A strategic research plan (2010–15) to underpin management goals of the 2009 Fisheries Plan for Foveaux Strait oysters (*Ostrea chilensis*, OYU 5)

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New Zealand Fisheries Assessment Report 2010/21
August 2010

Published by Ministry of Fisheries
Wellington
2010

ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

Michael, K.P. (2010).
A strategic research plan (2010–15) to underpin management goals of the 2009 Fisheries Plan for Foveaux Strait oysters (*Ostrea chilensis*, OYU 5).
New Zealand Fisheries Assessment Report 2010/21.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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This report outlines a strategic research plan (2010 SRP) for the Foveaux Strait oyster fishery (OYU 5) for the next five years. This plan was collaboratively developed with the Foveaux Strait Oyster Fisheries Plan Management Committee (FSOFPMC) comprising shareholders and skipper representatives from the Bluff Oyster Management Company (BOMC), customary and recreational fishers' representatives, and the Ministry of Fisheries. The strategic research plan is a living document that can change in response to new information, management needs, and changes in the fishery. The Foveaux Strait Oyster Fisheries Plan (FP, May 2009) is scheduled for full review in 2012, but a partial review may be carried out by the Ministry of Fisheries in 2010. This strategic research plan may change as a result of these reviews.

The 2010 SRP provides a broad range of research programmes aimed at maximising production from the oyster fishery and meeting FP goals and objectives. These research programmes range across improving stock assessment and monitoring for better management decisions; improving fishing technology, procedures, and strategies; ecosystem approaches to fisheries management; and building the capability of BOMC staff to implement informed management and fishing strategies. It provides high level descriptions of the research required to underpin management goals; how these programmes are linked to each other; the research priorities set by FSOFPMC; and funding and scheduling proposed by BOMC. This report is not intended to document detailed research proposals. Once the 2010 SRP has been reviewed by the Shellfish Working Group, detailed research proposals will be drafted for review before each new research programme being undertaken.

Key research themes cover a number of FP goals and include information and tools to minimise oyster losses from bonamia; the acquisition of fishery data and development of tools for less frequent stock assessment, and fishery indicators to monitor the fishery between assessments; developing a better understanding of the drivers of oyster production and how they vary in different parts of the fishery information to optimise fishing strategies; and increasing the efficiency of fishing while minimising any negative effects of dredging. The basis of the 2010 SRP is informed from research 2000–09 and summarised in a previous report under project OYS200701 (Objective 2). There are no standard formats for stakeholder research plans and this report presents an overview of strategic research with linkages to FP goals and objectives, priorities for research, and the rationale and an overview of likely methods for each programme, with an indication of scheduling and funding sources. These can be further refined after a review of the 2010 SRP.

1. BACKGROUND

The Foveaux Strait oyster (*Ostrea chilensis*) fishery (OYU 5) is a high value, iconic fishery that has been fished for about 140 years. It is an important fishery nationally and is of high socio-economic importance to Southland. The fishery has a long history of research since the early 1900s. Early surveys have generally been in response to reduced catches. Since the 1960s, research has focused on providing information for management of the fishery that includes surveys to estimate population size and distribution, and research for stock assessment. More recently, research has included investigations of the status of *Bonamia exitiosa* (bonamia) infection in oysters and oyster mortality, the effects of fishing, developing new fishing technology and procedures, and oyster enhancement strategies.

Catch has been recorded since 1907, and some fishing effort data have been recorded from 1948. Boundaries of statistical areas for recording catch and effort were first established in 1960 (and have been revised periodically since) and the outer boundary of the licensed oyster fishery was established in 1979. Population surveys of the fishery were undertaken from 1906, with two major surveys from 1960 to 1964, and 1976 to 1979. Thereafter the fishery was monitored from fishery catch rate data until 1986, after which more regular surveys have been undertaken for stock assessment and to estimate the effects of disease mortality from bonamia (see Fu & Dunn 2009 for details).

The total annual commercial catch of oysters from Foveaux Strait fluctuated close to 20 million (16–26 million) from 1907 to 1927, then steadily increased to 97 million in 1960 with a sharp, but short decline to 51 million between 1952 and 1954, and fluctuated around 90 million (73 to 127 million in 1967) from 1961 to 1985. There were two significant declines in catches between 1961 and 1985, one to about 50 million in 1962 and 1963 was attributed to disease mortality, and the other in 1969 when industrial action resulted in no commercial fishing for about half the oyster season (see Fu & Dunn 2009 for details). There were three changes to minimum legal size over this period, and catch rates generally fluctuated between 9 and 17 sacks per hour. If these data indicate the status of the fishery, the fishery was relatively stable over a 25 year period and supported a catch limit of 89 million oysters.

Significant and rapid declines in total annual catches and in commercial catch rates from 1986 to 1992 were caused by a bonamia epizootic. *Bonamia exitiosa* is thought to be endemic to oysters in Foveaux Strait. The decline in catches between 1962 and 1963 was originally attributed to *Bucephalus longicornutus*, but was most likely caused by bonamia. The fishery was closed in 1993 and reopened in 1996 with a reduced catch limit of 14.95 million oysters to allow the fishery to rebuild. The fishery steadily rebuilt until 2000 when another bonamia epizootic caused significant oyster mortality, reducing catch rates from about 7 sacks per hour at the time to below 2 sacks per hour in 2005. In 2003, BOMC voluntarily shelved half the TACC, and the total commercial catch since has been about 7.5 million oysters.

Since 2004, the TACC has been based on projections of future recruit size stock abundance under different catch limits and levels of mortality from bonamia, using the Foveaux Strait oyster stock assessment model (Fu & Dunn 2009). Stock assessments show that oyster mortality from bonamia is the principal driver of oyster population abundance in Foveaux Strait, and low catch limits are unlikely to have any significant effects on future stock levels.

Bonamia mortality has caused catastrophic declines in the oyster population and enormous economic losses. Research to date has focused on the spread of bonamia infection and oyster mortality. A number of fundamental questions regarding sources of infection, spatial and temporal dynamics of infection and mortality, and the course of infection in individual oysters remain unanswered. Drivers of infection within and between oysters are likely to be complex. Little can be done to prevent epizootics, but minimising losses from bonamia may provide significant gains for both the oyster populations and the economics of the fishery. Bonamia remains the primary research focus. Other ongoing research includes projects to better understand drivers of oyster production, recording fishery data to inform management and fishing strategies, the effects of fishing, and better fishing technology and fishing procedures.

2. INTRODUCTION

Fisheries plans document an operational procedure and management goals for New Zealand fish stocks. Fisheries plans can provide for stakeholder driven, "bottom-up management" within a Ministry of Fisheries framework and standards. In 2005, the Ministry of Fisheries (Allen Frazer and Rose Grindley, Ministry of Fisheries, Dunedin) facilitated the development of a Fisheries Plan for Foveaux Strait oysters (OYU 5) with fishery stakeholders (tangata whenua, recreational, and commercial fishers) and with NIWA as science provider for the fishery. This plan (Ministry of Fisheries 2009) was approved by the Minister of Fisheries, the Hon Phil Heatley in May 2009. The fisheries plan processes also established a Foveaux Strait Oyster Fisheries Plan Management committee (FSOFPMC) comprising Ministry of Fisheries and stakeholder representatives to implement and oversee the plan, and also to ensure management responded to changes in the fishery and incorporated new information. The Fisheries Plan (FP) documents a number of stakeholder goals. The development of fishing and management strategies to achieve these goals requires information from research. This document outlines a strategic research plan to underpin these management goals.

Strategic research for stock assessment of OYU 5 has been documented by the Ministry of Fisheries (MFish) in medium term research plans (MTR) since 1996. Commercial stakeholder strategic research plans were established in parallel to MTRs, to provide a broader range of research to underpin management and fishing strategies. The first Foveaux Strait oyster commercial stakeholder strategic research plan (SRP) was developed by Andrew et al. (2000) when a second bonamia epizootic indicated disease mortality could be a recurrent feature of the oyster fishery, and information on pathogenesis of bonamia was required to manage the Foveaux Strait Oyster Fishery. The 2000 SRP also proposed long-term research focusing on information for better management of the fishery that included a length-based stock assessment model for oysters and an epidemiological model of bonamiosis. The 2000 SRP was revised in 2004 (2005 SRP) by Michael & Dunn (2005) to address concerns that complex benthic habitats and benthic communities dominated by the bryozoan *Cinctipora elegans* were critical to the production of oysters and in reducing bonamia mortality, and that the effects of oyster dredging had reduced oyster productivity and increased mortality from bonamia. The 2005 SRP incorporated research into the effects of oyster dredging, and the development of strategies to mitigate, remedy, and avoid any effects identified. Key results from research undertaken from 2000 to 2009 from all funding sources (Bluff Oyster Management Company (BOMC) funded, Seafood Innovations Limited (SIL) co-funded, and MFish levies and reviews of the stock assessment and disease models were summarised by Michael (2010) to fulfil the requirements of OYS200701 objective 2. These data provide the basis for the development of a 2010 SRP and prioritisation of the research objectives.

The long-term goal of the FP is to maximise oyster production in the oyster fishery. That is, to manage the fishery so that the oyster population can rebuild to levels where it will support near historical levels of catch (about 80 million oysters). The FSOFPMC identified four key goals and

14 objectives that are consistent with the overall goal (Ministry of Fisheries 2009). These are reproduced from the FP in Table 1.

Table 1. Goals and objectives from the Foveaux Strait Dredge Oyster Fisheries Plan (sources: Ministry of Fisheries 2009).

Goals		**Objectives**	
1.	A fishery for the future – for our mokopuna	1	Catch is sustainable
		2	Production of oysters is maximised
		3	The impact of bonamia is minimised
		4	The impact of invasive marine organisms is minimised
2.	A fishery that minimises harm and enhances the environment	5.	Adverse dredging impacts are minimised
		6.	Ecologically sensitive and important habitats for other fisheries are maintained and enhanced
3	A fishery for all sectors – everyone has a fair share of this taonga	7.	Fishing access for all sectors is protected
		8.	Mana of tangata whenua and marae is maintained
		9.	The value of the recreational fishery is maximised
		10.	The value of the commercial fishery is maximised
		11.	Illegal fishing is minimised
4	A fishery based on the 'right' decisions with all groups sitting around the table together	12.	Decisions are understood and integrated
		13.	Stakeholders participate in decision making
		14.	Information is communicated effectively

The FP also documents proposed management strategies to meet objectives 1–14 (see Ministry of Fisheries 2009 for details). The 2010 strategic research plan is applicable to only a subset of these objectives (1–3 and 5–7), and provides research to develop a better understanding of biological and ecological processes, the oyster fishery, bonamia, and their interactions. In order to develop research programmes that are directly applicable to developing and evaluating management and fishing strategies, some of the original FP objectives have been refined to be more specific and measurable, and the linkages between research, management strategies, and objectives better defined (Figure 1). Throughout this document research programmes will be linked back to the original FP objectives with a (FP ***objective number***) notation.

In developing this strategic research plan, it was important for BOMC to set a soft target for medium-term (5–10 years) harvest limits, as these limits will determine short to medium term research priorities and how the fishery should operate. The higher the desired harvest level, the more information will be required for stock assessments to support it (Alistair Dunn, NIWA, Wellington, pers. comm.). BOMC decided on a target harvest limit of 15–30 million oysters, considered a low level of exploitation when compared to the recruit size oyster mortality during epizootics (30–750 million oysters annually). At the current TACC (15 million oysters), projections from the Foveaux Strait oyster stock assessment model indicate that current catch limits are unlikely to have any significant effects on future stock levels (Michael et al. 2009).

While absolute population size is important to stock assessment and meeting MFish harvest standards, BOMC is more interested in the numbers and total area of fishery areas with high (commercial) oyster densities to maintain economic catch rates, and high market quality oysters.

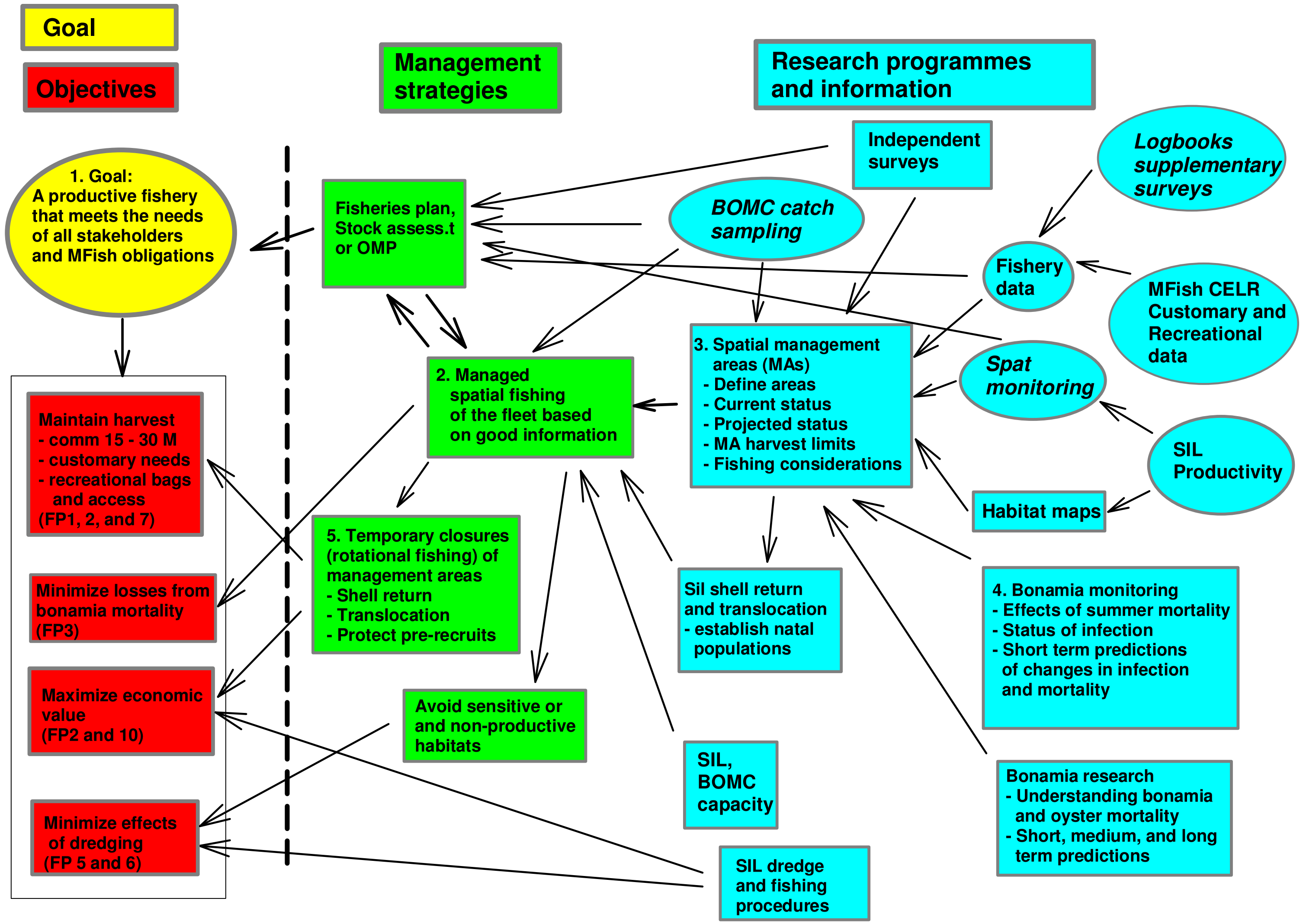

Figure 1: Flow chart showing links between management goals and objectives (yellow and red respectively), management strategies (green), and research programmes and fishery data (cyan). Dedicated research shown in rectangles; fishery data and collaborative research italicised in ellipses.

Research is not solely focused on MFish stock assessment and sustainability, but aims to increase fishery production and maximise market value using spatial fishing and management strategies. Research programmes aim to provide tools and sampling strategies to delimit areas with and without bonamia infection; to investigate the course of infection to provide a predictive capability of where and when disease mortality will occur; to allow infected areas to be fished to minimise losses from bonamia; and uninfected areas to be left to maximise their contribution to the rebuilding of oyster populations. Similar strategies could target areas with high market quality oysters or leave others where oyster quality could improve. The purpose of this strategic research is not only to develop these strategies, but together with BOMC and the FSOFPMC evaluate their effectiveness.

Research priorities would focus on incorporating logbook data into stock assessment and continuing with bonamia research to inform strategies that may help minimise oyster losses. There will also be a need to continue research on the drivers of oyster production, such as the spat monitoring programme. In the longer term, the 2010 SRP may provide the basis for future research to refine the information required for better spatial fishing and management strategies that will support higher levels of catch. For significantly higher levels of harvest in the long term, research priorities may include information for the development of fine spatial-scale models to predict harvest levels and fishing effort, along with developing and evaluating managed fishing strategies for the fleet.

This document (2010 SRP) outlines strategic research and research priorities to meet short to medium term objectives in the FP. The 2010 SRP documents core research areas; lists potential research projects along with the rationale to support them; provides an indication of when the research will be undertaken; and details prerequisites to the research project. The 2010 SRP is not intended to provide detailed research proposals; these will be submitted to the Shellfish Working Group (or Aquatic Environment Working Group) for evaluation before the research is carried out. MFish have indicated a review of the FP in 2012, and the SRP should also be reviewed at regular intervals to take into account new information from research, changes to MFish obligations, and changes in the fishery. This report fulfils reporting requirements for the MFish project OYS200801, objective 2.

2.1 Overview of strategic research

The oyster population size is primarily driven by disease mortality and recruitment. The fishery has rebuilt after two bonamia epizootics, but not to historical levels. Although the fishery has not been assessed against the MFish Harvest Strategy Standards (Ministry of Fisheries 2008a, 2008b), the Shellfish Working Group believes current catch (commercial, customary, and recreational) and catch limits are unlikely to significantly affect future stock levels. Therefore the strategy to ensure sustainability (FP1) can only monitor the status of the oyster population and bonamia. Fishery closure at low oyster population levels is unlikely to affect the sustainability of the stock or future stock status.

FSOFPMC management goals aim to maximise production in the fishery. These goals include: fishing and management strategies (Figure 1) to maintain consistent medium-term commercial catch for domestic supply of about 15–30 million oysters; to maintain fiscal returns to quota owners and the flow-on to the oyster industry and economy; to maximise the value of the resource; balance market supply with demand to maximise the commercial value of oysters; and to maintain oyster quality (meat condition and size) to maximise market value and the Bluff oyster brand integrity. Two key areas that may provide significant short-term benefits to the fishery are minimising oyster losses from bonamia (FP2) and more efficient fishing technology and procedures (FP5). Research to develop cost effective, sensitive molecular detection tools for bonamia to support large spatial and temporal scale sampling, investigations to determine the pathogenesis of bonamia to enable predictions of mortality, and managed fishing strategies to minimise oyster losses are important to achieving the first goal. Trials to improve the performance of dredges and fishing procedures and research to predict optimum harvest level matched to oyster productivity in distinctly different fishery areas are important to the second goal.

Oysters for customary purposes are mostly provided by fishers from commercial oyster vessels. Strategies to improve fishing success will also benefit customary fishers (FP7). Increases in the population size of oysters and, more specifically, the number and size of high oyster density areas will maintain consistent long-term access to areas where recreational fishers can take their bag limit of oysters. The recreational only fishing area inshore of the north coast of Stewart Island (within a line from Saddle Point to Garden Point to Mamaku Point) has been slow to rebuild after bonamia reduced oyster densities. Translocation of oysters and shell enhancement strategies may provide natal oyster populations to facilitate rebuilding in the recreational fishing area.

Research to underpin strategies to minimise the effects of dredging on oysters and benthic communities (FP5 and 6) is ongoing and centres around two main strategies: increasing fishing efficiency to minimise fishing effort and the annual foot print of the fishery; and spatially managed fishing to avoid ecologically sensitive areas. Fishery data show oyster densities tend to be high and oyster quality better on stable sand, gravel, and shell substrates; and catch rates significantly higher than in areas with patchy, erect, epibenthic bycatch. Detailed maps of the distribution of sensitive ecological habitats will be developed from fishers' logbook data, survey bycatch, and benthic video and still camera sampling. These maps will provide guidance to oyster skippers on areas to avoid, and those areas that may maximise catch rates.

Critical to achieving four of the FP goals (FP2, 3, 5, and 6) is the ability to guide fishing to specific areas and to fish to predetermined levels. BOMC intends to slowly introduce a system of spatially managed fishing based on an appropriate level of spatial partition of the fishery, guided by information that allows individual skippers choice in day to day activities, but maximises both production and oyster quality (value) from each spatial management area. The success of such a strategy will in part be dependent on oyster skippers recognising potential benefits to the fishery. This strategy requires extensive information from the fishery on a spatial scale of management areas. The most cost-effective sources of these data are from a fishers' logbook programme and industry monitoring. Fishers' logbooks can provide extensive spatial and temporal coverage of data, but need to be of a quality suitable for robust analysis. These data could be used to monitor the status of the fishery and for stock assessment. Further, spatial management based on oyster density and the quality of oysters, oyster recruitment indices, and infection status is similar to Operation Management Procedures (OMPs) used for stock assessment, where the OMP documents a range of predefined actions as responses to key changes in the fishery, one of which is chosen based on model simulations. If in the future spatial management proves to be beneficial in increasing oyster production, and logbooks could provide the range and quality of data required for OMPs, spatially explicit models could be developed to evaluate management strategies.

Spatial fishing strategies may require significant change to the operational nature of the fishery. An operational procedure that removes competition and puts vessels and crews on equal footing regardless of designated area and catch rate, and accommodates the nature of how individual vessels operate, may be required to implement managed fishing. Further, daily or regular reporting of logbook data will be required to ensure management area harvest limits are not exceeded.

These strategies require research to partition the fishery into spatial management areas with distinctly different oyster production, but not so many areas that stock assessments become problematic. The number of fishery areas should be sufficient to spread fishing effort, provide for rotational areas that can be closed for rotational fishing or enhancement activities, and provide sufficient options for different weather and sea conditions and travelling distances from port. Spatial management area boundaries will be determined in consultation with oyster skippers from research data; from the analysis of oyster density and bycatch data from surveys and fishery logbook data; from SIL research on the productivity of different areas determined from the availability of oyster larvae, oyster spat settlement on the seabed, post settlement survival, growth to commercial size; and habitat maps from available data, still and video camera sampling, swath mapping, and side scan sonar.

The information required to run spatial management includes the number and size of commercial oyster areas and the density of oysters within them to enable catch rates and harvest limits to be estimated. Also needed is information on meat quality to maintain a high proportion of high value oysters in the catch; some understanding of how condition may change within season and between seasons; and some factors that may drive oyster quality such as size and age, oyster density, reproductive cycle and speed of meat condition recovery; habitat considerations (competition and over-settlement); primary productivity; and sediment movement that may impede feeding. Information to estimate the speed of rebuilding in fished areas will include the population size structure (recruits, pre-recruits, and small oysters) to determine recruitment to the fishery in the short term, and management area productivity characteristics such as oyster spat settlement indices, spat survival and growth to "commercial" size. The linkages between research, fishing and management strategies, and FP goals are shown in Figure 1.

2.2 Research priorities set by stakeholders

The 2010 SRP has been developed in collaboration with the FSOFPMC, BOMC, and oyster skippers. A number of meetings and workshops have been held over 2009 to develop a draft plan. Research objectives were prioritised by oyster skippers at a workshop in Bluff on 8 December 2009 and a meeting of the FSOFPMC on 9 December 2009 in Invercargill. Research priorities are ranked below.

Agreed research priorities for the 2010 SRP set by oyster skippers and the FSOFPMC

High priority

- To develop cost effective molecular tools for bulk screening presence / absence of bonamia infection in oysters and to undertake investigations into the temporal course of bonamia infection in oysters (FP2 and 3)
- Experiments and data analysis to determine the utility of using fishery data to monitor the oyster fishery between stock assessments, to extend the period between stock assessments, and to compare fishery data against survey data for monitoring status of the fishery (FP1)
- To develop new dredge design and fishing procedures to increase fishing efficiency and reduce fishing effort (FP5)
- To quantify the effects of fishing (MFish project BEN200701, FP5 and 6)
- To delimit fishery areas with different physical, ecological, and fishery production attributes, and, with oyster skippers, to partition the fishery for spatial management trials

- To build BOMC capacity to record fishery data of a standard that will support robust analysis

Medium priority
- To design and evaluate structured fishing strategies
- Further development of stock assessment and disease models

Low priority
- To further develop and evaluate oyster and epibenthic community enhancement strategies using the return of oyster shell, and the translocation of oysters.

3. PROPOSED RESEARCH PROGRAMMES

3.1 High priority research

3.1.1 Bonamia investigations

Rationale

Bonamia epizootics are a recurrent feature of the oyster fishery, and during epizootics bonamia mortality is the main driver of oyster abundance and distribution. Bonamia mortality has the greatest effect in areas with high densities of oysters, and determines both patterns of fishing and catch rates in the fishery. Further, bonamia mortality affects oyster quality by removing large, high grade oysters. The level of mortality can be very high, up to 90% over a three year period in commercial fishery areas.

Constant monitoring of bonamia in February surveys, while it is detectable in the fishery, is important to stock assessment and projections of future stock size. Further, if logbook data are to be used to monitor the status of the oyster fishery between less frequent stock assessments, projected estimates of oyster density for the following season need to be adjusted for oyster mortality from bonamia. Information from pre-season surveys of the status of bonamia (infection and mortality) on oyster densities (recruit and pre-recruit size), and projections of mortality from category 3 and higher infections, will allow these adjustments to be made.

Critical to minimising losses of oysters from bonamia is the ability to predict mortality within a time frame that allows oyster density in infected areas to be fished downed by targeted fishing. Research that may provide some insights into the course of infection and allow future bonamia mortality to be predicted is of primary importance. Research to date offers little understanding of key processes (a summary of research information was provided by Michael (2010)). In order to progress our understanding of the pathogenesis of bonamia, a cost effective, sensitive, molecular tool that will distinguish light infections from no infection is required. Heart smears are the most time and cost effective method for screening large numbers of oysters for bonamia (Diggles et al. 2003), but heart imprints underestimate light infections by 30%. In-situ hybridisation is useful, but expensive. The development of PCR techniques since the trials of Diggles et al. (2003) has produced reliable PCR ELISA (96 sample) technique for bonamia (Peter Smith, NIWA, Wellington, pers. comm.). The challenge is to develop a cost effective technique that can be used for extensive sampling of the presence / absence of bonamia.

This tool will help to answer some key questions: is there complete clearance of infection or constant low level infection within and between spatially separated oyster populations; if there is complete clearance, what is the source of infection; and if infection is always present, what conditions and predisposing factors intensify infection to fatal levels? Histological samples will continue to be collected as part of routine sampling for bonamia to provide data on concurrent infections, physiological state, and reproductive stage. Further, to predict where and when oyster mortality is likely to occur, an understanding of how long it takes for light, detectable infections (category 1 and 2) to progress to fatal infections (category 3 and higher), how this course of infection may vary between individual oysters and between fishery areas. These later data could come from well structured spatial and temporal sampling of oysters over the fishery.

The re-infection and or the spread of infection, and the intensification of bonamia infection to fatal levels, may be complex, and driven by a number of factors. Although this research may be moderate to high risk, it may provide the ability to predict mortality on a spatial basis and with sufficient warning to reduce oyster density in infected areas with targeted fishing strategies. Any reduction in the loss of oysters to the fishery is likely to provide significant gains in economic returns and oyster productivity. If the time frame between infection and death is too short, research may focus on factors and conditions that intensify bonamia.

Research projects

1. Annual sampling to determine the status of bonamia infection and recent oyster mortality

Rationale

In the absence of disease, the Foveaux Strait oyster fishery is highly productive, has shown the ability to rebuild from low population levels, and has sustained high levels of catch over a long time. During bonamia epizootics, there is a rapid decline in the recruited oyster population size, and the level of bonamia infection and resulting oyster mortality determines the future status of the fishery. Annual monitoring of disease status is critical for stock assessments and projection of future stock size.

Until molecular tools become available, sampling will continue to use ventricular heart imprints to estimate prevalence and intensity of infection, and histological samples will be archived for future examination for concurrent infections. Hine (2002) used oyster histology sections to estimate the prevalence and intensity of an undescribed apicomplexan infection, a possible predisposing factor in bonamia infection. Diggles (2004) found very high prevalence of an undescribed apicomplexan, and a number of other concurrent infections including *Microsporidium rapuae*, rickettsia-like prokaryotes, and virus-like inclusions. The number of histology samples should be increased to provide material for future investigations of concurrent infections.

Overview of methods

Sites sampled for bonamia infection have mostly been selected from a subset of random stations in strata designated as commercial by oyster skippers for both stock assessment and bonamia surveys, where oyster density is highest and the effects of oyster mortality from bonamia greatest. A small proportion of sample sites have included exploratory and background strata with lower densities of oysters. Sampling will continue to target areas where bonamia mortality is likely to have the greatest effect: however, attempts to model the spread of bonamia infection and mortality were limited by the lack of temporal data from fixed sites. A set of fixed sites in key fishery areas will be established from 2010, and the number of sample sites increased, once molecular detection tools have been developed.

Samples of 30 randomly selected recruit-sized oysters from each site will be collected for the heart imprints and histology to estimate levels of bonamia infection. A subsample of 25 recruit-sized oysters from each site will be taken for heart imprints to estimate the prevalence among oysters and intensity within individual oysters. Data on size category, length and height, whether oysters are gaping, and incubating larvae will be recorded. Heart imprints, samples of tissue for bonamia DNA, and histological samples will be taken. Oyster heart imprints will be examined and scored using the five category scale of infection (Diggles et al. 2003).

Schedule and prerequisites

Annual surveys of the status of bonamia infection will be undertaken from February 2010. Funding source: MFish levies or direct purchase by BOMC.

Extensive spatial and temporal surveys of the status of bonamia infection will be undertaken from February 2011 using PCR techniques to estimate presence / absence of bonamia at sample sites, and heart imprints to estimate intensity of infection at infected sites only, depending on when PCR tools are available. Funding source: MFish levies or direct purchase by BOMC.

2. To develop a cost effective molecular tool for bulk screening presence absence of bonamia infection in oysters

Rationale

Crucial to understanding the pathogenesis of bonamia is the ability to identify oysters (and other organisms) with no infection from those with low levels of infection that may eventually intensify to fatal infections. This is essential to investigating potential sources of infection, the course of infection, and the role of predisposing factors and conditions in bonamia epizootics. Extensive spatial sampling at a fishery scale, with intensive initial temporal sampling to determine the course of infection, is required to develop the ability to predict where and when bonamia mortality is likely to occur and to inform targeted fishing to minimise oyster losses. Diggles et al. (2003) found in situ hybridisation (ISH) was the most sensitive method examined, followed by DNA amplification, heart imprints, and histology. ISH was useful for small numbers of samples, but very expensive. Heart imprints were the most time and cost effective method for screening large numbers of oysters; with reduced sensitivity, heart imprints can underestimate low level bonamia infections by 30%. The initial DNA amplification was based on a small region of the 18S rDNA, and identification was based on the size of a relatively short (300 base pair) DNA fragment (Diggles et al. 2003). Subsequently, a larger region (700 bp) of the 18S rDNA was amplified and sequenced (Smith et al. 2005). Sequencing is essential to confirm the identity of the amplified product and to distinguish amplified products from other haplosporidians (Carnegie et al. 2000, Burreson et al. 2004). However sequencing large numbers (>100) of individual oysters is laborious and expensive.

The need to screen large numbers of oysters with high sensitivity precludes the use of ISH because of the high associated cost and time. A more reliable PCR-ELISA technique has been developed, trialled, and evaluated against heart imprints to estimate the intensity of infection. PCR-ELISA appears to be more sensitive than heart smears for detection of bonamia at low intensities (NIWA, unpublished results). Further modifications are being made to speed up DNA extraction and reduce costs. The development of this tool is vital to advancing our understanding of bonamia.

The PCR ELISA technique is based on the selective amplification and labelling of a bonamia gene using bonamia specific primers. It was designed to be highly sensitive to the detection of the genus bonamia, but not for distinguishing *B. exitiosa* and other *Bonamia* spp. More recently, Robert et al. (2009) have developed a rapid, specific, and real-time PCR assay allowing detection and quantification of *B. ostreae* DNA in oyster samples. The real time PCR could be trialled with the primer combinations developed for the detection of bonamia in New Zealand with PCR-ELISA. Additional sequencing should be undertaken to identify the species of bonamia in New Zealand.

Overview of methods

To develop a cost effective, reliable, PCR technique based on the selective amplification and labelling of a bonamia gene, using bonamia specific primers. The labelled PCR products are detected on an ELISA multi-well plate format, which allows simultaneous detection from multiple samples. The PCR ELISA method provides high specificity, due to selective PCR amplification and target-specific capture probe technology, and high sensitivity, due to the nature of the detection substrate used in the ELISA test. The ELISA format (96 well plate) is suitable for screening large numbers of samples. Further work will test colorimetric detection for semi-quantitative evaluation of the amount of template (bonamia DNA) present in samples, once suitable standards have being developed.

Schedule and prior requirements

Continue development of PCR-ELISA method and high throughout DNA extraction systems from February 2010. Evaluate historical (2007) samples against heart smear results. Funding source: NIWA capability fund, direct purchase by BOMC, or SIL.

3. To establish fishery scale sampling protocol

Rationale

Regular sampling at a fishery scale will be required to monitor the status of bonamia infection in key fishery areas. These data will inform targeted fishing strategies to minimise oyster losses from bonamia, and detect developing epizootics when infection is either at low levels or absent from the fishery. The extensive scale of this sampling will not only require a cost effective detection tool, but an efficient sampling design that maximises detection power, but minimises sample size.

Fishery scale sampling will also provide temporal data on waxing and waning infection patterns at localised sites, together with changes in oyster density and size to follow the temporal course of infection.

Overview of methods

Establish a sampling design of replicated, fixed sites at locations determined from data on oyster density and bonamia infection from surveys and the fishery. Monitor sites for absence / presence and intensity of infection at regular intervals for one year. Analyse data to determine sampling efficiency based on spatial and temporal changes and their variance. Refine sampling design to minimise sampling.

Schedule and prerequisites

Sampling will be dependent on the development of a cost effective detection tool. The sampling design will be developed collaboratively with oyster skippers after the 2010 oyster season. Sampling will be initiated after October 2010. Funding source MFish levies.

4. To undertake investigations into the temporal course of bonamia infection in oysters

Rationale

Information on where and when bonamia is likely to cause mortality is critical to implementing targeted fishing strategies. If there is sufficient time between when at risk areas are identified and when oyster mortality occurs, fishers can target these areas to catch oysters that would be otherwise lost to the fishery. Oysters with high intensity infections (category 3 and higher) detected in February samples usually die before, or soon after, the oyster season begins in March. Because heart imprints are not sensitive enough to detect low level infections, or to positively determine that oysters with no detectable infection are not infected, it would be difficult to investigate the course of infection at local scales. It is important to establish whether fishery areas are completely clear of bonamia infection or whether there are always low level infections present in oyster populations.

An understanding of the temporal course of infection will determine whether spatial management and targeted fishing is likely to be beneficial, i.e., if low level infections persist in the fishery and intensify to fatal infections, and determining the speed of intensification will determine if mitigation procedures are possible. The information from Diggles & Hine (2002) suggests that once the epizootic has begun, high mortality in high oyster density areas is likely to cause a cascade of infection through the fishery, with those oysters close to large numbers of dying oysters likely to be exposed to near lethal densities of bonamia parasites, and those oysters further away likely to have increasingly fewer bonamia constituting light and undetectable infections. The ability of bonamia to remain viable in seawater for four or more days, after being released from the tissues of dying oysters, provides the opportunity to spread infection over the entire fishery area. The diffusion of infection down a gradient could result in oysters distant to the source of infection becoming lightly infected. There is no known resistance to bonamia in oysters, but some oysters may have high tolerance of low intensity infections. Sampling needs to establish how long oysters maintain low intensity infections (categories 1 and 2) before these infections become fatal. Further, if fishery areas are completely clear of infection, investigations will focus on sources of infection and speed and range of transmission.

Cranfield et al. (2005) hypothesised that oyster dredging, through mechanical disturbance and the removal of epifauna, may predispose oysters to bonamia. Preliminary analysis of the distribution of fishing effort from fishers' logbook data and the distribution of prevalence and intensity of bonamia infection in oysters from fishery independent surveys between 2006 and 2009 shows no correlation. No direct or immediate effects of oyster dredging on disease status can be determined from these data. Increased spatial and temporal sampling giving good snapshots to the commercial fishery area, better detection of low level infections, and fishing effort data from logbooks will provide the opportunity to better investigate this hypothesis.

Overview of methods

Data from fishery-scale bonamia sampling will be analysed for spatial and temporal patterns of new infections, intensification of infection, and mortality. When sufficient data are available on the course of infection, further sampling will be carried out to investigate the reliability of projections of mortality.

Schedule and prerequisites

Preliminary analysis of the first year's infection and mortality data will begin in May 2012, and annual updates will follow thereafter. Funding source: MFish levies or direct purchase by BOMC.

5. To test structured fishing strategies to target infected oysters (fish-down experiments)

Rationale

With the ability to predict when and where oyster mortality from bonamia is likely to occur, those infected areas can be subjected to targeted fishing. This strategy aims to minimise oyster losses from bonamia mortality, reduce infection pressure from the reduced disease mortality, and reduce fishing effort and catch from other, uninfected areas to maximise rebuilding of those oyster populations. Structured fishing trials in both infected and uninfected areas need to be undertaken to assess the effectiveness of such a strategy.

Overview of methods

In collaboration with oyster skippers, to design an experiment based on fishing and not fishing fishery areas with no bonamia infection and those where mortality from bonamia is likely during the season. The trial will use a Before After Controlled Impact (BACI) design, with catch limits high enough to significantly reduce oyster density in fished areas.

Schedule and prerequisites

Assess fish-down strategy to minimise oyster losses starting in the 2013 oyster season or later when predictions of oyster mortality can be made. Research is dependent on information on the temporal course of infection and prediction of oyster mortality. Funding sources: MFish levies or direct purchase by BOMC.

3.1.2 Acquisition of fishery data

Rationale

BOMC established a paid industry logbook programme for the 2006 oyster season. Since then, fishers have recorded data from 100% of fishing, in addition to furnishing MFish catch effort landing reports (CELRs). These fishers' logbook data are recorded at a spatial-scale of one nautical mile square, and routinely record catch and effort, disease mortality, bycatch, and recruitment at low cost, but with high spatial and temporal coverage. A time-series of these data provide the opportunity to investigate spatial and temporal patterns of oyster production in the fishery, providing these data are of adequate accuracy and consistency across the fleet. The format of logbooks is not difficult to change (unlike changes to the data recorded by CELRs), allowing the logbook data recorded to meet the needs of changing management of the fishery. Fundamental to management of the oyster fishery is the ability to establish indices between catch and effort and the relative abundance of oysters. Catch and effort recorded from the fishery is a good indicator of oyster density (Alistair Dunn, NIWA, Wellington, pers. comm.), and unstandardised catch and effort data are used in the OYU 5 stock assessment model. Some analysis of logbook and survey data has been undertaken by Dan Fu (NIWA, Wellington).

The ongoing development and refinement of data recorded in logbooks and from monitoring systems is essential to ensure these data are relevant to specific harvest and management needs, and the continued development of BOMC staff capability is critical to managed fishing and spatial management of the fishery. BOMC staff have made significant progress in acquiring the ability to run BOMC research programmes and to use data to inform fishing strategies. Data quality recorded in fishers' logbooks continues to improve.

Stakeholders are keen to see logbook data used in monitoring the status of the fishery and for stock assessments. Under conservative catch limits, the fishery may be monitored from fishery data and annual surveys of disease status, with stock assessments at longer intervals (5 yearly instead of the current biennial assessments). In the case of new epizootics, or if higher catch limits are sought, stock assessments may be carried out more frequently. Conditional to any strategy to monitor the fishery from logbook data will be an assessment of the suitability of these data to provide robust analyses. These data could be incorporated in stock assessments.

Research projects

6. To build BOMC capability to record fishery data to a standard that will support robust analysis

Rationale

Building the research capability of BOMC staff is critical to developing, implementing, and evaluating new fishing and management strategies to maximise production in the oyster fishery. This capability includes recording data from the fishery (fishers' logbooks), and running adaptive fishing operations that include spatially managed fishing, to undertake monitoring programmes, and to implement enhancement strategies. BOMC staff and fishers are already involved in a number of collaborative research programmes and are taking an increasing role in industry initiated research. The key outputs include low cost, high quality data for management, building an understanding of the oyster fishery, its response to fishing, and to develop and evaluate strategies to increase the production of oysters and minimise the effects of bonamia mortality and fishing.

Information recorded from the fishery needs to be appropriate for the task and suitable for robust analysis. To fulfil these requirements, fisher sampling programmes need to be developed collaboratively with fishers, clear criteria established for data, and the application of these data effectively communicated. Real-time monitoring of the data recorded is vital when initiating new programmes, to minimise data loss, and to support skippers in the provision of better quality data. Further, the data need to be assessed for accuracy and consistency across the fleet to ensure they are suitable for analysis.

In addition to ensuring the quality of these data, skippers and BOMC require regular feedback and summaries of their fishery data, and these data need to be accessible to skippers. A software package (oysterTools) has been developed to summarise logbook data in real-time and provide numerical and graphical outputs. Ongoing development of data formats, improvements in data accuracy and consistency, and the development of data acquisition, storage, summary, and display technology is a high priority for future research.

Overview of methods

The main focus is to improve data quality and consistency. Results from research project 6 will be used to further refine logbook data. Future improvements to logbooks include tow-by-tow recording of catch and effort data, electronic data capture using touch screen technology and automated texting of data to a central depository, automated data range checks, error tagging, and data summaries posted to a fishers' website to allow real-time access.

Schedule and prerequisites

Logbook update for the 2011 oyster season based on the findings of research project 6 and requirement for fishery monitoring and stock assessment. Funding source: SIL.

7. To establish the consistency of logbook data within individual vessels and between vessels in the fleet, and to compare logbook data to survey data

Rationale

Fishers' logbook programmes require frequent monitoring and assessment in the initial years to ensure data are accurate, recorded in a standard format and within specific criteria, are recorded consistently by individual skippers, and are consistent between vessels, across all data fields. While we can summarise how well data fields have been recorded in these logbooks and undertake some analysis of data in common logbook recording grids, oyster vessels spread their effort over the commercial fishery area, and therefore the spatial and temporal coverage of these data are often restricted to a small proportion of the oyster fleet. Quantitative analysis of the accuracy and consistency of these data requires trials involving all vessels in the fleet over a short time.

The variation in the data recorded from selected logbook reporting grids, fished by all vessels during the 2009 fishers' supplementary survey highlights the complexity associated with small spatial scale variations in the distribution of oysters and bycatch, fishing practices, and the data recorded in logbooks. The next in-season, supplementary survey in 2010 will place a high priority on investigating sources of this variation. Sampling in the selected logbook reporting grids (common grids) will be undertaken in a highly structured manner with additional fishery independent sampling during the 2010 oyster season.

Overview of methods

During the 2010 oyster season, BOMC intends to unshelve some of the currently shelved TACC (7.5 million oysters), and to use this extra catch to undertake an in-season supplementary survey. This survey will structure fishing to give a complete snapshot the distribution of oyster density in the commercial fishery area (the 1999 stock assessment survey area), i.e., to sample grids not commercially fished during the 2010 oyster season. An important component of this survey is to assess the accuracy of logbook data against survey data, and the consistency of logbook data across the fleet.

The design of this structured fishing trial will be developed in collaboration with oyster skippers. A number of logbook recording grids representing fishery areas with relatively high oyster densities that are important to skippers will be selected from summaries of the 2009 and 2010 logbook data to represent spatially separated areas in the west, east, central, and southern fishery.

Tows in these grids will be sampled with standard survey (370 m straight line tows, down tide) tows before and after the sampling by commercial oyster vessels (elliptical tows covering a similar distance). Selected grids will be sampled after most of the commercial fishing for the 2010 season has been completed. Because vessels in the fleet fish between one and three oyster quotas, they finish commercial fishing at different times. If all vessels cannot sample all the survey grids over a relatively short time (about two weeks?), some consideration should be given to common grids being closed to fishing from the date the first vessel begins sampling until the trial is finished.

Each grid will be sampled in a standard sequence of five tows, roughly one in the centre and one near each of the grid corners, with start and finish latitude and longitudes for each of the five tows specified. Each tow position will be sampled with three replicate tows, and each tow recorded as a separate logbook record. Survey tows will record data on both the standard survey form and on fishers' logbook forms. These data will also allow within and between vessel variation to be established and to assess the comparability to survey data.

Supplementary survey grid cells will be allocated before June 2010 to accommodate the first vessels finished for the season. Allocated tows in common grids and remaining survey tows may use different prefixes, "S" and "A" respectively. Some consideration could be given to using only a subset of the fleet to sample supplementary survey grids not included in the structured trial.

The 2009 supplementary survey highlighted the need for real-time monitoring of the data. 2010 survey logbook forms will be collected daily to ensure compliance with procedures. These data will be used to inform the continued development of logbook accuracy and consistency.

Schedule and prerequisites

Confirm survey design and procedures at the end of February 2010, immediately before the oyster season. Finalise sampling design in May 2010. Begin structured fishing trial after the first vessel has finished catching its quota.

Funding source: SIL.

8. To develop fishery indicators using logbook data for monitoring the status of the oyster population between stock assessments.

Rationale

Between 1970 and 1990, total annual catch and catch rates were used to monitor the status of the fishery. Yield estimates were used for setting catch limits (TACCs) between 1996 and 2002. Since 2004, assessments have used projections of future stock status using the OYU 5 stock assessment model. The Foveaux Strait oyster stock is assessed biennially, and future stock status projected out to three years. Projections beyond three years become increasingly uncertain as the levels of disease mortality, and to a lesser extent recruitment, may change significantly from year to year. The next stock assessment is scheduled for 2012.

Stock assessments are primarily concerned with absolute population size and the risk of different levels of disease mortality on future stock status (Ministry of Fisheries 2008c). During epizootics, levels of disease mortality around 10% have allowed rebuilding of the stock at a commercial catch of 7.5 million oysters.

The numbers of fishery areas with "commercial" oyster densities, and the size of these areas, are more important to BOMC and fishers than total population size, as they determine catch rates and the distribution of fishing. Fishery indicators based on the spatial scale of fishers' logbook recording grids could be established, along with key decision rules to monitor status of the fishery between stock assessments.

Overview of methods

Catch and effort, oyster size structure, and disease mortality data from fishers' logbooks could be used to monitor significant changes in key indicators such as catch rate. Constant and increasing catch rates for the same catch limits, and low estimates of disease mortality are likely to provide good indicators of a positive fishery status. Increasing numbers of grid cells with "commercial" oyster densities further support a positive fishery status.

Dan Fu (NIWA, Wellington) has begun to evaluate the comparability between logbook data and survey data, and their application to stock assessment. This analysis aims to serve two purposes: help establish monitoring methods between assessments and to incorporate logbook data into assessments. These data can provide the basis for a method of monitoring fishery status; a set of fishery indicators could be developed by the Shellfish Working Group, MFish staff, and industry representatives in a workshop forum. These discussions could include agreements on the frequency of stock assessments.

Schedule and prerequisites

Develop key fishery indicators from logbook data for monitoring the status of the fishery before the next stock assessment in 2012. MFish to coordinate a workshop? Funding source: MFish levies.

9. To test and further develop fishers' logbook data for spatially explicit stock assessment

Rationale

Spatially explicit stock assessment is pivotal to the development and evaluation of spatial fishing and management strategies. Projections of future stock levels in spatially managed areas can be used to optimise catch and effort, and to assess their effectiveness in subsequent assessments. To be useful at a fishery-scale, this approach requires sufficient data from each spatial management area for assessments.

The fishery area needs to be partitioned into useful management areas, specifications for logbook data for assessment established, and a sufficient time series of data recorded. In the first instance, available survey and logbook data could be used to establish spatial and temporal coverage, data limitations and quality issues, and to test potential differences in production between spatial management areas.

Overview of methods

Some analysis of logbook and survey data has been undertaken by Dan Fu (NIWA, Wellington). The fishery will be partitioned into spatial management areas (see Section 3.1.5) and available data used to begin testing the utility of spatially explicit stock assessment in the fishery. If need be, logbooks will be modified to record data more useful to stock assessment and in-season surveys used to ensure data coverage in all spatial management areas.

Schedule and prerequisites

To assess data required before 2011 oyster season and to modify fishers' logbooks for the 2011 oyster season.

To include spatial assessment in the 2012 assessment stock assessment.

Funding source: MFish levies.

3.1.3 New dredge designs and fishing procedures

Rationale

Increasing the efficiency of fishing through new dredge designs and procedures has a number of immediate tangible benefits to the oyster industry. Doubling the efficiency of fishing is achievable (the current commercial dredges have an efficiency of 17%) and would reduce the costs of, and time, taken to harvest providing economic benefits to boat owners and quota holders. Reducing the amount of bycatch and small oysters in the dredge has benefit for culching efficiency and minimising disturbance and dispersal of oysters and other benthic organisms. A reduction in the number of dredge tows and their tow lengths reduces the footprint of the fishery, minimising localised benthic disturbance and incidental mortality of small oysters. This object links directly to the core goals of maximising economic value and minimising the effects of dredging in the oyster fisheries plan.

The development of new dredge designs and fishing procedures is being undertaken through a collaborative research programme between BOMC, SIL, and NIWA. A desktop study summarising information from the Foveaux Strait oyster fishery and dredges used in similar habitats overseas has been completed. These data suggest dredges and dredge performance is fishery specific, and the greatest gains in efficiency may come from modifying existing designs and refining fishing procedures.

Initial investigations focused on understanding how oyster dredges fish on the seabed using dredge mounted video (see Michael 2010). The most significant issues identified were dredge saturation, where the dredge becomes full and ceases to fish, sometimes within 2–3 minutes of the beginning of tow, and then inconsistent seabed contact by the bit bar of the dredge. Improving dredge filtration may increase dredge efficiency, increase the selectivity for oyster size, and reduce bycatch increasing culching (sorting efficiency). Improvements in seabed contact by the dredge can be translated into increased efficiency only if dredge saturation can be delayed or prevented.

Research has initially focused on dredge design, with fishing procedure to be developed once the best design has been identified. New dredge designs and procedures will be tested against the current commercial dredge and fishing practices in structured trials.

Research projects

10. To develop a more efficient dredge design

Rationale

The greatest gains in improving dredge design are likely to be made from structured dredge trials. Two concept dredge designs to address issues highlighted by the dredge video data were developed by skippers and an engineer: a box dredge and a triple dredge rig. Together with the current commercial dredge, these dredges are being used to investigate dredge filtration and bottom contact. Filtration trials will compare different square mesh and oyster dredge ring sizes for filtration efficiency and oyster selectivity. The effectiveness of bottom filtration panels held off the seabed can be tested using similar filtration panels on a box dredge with the bottom panel off the seabed and the commercial oyster ring bag dredge with the bottom panel on the seabed. The triple rig dredge comprises three narrow versions of the current commercial oyster dredge which are towed off a single bar with fixed wheels at each end. This design provides the opportunity to test individual variables such as ring size combinations in replicated, randomised trials.

The hypotheses that larger mesh sizes filter more bycatch and small oysters, and by reducing bycatch, the dredges will fish more effectively on the seabed for longer before they saturate, were tested in a structured trial. Larger mesh panels increase the proportions of large oysters in the catch, and therefore reduce culching effort. Results to date have shown that dredge, mesh, and ring bag configurations have an effect on dredge performance and that fine tuning mesh and ring bag configurations could significantly increase selectivity, and in some commercial areas minimise or delay dredge saturation.

The greatest gains from the next phase of these trials may come from investigating whether it is possible to prevent bycatch and small oysters from entering dredges in the first place, and therefore increasing dredge efficiency. Improving seabed contact will be the last phase of dredge development.

Overview of methods

Skippers were asked to submit dredge designs or design features to remedy issues illustrated by the video data. These designs were collated and distributed in a discussion document. Two concept dredges have been built, a box dredge and a triple dredge rig.

Initial investigations have involved quantitative, replicated, and controlled fishing trials to test the effectiveness of different mesh and ring size combinations. More of these trials are required to establish significant differences between combinations. Another concept to be trialled is the insitu sorting of the catch on the seabed before it enters the dredge. If successful, this will allow longer, more effective tows and minimise bycatch. Investigations of dredge design, especially towing configurations, will be investigated to improve seabed contact.

Schedule and prerequisites

These trials have been running since January 2009, and are due to be completed in February 2011. This is part of a SIL research programme funded by BOMC and SIL.

11. To refine fishing procedures to increase fishing efficiency and reduce fishing effort

Rationale

Tow length, towing speed, and warp to depth ratio, tidal current speed and direction all affect dredge efficiency (Stead 1966, 1971, Cranfield 1977, Cranfield et al. 1991, 1997, Doonan et al. 1994). These effects vary with different seabed topographies and habitats. The primary cause for the loss in dredge efficiency and an increase in the adverse effects on benthic habitat is saturation of the dredge. Saturation is a function of tow length and habitat type. Fine tuning tow length on different habitats could minimise the impacts of dredging on benthic habitat. Dredge contact with the seabed is determined by towing speed, warp to water depth ratio, current speed and direction in relation to tow direction. These dredging parameters could also be optimised for different dredges on different benthic habitats, to optimise dredge efficiency.

Overview of methods

Catches of oysters and bycatch will be quantified in structured, replicated trials in different survey areas to determine the effects of tow length, towing speed, and warp to depth ratio, current speed and direction on catches. These trials will be designed and undertaken collaboratively with oyster skippers, with as many skippers as possible present during the trials. The data will be analysed and used to develop a code of best practice for the fishery.

Schedule and prerequisites

These trials will begin February 2010 and be completed in February 2011. This is part of a SIL research programme funded by BOMC and SIL.

12. To test new dredge designs and fishing procedures against the current commercial dredge

Rationale

If a more efficient dredge can be developed, trials to compare the efficiency of the current commercial dredge and the new dredge will be undertaken. These trials will also include BACI experiments to compare the rebuilding of oyster populations and the responses of benthic fauna to fishing. These experiments will investigate whether there is a difference in the recruitment and growth of oysters in areas fished with the different dredges, quantify changes to benthic habitats and communities, and determine the nature and speed of colonisation by epibenthic animals.

Overview of methods

Experiments will be undertaken in commercial fishery areas with the greatest bycatch of epifauna, especially erect epibenthic fauna identified from survey and fishers' logbook data. A homogeneous area will be divided into nine cells to facilitate the replicated, randomised, control experiment. Three cells will be randomly allocated to each of two dredge types and three as controls. The experimental design will need to account for the effects of experimental scale. The BACI design will sample all plots before, and immediately after dredging, and annually thereafter. Sampling will include benthic video and still images, side-scan sonar, dredging with lined dredges, and possibly direct sampling by divers (depending on depth). Analysis of these data will test for significant differences between treatments.

Schedule and prerequisites

This experiment will begin in 2011. This is part of a SIL research programme funded by BOMC and SIL.

3.1.4 The effects of fishing

Rationale

Implementation of the Fisheries Act 1996 in 2001 requires the effects of fishing to be managed, that is, to avoid, mitigate, and remedy fishing effects. In overseas fisheries, the effects of fishing are gear and site specific; dredging and bottom trawling on erect, biogenic habitats are considered the worst gear type and habitat combinations.

Dredging is the only cost effective method of harvesting oysters in Foveaux Strait and the short-term effects of dredging on benthic habitats, epibenthic fauna, and oysters cannot be avoided. The 2010 SRP contains fishing strategies to avoid fishing in unproductive, but sensitive, ecological areas, to develop new fishing technologies and procedures to minimise any effects, and oyster and habitat enhancement strategies to remedy any effects. Fundamental to managing the effects of fishing is information on the short, medium, and long-term effects, if any.

Foveaux Strait is a high energy environment where physical factors produce gradients of habitats (substrate type and stability, and benthic communities), and any effects of fishing will vary along these gradients (see Michael 2010). Communities in high energy environments are considered resilient to fishing. Logbook data show almost all commercial fishing for oysters occurs on sand, gravel, and shell substrates with little or no epifauna. These areas have considerably higher oyster production and oyster quality than areas dominated by rich biogenic epifauna. Anecdotal evidence suggests no direct effects of dredging on oysters or other fisheries' productivity and no correlation between dredging and the status of bonamia infection (given the data limitations) in commercial fishery areas. Any effects are thought to be relatively short-lived (2–4 years).

A key focus for the 2010 SRP is identifying and quantifying any localised effects of dredging and their persistence in the fishery. Two approaches will be used to investigate these effects: a project to evaluate the use of existing data to detect the effects of oyster dredging and to describe these effects (MFish project BEN200701); and the use of logbook data to investigate areas where significant bycatch was encountered, spatial and temporal changes with fishing effort, and structured dredging trials to quantify the effects of oyster dredging (SIL programme, objectives 1 and 4).

Research projects

13. To quantify the effects of oyster dredging

Rationale

Foveaux Strait has been fished for oysters for 140 years, and, as for many other fisheries, studies of the effects of fishing lack control sites or "baseline" data. We will not be able to determine how the commercial oyster fishery has changed over the history of the fishery, nor what role the effects of dredging may have played. Insights into the response of the fishery to fishing can come from studies of localised effects, how long they persist, and how these effects may accumulate spatially, and the likely effects of these changes on substrates, habitats, and fisheries production. These need to be considered in the context of the high levels of natural disturbance. New analytical techniques such as gradient analysis can be used to investigate differences in benthic communities and habitats with different levels of fishing effort. Research into the effects of fishing will be undertaken in two separate, but complementary, programmes: in BEN200701, the effects of oyster dredging will be investigated as one of three case studies, and a SIL programme will use structured dredge trials and logbook data to investigate the immediate, localised effects of dredging, and spatial and temporal changes to bycatch from fishery data.

Overview of methods

a. BEN200701

A pilot trial to evaluate the efficacy of bycatch sampling as a tool for describing and quantifying macrobenthic assemblages in Foveaux Strait was completed in February 2009. Three methods were assessed: directly recording the presence / absence of benthic taxa from bycatch, still images of bycatch (providing presence / absence, perhaps categorical abundance), and quantitative subsamples of bycatch paired with the still images. These samples were processed for species lists, weight of taxa, and numbers of taxa or colonies. These data will be analysed in September 2010 and a sampling design developed for January–February 2011.

Before further sampling is undertaken, the Foveaux Strait fishery data will be evaluated to ensure the assumptions of gradient analysis are met. The analysis requires a gradient of fishing effort along an axis of homogeneous habitat (and oyster density). Problems in the data could include the rotational patterns of fishing for individual fishing vessels within and between seasons, and the extensive spread of fishing effort by the fleet across the commercial fishery area. The gradients of physical disturbance and habitats run along several axes, and bonamia mortality during epizootics also determines fishing patterns.

Depending on the outcome of the pilot trial, sampling along a fishing effort gradient will include bycatch, benthic still images and video, side scan sonar, and direct sampling by divers.

b. SIL research programme

If a more efficient dredge can be developed (Objective 1), trials to compare the efficiency between the current commercial dredge and a new design will be undertaken. These trials will also include BACI experiments quantifying changes to benthic habitats and communities, and the nature and speed of colonisation by epibenthic animals after dredging.

Fishery data recorded in fishers' logbooks include catch and effort data, and bycatch data. Once the quality of these data is known, analysis of these data could investigate the spatial and temporal pattern of changes in bycatch to describe speed of colonisation and the characteristics of assemblages.

Schedule and prerequisites

BEN200701, analysis of pilot trial data in June 2010, fishery sampling in early 2011, and analysis later in 2011. MFish funded, non-recovered.

Dredging trials will be carried out in 2011 concurrent to the BEN200701. The analysis of patterns of catch and effort and bycatch composition can begin once the assessment of data quality and consistency has been established (project 7). The SIL research programme is funded by BOMC and SIL.

3.1.5 Partition fishery for spatial management

Rationale

Spatial management of the commercial fishery area may assist in maximising production from the oyster fishery. Fishery data on recruitment, growth, and the distribution of relatively high oyster density suggest markedly different levels of oyster production within the commercial fishery area. The hypothesis that spatial management could increase oyster production is based on two assumptions: during epizootics spatial management strategies focused on minimising oyster losses from bonamia through timely targeted fishing of infected fishery areas, and deferring fishing effort from uninfected fishery areas to increase the speed of population rebuilding; and in the absence of disease mortality, optimising catch and effort to the characteristics of spatially managed areas may increase oyster production, specifically the numbers and sizes of fishery areas with high oyster density.

Before this hypothesis can be tested; spatial management areas need to be delineated, a time series of fishers' logbook data for stock assessment needs to be available (project 8), and spatially explicit assessment developed to evaluate the efficacy of different fishing strategies. Once this capability is established, structured fishing to test the efficacy of spatial management in controlled trials can be undertaken.

Research projects

14. To delimit fishery areas with different physical, ecological, and fishery production attributes, and with oyster skippers to partition the fishery for spatial management trials

Rationale

Fundamental to spatial management strategies is the partitioning of the fishery area into management areas. Development and validation of a preliminary habitat map (Michael 2010) has begun using benthic video and digital images. This map along with information on the location of commercial oyster fishery areas will provide the basis for defining spatial management areas. Additional information on the distribution of benthic communities and their compositions, and sediment type from bycatch, will come from fishers' logbooks, survey data, and data from a SIL programme investigating the drivers of oyster production to delimit high production areas from low areas.

Analysis of fishers' data may provide information on key fishery areas where oyster production is high; those areas where vulnerable habitats with low oyster densities occur, and need to be avoided; and any overlap between these two classifications. The fishery will be partitioned into spatial management areas in collaboration with oyster skippers. The number of areas should represent spatially distinct parts of the fishery with different levels of production. The number of areas should be sufficient to spread effort, large enough to allow skippers choice in where they fish, but not too numerous to be problematic for management and stock assessment.

Once the fishery area is partitioned, data can be used to investigate differences in production.

Overview of methods

Skippers' information and knowledge and, survey and fishery data will be used to delimit distinctly different areas in the fishery based on oyster density, habitat, and proximity to the boundaries of other spatial management areas. The one nautical mile logbook reporting grid could provide the basis for defining spatial management areas, as this system is already established in the fishery. Areas for spatial management could be based on their long-term rates of production (number and size of high oyster density patches), speed of recovery based on the size structure of oysters and the time for each size group to recruit into the fishery, and habitat type. Other considerations could include distance from port, access in different weather condition, and oyster quality.

These areas could be provisionally determined from the analysis of fishery (logbook) and survey data, and using the OYU 5 stock assessment model to explore whether provisional areas have markedly different population sizes and projected future stocks. Investigations of the drivers of oyster production in spatial management areas will investigate; oyster larval supply, settlement and survival of oyster spat, and differences in substrate and benthic communities using benthic camera systems. Some of these investigations are currently funded by SIL: a spat monitoring programme will help define areas with good oyster larval supply from those with poor supply, and further, research under the SIL and the MFish BEN200701 projects could begin to investigate the seabed characteristics and benthic communities in these distinctly different fishery areas using swath mapping, side-scan sonar, and benthic video and still camera systems. These data will allow better definition of spatial management area boundaries.

Schedule and prerequisites

Partitioning and validation of spatial management areas will continue in 2010 and will be completed in time for the 2012 stock assessment to investigate the effectiveness of the partition.

This programme will be funded SIL and MFish levies research.

Research projects

15. To build BOMC capability to record fishery data to a standard that will support robust analysis

Rationale

Developing BOMC capability to undertake monitoring programmes and to record accurate, consistent, and standardised data from the fishery at spatial scales and in the detail required to better harvest and manage the fishery is critical to meeting all the fisheries plan goals. Building this capability is likely to be a step by step process, driven by gains made through the implementation of new harvest and management strategies, constant monitoring, and support to achieve data standards. Further, good communication and the willingness to try new strategies, and to evaluate them, are vital to the ongoing development. It will take a whole-of-industry approach to continue the momentum for change that has been established so far.

Critical to spatial management of the fishery is the ongoing development and refinement of logbooks and monitoring programmes, such as the spat settlement and catch sampling programmes, to ensure fishery data are relevant to specific management needs and at a standard required for robust analysis.

Whether the stock is driven down by disease mortality, or up by the high productivity of the fishery in the absence of disease, appropriate harvest strategies based on good information and effective spatial management are likely to provide greater certainty and the greatest value for all stakeholders.

Overview of methods

To continue building the capacity of fishers and BOMC staff through good communication, mentoring, and the implementation of collaborative research that could be fully transitioned to BOMC.

Schedule and prerequisites

Continue with Objective 4 of SIL research programme until March 2011. Thereafter BOMC or SIL funding to continue.

3.2 Medium priority research

Medium priority projects are important to achieving long-term fishery plan goals, but the strategies either lack sufficient data to be usefully implemented and / or their implementation is dependent on other research projects being completed.

Research projects

16. To design and evaluate structured fishing strategies

Rationale

Structured fishing strategies will be dependent on sufficient data to inform spatially explicit stock assessments and fishery scale snapshots of the status of bonamia infection in oysters. This will require partitioning of the fishery into spatial management areas to be completed, logbook data incorporated into stock assessments, and sensitive bonamia detection tools established to delineate areas infected with bonamia from non-infected areas. For this reason, research priorities will focus on developing the base tools and information to allow structured fishing strategies to be evaluated.

Overview of methods

Structured fishing strategies will be developed in collaboration with oyster skippers and BOMC staff. The structured fishing trials will follow a replicated control experimental design to allow analysis of short and medium-term success. The design will be informed by the disease status and oyster density in spatial management areas. The stock assessment model will be used to determine optimal harvest strategies for each experimental plot, and projections of future stock status compared with subsequent survey data.

Schedule and prerequisites

Structured fishing strategies will be dependent on PCR tools being available for low level infection status and spatially explicit stock assessment using logbook data. Expected start date 2013. Funded by MFish levies or BOMC direct purchase projects.

17. Further development of stock assessment and disease models

Rationale

Further development of the OYU 5 stock assessment model to improve estimates of future stock status, to extend projections beyond three years, and to run spatially explicit assessments is ongoing, but medium priority. Stock assessment of Foveaux Strait oysters uses a length-based, single sex, Bayesian model (Dunn 2005, Fu & Dunn 2009) to determine the risk of different harvest levels to future stock size, based on different levels of bonamia mortality. Two models (a base case model and revised model) were presented to the SWG. The SWG has asked that the stock assessment model performance be evaluated under MFish project OYS200901 during the 2012 stock assessment. The diagnostics required to evaluate the model performance are complex and include detailed analysis of model fits to observed data and chain performance of MCMCs. Further improvement of the model will require better estimates of oyster mortality, growth, and recruitment. Model projections have been consistent with subsequent estimates of oyster population size, estimated from stock assessment surveys. No immediate, further development of the stock assessment model is proposed, at least until the evaluation of model performance is complete in 2012. Sampling length frequencies from the commercial catch for length at catch data will continue, as well as some sampling length frequencies from the oyster population for stock assessment.

In the medium-term, spatially explicit assessments may not require further model development, but additional data to run these models. These data will include catch and effort data, population estimates, length frequencies from both the population and commercial catch, and biological parameters such as recruitment, growth, and mortality that are likely to be different if spatially managed areas have distinctly different productivities.

Should a new epizootic reduce the oyster population below 10% B_0, some consideration needs to be given to the MFish harvest strategy standards and their applicability to the unique conditions experienced in the fishery. Stock assessments show conservative harvest limits have no effect on future stock status.

An epidemiological model of bonamia (SIR model of susceptible, infectives, removed) was developed (Gilbert & Michael 2006, 2008; and see Michael 2010) to provide a better understanding of bonamiosis in the oyster population so that when an outbreak occurred, the model could be used to predict the spatial spread of bonamia in the fishery, oyster mortality from infection, and the decline of infection and oyster mortality that would allow fishery areas to rebuild. By integrating the disease model into a larger, spatially explicit stock assessment model, management and fishing strategies could be evaluated with simulations of alternative management strategies so that an optimum strategy could be applied. Further development of the original 12 cell model to a 48 cell model has only marginally improved fits to these data. This disease model has highlighted limitations about our knowledge of the pathogenesis of bonamia and the limitations of the available data.

No further evaluation of the present model or future development is proposed until a better understanding of the pathogenesis of bonamia is available, and a time-series of bonamia infection and oyster mortality data are available from sites at fixed locations. Annual monitoring of the status of bonamia will include sampling a number of fixed sites in key fishery areas.

Overview of methods

Research will focus on providing data for spatially explicit stock assessment and disease models including fishery data, biological parameters, catch and population size structure, and disease status at fixed stations. Some of these data will be provided by modifying the logbook data and incorporating these data into stock assessments.

Schedule and prerequisites

Continue sampling the commercial catch for data on catch at length and recruitment each season.
Continue annual monitoring of bonamia status, including fixed stations.
Establish data requirements for spatially explicit assessment after spatial management areas have been identified in 2010 and modify sampling programme to attain full spatial coverage.
Initiate research to better estimate biological parameters and their temporal variance from spatial management areas from 2011.

These programmes are integral to stock assessment and will be funded through MFish levies.

3.3 Low priority research

In the absence of significant disease mortality, the fishery has shown the ability to rebuild relatively quickly without enhancement strategies. However, low population levels are associated with low recruitment to the fishery, generally detected in survey data with a two year lag between lows in recruited oyster population size and lows in the population size of small oysters. Enhancement strategies could be useful in areas where larval supply and settlement surfaces are limited, especially in areas where the population size of oysters has been reduced by disease mortality, but has not recovered. New populations could also be established in areas with favourable conditions and habitats, but no source of recruitment.

Research project

17. To further develop and evaluate oyster and epibenthic community enhancement strategies using the return of oyster shell, and the translocation of oysters

Rationale

The return of oyster shell to increase oyster production has been practised for hundreds of years and is still an important practice in many commercial oyster fisheries, especially in the United States. Three oyster shell return programmes in have been trialled in Foveaux Strait: 1970–71 (Street et al. 1973), 1996 (Cranfield et al. 2001), and a pilot shell return trial undertaken by BOMC and SIL in 2005–07 (authors' unpublished data). These trials showed increases in localised oyster larvae settlement and early spat survival; colonisation by diverse benthic taxa (ascidians, sponges, molluscs, and bryozoans) within 20–30 months; the immigration of mobile benthic taxa (echinoderms and gastropods); and the aggregation of fish mainly blue cod (*Parapercis colias*) and tarakihi (*Nemadactylus macropterus*). These shell areas were either disrupted by storms or dredging before the success of the trials could be quantified, but anecdotal evidence suggests some value in shell return when and where recruitment to localised populations is limited. It is not known how significant these strategies are in increasing recruit size oysters.

Shell return strategies to enhance oyster production are more cost effective using weathered oyster shell deployed in early November. Site selection is critical, as oyster shell may act as sedimentary particles that can be moved out of the area, the shells tumbled over the seabed resulting in high post-settlement mortality, or buried by moving sand transported by the high energy oceanic swells and strong tidal currents of Foveaux Strait. Deploying shell in a one-shell thin layer is probably more effective than shell piles that are bound by benthic organisms and filled with fine sediment, smothering oyster spat within them.

At the current status of the fishery, shell return strategies would probably not significantly increase recruitment to the commercial fishery. However, the oyster population in the recreational fishing only area on the northern Stewart Island coast has been reduced to low levels by bonamia mortality and has not rebuilt. Oyster enhancement strategies that include shell return and translocation of shells with settled oysters will be trialled to increase the numbers of oyster areas available to recreational fishers in sheltered waters.

Overview of methods

Oyster spat settled on shells will be deposited at specific locations with suitable habitat (low or exposure to wave energy, stable, gravel habitats with little epifauna) identified by recreational fishers and the FSOFPMC. The enhancement trial will use a BACI design with sampling immediately prior to enhancement, immediately after, and then annually to monitor growth and survival, and over settlement by oyster spat.

Schedule and prerequisites

Meeting to design trial early February 2010 with relocation of spat before 1 March 2010

4. ACKNOWLEDGMENTS

I thank Dan Fu, Alistair Dunn, and Peter Smith at NIWA. Thanks also to Graeme Wright of BOMC for his helpful comments on the draft, and to Reyn Naylor for refereeing this report.

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Appendix 1: Fishing strategy for the 2010 season

Harvest limit 7.5 million
Unshelve some additional quota for special projects
Fishing strategies

- Core commercial fishing
- Supplementary survey
- "Working the beds" to improved oyster growth and condition experiment (structured fishing)

Suggested schedule
Present research designs to Shellfish Working Group 2 February 2010

- Bonamia survey
- Supplementary survey method
- Logbook data required for management of the fishery
- Methods, background, define areas for "working the beds" experiment
    - Skippers' data (GPS positions of tows in B5/D6)
    - Habitat
    - Oyster size and meat quality
    - Sediment structure

Bonamia survey February 2010

- Status of infection
- Some indication of small, pre-recruit and recruit oyster density
- More data on fishing effort and bonamia
- "Working the beds" experiment baseline survey
- Samples for bonamia detection tools

Skippers' preseason meeting

- Logbooks
- Bonamia survey interim results and population size indication
- Provide supplementary survey detail and method
- Outline fishing strategy

Three week season review

- Skippers' season update
- Bonamia survey and oyster density results
- Logbook summary
    - Three weeks 2010
    - First 3 weeks 2009
    - All season 2009
        - Logbook summaries to include number of tows and catch rate (s/h)

Appendix 2: Proposed schedule for research programmes

Objectives And Tasks: | Task In Progress: ⇨ | Milestone: ◆

Research prog.	Priority	Objective And Task Description:	Jan-10	Apr-10	Jul-10	Oct-10	Jan-11	Apr-11	Jul-11	Oct-11	Jan-12	Apr-12	Jul-12	Oct-12	Jan-13	Apr-13	Jul-13	Oct-13	Jan-14	Apr-14	Jul-14	Oct-14	Jan-15	Apr-15	Jul-15	Oct-15	Jan-16
		Bonamia investigations																									
1	H	Sampling to determine the status of bonamia infection mortality	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆
2	H	Sensitive detection tool for bonamia infection	⇨	⇨	⇨	◆	⇨	⇨	⇨	⇨	◆																
3	H	To establish fishery scale sampling protocol					⇨	⇨	⇨	⇨	◆	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆
4	H	Investigations into the temporal course of bonamia infection					⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆												
5	H	Structured fishing strategies to remove infected oysters										⇨	⇨	⇨	◆												
		Acquisition of fishery data																									
6	H	Build BOMC capability	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆
7	H	Establish the consistency of logbook data	⇨	⇨	⇨	◆																					
8	H	Fishery indicators using logbook data for monitoring the fishery	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆																
9	H	Test and further develop logbook data for spatial assessment					⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆											
		New dredge designs and fishing procedures																									
10	H	Develop a more efficient dredge	⇨	⇨	⇨	⇨	⇨	◆																			
11	H	Refine fishing procedures			⇨	⇨	⇨	◆																			
12	H	Test new dredge and procedures against the current dredge			⇨	⇨	⇨	◆																			
		Effects of fishing																									
13	H	Quantify the effects of oyster dredging						⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆								
		Spatial management																									
14	H	Delimit fishery areas for spatial management	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆																
15	M	Design and evaluate structured fishing strategies													⇨	⇨	⇨	◆	⇨	⇨	⇨	⇨	◆	⇨	⇨	◆	
16	M	Further development of stock assessment and disease models																									
16a	H	Sampling the commercial catch	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	
16b	M	Sampling population LFDs					⇨	◆			⇨	◆			⇨	◆			⇨	◆			⇨	◆			
16c	M	Research to better estimate biological parameters								⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	⇨	◆
17	L	Further develop and evaluate enhancement strategies	⇨	◆	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆	⇨	⇨	⇨	◆