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NEWSLETTER OF THE RESEARCH AND MONITORING SECTION

REEF RESEARCH

Great Barrier Reef Marine Park Authority

VOLUME 3 – No. 1 MARCH 1993

EDITORIAL

Welcome once more to Reef Research.

One aspect of the Great Barrier Reef Marine Park Authority (GBRMPA) of which readers may not be aware is its status as a Registered Research Agency (RRA). RRAs are organisations that have applied to, and been accepted by, the Australian Industry Research and Development Board and are eligible to either conduct or manage research that, if it meets certain guidelines, will attract a one hundred and fifty per cent tax concession.

The Board has agreed that GBRMPA has specific expertise in the following fields: fisheries management and fish biology; inorganic marine chemistry; computer hardware, software and security; environmental management particularly in the fields of experimental design, impact assessment, social surveys, tourism planning and water quality; coral reef and other environmental ecology; population assessment and technologies associated with petroleum, waste management and general pollution control. All clients of GBRMPA contracting research in these categories may be eligible for the tax concession. There are no upper or lower limits for expenditure on a project for the concession to apply and intellectual property rights will be retained by the organisation contracting the work whether it is actually carried out by GBRMPA or subcontracted.

If you think that you have an R and D project that could be managed for you by GBRMPA then the contact in the Research and Monitoring Section is Ray Berkelmans. Full details are available from the Australian Industry Research and Development Board, GPO Box 2704, Canberra City, ACT, 2601.

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The Editor REEF RESEARCH
Great Barrier Reef Marine Park Authority
PO Box 1379
TOWNSVILLE QLD 4810
FAX:(077) 72 6093

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Assistant Editor.....Trish Drury
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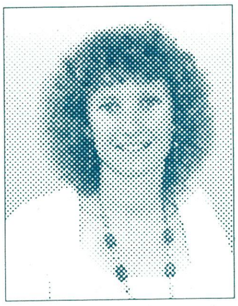
WHAT'S IN THIS ISSUE

RESEARCH AND MONITORING SECTION STAFF

Simon Woodley	Director, presently guest lecturer at JCU
Jon Brodie	Acting Director and Coordinator - Water Quality
Steve Hillman	Acting Senior Project Manager and Editor, Reef Research
Andy Steven	Project Manager - Water Quality
Brian Lassig	Coordinator - Crown-of-thorns Starfish
Udo Engelhardt	Project Manager - Crown-of-thorns Starfish
David Lawrence	Coordinator - Torres Strait Baseline Study
William Gladstone	Project Manager - Torres Strait Baseline Study
Vic McGrath	Assistant Coordinator - Torres Strait Baseline Study
Bruce Mapstone	Coordinator - Effects of Fishing
John Robertson	Project Manager - Effects of Fishing
Janine Kuhl	Assistant Project Officer - Effects of Fishing
Leon Zann	Coordinator - State of the Marine Environment Report
Elaine Eager	Project Officer - State of the Marine Environment Report
Jamie Oliver	Acting Coordinator - Monitoring
Ray Berkelmans	Project Manager - Monitoring
Lea Scherl	Project Manager - Human Use / Social Impact
Dominique Benzaken	Assistant Project Officer - Human Use / Social Impact
Steve Raaymakers	Project Officer - Oil Spills & Sea Dumping Seconded to QDEH to be EnvironmentalSupervisor for the Townsville Port Development
Jamie Storrie	Acting Project Officer - Oil Spills & Sea Dumping
Christine Dalliston	Assistant Project Officer
Beryl Dennis	Administration Assistant
Trish Drury	Administration Assistant & Assistant Editor, Reef Research

DR LEA M. SCHERL



Lea coordinates the Human Use/Social Impact program of the Research and Monitoring Section. She has been with the Authority since July 1990. Her general area of expertise is social sciences in resource management and more specifically the public participation process, outdoor recreation/tourism research and planning and management, social impact assessment, human use of outdoor environments, organisational behaviour and group dynamics. Her Ph.D. from James Cook University was in the discipline of environmental psychology. Her previous degree and coursework were more in the area of management and organisational behaviour.

Before joining GBRMPA Lea was working as an environmental consultant for resource management agencies in Queensland. Lea has had an active interest and involvement in a wide range of environmental policy and management issues, particularly in Queensland, and brings a social perspective to these issues. Currently, she is also the social sciences representative on the Scientific Advisory Committee of the Wet Tropics Management Authority.

UDO ENGELHARDT

Udo has been with the GBRMPA since January 1988 when he joined the interpretive section of the Great Barrier Reef Aquarium. He was actively involved in both the preparation of interpretative materials as well as the conduct of public presentations on *reefy* issues. Since November 1990 he has been employed as a marine biologist in the Research and Monitoring Section of the Authority. He is now the project manager of the Authority's crown-of-thorns starfish research program. Udo has a wide ranging interest in aspects of coral reef ecology, however, his *pet* area is in the role of predator-prey relationships and their effects on coral reef communities. Udo is currently studying toward a Master's degree in Tropical Marine Ecology and Fisheries Biology.

EFFECTS of fishing

THE CATCH TO DATE

John Robertson

The Effects of Fishing Programme is now into its second year of research. Much of the research programme, however, did not commence until early to mid 1992, resulting in research projects having either just been completed or field sampling continuing into early 1993. The progress of each of the projects presently funded under the Effects of Fishing Programme is as follows:

Visual Surveys of Cairns Section Closed Reefs Opened under the New Zoning Plan, Dr Tony Ayling of Sea Research.

In January 1992, Tony Ayling conducted baseline surveys on five protected Marine National Park B reefs in the Cairns Section, that were to be opened to fishing under the new zoning plan, and on five open 'control' reefs. Surveys were conducted using underwater visual census and were aimed primarily at large reef fishes targeted by commercial and recreational fisherfolk, including coral trout and all lutjanid and lethrinid species. In addition, surveys were made of potential prey species (pomacentrids), other important reef organisms (chaetodontids, crown-of-thorns starfish, giant clams) and hard and soft coral.

The pre-opening survey found that for the common coral trout (*Plectropomus leopardus*) there was no difference in the length or the number of fish between open and closed reefs. A 30% difference was noted, however, in the numbers of the blue-spot coral trout (*Plectropomus laevis*) on closed as opposed to open reefs. The red-throat sweetlip (*Lethrinus miniatus*), another prime target for both commercial and recreational fishermen, as well as the yellow-tailed emperor (*Lethrinus atkinsoni*) had significantly higher densities on protected reefs compared to fished reefs.

A post-rezoning survey, 12 months after the baseline survey, is proposed for early February 1993. The post-rezoning survey will quantify changes in densities of the same fish and coral communities, after the reefs have been open to commercial and recreational fishing for approximately 11 months.

Effect of Zoning Changes on the Fish Populations of Unexploited Reefs, Dr Ian Brown of Queensland Department of Primary Industries (QDPI).

The project aims to assess the effect of fishing on the population age structure of the serranid, lethrinid and lutjanid species targeted by both recreational and commercial fisherfolk. The project compliments the underwater visual surveys being undertaken by Dr Tony Ayling.

In Stage I of the project, the pre-opening assessment, sampling was conducted by line and spearfishing in February 1992 on two pairs of reefs in the Cairns Section. Each pair of reefs comprised one reef (zoned Marine National Park A) which was open to fishing and one reef (Marine National Park B) which was closed to fishing but opening with the introduction of the new Cairns

Zoning Plan. Diver counts by this team indicated a greater abundance of coral trout (*P. leopardus*) on closed reefs than on open reefs which does not confirm the Sea Research surveys. The blue-spot trout (*P. laevis*) was significantly more numerous on closed reefs. Analysis of the population age structure of coral trout showed that fewer fish in age classes 1-3 were captured by line fishing than by spearfishing. A greater proportion of the total catch on open reefs belonged to these early age classes than was the case at the closed reefs.

The second stage of this study, the post-rezoning assessment, will involve a re-assessment of the demersal fish populations, principally coral trout and stripeys, at the same four reefs. The re-surveys will be 12 months after the initial assessment and some 11 months after the closed reefs were officially opened to fishing under the new Cairns Section Zoning Plan. It is hoped that, with information on fishing effort over the last 12 months, changes in population age structure density can be related to exploitation levels.

Development of Trap and Drop-Line Sampling Techniques for Reef Fishes, Dr Dave Williams of Australian Institute of Marine Science.

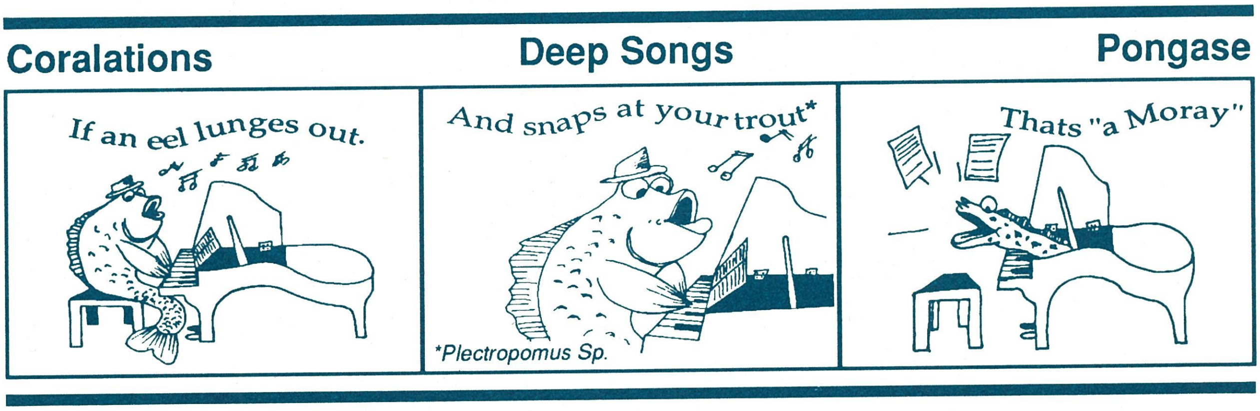
Since part of the pilot phase of the 'GBR Experiment' is to develop and refine sampling techniques the team led by Dave Williams have been evaluating the feasibility of using trap and drop-line techniques to sample reef fish populations at depths beyond the effective depth limit of SCUBA, and on reef slopes and rough bottoms inaccessible to trawling. Trapping trials were carried out on Rib and Davies Reefs at depths of approximately 40m. Drop-line sampling, carried out simultaneously with trapping on Davies Reef resulted in very low catch rates and the value of this technique for future systematic sampling on monitoring of reef fishes is being considered by the group.

Over 1,000 fish, mostly lutjanids and lethrinids were caught using traps during ten days sampling at each reef. Catch rates of traps, however, were characterised by a dominance of zero catches, by low means, and high variances. The group considers that traps are an effective monitoring tool if large amounts of time are available to sample in each critical habitat or each reef. The group believes that traps are the most effective sampling tool for most snappers, emperors, nocturnal species and others below divable depths.

A workshop on trapping techniques was convened by GBRMPA in September 1992 to discuss the effectiveness of traps as sampling tools and the major sources of bias and variation associated with their use. The workshop was very successful in that the major problems associated with trap sampling were identified and possible solutions were discussed. The workshop also suggested directions in which the development of trap sampling methodology should proceed so as to be suitable for effects of fishing research.

Inter-reef Movements of Large Reef Fishes, Campbell Davies of James Cook University.

The study commenced with an initial tagging exercise in April 1992 on the southern cluster of the effects of fishing experimental reefs. Commercial reef line fisherfolk were employed to capture the fish which were tagged by personnel from JCU. The perimeter of each reef was divided into blocks and the total fishing effort was distributed as evenly as possible between



the blocks on each reef. A total of 2,153 fish of 48 species were caught which included the tagging and release of 1,136 coral trout.

A tag recovery trip was undertaken in September 1992. Fishing and tagging was undertaken in a similar fashion to the initial fishing trip. A total of 1,749 fish were caught of which 78% (1,349) were coral trout. Thirty-nine recaptures, which represented 3.4% of the total number of fish tagged previously, were obtained during this exercise. Combined with the recaptures from recreational and commercial fisherman a total of approximately 200 returns have been obtained to date. The data suggests that the movement of coral trout is limited and if movement does occur, it usually occurs within the reef boundaries.

The next tag recovery exercise is scheduled for April 1993 which will be 12 months since the initial tagging exercise.

The Effects of Prawn Trawling in the Far Northern Section of the Great Barrier Reef, Commonwealth Scientific and Industrial Research Organisation Fisheries Research and Queensland Department of Primary Industries

A descriptive survey of the biota of the cross shelf closure area (the 'green zone' closed to trawling) and adjacent areas in the Far Northern Section of the Marine Park was conducted in May 1992. Particular attention was given to the distribution and abundance of the epibenthic, fish and prawn communities and the substratum types in the study area.

A variety of sampling equipment were used in the survey including fish and prawn trawls, dredges and sediment grabs. As expected, however, not all operations could be carried out on each station as it depended on availability of trawlable ground.

Data analysis is still being conducted. Results of the descriptive survey will be presented in the final report due in early 1993. The report will contain a comparison of the benthic, prawn and fish communities of areas closed to trawling with the adjacent area open to trawling. This will include a quantitative description of the composition and amount of bycatch from prawn trawling. An analysis will also be made of what components of the bycatch float or sink after discard. The report will also describe the results of fieldwork assessing the role of discards by prawn trawlers in the diet of seabirds.

The first year of sampling will provide valuable information on which to base the design for future sampling and experiments.

Sampling in the 'green zone' should continue in March 1993.

Other Projects

A number of other projects also come under the umbrella of the Effects of Fishing Programme. An extensive liaison programme is currently being conducted to increase public awareness of effects of fishing issues. The liaison programme aims to promote GBRMPA's commitment to addressing these issues through the Effects of Fishing Programme of research, and is seeking support for, and participation in, the research particularly from recreational and commercial fisherfolk. An evaluation of Coastwatch aerial surveillance data to provide estimates of commercial and recreational fishing effort has been completed. In addition, GBRMPA in conjunction with QDPI, Queensland Fish Management Authority and Queensland Department of Environment and Heritage, is developing a recreational fishing database for the entire GBRMP.

Summary

The research to date has been of a very high standard. The present research continues to develop our understanding of the direct and ecological effects of fishing on reef associated communities. This information is central to the long term management of the Marine Park. The continuity of effects of fishing research has been dependent on the longer term funding commitment by the Federal Government. The recent Prime Minister's Statement on the Environment, in which a commitment to funding over the next three years has been made to effects of fishing and water quality research, is a major step towards ensuring that both fishing activities and the ecological integrity of the Great Barrier Reef can be sustained.

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What's out there

AERIAL MONITORING OF REEF FLAT COMMUNITIES

Dr Jamie Oliver

Earlier this century, scientists who wished to study corals and other reef organisms were forced to restrict their attentions to a single habitat - the reef flat. This was the only area that could be accessed at low tide for any reasonable period of time. While a great deal of significant work on coral ecology and physiology was carried out on reef flat species, it was frustrating to these scientists that the most diverse and actively growing reef areas were inaccessible except for very brief periods using extremely cumbersome diving apparatus. One of the great pioneering reef scientists, once referred to the upper reef slope as the *mer incognitum* due to the paucity of experiments and observations carried out in this habitat. The advent of SCUBA diving radically changed things, and today most coral research occurs below low tide on the reef front and the lagoon. Reef flat research has fallen behind since the flat is only accessible on foot at extreme low tides and can be almost impossible to dive on except during very calm weather. A friend of mine likened doing surveys on the reef flat to 'working in a washing machine'. I suspect that aesthetics also plays an important role in determining which habitats are more intensively studied since, in comparison with reef slopes and lagoons, reef flats tend to be rather monotonous and (not surprisingly) flat. Ironically, as a result of this change in emphasis, reef flats may become a *terra incognitum*, especially from a monitoring point of view. On the Great Barrier Reef, the vast majority of all reef monitoring occurs subtidally even though the reef flat is particular vulnerable to anthropogenic affects. Anecdotal reports also suggest that reef flats have been the principal habitat to show degradation over the last 50 years.

One way in which reef flat habitats might be monitored is through remote sensing. This technique can be applied to subtidal habitats but is much more effective on areas which are exposed since this allows the subtle colour differences between different substrate categories to be distinguished. The obvious advantage of using remote sensing techniques (aerial photography, satellite imagery) is that large areas can be assessed in a short period of time and at comparatively low cost.

Because reef flats are one of the first habitats which would be affected by a rise in sea level, GBRMPA has been successful in obtaining funds from the Climate Change Impacts Program within the Department of Arts, Sport, the Environment and Territories. A collaborative project has been initiated with James Cook University involving research students Thon Thamrongnawasawat and Chris Linfoot under the supervision of Professor David Hopley, Pauline Catt and myself.

The project extends earlier work of Hopley and Catt who used low level infrared and true-colour photography to map reef flats at low tide. Their work suggested that it was possible to distinguish between major substrate categories (and in particular between hard coral, soft coral and algae), however further detailed comparisons between aerial photographs and actual ground observations are necessary in order to establish how reliable this technique might be for monitoring changes in reef flat communities over time.

The first stage in the project involved near simultaneous aerial photography (using both colour and infrared film) and ground based photographic transects within 4 different zones of the north-east reef flat of Orpheus Island. This exercise was carried out during the spring low tide of August 1992 and the preliminary analysis has been completed. The results are most encouraging and indicate that aerial photographs can be used to reliably differentiate between live and dead coral areas in at least some zones.

An example of the procedure use to analyse the data is presented here (see figure 1).` Once the aerial photographs have been developed (a) they are converted into a digital, computer readable form and analysed using the same program (microBrian) which has been used to analyse satellite images of the GBR. The microBrian program is then used to classify the whole range of colours on the original image into a small number of categories based on similarities in colour (b). This process is assisted by initially categorising small homogeneous areas on the image where ground cover is known (based on the ground-truth photographs). Using this initial information the entire image is classified.

If the process has been successful the classified image will represent a map of the major types of ground cover. The success of the exercise can be determined by checking how closely relevant sections of the classified image (c) correspond to the patterns found in the ground-truth photographs (d). In the example shown here there is a clear correspondence between areas of low bushy coral on the ground-truth photo and the black areas on the classified image (i.e. c vs d). Although further quantitative analysis is required, the results so far indicate that the classification is able to map out the major cover types with a high degree of accuracy in 3 of the 4 reef flat habitats studied. While this is a very exciting outcome, with important implications for future monitoring, additional work is still required before low level aerial photography can be considered a proven technique for detecting long-term changes on reef flats. The priorities for the next year are, firstly, to obtain additional ground truth information from Orpheus Island in order to test the accuracy of the classification in areas some distance away from the original ground truth transects and, secondly, to carry out similar exercises at inshore and offshore areas dominated by different communities such as macro-algae and coralline algae.

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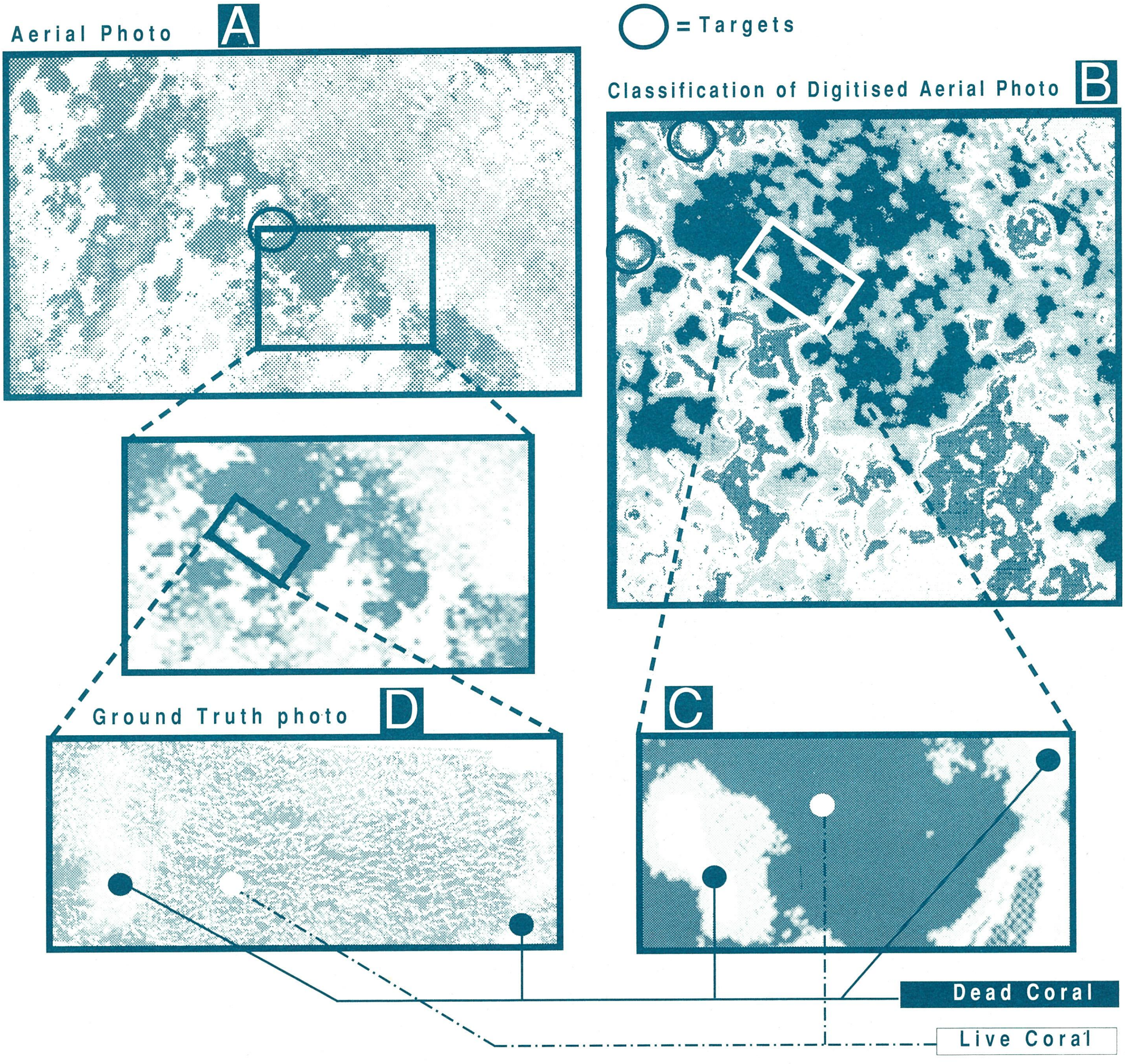

Figure 1. Aerial photoqraphs (a) are digitised and then classified to produce a computer generated map of different cover types (b). Small sections of this map (c) can then be compared with actual ground based observations (d) to determine how accurate the classification was. The 'targets' are large plastic sheets used to identify and locate the ground-truth transects on the aerial photographs.

HUMAN use DATABASE PROJECT update

Dominique Benzaken

The management of the Great Barrier Reef Marine Park (GBRMP) presents a challenge of protection, and sustainable multiple use. Management of uses is based on the zoning, in consultation with users, of the Marine Park into areas of permitted activities. This reflects the philosophy of the Great Barrier Reef Marine Park Authority (GBRMPA) of management 'through the community's commitment to the protection of the Great Barrier Reef, and its understanding and acceptance of the provisions of zoning, regulation and management practices' (Annual Report 1992, p. 7). Effective management of uses therefore requires appropriate knowledge and monitoring of uses and users. While management has been primarily based on biophysical knowledge of the Reef (see Watson 1988 for a review of GBRMPA research effort from 1976 to 1986), the integration of social knowledge into decision making processes must take place for effective management of environmental impacts while providing reef users with economic, social and cultural benefits.

At an initial workshop with managers, a number of issues were identified regarding information needs for the social sciences. These were characteristics of users, effectiveness of educational material, the nature of reef experiences, attitudes towards the GBR and GBRMPA strategies (zoning, public participation and education) and economic and social impacts assessment (Scherl 1990). There was also a perceived need to integrate information on human use from a wide range of sources and to build up corporate knowledge.

The socio-economic research program has been concerned with providing baseline research in recreational management, having an active participation in decision making and management planning, developing social impact assessment guidelines and initiating a database of social information (Scherl 1992) . Those projects are the starting point towards an integrated social research strategy for GBRMPA.

The human use database project

The terms of reference of the project are to present an overview of all available information sources on tourism and recreation and their main characteristics with the aim of producing a list of information parameters and recommendations for future data collection. These data are to be integrated into the larger GBRMPA dataset.

The project consists of four overlapping phases: the identification and selection of information sources, the design of a database (with programming assistance from the computer section), the entry of selected information into the database and the preparation of a report.

There are two reasons for compiling the existing information using a database. Firstly, it provides suitable storage, retrieval and update facilities and comprehensive documentation of the status of corporate knowledge on tourism and recreation. Secondly, it can be used as a pilot exercise to identify problems associated with setting up a social database *following*, rather than *prior to*, information collection.

At the design stage, consideration was given to compatibility with existing GBRMPA information systems (an Oracle database with a Macintosh front end has been used) and to spatial and temporal referencing, to allow the use of the data with developing spatial information systems. The result is a complex set of related tables whose attributes were defined using both recreational management and economic analysis theories and the constraints of the information. Major categories used include bibliographic details, availability of raw data, research methodology, visitation, activities, user characteristics, user experience and attitudes, economic analysis and effectiveness of management (see figure 1).

The selection of information sources to be entered into the database was based on two criteria: the information was derived from original research and, it was directly relevant to the GBR region. Three main sources were initially identified: GBRMPA and other relevant agencies' reports, databases and federal and state tourism and recreation statistics (figure 2). Only the first two were compiled, since most statistical information lacked specificity, used inappropriate spatial boundaries or could not be extrapolated with sufficient confidence at a regional level. They were not overlooked, however, as possible avenues for future data collection.

To date, 74 projects from the Research and Monitoring project database have been selected from the categories *human use, analysis of use* and *management strategies* and a library search identified further material from universities and research institutions. However, a significant number of information sources were gathered in an *ad hoc* manner following informal meetings with staff from all GBRMPA sections, reflecting the need for a procedure for centrally storing human use information.

The GBRMPA permit database, data returns database, IRIS database, aerial surveillance database, public participation database and strategic plan database have been investigated at this stage. A number of constraints made the examination of some databases difficult with some being currently under review, others not yet fully documented. Exceptions to this were the strategic plan database, IRIS database and aerial surveillance database (a report is currently being prepared on the use of the aerial surveillance data for monitoring visitor use).

Other government agencies have been approached, in particular Queensland Department of Primary Industries, Queensland Fish Management Authority and Queensland Department of Environment and Heritage in the context of recreational fishing and permits information.

Data entry is proceeding rather slowly since each report (or database) has to be carefully assessed and fitted into the database categories, an exercise akin to writing a film script after the shooting has occurred! However, a number of comments can be made even though all information has not yet been processed.

The frequency and type of request for human use information being made by Authority staff and other Departments clearly indicates the need for systematic information collection and easy retrieval procedures. Most common requests include statistics on visitor use, economic evaluation of the GBR and other specific activities. At present, this information cannot be provided with sufficient accuracy and specificity or has not been recently updated.

A large amount of the social information is collected prior to or following zoning or planning, either being the object of investigation or incidental to other projects or databases.

There are a diversity of methods, approaches, parameters and values used to measure human use which makes the use of reports' information limited to a one off snap shot usually answering a specific management question. This precludes any comparison between studies, trend analysis or prediction. Some studies however may be replicated and become very useful. In many cases, existing databases are designed for administrative rather than for long term analytical purposes.

There is a paucity of raw data available with reports and the provision of properly formatted data and documentation should be required from consultants at completion of their project. If they were available, a spatial rearrangement of raw data could be considered for purposes other than those of the study, provided resultant sample populations were representative.

Emphasis has been on visitation levels, and economic impacts rather than on user characteristics and recreational experiences or social impacts. However, a documentation of users' experience is very important in identifying the spectrum of recreational experiences, conflicting uses and in determining recreational settings and amenity classes.

Visitor numbers can be found in federal and state statistical reports (such as those from the Australian Bureau of Statistics, the Bureau of Tourism Research, and Queensland Tourist and Travel Corporation) but these reports fail to give information specific to the GBR region. On the other hand, specifically targeted studies providing information on visitation cannot be generalised because of methodological constraints (often a small sample size).

Economic evaluations of GBRMP based activities have not been recently updated and have not as yet significantly used contingent valuation analysis techniques.

Some thoughts for the future

The absence of an overall strategy has precluded the establishment of standard measures and sampling procedures that could be monitored at regular intervals consistent with management strategies. Such an overall strategy would build up corporate knowledge, while avoiding unnecessary duplication, and streamline consultants' research.

The integration of scientific and social information should be part of corporate information support systems. The relevance of using Geographic Information Systems to present social and cultural information (customary and traditional knowledge for example) should be considered - the digitising of maps representing public participation is already under way in the Planning and Management Section.

The development of procedures for cooperative arrangements between GBRMPA and other organisations with similar interests should be promoted. Ownership of information, conditions of access, and design of compatible, if not common, sampling design and data collecting instruments should be discussed by interested parties.

Existing social databases are being investigated as possible models for GBRMPA.

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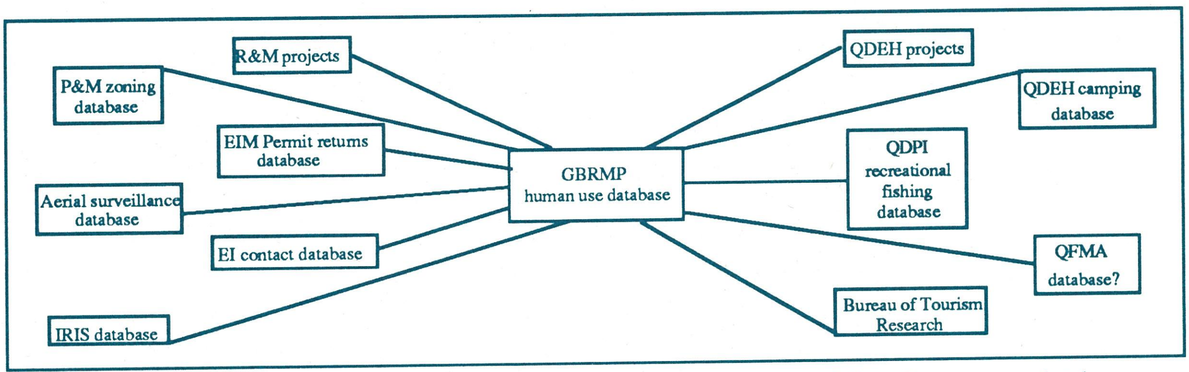


Figure 1. Range of information sources on human use that may be used in a human use database on tourism and recreation.

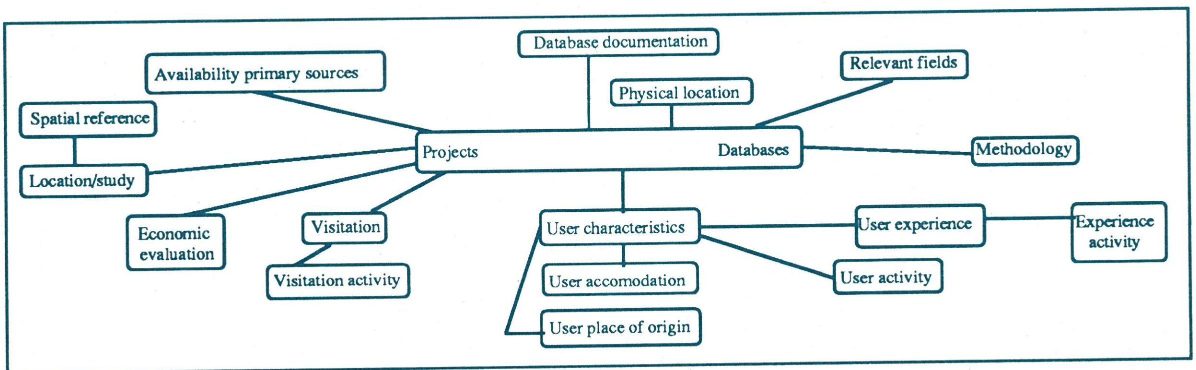


Figure 2. Human use database description. Each box represents a table and lines relationships between them.

COTS COMMS

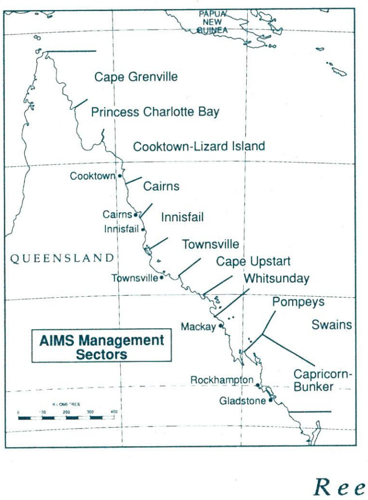
Dr Brian Lassig and Udo Engelhardt

Current COTS

Since the last issue of COTS COMMS the AIMS survey team has been to the two extremes of the Marine Park - the Swain and Capricorn/Bunker Sectors in the south and the Far Northern Section (I'll resist the tautology!). Active crown-of-thorns starfish (COTS) outbreaks were observed on two reefs in the Swains (Gannet Cay and Snake Reef) and, with coral cover on these reefs exceeding 50% away from the localised aggregations, the outbreaks seem likely to be around for some time to come.

The Capricorn/Bunker reefs maintained their consistency of having no COTS visible to manta towers, but they too have problems. The cover of hard corals was less than 30% on all of the four reefs in this sector surveyed. The coral cover at One Tree Island and Lady Musgrave Island had decreased significantly since last year's survey, probably as a result of cyclone Fran which visited the area in March last year. Lady Musgrave in particular seems to be suffering, going from a hard coral cover of >75% in 1986/87 to a level of <10% this year. A bid by the Authority for additional funds from the Federal Government to more closely investigate this dramatic decline was unsuccessful.

Sixteen reefs were surveyed in the Far Northern Section which includes three of AIMS' Sectors - Cape Grenville, Princess Charlotte Bay and Cooktown/Lizard Island. No outbreaks were observed although several of the surveyed reefs are recovering from previous outbreaks.



Swan ~~Song~~ Poem

As the last issue of COTS COMMS announced, Professor John Swan has retired from the chair of the Crown-of-thorns Starfish Research Committee (COTSREC) and been succeeded by Professor Graham Mitchell. John commemorated the occasion of his retirement by bequeathing the following literary legacy:

***The Age of Reason and* Acanthaster planci**

Under the December moon, more often under sun,
Chance encounters during spawning, there are almost none.
The female egg, as ever was the case,
Attracts the male sperm to her embrace.
And chemotaxis, as the name implies,
Makes no distinction 'twixt the foolish and the wise.
And what is more, the oft-observed communal aggregation,
Ensures for all a most successful starfish propagation.

Gastrula! Bipinnaria! Brachiolaria!
Fourteen days of buoyant freedom, sometimes twenty-eight,
A pea-soup diet, *Dunaliella*, presently their fate.
Then down they go! To bed with crustose algae and *Lithothamnium pseudosorum*.
Now watch each starfish grow from its remarkable primordium.

Then come the fish, the crabs, the worms
Their brothers, sisters, cousins,
That finally reduce our *Acanthaster* population
From the millions to the dozens.

A few more months and then, the promised land!
Where milk and honey flow from coral strand.
White scars appear on branching staghorn corals,
And far away - the muted roar of academic quarrels.

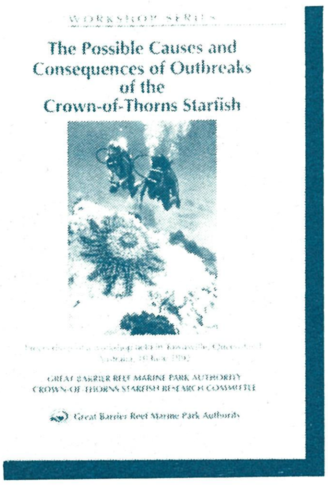
"It's predator removal"; "Heavy rainfall after drought";
"It's the farmers"; "It's El Nino"; "Larval transport without doubt".
It seems the reef is "under threat",
And who to blame? - the Managers, I'll bet.

But Johnson points to H. McCallum's optimistic simulations:
"The patterns of the starfish plagues in reef sub-populations,
Are cyclical, or quite chaotic, numbers high or low,
Depending on the larval pulses, water movement, ebb and flow."

The oceans are resilient, their systems are robust,
Life forms adapt, evolve and flourish; corals will adjust.
So shoot the foxes, feral cats, the pigs, the goats and rabbits,
But learn to love the crown-of-thorns;
accept its natural habits.

Causes and Consequences

The proceedings of a COTS workshop ('The Possible Causes and Consequences of Outbreaks of the Crown-of-Thorns Starfish') held in Townsville in June last year has finally been printed. The publication contains 17 contributions covering a variety of research and management aspects of the Authority's COTS program. Abstracts of the papers were included in Issue #10 of COTS COMMS. The real thing (168 pages) can be obtained by contacting either Brian Lassig or Udo Engelhardt of the Authority.



COTSREC Confabulates

COTSREC met in Townsville on 19 January 1993 for its first meeting with Professor Graham Mitchell as Chair. The meeting was primarily concerned with the research program's progress with some discussion of directions in the 1993/94 financial year.

The Committee made a number of recommendations that will be put to the Marine Park Authority for approval. These included support for a project by Dr Kerry Black of the Victorian Institute of Marine Sciences to investigate field testing of hydrodynamic models (contingent upon substantial Australian Research Council funding); maintenance of the Australian Institute of Marine Science crown-of-thorns starfish rearing program for a further 3 years (subject to the availability of funds and specimens), and collaboration with the Cooperative Research Centre (a consortium of agencies comprised of AIMS, GBRMPA, James Cook University, Queensland Department of Primary Industries and the Association of Marine Park Tourist Operators) in hydrodynamic and water quality programs to achieve mutual goals.

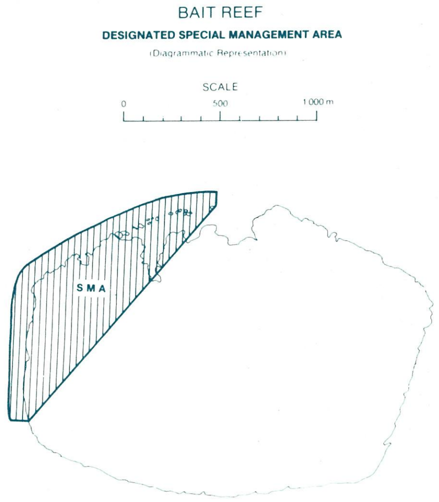
Local Controls

Can and should outbreaking populations of COTS be controlled? This rather emotive question has split public and scientific opinion for many years. The long standing policy of the Great Barrier Reef Marine Park Authority (GBRMPA) on this issue is not to interfere on a large scale unless it can be shown that outbreaks are initially caused or exacerbated by human activity (Kelleher 1993). However, local control efforts may be initiated in an attempt to protect sites of particular value to tourism or science. Scientific reviews of this matter have supported the Authority's policy.

Historically (ie. in the past 10-15 years), local-scale attempts to control starfish populations have relied largely on the use of a toxic agent such as copper sulphate ($CuSO_4$). Preliminary field experiments into methods suitable for controlling the starfish were conducted at Green Island in the early 1980s. The researchers concluded that of the variety of chemical agents tested, $CuSO_4$ had some outstanding properties, making it the most effective and efficient agent available (Hicks and Blackford 1981). Their work suggested that approximately 7 - 9.5 ml of $CuSO_4$ may be sufficient to kill individual starfish. However, their report did not provide any information on possible seasonal or size dependent variability in the actual amount of toxic compound required to kill starfish. Copper sulphate injections have since been the preferred means for controlling local scale populations of starfish.

Although the latest *wave* of COTS outbreaks appears to be coming to an end, some relatively large populations remain on reefs in the Whitsunday Region and further south in the Swains complex. A relatively large, *outbreaking* (?) population of COTS can still be found at Bait Reef off the Whitsunday Islands. This *typical* mid-shelf reef is located some 35 nautical miles off the coast in the Central Section of the Great Barrier Reef Marine Park.

Bait Reef is the main focus for the local diving industry in this region. More than a dozen tourism operations frequently visit the area. The close proximity to the mainland centre of Airlie Beach and the availability of safe, permanent mooring sites have made this reef a preferred site for dive charters. In May 1992 a number of local dive operators expressed their growing concerns about an apparent and sudden increase in the number of COTS in an area known as the *Stepping Stones*. This chain of large coral bommies is located in a Special Management Area (SMA) at the southern end of the reef.



The great majority of starfish found in this area are between 30 and 50 centimetres in diameter. However, a number of smaller starfish (< 10 cm) have also been recorded. Feeding damage is mainly restricted to extensive *Acropora* thickets in the back reef area with relatively minor damage to massive-type corals. Local dive operators responded to the *influx* of starfish with increased efforts aimed at controlling the population. Copper sulphate injections are again being used as the principal means of control.

Between October 1991 and October 1992 staff from both GBRMPA and QDEH conducted a number of opportunistic controls at Bait Reef. These opportunistic controls were made possible through the cooperation of the local District Manager of QDEH, Mr Arti Jacobson and his Marine Park staff. Over the past 12 months, more than 1200 mature (i.e. 35-45 cm) COTS have been injected by Marine Parks staff alone. In addition, local dive operators have injected more than 900 starfish in the same period. It should be noted that due to the highly cryptic behaviour and mobility of most starfish, these measures will not achieve *total* control of the COTS population.

Intense, small-scale control efforts of this nature have the potential to result in local contamination of other reef organisms. Following a series of controls targeting a relatively small COTS outbreak at Holbourne Island (Central Section), Zann and Weaver (1988) reported elevated levels of copper in a tridacnid clam and an alga. The toxic side effects of chemical agents may not always be immediately detectable. The more subtle, long term effects of the often excessive use of $CuSO_4$ during such operations are not understood and warrant further investigation.

As part of the ongoing opportunistic control measures a small research project aimed at assessing the current practices has been initiated. A series of injection experiments is being conducted over a period of 9 to 12 months. The main objective of this research is to provide information on the minimal doses of copper sulphate required. This essential information will in future help to minimise potential environmental pollution and detrimental effects on other marine organisms as a direct result of COTS controls.

A first series of trials was conducted in December 1992. Starfish were collected by divers and transferred to holding cages where the trial injections were conducted some 24 hours after collection. Preliminary results indicate that during the pre-reproductive period just prior to their main spawning, as little as 4 ml of saturated copper sulphate solution may be sufficient to kill mature starfish (35 - 45 cm diameter). The injection trials will be repeated several times over the next 6 to 9 months. Subsequent trials of alternative, less toxic substances are also planned. A detailed field manual providing information on the safe conduct of small-scale COTS controls will be produced and distributed to interested parties.

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WHERE are all the CORAL TROUT

Drs Tony Ayling and Avril Ayling

Everyone wants to know where all the coral trout are. Recreational fisherfolk want to know so that they can catch enough for a feed and add the perfect touch to that day on the water, commercial fishermen want to know so they can make a good living and the Great Barrier Reef Marine Park Authority wants to know so that it can manage the resources of the Great Barrier Reef (GBR) more effectively. We have spent hundreds of days at sea between 1983 and 1986 trying to find out for the Marine Park Authority just how many coral trout there are on the GBR and where they live.

The Marine Park Authority held a number of workshops in the late seventies and early eighties to develop techniques for counting coral trout. We used a method that involved two divers searching for coral trout along 50 metre long by 20 metre wide survey transects (1000 square metres). To cover as big a depth range as possible we ran the 50 metre fibreglass surveyors tape that defined each transect down the reef slope from the edge of the reef flat. On most reefs the transect ended in about 15 metres of water but on some shallow reefs the end of the tape was only at 8 or 10 metres depth and on the steep slopes of some outer reefs we reached depths between 20 and 30 metres. We surveyed ten separate transects on each reef scattered along about a kilometre length of reef edge.

But where on each reef was the best place to make our counts? Obviously we could not cover the entire reef with only ten transects twenty metres wide. We made surveys in a variety of habitats on a few reefs to see where most coral trout were found on a reef. There were very few coral trout on the reef flat or in shallow lagoon areas compared to the reef slopes. On the reef slopes we found that there were fewer coral trout on the exposed wind-ward or front side of the reef, facing toward the predominant south-east wind, than on the more sheltered leeward or back reef. On average there were about 40% more coral trout on the back reef than on the front so we decided to confine our counts to the back reef slope habitat. This also has the advantage of being a safer place to work when strong south-easterly trade winds are blowing.

Great Barrier Reef Survey of Coral Trout

To cover the entire GBR region we had to make some other decisions. Clearly we could not count coral trout on all the 2900 separate reefs the Marine Park Authority has listed. After consultations with the Marine Park Authority we chose reefs to survey at a wide range of positions from Triangle Reef at the top of Cape York, with a latitude of $10^{o}30'$ south, to Lady Musgrave Island in the Capricorn-Bunker Group at a latitude of 24^{o} south. The selected reefs also ranged across the shelf, from turbid coastal reefs where even seeing the coral trout was a problem, out to the reefs of the outer barrier rampart on the edge of the continental shelf where visibility was often over 30 metres. We surveyed a total of 156 different reefs over a three-year period, spending more than 200 days at sea. The sea time was spread over four major field trips on large charter boats, spending up to 50 days at a time at sea.

Different Coral Trout Species

As most fishermen know there are actually several species of coral trout. All of them are fish eating predators and they are the most important reef-living predators on the GBR. They have a life cycle that sees all individuals start life as females and spend one or two years reproducing as a female before changing sex to become a male. All large coral trout are males. They are rapid growing fishes, becoming reproductively mature in their second year and reaching the 35 cm legal minimum catchable length in one to two years.

We started off counting five species. The common coral trout, known by the scientific name of *Plectropomus leopardus* and sometimes called the leopard trout was the one most often seen. It ranges from white-grey to green-grey to red-brown, and is covered with small blue spots with a distinctive blue eyebrow. On turbid inshore and coastal reefs we have encountered the bar-cheeked coral trout *Plectropomus maculatus*, a species that was usually orange-brown in colour with larger, bright blue spots, and those spots on the side of the head elongated into bars. Occasionally we would see a footballer coral trout *Plectropomus laevis* (the scientific name *Plectropomus melanoleucas* is sometimes used for this species), sometimes known as the tiger trout, with its distinctive colour pattern. The five black saddle markings with outlines of blue dots on a blue-spotted white body and bright yellow fins make this species unmistakable. On outer barrier reefs the blue-spot coral trout was common. This species apparently had not been given a scientific name and was known as *Plectropomus* sp. The blue-spot reached a larger size than the other coral trout; we saw individuals up to 120 cm long compared to the around 65-70 cm maximum of all the other species. Blue-spot coral trout are red-brown with darker brown saddles and a scattering of widely spaced large blue spots on the body. A rare species that we only saw a few times was the passionfruit coral trout *Plectropomus areolatus*. The colour pattern of this species incorporates numerous large blue spots set close together over the entire body; the other species do not have blue spots on the belly.

We discovered part-way through the project that the footballer coral trout and the blue-spot coral trout were in fact dramatically different colour forms of the same species, with the scientific name *Plectropomus laevis*. At first we doubted that this could be true, but as we thought about it the pieces fell into place. We had never seen any young blue-spot trout, the smallest we had seen were about 20 cm long. The reason for this is that all blue-spot coral trout start life in the footballer colour pattern and later change colour to the blue-spot pattern; all individuals over about 65 cm long were in the blue-spot pattern.

Why does this species have two such different colour patterns? The reason for this became obvious when we saw some very small footballer coral trout and observed their behaviour. The footballer colour pattern with its black saddles, blue spots and yellow fins is almost identical to that of a small pufferfish, the black-saddled toby *Canthigaster valentini*. This pufferfish is highly toxic and is recognised and avoided by predatory fishes.

There is a small leatherjacket that mimics the pufferfish colour pattern so that predators mistake it for a toxic pufferfish and do not eat it, and it appears that the small footballer coral trout are attempting the same mimicry, with some behavioural traits that enhance the similarity. Unlike juveniles of the other coral trout that swim with body undulations like the adults, juvenile footballers hold their body rigid, fold their tail to resemble the puffer, and swim with pectoral fin beats. They also hold the front half of the dorsal fin partially erect in a triangular shape to make the body outline more similar to that of the pufferfish. Many of the footballers change to the blue-spot colour pattern at around 20-25 cm total length when the mimicry is no longer effective or necessary but a number of individuals apparently do not bother to change colour until they are much larger, with occasional individuals reaching a length of 70 cm and still retaining the footballer colour pattern.

So we were actually dealing with three common species, the common coral trout, the bar-cheeked coral trout and the footballer/blue-spot coral trout, as well as the rare passionfruit coral trout.

Cross-Shelf Abundance

When the results from our surveys started to come in, it became apparent that the major factor influencing where coral trout were found was the position of each reef on the gradient across the continental shelf.

Anyone who has driven up the Queensland coast will realise that coastal and inshore reefs are usually very turbid. Underwater visibility is usually poor and if you can see five metres you are lucky. When the trade winds are blowing the waves stir up the silt and turn the water brown, reducing visibility to less than a metre. Animals that live on coastal reefs must be able to cope with this turbid water and with the seaweed forests that are often found in shallow water on these reefs.

The bar-cheeked coral trout is able to thrive in these conditions and is the only species of coral trout we found on the most turbid coastal reefs such as those around the Barnard Islands near Mourilyan Harbour. Average densities of bar-cheeked coral trout on these reefs were around eight per hectare (figure 2). On inshore reefs where conditions are a bit better such as around the Palm Islands north of Townsville, on Low Isles off Port Douglas and on the Cape Tribulation reefs, this species was also common (10 per hectare) but a few common coral trout were encountered as well (about 7 per hectare).

On mid-shelf reefs that are less than half way across the continental shelf water conditions are usually a lot better, with visibility around 10 metres, although in windy conditions this may drop to about 5 metres. In these conditions the common coral trout starts to come into its own, with average densities of over 25 per hectare. but the bar-cheeked coral trout is still found on the back reef slopes here (about 5 per hectare).

As we get out into the clearer water around the reefs more than half way across the shelf where visibility is usually between 15 and 20 metres, we get into the heart of coral trout country; the combined number of all species of coral trout is about twice as high here as anywhere else (figure 2). The common coral trout is the only common species on these reefs with average densities of almost 60 per hectare. So imagine, if you will, next time you are on one of these reefs - the majority of reefs on the GBR fall into this category - and the fish are not biting that there are around 60 coral trout within a stones throw of your boat. We also start to find a few footballer/blue-spot coral trout on these reefs but only about 1.5 per hectare.

When we start to get out wide, as the fishermen call it, out near the outer edge of the continental shelf where the underwater visibility approaches 30 metres, coral trout are less abundant. On the back of these outer shelf reefs the common coral trout is still the species most often encountered but only at densities of around 15 per hectare. The footballer/blue-spot coral trout becomes more abundant on these reefs (6.5 per hectare).

On the exposed front of these outer reefs where the Coral Sea swell crashes unhindered, the reef slope is often very steep, falling quickly to depths of over 50 metres in visibility that often exceeds the same distance. Large blue-spot coral trout are dominant here, occurring at average densities of over 11 per hectare and fish over 20 kilograms in weight are sometimes caught around these reefs. A few common coral trout are also seen on these steep front reefs but they do not seem to like these conditions and on reefs such as Raine Island they are not found at all.

When the footballer/blue-spot coral trout is found on mid-shelf reefs about half the individuals seen are of the footballer colour pattern and half are blue-spots. On the clearer outer shelf reefs the majority of individuals are of the blue-spot colour pattern; over four times as many as there are footballers. Such a result would be possible if footballers were changing colour to the blue-spot form, at a larger size on mid-shelf reefs, or if blue-spots had far less chance of survival on these reefs. If either of these mechanisms were operating then the average length of the two colour forms would be different on mid-shelf reefs compared to outer shelf reefs. If we calculate averages for these fishes on the two groups of reefs from our estimates of length for all coral trout counted we find that they were very similar: 40 cm versus 39 cm for the footballer form and 58 cm versus 59 cm for the blue-spot form. Implying that these mechanisms are probably not the correct explanation for the different colour pattern ratios. A more likely explanation is that blue-spot coral trout prefer conditions on outer shelf reefs and migrate between reefs until they reach an outer shelf reef, moving tens of kilometres across the open bottom.

We can sum up by saying that in general the three common species of coral trout replace each other as we move across the continental shelf with the bar-cheeked coral trout found on inner shelf reefs, the common coral trout on mid-shelf reefs and the footballer/blue-spot coral trout on outer shelf reefs.

North-South Abundance

There were also some dramatic effects on coral trout numbers caused by the vast latitudinal spread covered by the GBR. The GBR reef complex stretches a distance of over 1,800 kilometres, from $10^{o}30'$ south to 24^{o} south, with a winter water temperature difference between the north and south extremes of almost 5^{o}C. There are changes in reef type along this huge distance and we might expect there to be changes in the reef animal communities as well.

To the north of Cape Tribulation there is an almost continuous rampart of outer barrier reefs along the edge of the shelf and reefs in this northern region are different from those in the middle of the GBR, between Cape Tribulation and Cape Upstart, where the reefs are smaller and more widely spaced, without the protection provided by the outer barrier rampart. To the south, reefs become larger and closer together again, but they are a long way offshore, and subjected to much stronger currents than elsewhere on the GBR. Very few reefs in this southern region are close to the outer edge of the continental shelf. At the southern end of the GBR, and separate from the main body of reefs, is the Capricorn-Bunker Group of about 22 reefs, that includes Heron Island and Lady Musgrave Island.

The density of some of the coral trout species changes markedly along the length of the GBR, although these changes are not as dramatic as those that occur across the continental shelf. On those mid-shelf reefs where it is most abundant the common coral trout has similar average densities throughout the northern and middle regions of the GBR. In the northern region there are an average of 28 common coral trout per hectare on mid-shelf reefs, while in the middle region the average is 35 per hectare (figure 3). As we get into the reefs of the southern region there are far more common coral trout with average densities of 76 fish per hectare. On some reefs in the Swain Group at the south end of this region we counted more than 150 coral trout in a hectare of transects. In the Capricorn-Bunker Group of reefs there were also a lot of common coral trout, with average numbers of around 50 per hectare.

We are not sure why there should be such large numbers of coral trout on the southern region reefs. From the information available the levels of commercial fishing are higher, if anything, in this region compared to areas further north and there is a lot a recreational fishing from charter boats. It is possible that there is more food available to coral trout on these southern reefs. During the summer months large schools of hardyhead bait fish are found around these reefs but they do not occur further north and diet studies have shown that these are extensively preyed upon by coral trout. It may be that the reefs can support higher numbers of coral trout because of the seasonal availability of this abundant food supply. Interestingly, there were no differences in the numbers of the common coral trout along the length of the GBR on outer shelf reefs where the bait fish schools do not occur. There is probably insufficient plankton to support these schools of small fish in the clear oceanic waters around reefs near the edge of the shelf.

The footballer/blue-spot coral trout also shows marked latitudinal changes in density, but only on outer shelf reefs where this species is most abundant. For this coral trout there are higher numbers in the northern region, on the reefs of the outer barrier rampart, where there are an average of 9.5 fish per hectare, far more than the average of 3.6 per hectare on reefs further south (figure 4). In this case it is clearly some feature peculiar to these outer barrier reefs that these large coral trout prefer, but at this stage we have no real idea of what this could be. Numbers were even higher on the clear, steep fronts of these reefs with over 11 fish per hectare.

These surveys have given us some idea of the major patterns in the distribution of the different species of coral trout. If we want to say anything useful about the effect of fishing on these species we have to know something about the underlying natural density differences between reefs in different positions on the GBR. We documented order of magnitude density differences between groups of reefs across the continental shelf and differences of two to three times along the latitudinal range of the GBR. We also got some information on the effects of fishing on coral trout density but that is a separate story.

Figure 1. Length frequency distribution of the two colour forms of the footballer/blue-spot coral trout showing the differences in size.

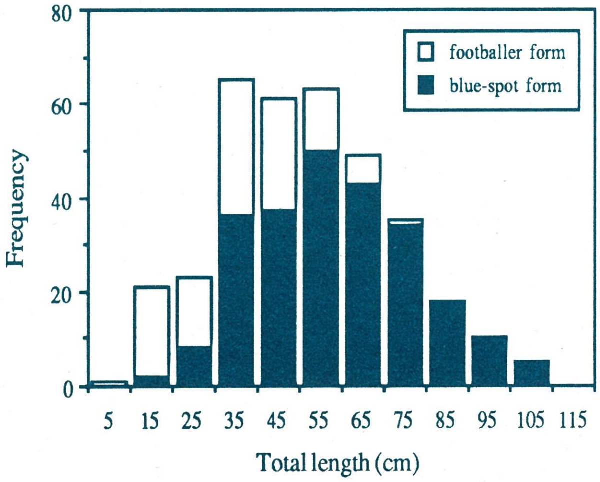


Figure 2. Changes in numbers of the different coral trout species across the continental shelf from turbid coastal reefs to the front of outer shelf

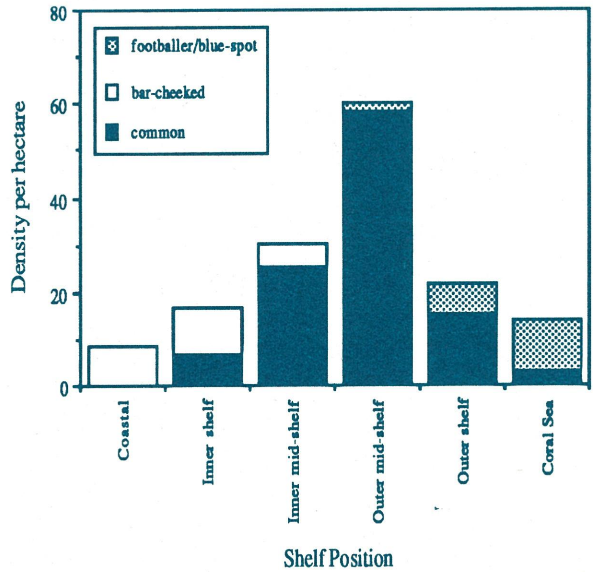


Figure 3. Numbers of the common coral trout on mid-shelf reefs in four major regions along the length of the GBR.

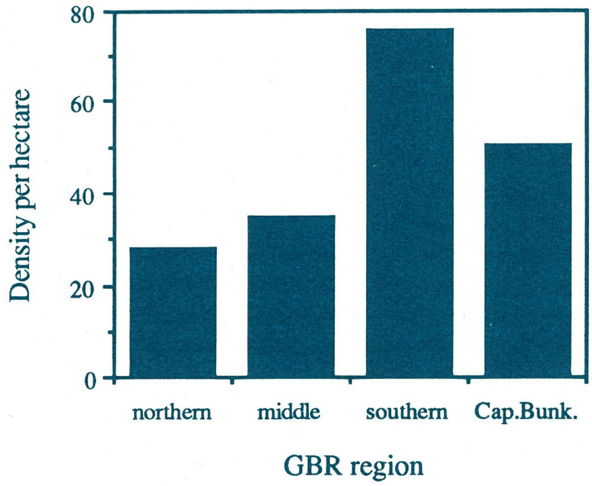
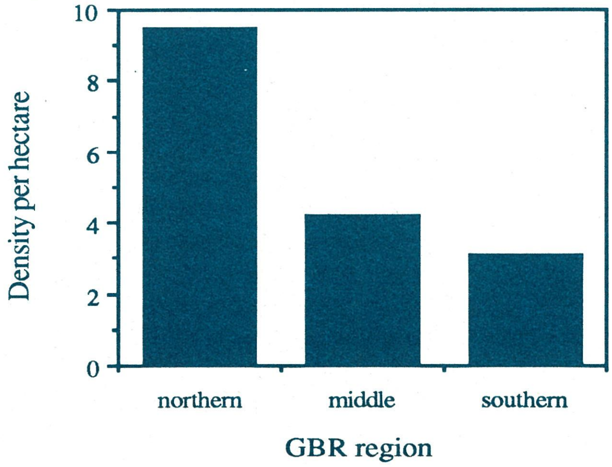


Figure 4. Numbers of the footballer/blue-spot coral trout on outer shelf reefs in three major regions along the length of the GBR.



SLICK TALK 4

with Steve Raaymakers

After an update from the Northern Territory in 'Slick Talk 3', in this issue we return to the Great Barrier Reef. Three major oil spills overseas in the last few months, the "Aegean Sea" in Spain, the "Braer" in the Shetland Islands and the "Maersk Navigator" off Sumatra, have provided us with a stark reminder of the threat posed to the Great Barrier Reef should a similar spill occur in its waters. These spills have generated numerous calls to upgrade our oil spill response capabilities. While there is no doubt that our response capabilities can be upgraded substantially, it is important to realise that a marine pollution contingency plan, known as REEFPLAN, has been in place for the Great Barrier Reef since 1987. REEFPLAN is regularly exercised and reviewed, and in this issue we report on a recent major oil spill exercise.

It is my belief that while the threat of a large spill on the Great Barrier Reef is a major cause for concern, incidents such as the "Aegean Sea" and "Braer" serve to divert our attention away from a more insidious and very real source of oil pollution in Reef waters, one that is occurring every day. In this issue we also look at "operational discharges" from large ships.

Exercise "Northern Reaches"

Under REEFPLAN a major exercise is held somewhere on the Reef every two years. These exercises are generally table-top only, the primary objective being to exercise and confirm divisions of responsibility, organisational structure and lines of communication and to allow the oil spill team to test decision-making processes in response to particular scenarios. Generally there is no physical deployment of equipment although this is carried out during regular training courses and demonstrations throughout the year.

The latest of these exercises, dubbed 'Northern Reaches', was held at Thursday Island on 19 and 20 November 1992. The scenario involved a grain carrier with 1900 tonnes of fuel oil running aground on Wyborn Reef and losing 500 tonnes of oil. The far northern Great Barrier Reef was chosen for the exercise as it is an area subjected to significant risk of a major oil spill due to traffic along the inner route. There was also a need to exercise response arrangements for Torres Strait, which now receives approximately 100 extra tanker transits per year as a result of the commissioning of the Kutubu oil terminal in the Gulf of Papua.

Responsibility for dealing with oil spills in the Great Barrier Reef rests with a multi-agency committee known as the Queensland State Oil Pollution Committee, with the lead agency being the Queensland Department of Transport (QDoT). The other main players are the Australian Maritime Safety Authority (AMSA), who have national oil spill responsibilities and should not be confused with the Australian Marine Science Association, the Great Barrier Reef Marine Park Authority (GBRMPA) and the Queensland Department of Environment and Heritage (QDEH).

The scenario for "Northern Reaches" dictated that the QDoT Regional Harbourmaster based in Cairns took control of the response and was appointed as the On Scene Coordinator (OSC), rapidly establishing an operations base close to the incident at Thursday Island.

The OSC was provided with operational support from his own local QDoT staff as well as environmental advice from Torres Strait Islander staff of the Australian Fisheries Management Authority (AFMA) and Queensland Department of Primary Industries (QDPI). Environmental and scientific advice and support was rapidly supplemented with the arrival of two Scientific Support Coordinators (SSCs) from GBRMPA and QDEH. AMSA provided a Technical Adviser to assist the OSC with operational and equipment considerations, and to assume the OSC role should it be necessary.

It became apparent early in the 'spill', based on predictions from the computer model and coastal resource atlas operated by GBRMPA (known as 'A Strategic Atlas Program' or 'ASAP'), that extensive mangroves and seagrasses located in Newcastle Bay and Kennedy Inlet and pearl farms in Albany Channel were at risk (figure 1). Impact on the shoreline was likely to occur within 20 hours. After careful consideration of the terrain and environmental constraints, including tides, currents and the presence of crocodiles, it was determined that it was not possible to place defensive booms to protect the mangrove areas. The only option available was to break the oil up near the source, using chemical dispersants and boats towing breaker boards. This would cause some impact to marine life, including reef organisms and commercial crayfish, but mangrove habitat has a higher protection priority than coral reefs or individual species.

The necessity to accept some impact on one resource in order to minimise impact on a more valuable resource is a very important consideration in oil spill response, and one that scientific and environmental advisers must bear in mind when providing advice and recommendations to the OSC. Unfortunately, the OSC will never have enough resources to protect everything and the SSC must prioritise. It was agreed that dispersants would not be used in the vicinity of pearl farms, in any water shallower than 5m and over any coral reef except Wyborn Reef. It was necessary to use dispersant over Wyborn Reef as this was the source of the oil and the most effective place to disperse it.

It rapidly became apparent that due to the absence of dispersants and other response equipment at Thursday Island delays would be caused by the need to fly equipment up from southern stockpiles. This meant that dispersant spraying operations could not commence until the next day, when oil was due to impact the coastline. The pearl farms at Albany Island were contacted and advised to lower all pearl racks to the seabed. In addition arrangements were made to deploy booms, when they eventually arrived, in deflective mode at the pearl farms, in order to channel oil away from the pearl racks. This decision created an interesting debate when the media queried what appeared to be a commitment of resources to protect commercial interests when no booms were going to be used to protect the pristine mangroves and seagrasses of Newcastle Bay. It took some explaining to convince the media that Newcastle Bay indeed had a higher priority, it was just that it was not physically possible to boom that area and the booms were best used where they would at least be of some benefit.

The response team expected that significant numbers of sea birds would become oiled. Arrangements to deal with oiled birds involved mobilising a team of QDEH Rangers from Cairns and the specialist oiled wildlife response team from Taronga Zoo in Sydney. A source of salt-water soluble detergent concentrate was identified and arrangements made for the Cape York Wilderness Lodge to be used as a bird cleaning and rehabilitation centre.

An invaluable component of the response was the local knowledge provided by Torres Strait Islander staff of AFMA and QDPI, and a representative from the Island Coordinating Council (who also happens to be a GBRMPA officer stationed in Torres Strait). Such support and advice is absolutely vital in any oil spill, and even more so on Cape York and Torres Strait, where there may be several different local names for the same geographical location, where maps of roads, boat ramps and other infra-structure vital to the transport and deployment of personnel and resources are not always accurate and where the support of local organisations in providing people and equipment such as fishing boats is essential.

All in all the exercise was deemed a success in terms of testing REEFPLAN and providing valuable experience to all those involved. It was the first major exercise ever based at Thursday Island, and was successful in demonstrating the capabilities of REEFPLAN in this extremely remote area as well as identifying a number of serious deficiencies and areas for improvement. As a result of the exercise recommendations have been made to:

- develop a site specific contingency plan for Torres Strait to ensure that the unique geographical, environmental, socioeconomic, cultural and political characteristics of Torres Strait will be better addressed than they are in the more general REEFPLAN,
- establish a major equipment stockpile, including dispersants, at Horn Island to provide an immediate response capability which currently does not exist and avoid delays in transporting equipment from southern stockpiles,
- hold another exercise in Torres Strait once these recommendations are in place to test their applicability.

It is understood that QDoT and AMSA, as the lead oil spill agencies, are taking action on these recommendations.

Operational Discharges

Sources of oil pollution on the Great Barrier Reef far more insidious than headline-grabbing mega spills are accidental or operational discharges from large ships transiting the Reef.

Large ships can generate significant quantities of waste oil from a variety of sources. It may be lubricating oil from motors and engines such as the main power plant, generators, pumps, winches and cranes, residual fuel oil lining empty fuel tanks which may be used for ballast, or general oil "leakage" from engine spaces into the bilge.

Under the MARPOL Convention and the Australian *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* it is illegal for ships to discharge any oil what so ever anywhere within the Great Barrier Reef, with fines of up to $1 million. Waste oil generated on board a ship is supposed to be stored in a slops tank and discharged to appropriate waste reception facilities in port. Bilges are supposed to be equipped with oil/water separators and bilge alarms, ensuring bilge water pumped overboard is oil free.

Despite both the International Convention and the Australian legislation authorities receive an average of one report per week of an oil spill somewhere in the Reef Region that can be related to ship operations and illegal discharges. These spills range from a few litres to four or five tonnes. In one instance (outside the Great Barrier Reef) a spill from an operational discharge was estimated at 10 tonnes. Between June 1991 and November 1992 GBRMPA has been involved in the response to fifteen oil spills attributed to operational discharges by large vessels (see table 1), with many others being reported but not warranting an active response.

Given the relatively small amounts of oil spilt from each operational discharge, the large size of the Great Barrier Reef Region and the biodegradable nature of oil it would seem that this source of oil pollution is negligible. However, small day-to-day spills over time may produce chronic pollution much larger in volume with greater biological consequences than headline-grabbing mega-spills. Numerous studies now indicate that the sub-lethal effects of low-level chronic pollution can seriously impact on marine ecosystems (Loya & Rinkevic 1980). Studies of the distribution of hydrocarbon-associated bacteria in Great Barrier Reef waters show higher concentrations of these bacteria in areas of greatest shipping activity, presumably indicating that background levels of hydrocarbons are already elevated in these areas (Reicheldt, pers. comm., 1991). The importance of general water quality to the health of coral reefs has been firmly established and the addition of any pollutant to pristine Reef waters represents an undesirable and unnecessary impact. There is a need for further research into the impacts of low-level oil pollution on Great Barrier Reef ecosystems.

Spills from operational discharges can be of sufficient quantity to cause immediate ecological and economic impacts should they contact resources such as a reef at low tide, a stand of mangroves or a heavily used beach or tourist resort. Spills in the Reef Region have resulted in oiling of beaches and shorelines, including heavily used recreation and tourist beaches at Magnetic Island and even the Strand in Townsville. Visits by Marine Parks patrols to remote sand cays have on occasion discovered tar balls on the shore and even pools of oil amongst beach rock. In some cases slicks estimated to contain up to five tonnes of oil have narrowly missed both ecologically and commercially valuable sites such as Low Isles off Port Douglas. A five tonne slick impacting on Low Isles would have undoubtedly had a deleterious effect on the heavy tourism use of this site as well as impacts on its extensive seagrass flats and mangrove area. Only good fortune and favourable winds and tides prevented this from happening.

There are a number of reasons why these discharges continue. Some ship operators may be unaware of the legislation (which seems unlikely), the Master of the vessel may not always be aware of what is occurring in the engine room, or the operators may simply be irresponsible or lazy. It is a lot easier, cheaper and quicker to simply pump your waste oil over-board while en-route than to hang around in port discharging it ashore. There is little doubt that a significant contributing factor is the dismal lack of adequate waste oil reception facilities at ports in the Reef Region. At Cairns, Townsville and Gladstone waste contractors with vacuum trucks are available to take waste oil from ships in port, however at the bulk-product ports of Cape Flattery, Lucinda, Abbott Point and Hay Point, which together handle a very significant proportion of large ships visiting reef ports each year, no waste-oil reception facilities are provided at all. Under the MARPOL Convention member States are obliged to provide adequate waste oil reception facilities.

Oil spills from operational discharges are real, they are occurring every day, yet they are illegal and easy to avoid with responsible and professional running of vessels and provision of adequate waste oil reception facilities in ports.

References:

Loya, Y & Rinkevich, B., 1980, Effects of Oil Pollution on Coral Reef Communities, Mar. Ecol. Prog. Ser. V3, pp 167 - 180.

Table 1. Some Oil Spills from Operational Discharges in the GBR Region: June '91 - Nov. '92.

Date	Location	Nature of Incident
13 June '91.	Kay Is. Temple Bay.	3nm slick. Degraded at sea. No suspects.
10 Sept '91	Magnetic Is.	3 tourist beaches closed by tar balls. Clean-up required. No suspects.
16 Oct.'91	Whitsundays.	10nm slick trailing ship. Degraded at sea.
4 Feb. '92	Forrest Bch - Ingham.	3Km of beach impacted by tar balls. No clean-up. No Suspects.
12 Feb. '92.	NE of Low Isles	7nm slick. Degraded at sea. No suspects.
12 Feb. '92.	E of Cape Tribulation.	4nm slick. Degraded at sea. No suspects.
5 March. '92	Palm Passage.	40nm slick trailing ship. Reef impacted. Degraded at sea.
21 April '92.	Piper Reef, Temple Bay	15nm slick. Reef impacted. Degraded at sea. Suspect under investigation.
23 April '91.	Eden Reef, Princess Charlotte Bay.	5nm slick. Degraded at sea. Suspect under investigation.
25 May '92.	Yongala Wreck.	2nm slick. Divers surfaced through slick. Tourist boat oiled. Degraded at sea. No suspects.
23 May '92.	Offshore Mackay.	3nm slick. Degraded at sea. No suspects.
24 May '92.	Beach near Hay Point.	Oiling of beach. No clean-up. No suspects.
4 August '92.	King Beach Cairns.	3.5 km oiled beach. Two dead oiled birds. Clean-up conducted. No suspects.
27 August '92.	SE Low Isles.	2nm slick trailing ship. Degraded at sea. Suspect under investigation.
1 October '92.	E Cape Flattery.	4nm slick. Degraded at sea. Suspect under investigation.

(NB: This table is not exhaustive and only represents spill reports to which some form of management response has been mounted during the period indicated. Many other spills are reported to which a response is not possible or necessary, and many spills occur which are not reported)

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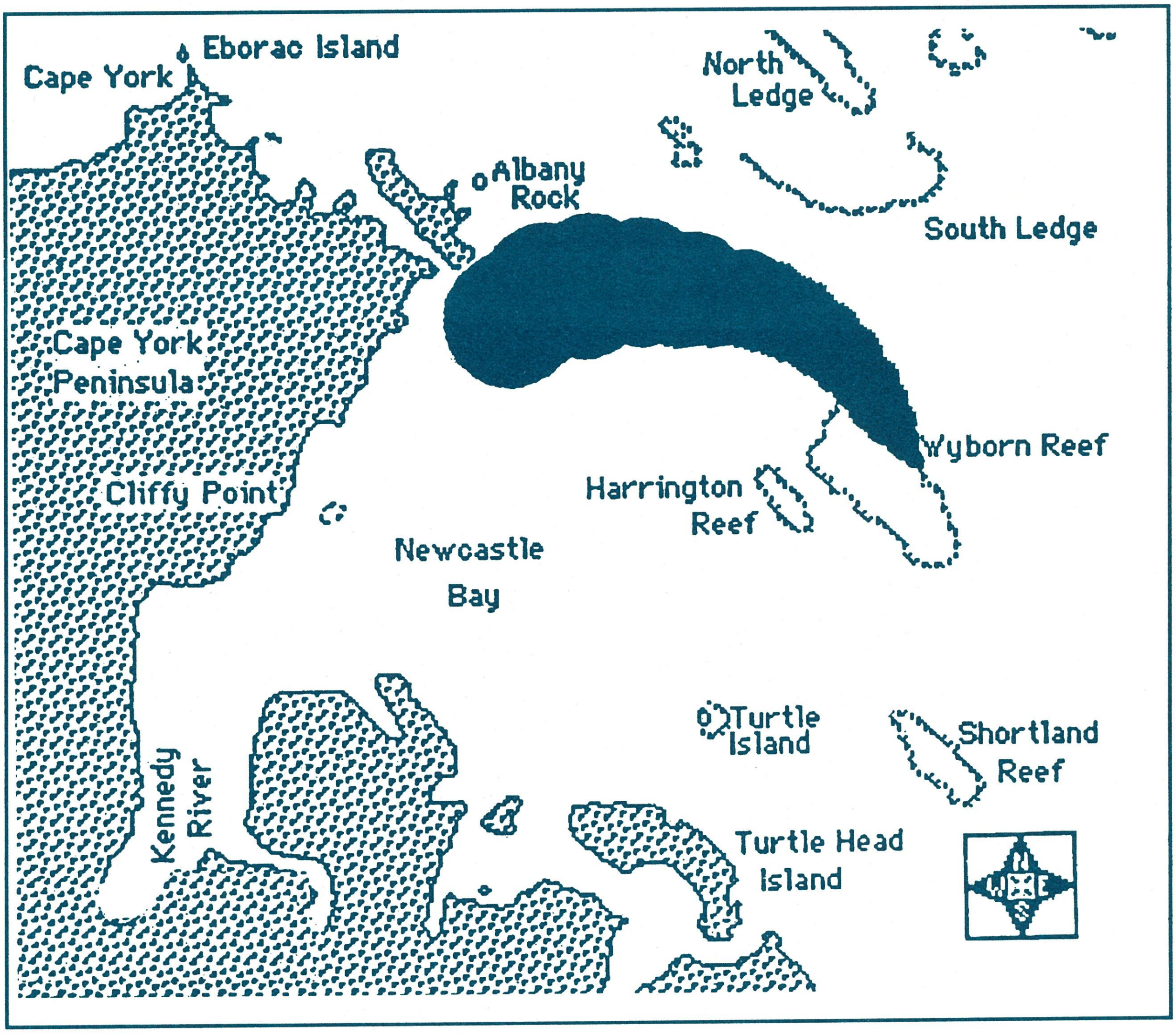
Figure 1.
Spill scenario, exercise 'Northern Reaches', 24 hour trajectory as predicted by ASAP program.



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Biological Basis for Managing Dugongs and Other Large Vertebrates in the Great Barrier Reef Marine Park. (January 1989) H. Marsh. (Research Publication No. 21) has now been published as one volume. This single volume will be selling for $82.50 including postage and handling within Australia. For overseas orders please add $10 Aus for Cheques and $3 Aus for Sea Mail or $7 Aus for Economy Air.

AN OVERVIEW OF GEOGRAPHIC INFORMATION SYSTEMS WITHIN THE GBRMPA

by Michael Hartcher

The history of using computers for mapping and spatial analysis shows that there have been parallel developments in automated data capture, data analysis, and presentation in several broadly related fields. These fields include cadastral and topographical mapping, thematic cartography, civil engineering, geography, mathematical studies of spatial variation, soil science, surveying and photogrammetry, rural and urban planning, utility networks, remote sensing and image analysis and environmental management. These disciplines are basically attempting to develop a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. Such a set of tools constitutes a Geographic Information System (GIS) (Burrough 1989).

Geographical data describe objects from the real world in terms of (a) their position with respect to a known coordinate system, (b) their attributes that are unrelated to position (such as colour, cost, pH, incidence of disease, etc.), (c) their spatial interrelations with each other or topological relations which describe how they are linked together or how one can travel between them. GIS technology has provided a medium for controlling the vast quantity of geographical data which is required for understanding and making decisions concerning the environment we live in.

Information can be stored within a GIS in two forms, namely, polygon or 'vector' data and grid cell or 'raster' data. With polygon data each feature from a map can be stored using points (e.g. location of sampling sites), lines or arcs (e.g.. roads and rivers), and polygons (e.g. soil type, management zones, seagrasses, etc.). Polygons are discrete units which designate homogeneity within their boundaries.

Raster or grid data stores information in grid cells having a particular cell size. The cell size is known as spatial resolution, meaning that the cell size is the smallest resolvable detail. Satellite imagery is captured and processed in raster format with different satellite sensors having various spatial and spectral resolutions. Spectral resolution refers to the sensors sensitivity to wavelengths in the electromagnetic spectrum. For example, Landsat Multispectral scanner (MSS) data has a spatial resolution of about 80m and contains four wavebands of data covering visible light energy, red, blue, green, and near-infrared energy, whereas Landsat Thematic Mapper (TM) data has a spatial resolution of 30m and contains seven wavebands of spectral data covering visible light energy, as well as a near-infrared, two mid-infrared channels, and thermal infrared. TM data, therefore, has a greater spatial resolution (or greater resolving power) and greater spectral resolution than MSS data.

A GIS has been implemented at the Great Barrier Reef Marine Park Authority (GBRMPA) and consists of a variety of software and hardware. These include ARC/INFO (polygon based) running on a Sun SPARC IPX workstation and IDRISI and SPANS (both grid based) mounted on a PC 486. Digitising equipment enables the input of data from sources such as maps and aerial photographs. A colour printer and large format plotter are used for creating hard copy maps.

ARC/INFO software has been used primarily because polygon data best suited the nature of the information. Each polygon in a ARC/INFO coverage is given a label-id which corresponds to an item in an associated database.

ARC/INFO has a number of modules designed specifically for:

inputting and editing data (ARCEDIT);

creating map compositions and plots (ARCPLOT);

building coverage topology, transforming and projecting data into various coordinate systems, and performing various geographical analysis (ARC);

access to a number of databases (INFO, ORACLE, dBASE, etc.) and statistical analysis of information within the database.

Additional modules can be acquired for ARC/INFO including GRID modelling, TIN (Triangulated Irregular Networks) or three-dimensional modelling, and NETWORK modelling for performing cost/flow or accumulative/flow analysis. All of these tools constitute a generic GIS where data can be generated and provided in a usable form ready for application.

In addition to ARC/INFO is the ARCVIEW package which is basically a 'user-friendly' desktop mapping tool. ARCVIEW allows access to data which has been created in ARC/INFO and employs a pull-down menu system thus eliminating the need to learn a large number of commands. ARCVIEW can be acquired for Workstations and PCs, and will be available for Macintosh soon. It can be used to query spatial data and/or database information via the use of a number of intuitive selection tools. Other functionality includes a query builder, which uses logical expressions to query the database, a variety of measurement tools for spatial query, zooming to specified areas, and creation of snapshots of images for plotting. The next version of ARCVIEW will include many improvements on the current version such as faster drawing and use of less computer memory, access to an external database, creation of tables for export to spreadsheets and wordprocessors, adding of fields to tables, and an in-built drawing package for use over maps.

The grid-based software SPANS and IDRISI have not been put to significant use mainly due to a lack of available, current remotely sensed data, but also due to a number of issues such as data compatability and software functionality. Remotely sensed information is an important data source within a GIS as it can provide both spatial and temporal information. Such information could prove invaluable in many projects, considering the dynamic nature of the marine environment.

The information currently available on the GBRMPA GIS is limited to base mapping such as reef, island, coastline, mangroves, cay, etc., at 1:250,000 scale, and the GBRMPA zoning plan information also at 1:250,000 scale. Further information input is continuing and includes seagrass beds and dive sites, inter-reefal plots for attachment of aerial surveillance and effects of fishing data (trawl and line), sector plots for aerial surveillance, some Whitsunday Management Plan information, as well as information at finer scales concerning a number of individual islands and reefs such as Heron Island, Green Island and Low Isles. The linking of Authority databases is also currently being pursued with the aim being to have all the databases and GIS information available through the same software interface. The ease of access of information however is of little value if the information itself is not current or not appropriate for a specific project.

The use of GIS in scientific research is becoming more widespread yet it is hampered by the cost and availability of current information. In the context of the Great Barrier Reef the situation is further complicated by the presence of the water column, the dynamic nature of marine ecosystems and the extent of the area which requires study. Remotely sensed information can overcome these problems to some extent yet the ability to penetrate the water column remains a major consideration. With further enhancements in remote sensing data and the use of appropriate image processing software these data sets could provide valuable information neccessary for observing marine phenomena both spatially and temporally.

If GIS is to become a useful tool in marine research a great deal of consideration should be given to information requirements, costs, availability, and research techniques such as image modelling, to ensure that the time employed in using this technology is not just another exercise in mapping.

References

Burrough P.A. (1989), 'Principles of Geographical Information Systems for Land Resources Assessment, ' Oxford University Press, pp.6-7.

Michael is a planning officer in Planning and Management Section responsible for developing GIS applications.