpart staff participated in field cruises of the research vessel.

The following formal seminars and training sessions were undertaken:

- Project pre-start seminar was held on 30th January 2002 for ERWDA, Ministry of Agriculture and Fisheries and other Government organization staff. The seminar addressed the issues of survey design, objectives and analysis.

- Oceanography review and training seminar was held on March 19/20th 2002 by Dr. Fayza Yamani. This training had application to both the interpretation of fish distribution and abundance and also to the general oceanography of the region.

- Two specialist staff from NIWA provided training in (a) echoacoustics, including acoustic data analysis and (b) fish aging during the period 2-4th September 2002. The training provided hands on instruction for ERWDA, Ministry of Agriculture and Fisheries and other staff on these aspects that are related to demersal fish analysis.

- The research manager presented a training seminar to approximately 25 ERWDA, Ministry of Agriculture and Fisheries and other staff on 28th September 2002. The training seminar covered the concepts of fish population dynamics, parameter estimation and modeling approaches with an emphasis on how the data being collected by the project will be incorporated within a modeling approach for fish stock assessment.

- A second oceanography and plankton training workshop was held by Dr. Yamani on 13/14th January 2003 and included plankton identification issues as well as oceanographic analysis related to fish distribution and abundance.

Throughout the duration of the project, the opportunity was also provided for counterpart staff to participate in the activities of each research cruise so as to receive on-job training in the techniques of field data collection and the undertaking of demersal fish surveys. These opportunities were provided to ERWDA staff, staff of the Ministry of Agriculture and Fisheries and to other Government agencies.

In total, 18 individuals from 4 organizations took part in some aspects of the cruises. This resulted in a total of 210 person days of training provided on aspects of demersal surveys. The greatest number of these person days was by ERWDA staff (149) followed by the Ministry of Agriculture and Fisheries staff (51).

Training and capacity building activities of the project related to small pelagic species also involved the formal training seminars as outlined above, and secondly, counterpart staff participated in acoustic field cruises of the research vessel. The intensity of training activities in the undertaking of acoustic surveys and in subsequent data analysis was not as intensive as with the demersal trawl surveys, mainly because of the background and interests of counterpart staff and the lack of mathematical training (as opposed to biological training) of many staff.

Only 4 individuals from 2 organizations took part in some aspects of these acoustic field cruises, compared with a much larger participation in demersal trawl survey cruises. This resulted in a total of 22 person days of training that was provided on aspects of acoustic surveys.

The issue of developing specialist skills through continuous learning is particularly important in fisheries acoustics where considerable skill and experience is needed to not only operate the equipment and undertake analysis but, most importantly, to interpret the recordings in a consistent way. Given both the small numbers of counterpart staff participating in acoustic survey cruises and also the absence of full time involvement of any counterpart staff in the acoustics work, there remains a lack of skilled national personnel to continue this work. This is a disadvantage to the UAE because fisheries acoustics have the capacity to provide rapid and effective surveys of resources. Also, without the availability of specialist staff, the large amount of acoustic data and recordings collected by the project and deposited with ERWDA will be underutilized.

In summary it is recommended that future project training activities be undertaken in a more structured way by:

- Allocating counterpart staff for the duration of the project;
- Ensuring that the counterpart staff's job responsibilities (both present and future) match the training to be provided. This would ensure the long term development of specialist skills in the work of the project;
- Setting specific training goals to be achieved by the participants;
- Undertaking regular training reviews to ensure that the training being provided is appropriate to the needs of the individual and the organization and is effective in upgrading skills.

6 DISCUSSION AND CONCLUSIONS

The project has provided the first fisheries-independent survey of the UAE's demersal and small pelagic fish resources for some 25 years and also the first ever comprehensive survey of those resources, covering as it did all UAE waters for an entire year. The results were able to be compared with the results of the last survey undertaken by the Food and Agriculture Organization of the United Nations, FAO, in 1978 (FAO, 1981a and b).

The oceanographic environment that the demersal and small pelagic fish species of the UAE inhabit was found to comprise two very different water bodies. On the one hand, the high salinity, shallow waters of the UAE's Arabian Gulf coast exhibit extreme seasonal fluctuations in hydrography that are characteristic of shallow embayments. On the other hand, the deeper waters of the East Coast exhibit oceanographic characteristics that are much more like open ocean conditions with only small seasonal fluctuations in hydrographic conditions.

The interesting area hydrologically is where these two water bodies meet near the Straits of Hormuz and the Northern Emirates. This area exhibits characteristics that are, as one would expect, a mixture of the two water bodies.

The general oceanographic conditions in the UAE were found to be characterized by:

- Generally extreme conditions within the Arabian Gulf area, with a high seasonal range of surface water temperatures and salinities. Summer water temperatures reached 35°C during the mid-summer months of August/September while surface salinities were also high, at over 40 ppt. In winter, surface temperatures dropped to 21-22°C giving a seasonal range of some 14 degrees. This is extreme for a marine environment and is much more characteristic of an estuary or shallow embayment. Surface salinities remained high throughout the year and were in excess of 39 ppt.

- Complete mixing of the water column within the Arabian Gulf area throughout the year, in particular in Abu Dhabi Emirate. In Abu Dhabi Emirate, water depths are generally shallow at less than 20 meters and it is therefore not surprising that such complete mixing occurs.

- In the East Coast Emirates, much more oceanic conditions prevail. Although inshore, surface water temperatures and salinities exhibit large seasonal fluctuations, bottom water temperatures in the area remain almost constant throughout the year with a range of only 1-2 degrees C. Surface salinities are generally much lower than in the Arabian Gulf region and exhibit only a small seasonal range.

- The Northern Emirates exhibit characteristics of both the Arabian Gulf waters (as shown by the waters off Abu Dhabi Emirate) and of the more oceanic Arabian Sea environment off the East Coast. During some months, there is good vertical mixing of the water column with surface and bottom water temperatures being similar while in other months, a distinct stratification is evident. While surface salinities are generally lower than bottom salinities, these surface salinities are intermediate between the oceanic conditions of the Arabian Sea (around 35-36 ppt) and the more extreme salinities of Abu Dhabi Emirate where surface salinities rarely drop below 39 ppt.

Therefore, the results showed that the study area is comprised of three very different hydrological zones: (1) The oceanic East Coast (2) the embayment-like Abu Dhabi Emirate (Strata 1,2 and 3 of Figure 2) where extreme seasonal variations in hydrological conditions predominate and (3) the mixing zone of the Northern Emirates (Strata 4 and 5 of Figure 2).

Biomass of important demersal species was measured across all areas (trawlable and non-trawlable) of the UAE using a combination of trawling, fish trapping and acoustic methods. Fish trapping provided useful additional data on the distribution and abundance of many of the key species and how distribution varied between trawlable and non-trawlable areas.

Overall, total and relative (t/sq. km) biomass of demersal species is small to moderate when compared with the sea area and with the reported commercial catches of demersal species (FAO, 2001). Total biomass estimates of the 20 key study species (which comprise the majority of the commercial species of demersal fish) did not exceed 16,000t in trawlable areas and 26,000t over all areas (Figures 8 and 14). During the study period *Lethrinidae* comprised the bulk of this biomass. For the summer months, estimates of the total biomass for the 20 key study species decreased significantly to around 11,000t, with Abu Dhabi Emirate showing the greatest decline.

When compared with the results of the 1978 FAO study of demersal resources of the region (FAO, 1981a) the biomass of all major species and species groups show large declines, particularly on the East Coast. Biomass density of the major species and species groups (expressed in tons/ sq. km) from the 1978 and the current survey is presented in Table 14.

Several interesting features are apparent from Table 14. First, declines in biomass of both commercial and non-commercial species since 1978 are particularly evident in the East Coast areas where current total biomass is around 7% of the biomass in 1978. The decline in the deeper water areas seems very pronounced where currently there are practically no fish resources compared with the very high biomass estimates (>6 tons per sq. Km) in 1978.

The Arabian Gulf waters of the UAE have also shown major declines in fish abundance with current biomass density estimates at around 19% of the 1978 values. Most interestingly, this decline in biomass has occurred for both commercial and non-commercial species (although a precise comparison is difficult because of the uncertain nature of what constituted a ‘commercial’ species in the 1978 survey). The only species group that has maintained the levels of the 1978 biomass is the *Mullidae*, a non-commercial species in UAE.

Table 14: Biomass density estimates (t/sq. km) of demersal species (based on trawl surveys) from the current survey and the demersal fisheries survey of 1978 (FAO, 1981a).

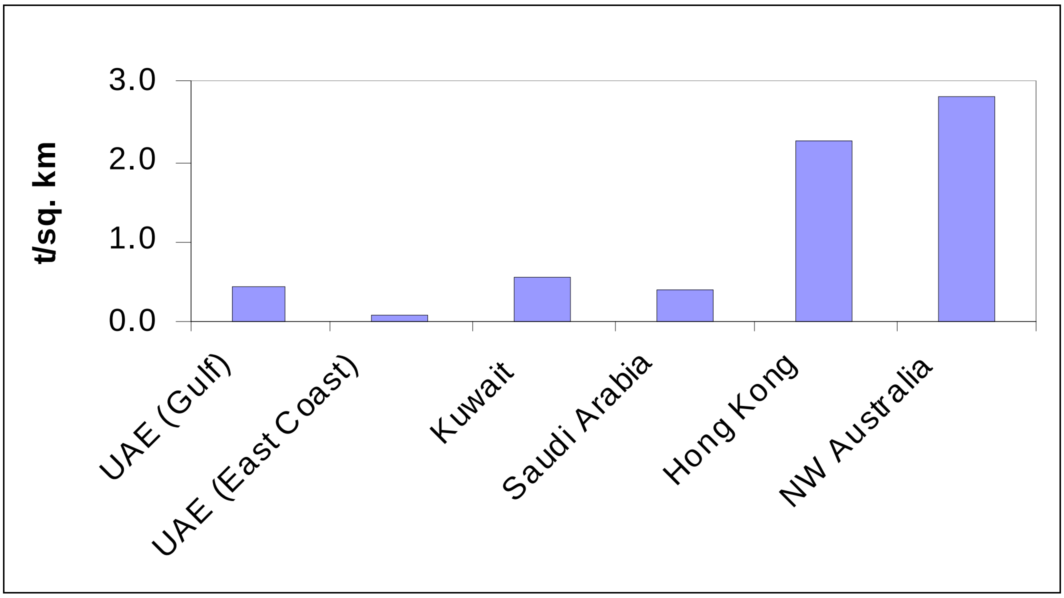
Species/Species group	Biomass - Arabian Gulf Waters (t/km^2)		Biomass - East Coast (t/km^2)	
	1978	2002	1978	2002
Carangidae	0.8-1.0	0-0.02	>1.0	0-0.01
Epinephelus spp	0.25-0.30	0.02-0.04	0.20-0.25	0-0.01
Haemulidae	0.01-0.05	0	0.20-0.30	0
Lethrinus spp	0.60-0.90	0.05-0.16	0.40-0.50	0-0.04
Lutjanus spp	0-0.05	0-0.02	>0.5	0-0.71
Mullidae	0-0.2	0.10-0.19	0-0.2	0.01-0.47
Nemipteridae	>1	0.19-0.26	>1.0	0-0.01
Synodontidae	0.40-0.50	0.02-0.18	0.20-0.30	0.01-0.11
Total non-commercial	2.0-3.0	0.44-0.53	2.0-3.0 (>6 in deeper waters over 50 meters)	0.03-1.04 (<0.02 in deeper waters)
Total Commercial	2.0-3.0	0.26-0.65	4.0-5.0	0.03-0.16
Total (all species)	4.0-6.0	0.70-1.18	8.0-10.0 (>10 in waters over 50 meters)	0.06-1.20
% of 1978 biomass present in 2002 **of commercial species** (mean & range).		15.2% (13-22%)		2.1% (0.8-3.2%)
% of 1978 biomass present in 2002 **of non-commercial species** (mean and range).		19.4% (18-22%)		21.4% (1.5-34.6%) (<0.3% in deeper waters)
% of 1978 biomass present in 2002 **of all species** (mean & range).		18.8% (17-20%		7.0% (0.8-12.0%)

The reasons for these declines are not known. The decline on the East Coast is particularly dramatic and parallels similar declines that have been noticed on the North East Coast of Oman and in the Arabian Gulf generally over the past decade (Siddeek, et al; 1999).

Siddeek et al (1999) suggested that declines in demersal fish stocks within the Arabian Gulf are a result of the combination of nursery area degradation, pollution and over-exploitation. The current study does not provide any evidence to the contrary.

Compared with other regions around the world, the biomass density of demersal species is medium to low. The average annual total demersal biomass density for the Arabian Gulf regions of the UAE was found to be 1.11t per square km. while the average biomass density for the East Coast areas is 0.63t per sq. km. This is compared with estimates from other similar regions and species assemblages shown in Figure 23.

Figure 23: Demersal biomass density (t/sq km.) for commercial species measured in UAE waters and other areas.



Modeling of some of the most important commercial demersal species showed that, theoretically, the present commercial catch could be increased by approximately 35% over 2002 levels by a combination of a:

(a) 20% increase in the size of first capture, and

(b) doubling of fishing effort from the 2002 level.

However, this is an extremely high-risk strategy because, with such management measures, spawning stock biomass of these major species would be reduced by around 43% from current levels. Such a significant reduction in spawning stock abundance would most likely be unsustainable and would adversely affect future recruitment, leading to long term biomass and catch reductions.

The study therefore concluded that the level of sustainable catch from the demersal resources that are currently exploited is probably not significantly higher than the present catch. In fact, given the declines in biomass that have already occurred (Table 14), a prudent strategy would seem to be to move towards increasing the spawning stock biomass of the major demersal species.

Modeling undertaken as part of the project showed that the most effective way of increasing this spawning biomass in the long term would be to increase the size at which fish are caught by the commercial fleet. This would inevitably involve changes to currently used fishing gear and, in particular, the use of a larger mesh size in fish traps (gargoor).

The study identified only two species that would seem to have potential for further development. *Saurida tumbil*, the giant lizardfish is abundant, largely unexploited and is a prime species in countries of South East Asia (e.g. Pitcher et al, 1997). This species could provide a substantial additional resource for the UAE although the current prohibition on trawling may have to be lifted in order for it to be exploited.

Secondly, the barracuda, *Sphyraena qenie* is also abundant and may be underexploited.

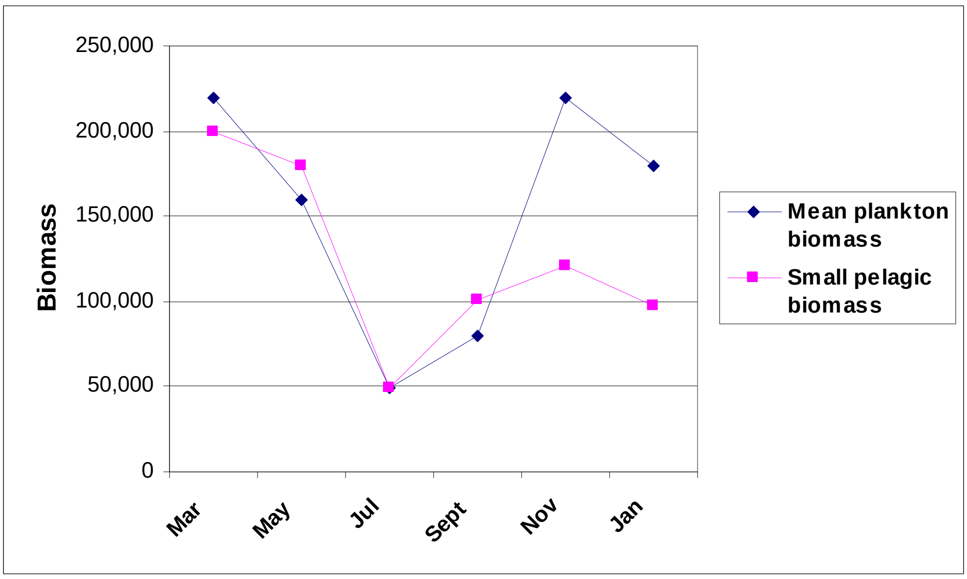
In addition to these two species (which were the subject of specific study by the project) there may be other opportunities. Several species of *Nemipteridae* were captured during the trawl survey in significant quantities and, although biomass estimates were not made for these species, their potential may be worthy of further investigation. Table 14 shows that the potential sustainable yield of all small pelagic species found in UAE is estimated to be in the order of 70,000t with the majority of this potential being in the baitfish resources.

However, to realize this potential may be extremely difficult and perhaps not desirable. The small pelagic species provide a food source for the large pelagic stocks in UAE waters and hence the development of any major fishery on these small pelagic resources may have unknown impacts on the abundance of large pelagic species.

These species are known to show, characteristically large fluctuations in year-to-year abundance as a result of oceanographic conditions. Since no continuous monitoring of these resources in UAE waters is in place, the extent of such year-to-year fluctuations is not known. The development of a market for some of these species also poses challenges.

Seasonality of abundance of small pelagic species was shown to be a significant feature in the UAE. In general, biomass estimates peaked during the late winter period and were minimal in summer. Seasonality in biomass of small pelagic species followed the changes in plankton biomass that was recorded as part of the project. Figure 24 provides data on total plankton biomass compared with total small pelagic biomass. From this figure, the concordance between the seasonal patterns of plankton and small pelagic biomass is apparent.

Figure 24: The relationship between the total biomass of small pelagic fish and biomass of zooplankton. Pelagic fish in tons, plankton in mg/600,000 ml.



The geographical distribution of small pelagic species varied both with season and place. Species such as jellyfish were only recorded on the East Coast (Stratum 6 of Figure 2) where they formed extensive bands in 100-200m of water. However, of the baitfish, *Decapterus* and *Alepes* species, the Strata 4 and 5 in the Northern Emirates (Figure 2) were found to have the greatest density of fish at the peak of the season of cyclical abundance. This distribution coincided with the distribution pattern of chlorophyll-a and phytoplankton biomass which was greatest in the northern Emirates areas. However, because of the larger geographical area of Abu Dhabi Emirate (Strata 1, 2 and 3 of Figure 2), the total biomass of small pelagic species was greatest in that Emirate.

The present survey has also documented the small school size of many of these small pelagic species (which was also noted during the FAO survey of 1978). This small school size could prove a major hindrance to the development of any fishery on these species.

In summary, the study has found:

1. The Arabian Gulf area of the UAE is a significant spawning area for both highly mobile and resident demersal species.

2. There have apparently been major declines in the abundance of demersal species, both commercial and non-commercial, since 1978 in both the Arabian Gulf and the East Coast. The deeper water areas of the East Coast seem to have been most affected by this decline.

3. Potential sustainable yields from currently exploited demersal species are probably no greater than current levels. In fact, it is considered that the current management emphasis for these demersal species should be on increasing spawning stock levels so as to ensure long-term sustainability. Modeling undertaken as part of the project showed that the most effective way of achieving this is by increasing the size at which the fish are captured.

4. There may be some opportunity for harvesting presently unexploited species such as lizard fish (*Saurida spp*) and *Nemipteridae*. However, exploiting these species may involve introducing potentially undesirable fishing practices such as trawling.

5. Management measures that achieve an increase in the size of first capture of demersal species would increase both spawning stock abundance and catch more effectively than changes in fishing effort.

6. The abundance of small pelagic resources does not appear to have changed significantly since 1978 and estimates of potential yield from these resources are in the order of 70,000t. However, achieving these yields may not be practical or desirable.

7. School size of small pelagic species is very small, making commercial exploitation difficult.

These major conclusions of the study have important management implications.

Like all management, the management of fisheries is always undertaken with imperfect information. This does not, however, prevent effective management but rather points to the direction where additional research and other information is needed to make the existing management regime even more effective. This approach of recognizing that management is still needed even though information might not be complete or comprehensive is summarized in FAO's Code of Conduct for Responsible Fisheries, which was adopted by the 28th Session of FAO in 1995. This states, among others, that lack of complete information should not be an excuse for a lack of management.

The UAE has suffered for many years because of a lack of information on its fisheries resources. What information was available often came incidentally from surveys that were part of Arabian Gulf-wide investigations. As a result, fisheries management has been not only difficult but also ineffective.

With the completion of this project which has provided the first comprehensive survey of the UAE's demersal and small pelagic resources, the broad directions for long term sustainable management are clear.

The study has shown that there are very few species (hamoor being a possible exception) that lie wholly within the jurisdiction of the UAE. Rather, it is clear from the results of this (and other) studies that both the demersal and small pelagic fish resources occurring in the UAE are almost certainly part of larger stocks that inhabit the Arabian Gulf and, for many species, are probably closely connected with the stocks in the Arabian Sea. Extensive movement of both demersal and small pelagic species into and out of UAE waters (documented by this project) is a significant characteristic of many of the fish stocks occurring in the UAE .The UAE therefore cannot manage these stocks in isolation. Regional co-operation is essential.

One mechanism for such regional co-operation is the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and the various international agreements (for example, and pertinent to the UAE's situation, the Agreement on Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks) that comes under the umbrella of UNCLOS. To date the UAE has not ratified UNCLOS.

It is therefore recommended that, for better long-term management of the UAE's fish stocks, the UAE examines mechanisms for regional co-operation in fisheries management, perhaps through the mechanisms provided by UNCLOS, which could provide the umbrella framework for such regional co-operation.

While regional co-operation in management is essential, the present study has also highlighted the importance of the Arabian Gulf waters of the UAE as a spawning and nursery area for many demersal fish species. Many of the species studied as part of this project move into UAE waters (usually in winter) to spawn. This imposes significant additional responsibility on the UAE to protect these areas for the benefit of the stocks as a whole and not only that portion of the stock that occurs in UAE waters.

The study has shown that demersal fish resources in both the Arabian Gulf and East Coast areas of the UAE appear to have declined significantly since 1978. While the impact of fishing may have been a contributing factor to this decline, other causes cannot be ruled out. There is an urgent need to better understand the role that UAE waters have in providing a spawning and nursery area for these regional fish stocks and for minimizing the impacts of coastal development and other activities on these spawning and nursery areas.

To this end, management approaches (such as an ecosystem-based approach) that address the integrated nature of fisheries and the inter-dependence of fish stocks on the marine and coastal environment appear particularly appropriate in the UAE. The framework for such ecosystem-based approaches to fisheries management has been formulated in the UN Rio Declaration relating to Ecological Sustainable Development (ESD) and such an ESD-based approach may be relevant for the UAE.

The establishment of marine protected areas in the UAE seems to be a step in the right direction. However, better information is needed as to the importance of these marine protected areas for demersal fish.

By contrast with the declines shown in demersal fish abundance, it appears from the study that the abundance of small pelagic species is of the same order as it was in 1978. However, the further development of this fishery may be neither desirable nor practical, particularly given the lack of markets for the more common species and the practical difficulties of generally small school sizes making capture in quantities difficult.

The project has provided the information base on the demersal and small pelagic fish resources of the UAE to enable effective management decisions to be taken to address long term sustainability issues. However, effective long term sustainable management of the UAE’s fisheries resources first of all requires a clear vision as to what are the objectives of management.

Once the objectives are clear, then the methods for achieving (and for monitoring progress towards) those objectives become easier to formulate and easier to communicate to those involved in the industry.

It is recommended that the most effective way of achieving a clear vision of the objectives of management in the UAE is for the preparation of Management Plans for each of the major fisheries of demersal, small pelagics and large pelagics. Once objectives are agreed upon, the monitoring of progress towards those objectives becomes simpler, but also essential.

Such a planned approach using tools such as fishery management plans is a common feature of other countries’ fisheries management arrangements. These are usually developed in those countries through a close dialogue between Government and industry. In this way, the objectives of management become shared objectives with all parties moving towards the same goals.

Without a clear statement of the objectives of fisheries management through such management tools as management plans, there is no way for the Government or others (including fishermen) to know whether management of fisheries resources is being carried out successfully.

It is therefore also recommended that the UAE develop Management Plans for its three major fisheries of demersal, small pelagics and large pelagics. These Management Plans should contain, at a minimum:

- a clear set of objectives for management (which can include the objective of biological reference points),

- an implementation plan which explains what processes are to be put in place to achieve the stated objectives (including monitoring, surveillance and research) and

- a system of monitoring progress towards those objectives.

Suggested frameworks for management plans for demersal species and small pelagic species have been recommended as part of the project. A further framework for a management plan for large pelagic species needs to be completed although this was outside the scope of the present project.

The two management plan frameworks provided as part of the project, address two very different situations. For demersal resources, the emphasis of the management plan should be on stock-rebuilding since all the evidence suggests that the demersal species have declined significantly since 1978. This rebuilding strategy includes plans for increasing the abundance of the spawning stock by:

(a) better protection of juvenile fish, and

(b) a closer examination of the reasons for the decline in demersal resources, including the issue of coastal habitat loss and its influence on demersal stock abundance.

By contrast, the emphasis of the management plan for small pelagic resources could be on developing the fishery rather than rebuilding or constraining it since all the evidence points to the stock levels being more or less the same as in 1978. Despite the occurrence of small pelagic resources in the UAE, there has however been no successful (although there have been several unsuccessful) attempts at exploiting these resources.

However, to realize this potential may be extremely difficult and perhaps not desirable. The small pelagic species provide a food source for the large pelagic stocks in UAE waters and hence the development of any major fishery on these small pelagic resources may have unknown impacts on the abundance of large pelagic species.

These species also show, characteristically, large fluctuations in year-to-year abundance as a result of oceanographic conditions. Because of these fluctuations and market uncertainty, the management approach for the small pelagic fishery will need to be based on a careful consideration of the options as the first stage of the planned management approach.

7 REFERENCES

Abdessalaam, T. bin Z. 2001: Population dynamics of some demersal fishes off Abu Dhabi. *Environmental Research and Wildlife Development Agency* (ERWDA) Internal report, 11pp.

Al-Sayes, A.; Al-Sedfy, H.; Al-Mulla, A. 1988: Some biological characters of *Lethrinus nebulosus* (Forskal) in the Arabian Gulf. *Bulletin of the National Institute of Oceanography and Fisheries Egypt 14*: 227–237.

Ali, R.M. 1987: An outline of fisheries development in the UAE. *INFOFISH International*. Kuala Lumpur, no. 5, pp. 34-35,

Anon 1974: Experiment fishing. Arabian Gulf fishery-oceanography survey by the Umitaka-Maru, training-research vessel, Tokyo University of Fisheries with collaboration of Kuwait Institute for Scientific Research, December 1968. no. 1, [Tokyo Suisan Daigaku Tokubetsu KenkyuHokoku/Trans.Tokyo Univ.Fish.]. Oceanography and fisheries of the northern Arabian Gulf with special reference to Kuwait waters.

Beddington, J.; J.G. Cooke 1983: The potential yield from a fishery. *FAO Fish. Tech. Pap. 242*, Rome, 47pp.

Cotel, P.; Petit, D. 1995: TS measurements in the Java Sea on *Decapterus russelli*, *Selar crumenophtalmus*, and *Rastrelliger kanagurta*. Presented at the ICES International Symposium on Fisheries and Plankton Acoustics, Aberdeen, 12-16 June 1995. Poster presentation.

Edwards, R.R.C.; Bakhader, A.; Shaher, S. 1985: Growth, mortality, age composition and fisheries yields of fish from the Gulf of Aden. *Journal of Fish Biology 27*: 13–21.

FAO, 1981a: Demersal resources of the Gulf and the Gulf of Oman. Regional Fishery Survey and Development Project. FI:DP/RAB/71/278/10. 122p.

FAO, 1981b: Pelagic Resources of the Gulf and the Gulf of Oman. Regional Fishery Survey and Development Project. FI:DP/RAB/71/278/11. 143p.

FAO, 2001: Annual Yearbook of Fisheries Statistics: Catches and Landings. FAO, Rome.

Francis, R. I. C. C. 1981: Stratified random trawl surveys of deep-water demersal fish stocks around New Zealand. *Fisheries Research Division Occasional Publication No. 32*. 28p.

Francis, R. I. C. C. 1989: A standard approach to biomass estimation from bottom trawl surveys. N.Z. Fisheries Assessment Research Document 89/3. 4 p. (Draft report held in NIWA library, Wellington.)

Froese, R; D. Pauly, (Eds) 2003: FishBase. World Wide Web electronic publication. www.fishbase.org, version 19 February 2003.

Gulland, J. 1969: Manual of methods for fish stock assessment, Part 1: Fish population analysis. *FAO Man. Fish. Sci. 4*:154pp.

Ibrahim, M.A.; El-Bary, K.A.; Al-Khayat, J.A. 1988: Stock assessment and management of *Lethrinus nebulosus* (Family Lethrinidae) of Qatar waters, Arabian Gulf. *Bulletin of the National Institute of Oceanography and Fisheries Egypt 14*: 99–111.

Johannesson, K. 1991: Assessment of the major marine fish stocks of demersal, small pelagic and mesopelagic species of the Sultanate of Oman. *FAO Technical Report FI/DP/OMA/88/005*. 231pp.

Mathews, C.P.; Samuel, M. 1987: Growth, mortality and assessments for groupers from Kuwait. *Kuwait Bulletin of Marine Science 9*: 173–191.

Messiah, S.N. 1983: Fisheries in the UAE: Present status and future outlook. FAO/UNDP, Rome (Italy), 1983, 65 pp.

Morgan, G.R. 1985: Assessment of sheim (*Acanthopagrus latus*) in Kuwait waters. In Mathews, C.P. (ed.), Final Report: *The proceedings of the 1984 shrimp and fin fisheries management workshop. Kuwait Institute for Scientific Research*. pp. 116–124.

Nakken, O.; Olsen, K. 1977: Target strength measurements of fish. *Rapports et Procès–verbaux des Réunions. Conseil Permanent International pour l'Exploration de la Mer **170***: 52–69.

Pauly, D. 1980: On the inter-relationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. Int. Explor. Mer. 39(3)*: 175-192.

Pauly, D. 1996: Biodiversity and the retrospective analysis of demersal trawl surveys: a programmatic approach. *In* D. Pauly and P. Martusobroto (Eds); Baseline studies of biodiversity: the fish resources of western Indonesia. *ICLARM Stud. Rev*. 23: 312pp.

Pitcher, T.J; R. Watson, A. Courtney; D. Pauly 1997: Assessment of Hong Kong's Inshore Fisheries Resources. Fisheries Centre, University of British Columbia Report, 81pp.

Siddeek, M.S.M., Fouda, M.M.; Hermosa, Jr G.V. 1999. Demersal fisheries of the Arabian Sea, the Gulf of Oman and the Arabian Gulf. *Estuarine, Coastal and Shelf Science, 49:* 87-97.

Subba Rao, D.V; F.al-Yamani 2000: The Arabian Gulf *in* C. Sheppard (Ed) Seas at the Millennium: An environmental evaluation. Pergamon Press.

Vignaux, M. 1994: Documentation of Trawl Survey Analysis Program. MAF Fisheries Greta Point Internal Report No. 225. 44 p. (Draft report held in NIWA library, Wellington.).

8 GLOSSARY

Term	Description
Acoustic survey	High–tech sonar equipment used to find schools of fish and estimate the total weight. Sound waves are sent out from a research vessel, strike schools of fish and are reflected back. As the energy of the sound waves is known it is possible to estimate the biomass.
Amateur fishers	Fishers that fish for fun, sport or to obtain food for themselves and their families. Also known as recreational fishers or anglers.
Aquaculture	The farming of fish or shellfish. The most common species currently being farmed are mussels, oysters and salmon. Also known as marine farming.
Aquatic Ecosystem	The natural systems of interacting aquatic life within the biological and physical aquatic environment.
Aquatic Environment	The natural and biological resources comprising any aquatic ecosystem, including all aquatic life and the oceans, seas, coastal areas, intertidal areas, estuaries, rivers, lakes and other places where aquatic life exists.
Beach seining	A fishing method where a net and a length of rope are laid out from and back to the shore and retrieved by hauling on to the shore.
Billfish	These are species such as marlin and sailfish that have an elongated, sword-like or spear-like snout and upper jaw.
Biodiversity	The continued existence of the full range of genetic material, species and ecosystems.
Biomass	The sum of the weight of all fish in a stock.
Bony fish	These fish have a bony skeleton and a single pair of external gill openings.
By-catch	These are the other fish species, birds and marine mammals that fishers may catch while targeting a specific species.
Catch per unit of effort	CPUE: These values are obtained by dividing the catch by a measure of the fishing effort required to catch it.
Closed areas	Area where form of restriction applies. For example, some areas may be closed to all fishers to protect juvenile fish and local reef species. Others areas may be closed to certain types of commercial bulk fishing methods e.g. trawling, but not to other more targeted types of fishing such as longlining.
Closed seasons	Some areas are closed for a specific time to protect the fish stocks by reducing the opportunities people have to fish them.
Commercial fisher	A person that fishes for a living.
Continental shelf	A submerged border of a continent that slopes gradually and extends to a point of steeper descent to the ocean bottom.
Continental slope	The descent from the continental shelf to the ocean bottom.
CPUE	Catch per Unit of Effort: These values are obtained by dividing the catch by a measure of the fishing effort required to catch it.
Crustaceans	These are mainly aquatic animals with gills and a dorsal carapace or shell, e.g. crabs, lobsters, shrimps etc.
Declining fishery	The state a fishery is said to be in when a fish stock is overfished.
Demersal fish	Bottom feeding fish.
Density	The number of individuals that may be present in each unit of area.
Depletion	The gradual use or consumption of a resource, especially a natural resource.
Developing fishery	A fishery where there is a period of low catches followed by a rapid rise in catches. This may be because a new stock of a known species has been found, or a new species discovered or because catching and processing technologies and/or new markets have developed.
Distribution	The way individual fish of a species are spread through an area.
Drift netting	A fishing method used for catching pelagic fish, the vessel remains tied to one end of the net to stop it drifting too far. Fish swim into the net and are caught behind the gills.
Echo sounders	An instrument that sends out an acoustic pulse in water and measures distances in terms of the time for the echo of the pulse to return.
EEZ	Exclusive Economic Zone:

Term	Description
Term	**Description**
Enhancement	Work done to build up “wild” stocks. Can involve releasing hatchery-reared young into the wild or providing additional protection to naturally spawned juveniles.
Finfish	True fish, as distinguished from shellfish.
Fish stock	A group of individuals of the same species which are living together in the same area and can intermingle and interbreed freely. Different stocks of the same species, e.g. snapper, can be genetically different.
Fishery	A general term for the combination of fishers, vessels and fishing gear involved in catching fish from a stock, as well as the fishing grounds and the catch.
Gamefish	Fish hunted for sport.
Gear restrictions	These are usually imposed to protect young fish, e.g. mesh size restrictions, net size restriction and restrictions on how a net can be set, or to limit by-catch problems.
Habitat	Where organisms live.
Input controls	These are attempts to control fishing effort, e.g. limited licensing/ permitting, gear restrictions, closed fishing grounds and closed seasons.
Intermittent cycles	A pattern of fish stock population stability where periods of high abundance are followed by collapse.
Invertebrates	Animals that have no spinal column.
Marine reserves	These are places where all fishing is prohibited to preserve areas for scientific study of marine life.
Maximum Sustainable Yield	MSY: The largest average annual catch that can be taken over time without reducing the stock’s productive potential.
MAY	Maximum Average Yield: Average of a sequence of CAYs.
MCY	Maximum Constant Yield: The catch that is estimated to be sustainable with an acceptable level of risk at all probably future levels of biomass.
MEY	Maximum Economic Yield: Marginal cost = marginal revenue i.e. if effort is increased the additional revenue is less than the additional cost.
Mollusc	Invertebrate having a soft unsegmented body usually enclosed in a shell.
Mortality	Death rate.
MSY	Maximum Sustainable Yield: The largest average annual catch that can be taken over time without reducing the stock’s productive potential.
Natural mortality	Deaths from disease or predation.
NIWA	National Institute of Water and Atmospheric Research: A Research Institute that carries out a large amount of fisheries research under contract to New Zealand the Ministry of Fisheries.
Non-commercial fishing	Recreational and customary fishing.
Offal	The waste parts of a cleaned fish.
Open access fishery	A fishery without controls. Can lead to over-capitalisation and over-harvesting of fisheries.
Otolith	Part of the inner ear of the fish important for balance and hearing. This grows from the centre out in a series of daily rings and seasonal bands or growth zones. Otoliths can be used to help identify the age of fish.
Output controls	These are attempts to control the catch level of a fish stock, e.g. all forms of quota.
Overcapitalisation	Occurs when too much fishing effort goes into a fishery.
Overfishing	Occurs when the aggregate harvest of a fish stock exceeds the total allowable catch (TAC)for that stock.
Pair trawling	A fishing method where two vessels tow a large netting bag (trawl net) behind them. (Compare with single trawling).
Pelagic fish	Surface feeding or free swimming fish. (Compare with demersal fish)
Phytoplankton	Minute, free-floating aquatic plants
Plankton	Simple forms of life stimulated to grow and multiply by light and nutrients in the water. Base of the marine food chain.
Productivity	The rate at which fish stock produces young.
Purse seining	A fishing method where a net is laid in a circle around a school of fish and then the bottom is drawn closed, entrapping the fish.
Reclamation	This is where shallow marine areas have been built up to create extra land.
Recreational fisher	Fishers that fish for fun, sport or to obtain food for themselves and their families.

Term	Description
	Also known as amateur fishers or anglers.
Recruitment	This is when fish come into the fishery and are big enough to catch. Sometimes this is just a question of them growing bigger, but sometimes fish migrate from one habitat to another.
Regular cycles	Patterns of fish stock population stability where annual catches vary, but monthly catches are seasonal, reflecting each year's growth and mortality.
Salinity	Salt content of seawater.
Scarcity	Insufficiency of amount or supply.
Set netting	A fishing method where a net is placed in the water with floats at the top and weights on the bottom. Fish are caught as they swim into the net.
Shellfish	An aquatic animal, such as a mollusc or crustacean, that has a shell or shell-like exoskeleton.
Single trawling	A fishing method where a single vessel tows a large netting bag (trawl net) behind the vessel. (Compare with pair trawling)
Size limits	These are imposed on most species to protect fish stocks.
Sonar	Can be used to measure the density of fish layers under water by transmitting sound waves.
Spawning	The production of eggs.
Spawning grounds	The areas that a fish stock or species will move to, to spawn.
Species	Living things, which can interbreed.
Steady state	A pattern of population stability where the size and catch remain within about 25 percent of the long-term-average, or the catch increases steadily with moderately increasing fishing pressure.
Stock enhancement	Work done to build up "wild" stocks. Can involve releasing hatchery-reared young into the wild or providing additional protection to naturally spawned juveniles.
Sustainability	Maintaining a population at levels so that exploitation does not affect its reproductive ability and genetic diversity.
TAC	Total Allowable Catch: Total quantity of each fish stock that can be taken by both commercial and non-commercial (or amateur) fishers to ensure sustainability of that fishery.
Tagging	Process where scientists catch fish record their physical characteristics, tag the fish and release them. When fishers catch tagged fish they return the tags (and if possible the fish) with information on the fish and where the fish was caught.
Total Allowable Catch	TAC: Total quantity of each fish stock that can be taken by both commercial and non-commercial fishers to ensure sustainability of that fishery.
Trapping	These are fishing methods where traps are made from a steel frame covered with wire mesh. They are baited with fish and dropped from the boat on the end of a rope long enough to reach the bottom. The position of the pot is marked with a float.
Trawl surveys	Scientists catch fish with a trawl net and record what they catch and note the changes when they fish the same area later.
Trawling	Fishing methods where a single vessel or a pair of vessels tow a large netting bag (trawl net) behind the vessel.
Trolling	A fishing method where baited hooks or lures are towed behind a vessel.
Turbidity	Muddiness created by stirring up sediment.
UNCLOS	United Nations Convention on the Law of the Sea: This enabled countries to establish an EEZ out to 200 nautical miles.
Undersized fish	Fish that do not meet the legal size limit for that fish stock.
Underwater filming	This assists in the monitoring of stocks. Fish can be filmed up to 1200 meters below the surface.
Upwellings	Occurs when the wind blows surface water out to sea and deeper water moves up to replace it.
Zooplankton	The animal variety of plankton. These are mainly small crustaceans and fish larvae. Zooplankton graze on phytoplankton.