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EX POST BENEFIT/COST ANALYSIS

PROJECT NO: 1994/045

Development, Application and Evaluation of the Use of Remote Sensing Data by Australian Fisheries

Prepared for the FRDC

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TABLE OF CONTENTS

SUMMARY

The project was developed in the context of the expected imminent launching of a new American satellite designed to monitor changes in the concentration of phytoplankton chlorophyll (a measure of biological productivity) in oceanic waters. The availability of such data was expected to substantially advance understanding of the role of the environment on the distribution of many commercial fish species, allow the incorporation of environmental data in stock assessments, and assist fishers identify productive fishing grounds.

However, unanticipated events - a three year delay in the launching of the satellite, and a tenfold change in the cost of a real time commercial licence to access the satellite data - resulted in the focus of the project shifting to assessing the benefits to fishers from greater use of sea surface temperature (SST) data.

A catch prediction model was developed based on historical catch and SST data. The key rationale for developing the catch prediction model was to generate benefits to commercial fishers. However, aside from the trials conducted during the project, fishers have not been using the model on an ongoing basis. The model may possibly be used in the skipjack purse seine fishery for the 2004 season, but at this stage it is premature to estimate the benefits attributable to the model and a few more years of commercial-scale testing are required.

There have been expressions of interest from foreign companies wanting to develop and market the model, but these approaches have not as yet been encouraged as priority has been given to making the model available to Australian fishers. There is thus some future promise of commercial benefits should domestic development of the model fail to materialise. Similarly, the catch prediction methodology developed during the project may have future applications to other Australian fisheries such as the developing small pelagic fishery.

Despite these future possibilities, since the catch prediction model has not been utilised on an ongoing basis, the benefits expected from developing such a model have not as yet been realised.

The project demonstrated that SST data is also a good indicator of biological productivity. This information has helped explain why SST is significant in influencing fish distribution and has reinforced the value to fishers from using SST data. The information may also have encouraged those fishers that were not formerly using SST data to change their setting

practices and make use of such data. However, given that most fishers were aware of the importance of SST data prior to the project, this impact is considered to be negligible.

The project generated considerable interest among Mooloolaba fishers, a number of whom wanted their vessel to participate in the project. However, largely due to costs, only one Mooloolaba vessel could be selected. A CSIRO observer then spent up to one week onboard the vessel every two months, calibrating the gear and collecting data on each fish caught.

Such regular interaction between the skipper, crew and CSIRO observer over the 18 month period of the project can be expected to have led to a better understanding of the environmental factors influencing billfish and tuna availability, and hence, some increase in catch rates on that vessel. However, given the range of other factors that also impact catch rates, it is not possible to quantify the impact of the project had on catch rates from that vessel. Similarly, it is not possible to quantify the extent to which the improved knowledge from that one vessel subsequently spread through the remainder of the Mooloolaba fleet.

The project identified significant relationships between fish abundance, as measured by catch rates, and certain environmental conditions and the results have been used in subsequent scientific studies examining the impact of environmental conditions on fish growth and reproduction. Should any attempt be made in the future to develop some form of ecosystem model for the east coast fishery, the model will rely on using data such as that generated by the project.

The main objective of the project was to understand, and hence model and predict, the impact of environmental factors on fishery abundance. The project has made significant inroads towards meeting this objective, with information generated during this project providing the foundation for further work examining the impact of environmental conditions of growth and reproduction. The project has also generated a number of intangible benefits such as the development of technology capable of continuous monitoring of fine-scale oceanographic environmental conditions and a strengthening of the skills and expertise Australian scientists working in the remote sensing field.

1. Introduction

This report describes an ex-post cost/benefit analysis undertaken on FRDC project 1994/045, ‘Development, Application and Evaluation of the Use of Remote Sensing Data by Australian Fisheries’, implemented by CSIRO Marine Research, Hobart.

2. Background

As stated in the non-technical summary of the final report, the rationale for the project was to ‘*develop, evaluate and apply remote sensing data to Australian fisheries, with specific reference to the east coast tuna fisheries’*.

The project proposal was prepared in the context of the expected imminent launching of a new American satellite (Sea-viewing Wide Field of View Scanner, or SeaWiFS) designed to monitor changes in the concentration of phytoplankton chlorophyll (a measure of biological productivity) in oceanic waters. As reflected in the project proposal, the anticipated ability to use the SeaWiFS data to identify patches of highly productive waters, and to make this information known to commercial fishers, generated considerable excitement:

> *‘The satellite can provide for the first time almost real-time data on biologically productive regions to aid targeting on tunas in the east coast fishery as well as other pelagic and demersal fisheries. The proposal outlines the work necessary if we are to be in a position to benefit from this new data’.*

The proposal identified two practical issues that needed resolving if the SeaWiFS data was to be of practical use to Australian fishers:

i) validation of the SeaWiFS data;

The accuracy of the chlorophyll estimates obtained from the satellite data required checking. SeaWiFS coordinators had the goal of generating data with a 30% error on a global basis: however, regional differences could potentially lead to increased localised errors, such that on-the-ground validation of the SeaWiFS data was considered essential.

ii) developing appropriate processes to receive, process, archive and disseminate the satellite data.

The project was to focus on the yellowfin and skipjack tuna fisheries off south-eastern Australia. A detailed economic and technical evaluation of the value of the satellite data was also to be undertaken during the course of the project.

Changes in project design due to external factors

During the course of the research, the project had to respond to two significant and unanticipated events:

- a three year delay in the launching of SeaWiFS, from the intended launch in mid-1994 to the actual launch in August 1997; and
- a tenfold change in the cost of a real time commercial licence to access SeaWiFS data (from US$20,000 to US$200,000). Project researchers were able to access the data through a research licence, but the increased licence fees exceeded the project budget such that researchers were unable to transfer SeaWiFS images to fishers as initially envisaged.

These events necessitated a major change in the focus of the study. The initial intent - that of providing SeaWiFS-derived data showing spatial distribution of biological productivity to fishers in close to real-time - was no longer feasible. Instead, the focus of the project shifted to assessing the benefits to fishers from greater use of remotely sensed data - in particular sea surface temperature – that was readily available from other sources. Associated with this change, attention was also given to the design and manufacture of two automated continuous underwater sampling devices capable of providing continuous recording of water temperature, salinity, fluorescence (used as an indicator of phytoplankton concentrations) and GPS position.

The project also responded to the changes taking place in the east coast tuna fishery by:

- extending the list of species of interest to also include bigeye tuna and broadbill swordfish; and
- expanding the area of interest northwards to include the rapidly expanding broadbill fishery on the grounds off Mooloolaba and southwards to capture the skipjack summer migration in waters around Tasmania.

3. Project Objectives

Project objectives

1. To develop computational procedures for the validation, analysis and interpretation of ocean colour data and to provide derived data sets suitable as input to the analysis of selected fisheries;
2. To determine in conjunction with key industry operators of the east Australian tuna fisheries the utility of ocean colour and satellite temperature data in improving the catch efficiency for long-line tuna and to determine the economic cost-benefit of the use of satellite imagery in the operational fishery; and
3. To develop an operational (ie near real-time) catch prediction model for yellowfin, bigeye and skipjack tunas and broadbill swordfish in eastern Australian waters.

4. Research Findings

Validation of Satellite Data

Satellite data on sea surface temperature and biological productivity (as measured by chlorophyll levels) were validated. On the east coast, the validation was achieved by comparing the satellite estimates with actual data obtained on the fishing grounds from the placement on two commercial fishing vessels of purpose-designed sensors that continuously recorded temperature, salinity, fluorescence and position. As stated in the final report, the sensor packages '*proved to be robust and reliable*'. Additional east coast validation data was obtained from occasional research cruises.

Validation was also undertaken off Western Australia, using data obtained from 27 monthly cross-shelf transects taken from a chartered research vessel.

The results indicated the satellite-generated sea surface data was within 0.5°C of the actual temperature. Chlorophyll estimates from SeaWiFS were found to be within ±35% of the actual concentrations in the open waters off the western Australian coast, and within ±30% in the open waters off eastern Australia. Based on these results, the researchers suggested that '*the SeaWiFS chlorophyll estimates can be used with confidence in these areas*'.

Benefits of using ocean colour and sea surface temperature data

Use of sea surface temperature data

Using historical catch and sea surface temperature data, a model was developed to estimate the relationship between sea surface temperature and tuna catch rates.

A comparison of catch rates as predicted by the model and actual catch rates revealed '*considerable variability'* in the accuracy of the catch predictions. The final report identifies a number of factors likely to have contributed to this variability, such as inaccuracies in the position reports stated on the historical catch data, factors such as cloud cover restricting the usefulness of satellite data on any particular day, and difficulties in defining the effective sweep area of a longline set. The report also noted that catch rates would be affected by a large number of variables not included in the model – such as skipper skill, the fishing gear used, the depth of the set and the choice of bait.

Despite these limitations, the report found that where high catches were predicted, actual catches also tended to be high (though not necessarily increasing in proportion to the catch index). Based on this result, the report concluded that the catch index was effective at identifying 'core' areas of expected high catches, but not sufficiently sensitive to accurately predict the relative strength of these high catches.

Use of ocean colour data

The catch prediction model based on SST data was modified so as to be able to forecast chlorophyll concentrations on a broad spatial scale. A visual inspection of the output from the chlorophyll model indicated a close match with the satellite-produced SeaWiFS chlorophyll estimates. The researchers interpreted this as meaning that at a broad scale, the inclusion of chlorophyll indicators adds little additional value to information obtainable from sea surface temperature data. In other words, SST data was found to be a good proxy for sea colour data, such that accessing ocean colour data provides fishers with little additional information above that obtainable from SST data. As a result, the researchers concluded there was little additional benefit to fishers from having access to sea colour data.

The catch prediction model

Catch predictions based on the SST-based model were provided in near real-time to participating east coast tuna skippers on a twice-weekly basis over the period August 1997-February 1998. Predictions were made for four species – yellowfin, bigeye, broadbill and skipjack – and five geographical areas – northern Queensland, southern Queensland, northern NSW, southern NSW and Tasmania.

Assessment of benefits

The planned quantitative assessment of the benefits gained by fishers as a result of using satellite-generated sea surface temperature data did not proceed, due to the reluctance of fishers to provide pre-trip information on their intended fishing strategy, delays in the forwarding of real time catch forecasts to fishers, and communication problems with participating skippers while at sea.

The report notes that subjective feedback on the usefulness of the catch prediction and/or sea surface temperature data was received from 10 skippers, 7 of whom considered the information to be useful. Perceived benefits identified by these skippers as a result of accessing the data were reduced search time and higher catch rates of target species.

<u>Finescale modelling</u>

The relationship between catch rates and environmental variables were modelled using data obtained from the underway samplers installed on two commercial fishing vessels, catch data verified by at-sea observers on these two vessels, oceanographic data obtained from research cruises, and sea surface temperature data obtained from satellite. Note that this was not the SeaWiFS satellite: the cloudy conditions experienced during much of the study period limited the usefulness of much of the satellite data, and ocean colour data from the SeaWiFS satellite was not used at all in the modelling.

Two models were developed – the first using data from both vessels, and thus covering virtually the entire east coast tuna fishery, the second only using data from the Mooloolaba-based vessel and thus pertaining to the northern area only. At each spatial scale, three species were considered – broadbill, yellowfin and bigeye.

Those environmental factors estimated to have a significant influence on catch rates for each species and in each model are presented in Table 1.

Table 1: Environmental factors significant in influencing catch rates

	Broadbill swordfish	Yellowfin	Bigeye
Model 1 (regional)	fluorescence, area, month	temperature, fluorescence, moon, area, month, wind	salinity, fluorescence, nearness to front, moon
Model 2 (Mooloolaba)	salinity, fluorescence, nearness to front, moon, year	salinity, fluorescence, moon, year	salinity, fluorescence, nearness to front, moon

5. Cost/Benefit Analysis

There are two major components of net economic benefit in cost/benefit analysis - producer's surplus and consumer's surplus. In the context of this study, producer's surplus can be considered as the net economic benefits generated in the fishing industry as a result of the research project. Although somewhat simplified, producer's surplus can be thought of as additional profits generated. In addition, if the research findings induce increases in production and employment, then to the extent that previously unemployed labour is hired, the associated wages would also be included as a benefit in producer's surplus.

Consumer's surplus is a measure of net economic benefits to consumers. For example, if a research project induces an increase in product supply that in turn results in a decrease in prices on the domestic market, then domestic consumers would be better off. Consumer surplus is a measure of this improvement in consumer well-being.

Cost/benefit analysis involves the calculation of the net economic benefits that are generated from the research investment, which are in turn compared to the initial research investment.

a. Project Costs

Total costs of the project are estimated at almost \$3.8m, of which FRDC contributed around 16% (almost \$613,000).

Table 2: Costs of Research Investment for Project 1994/045

FRDC	Applicant	Other	Total
\$612,539	**\$1,722,926**	**\$1,462,875**	**\$3,798,340**

b. Potential Benefits

The potential benefits from the use of remote sensing data in Australian fisheries are:

i) increased profitability of commercial fishers arising from increased catch rates given their improved ability to target commercial species and/or reduced fishing costs resulting from their needing to spend less time at sea searching for productive fishing grounds;

ii) increased employment in the Australian fishing industry that might arise from any increase in industry profitability referred to in (i);

iii) benefits to Australian consumers as a result of any fall in domestic tuna prices as a result of the increased domestic catch referred to in (i);

iv) any profits that may arise from the commercial development of catch prediction models, the underway sampler and/or the Australian remote sensing data industry; and

v) intangible benefits such as any improvements in fisheries management arising from the use of remote sensing data to strengthen stock assessments and/or other scientific advice to managers, and increased human capital expertise in remote sensing data that can be used for other applications.

c. Realised Benefits

Increased profitability of commercial fishers

<u>Use of the catch prediction model</u>

The catch prediction model developed during the project was intended to be suitable for commercial application. Negotiations involving representatives of the research organization and the East Coast Tuna Boat Owners Association (ECTBOA) to conclude an agreement for use of the model did take place, but no agreement was reached.

An ECTBOA representative advised that the test results had been positive and that the longline industry had been keen to use the model on an on-going basis, but a lack of resources within the industry organization, the emergence of other issues in the fishery, and logistical problems such as the lack of an effective feedback loop, led to the break-down in negotiations.

There is a market for the provision of satellite data to commercial fishers. For example, most of the active fishers in the southern and western tuna and billfish fishery subscribe to a remote sensing data service – Orbimage – which is based on the same SeaWiFS data that the initial proposal was designed. For around US$500/month, fishers at sea can obtain close to real-time data on SST, ocean colour, wave heights and currents. Orbimage also provides a catch prediction service, though industry sources advise that most fishers base their fishing decisions on their individual interpretation of the data rather than the Orbimage predictions.

- the principal investigator of the project remains confident in the ability of the model to help east coast longline fishers improve their fishing effectiveness and considers the model is more effective than the catch prediction tool available from Orbimage. However, the model is not currently being used by east coast longline fishers, and the low priority given to coordinating the use of the prediction model by the industry association suggests that longline fishers perceived the model as having only limited practical value.

The project is unlikely to have influenced west coast longline fishers to utilise the Orbimage data. Despite the validation work that was conducted in Western Australia, prominent west coast fishers contacted during the course of this review were unaware of the project, indicating there was little if any extension of the information to west coast fishers.

Similarly, while the validation of the SeaWiFS data undertaken in the project confirmed the accuracy of the data was within targeted guidelines, such validation is unlikely to have influenced any fisher's initial decision to subscribe to the service.

The purse seine fishery

With respect to purse seining, the catch prediction information was used by industry for the two seasons 2000 and 2001. Results from those two years were mixed – a very positive performance of 2000, where catches were almost 4000mt, was followed by a dismal performance in 2001 with catches less than 300mt. However, catch is not necessarily a good indicator of the accuracy of the model: given that the skipjack taken in Australian waters are thought to be part of the larger western Pacific stock and that the Australian fishing grounds are at the southern extremity of the skipjack's range, skipjack abundance off the Australian east coast is highly variable. In 2001 the model may have accurately predicted areas most suitable to attracting skipjack, but the skipjack abundance may simply have been too low in that year for skipjack to be found in commercially viable numbers.

Industry did not continue using the catch prediction information in 2002 and 2003, skipjack abundance remained low, and catches remained poor. However, with the expectation of higher skipjack abundance for the 2004 season, industry is considering possibly reusing the prediction model.

- It is premature to gauge the benefits attributable to the catch prediction model in respect to the skipjack fishery. The model performed well in the one year in which skipjack were abundant, but a few more years of testing the model when skipjack abundance is high are needed to assess the reliability – and hence usefulness – of the model.

The principal investigator on the project advised that there have been expressions of interest from foreign companies wanting to develop and market the model but these approaches have not as yet been seriously explored as priority has been given to making the model available to Australian domestic fishers.

Increased use of sea surface temperature data

East coast longline skippers advise that fishers have long known the significance of using SST data to help determine where to set longline gear. Prior to the project, there were practical problems in terms of fishers being able to access real time, reliable SST information while at sea. However, improvements in technology that would have occurred irrespective of this project have overcome most of these problems.

The finding from this project that SST data is also a good indicator of biological productivity has helped explain why SST is significant in influencing fish distribution and would have reinforced the value to fishers from using SST data. The project may have encouraged those fishers that were not formerly using SST data to change their setting practices and make use of such data. However, given that most fishers were aware of the importance of SST data prior to the project, this impact is considered to have been only negligible.

Commercial development of the Australian remote sensing data industry

Use of the underway samplers

The two underway samplers and associated equipment developed in the project have been used in other situations:

i) an underway sampler was placed on an Australian merchant vessel for a period of one year, and the data obtained from various ports throughout Australia used to calibrate oceanic data received from the SeaWiFS satellite;

ii) the software developed during the project to manage data received from the sampler was used in work undertaken by the Rivers Commission of Western Australia to manage data obtained in a study assessing the environmental status of the Ord River.

Aside from these examples, there has not been any other commercial application of the underway samplers, possibly due to the high costs associated with the samplers - $17,000 each.

Improved management of Australian fisheries stocks

The catch prediction model was used by fishery managers in an attempt to address the southern bluefin tuna (SBT) interaction issue in the east coast longline fishery.

- the Australian SBT fishery is managed using a system of individual transferable catch quotas (ITQs). At certain times of the year, SBT migrate along the eastern seaboard, where they are susceptible to capture by east coast longline fishers. Some SBT bycatch can be expected even when targeting other tuna species such as yellowfin and bigeye. However, few east coast fishers hold SBT quota - all but a very small amount of quota is linked to the SBT aquaculture operations in Port Lincoln, South Australia. AFMA – being the fisheries agency responsible for both the SBT and east coast longline fishery - faced the classical fisheries interaction issue of how to minimise the adverse impacts of one fishery upon another fishery.

The catch prediction model was used to forecast areas of high probability of SBT abundance. The results were made available to east coast fishers - via the AFMA website – and updated regularly over the period June-September 1999.

- the initial intent was that east coast fishers would use the information to minimise their SBT catch by avoiding fishing in those areas predicted to be most suitable for SBT;

- there was also the longer-term possibility of implementing real-time area closures in the east coast fishery based on model predictions. In other words, managing the interaction issue by closing parts of the east coast fishery, but with the boundaries of the closed area changing in time based on the model's predictions of SBT abundance.

AFMA advises that neither goal was achieved – implementing real-time changes to area closures were not considered feasible due to concerns over operational compliance issues, while the provision of model predictions on the AFMA website was discontinued after 1999 over concern that fishers were misinterpreting/misusing the information.

In 2000, AFMA introduced a seasonal area closure – with fixed boundaries – in the east coast fishery. The fixed boundaries were not based on the catch prediction model. Instead, the boundaries were based on a collaborative AFMA-CSIRO analysis of historical east coast SBT catch and SST data. However, the principal investigator from this project was involved in the analysis, such that the project did contribute to resolving the SBT bycatch issue - albeit in an indirect manner – by developing the expertise and capacity of CSIRO staff to better understand the relationship between SST and fish abundance.

Results from the finescale modelling

Understanding the significance of environmental factors is particularly relevant to Australia's tuna fisheries, since the tuna caught in Australian waters are part of larger regional stocks and the amount of tuna available to domestic fishers in any given year will be heavily influenced by environmental conditions inside and outside the Australian EEZ.

Developing an understanding of the impact of environmental conditions on tuna abundance requires a medium-long term timeframe. The finescale modelling can be viewed as an initial step towards this overall objective. While no tangible benefits have as yet been realised as a result of the finescale modelling, the work did identify significant relationships between fish abundance – as measured by catch rates – and certain environmental conditions and the results have been used in subsequent scientific studies examining the impact of environmental conditions on fish growth and reproduction. Should any attempt be made in the future to develop some form of ecosystem model for the east coast fishery, the model will rely on using data such as that generated by the finescale modelling.

The project generated considerable interest among Mooloolaba fishers, a number of whom wanted their vessel to be used for the finescale analysis. However, largely due to costs, only one Mooloolaba vessel could be selected. A CSIRO observer then spent up to one week onboard the vessel every two months, calibrating the gear and collecting data on each fish caught.

- it is reasonable to expect that the regular interaction between the skipper, crew and CSIRO observer over the 18 month period of the project would have led to a better understanding of the environmental factors influencing billfish and tuna availability, and hence, some increase in catch rates on that vessel;
- however, given the range of other factors that also impact catch rates, it is not possible to quantify the impact of the project had on catch rates from that vessel. Similarly, it is not possible to quantify the extent to which the improved knowledge from that one vessel subsequently spread through the remainder of the Mooloolaba fleet.

d. Net Benefits

The key rationale for developing the catch prediction model was to generate benefits to commercial fishers. However, aside from trials conducted as part of the project, the catch prediction model is not being used by commercial fishers on an-ongoing basis.

There may be promise of the model being used in the skipjack purse seine fishery for the 2004 season. The skipjack component of the model has been used in two previous years, with mixed results. Given this uncertainty, it is premature to estimate the benefits attributable to the model and a few more years of commercial-scale testing are required.

The catch prediction methodology developed during the project may also have applications to other Australian fisheries such as the developing small pelagic fishery.

There have been expressions of interest from foreign companies wanting to develop and market the model, but these approaches have not as yet been seriously explored as priority has been given to making the model available to Australian domestic fishers. There is thus some future promise of commercial benefits should domestic development of the model fail to materialise.

Despite these potential future benefits, the fact that the catch prediction model has not been used on an ongoing basis by east coast fishers means that the benefits expected from developing such a model have not as yet been realised.

The project has generated a number of intangible benefits such as:

i) reinforcing the value to commercial fishers of using SST data in deciding where to fish;

ii) developing technology capable of continuous monitoring of fine-scale oceanographic environmental conditions; and

iii) a strengthening of the skills and expertise Australian scientists working in the remote sensing field.

The project has also made significant inroads towards better understanding the impact of environmental conditions on fishery abundance, with information generated during the project providing the foundation for further work examining the impact of environmental conditions of growth and reproduction.