FINAL REPORT

An Impact Assessment of Investment in FRDC Project 2016-803:

the Future Oysters CRC-P: New Technologies to Improve Sydney Rock Oyster Breeding and Production

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An Impact Assessment of Investment in FRDC Project 2016-803: the Future Oysters CRC-P: New Technologies to Improve Sydney Rock Oyster Breeding and Production
FRDC Project 2016-134

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Contents

Tables

Figures

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Abbreviations

6-DMPA	6-dimethylaminopurine
CB	Direct Chemical Induction
CBA	Cost-Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
FRDC	Fisheries Research and Development Corporation
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
NP	Neuropeptides
NSW	New South Wales
NSW DPI	New South Wales Department of Primary Industries
PSFI	Port Stephens Fisheries Institute
PVB	Present Value of Benefits
RD&E	Research, Development and Extension
SCS	Southern Cross Shellfish
SRO	Sydney Rock Oyster
UoN	University of Newcastle
USC	University of the Sunshine Coast

Executive Summary

This report presents an impact assessment of investment in Fisheries Research and Development Corporation (FRDC) investment in Project 2016-803: *Future Oysters CRC-P: New Technologies to Improve Sydney Rock Oyster Breeding and Production*. The assessment was completed as part of a fifth annual series of impact assessments under the FRDC 2015-2020 Research, Development and Extension Plan. The fifth series of assessments included 20 randomly selected FRDC investments worth a total of approximately $5.30 million (nominal FRDC investment) and that were selected from an overall population of 81 FRDC investments worth an estimated $17.66 million (nominal FRDC investment) where a final deliverable had been submitted in the 2019/20 financial year.

The impact assessments followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. The approach includes both qualitative and quantitative assessment components that are in accord with the impact assessment guidelines of the Council of Rural Research and Development Corporations.

The investment in Project 2016-803 produced useful knowledge that has contributed to ongoing research to improve tetraploidy induction techniques, neuropeptide delivery to broodstock, spawn inducing factors, and oocyte storage for Sydney rock oyster (SRO) breeding. Findings from the project associated with improved SRO conditioning and strip-spawning already have been incorporated into the SRO breeding program manual. These technical improvements to SRO fertilisation processes have increased family production success from 27% to 45%.

The knowledge gained and the improvements to SRO breeding achieved within the project and the broader Future Oysters Cooperative Research Centres Project (CRC-P) have been synthesised into a new plan for SRO research that aims to reduce the annual cost of breeding by one third.

Investment in Project 2016-803 is likely to have contributed to a number of positive impacts including:

- Increased productivity and/or profitability for the Australian SRO industry through increased effectiveness of the SRO breeding program and hatchery production.
- Increased effectiveness and/or efficiency of resource allocation for SRO RD&E through the creation of new knowledge and methods relevant to SRO breeding and production.
- Future reductions in annual breeding and progeny testing costs for the SRO breeding program.

Total funding for the Project was $0.50 million (present value terms). One impact was valued within the scope of the assessment. The impact valued was increased productivity for the SRO industry through improved growth performance and disease resistance. The impact generated estimated total expected net benefits of $1.54 million (present value terms). This produced an estimated net present value of $1.04 million, a benefit-cost ratio of 3.10 to 1, an internal rate of return (IRR) of 9.1%, and a modified IRR of 8.6% (over 30 years, using a 5% discount rate and 5% finance rate).

Given the conservative assumptions made and the fact that a range of economic and social impacts were not valued in monetary terms, the investment criteria reported are likely to be an underestimate of the true performance of the investment in Project 2016-803. The positive results should be viewed favourable by FRDC, the Australian Government, industry, and other RD&E stakeholders.

Keywords

Project 2016-803, Sydney rock oyster, SRO, breeding program, impact assessment, evaluation, cost-benefit analysis

Introduction

The Fisheries Research and Development Corporation (FRDC) required an annual series of impact assessments to be carried out on a sample of completed investments from the FRDC research, development, and extension (RD&E) portfolio. The assessments were required to meet the following FRDC evaluation reporting requirements:

- Reporting against the FRDC 2015-2020 RD&E Plan and the Evaluation Framework associated with FRDC's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to FRDC funding partners and other stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).
- Reporting RD&E impact and performance to FRDC levy payers and other fisheries and aquaculture stakeholders as well as the broader Australian community.

In April 2017, FRDC commissioned Agtrans Pty Ltd (Agtrans) to undertake the annual impact assessments for RD&E projects funded under the FRDC 2015-2020 RD&E Plan and completed in the years ended 30 June 2016 to 2020 (FRDC Project 2016-134). Between 2016/17 and 2020/21, four series of annual impact assessments were completed. Each of the four series of assessments included a set of 20 randomly selected FRDC RD&E investments as well as an aggregate analysis across all 20 investments evaluated in each year. Published reports for the annual FRDC evaluations can be found at: https://www.frdc.com.au/frdc-project-impact-assessments-benefits-research.

The fifth and final series of impact assessments under Project 2016-134 was for a set of FRDC RD&E investments completed in the year ended 30 June 2020, the final year of the FRDC 2015-2020 RD&E Plan. As in previous years, the fifth series of impact assessments included 20 randomly selected FRDC RD&E investments. The 20 investments had a total value of approximately $5.30 million (nominal FRDC investment) and were selected from an overall population of 81 FRDC investments worth an estimated $17.66 million (nominal FRDC investment) where a final deliverable had been submitted in the 2019/20 financial year.

The 20 RD&E investments were selected through a stratified, random sampling process such that investments chosen spanned all five FRDC Programs (Environment, Industry, Communities, People and Adoption), represented approximately 30.0% of the total FRDC RD&E investment in the overall population (in nominal terms), and included a selection of small, medium, and large FRDC investments (total nominal FRDC investment of ≤ $50.000, $50,001 to $250,000, and > $250,000 respectively).

Project 2016-803: *Future Oysters CRC-P: New Technologies to Improve Sydney Rock Oyster Breeding and Production* was randomly selected as one of the 20 RD&E investments completed in 2019/20 for evaluation in the fifth series of annual impact assessments (2019/20 sample). The current report presents the Project 2016-803 analysis and findings.

Method

The annual impact assessments of FRDC RD&E investments followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. The approach includes both qualitative and quantitative assessment components that are in accord with the current [guidelines for impact assessment] published by the CRRDC (CRRDC, 2018).

The evaluation process utilised an input to impact continuum RD&E project inputs (costs), objectives, activities, and outputs were briefly described and documented. Actual and expected outcomes, and any actual and/or potential future impacts (positive and/or negative) associated with project outcomes then were identified and described. The principal economic, environmental, and social impacts were then summarised in a triple bottom line framework and validated through consultation with expert personnel and review of published literature.

Once impacts were identified and validated, an assessment then was made about whether to quantify/value any of the impacts in monetary terms as part of the project-level analysis. The decision to value an impact identified was based on:

- Data availability and information necessary to form credible valuation assumptions,
- The complexity of the relevant valuation methods applicable given project resources,
- The likely magnitude of the impact and/or the expected relative value of the impact compared to other impacts identified, and
- The strength of the linkages between the RD&E investment and the impact identified.

Where one or more of the identified impacts were selected for valuation, the impact assessment used cost-benefit analysis (CBA) as a principal tool. The impacts valued therefore were deemed to represent the principal benefits delivered by the project investment. However, as not all impacts were valued (based on the selection criteria), the investment criteria estimated for the project investment evaluated are likely to represent an underestimate of the true performance of the FRDC project.

The qualitative and quantitative analysis processes, data sources, assumptions, specific valuation frameworks (where applicable), and evaluation results were clearly documented and then integrated into a written report.

Project Background

Background

The Sydney Rock Oyster (*Saccostrea glomerata*; SRO) is a native Australian oyster species and contributes more than $53 million in aquaculture production value to New South Wales (NSW). A SRO mass selection breeding program was established by NSW Department of Primary Industries (NSW DPI) in 1990 in response to a 60% production decline after the mid-1970s caused by disease, water quality declines and competition from the faster growing Pacific Oyster. Mass selection methods successfully developed oyster lines with superior growth and resistance to key SRO diseases.

However, mass selection did not enable selection for other commercially important traits in combination with disease resistance and faster growth. Additionally, mass selection over six generations caused a substantial loss of genetic diversity in selected lines to the extent that this method of breeding was not considered a viable long-term option for the SRO industry. Following two separate reviews in 2002 and 2012, an annual family-based production model commenced from 2014 at the Port Stephens Fisheries Institute (PSFI), NSW DPI to enable multi-trait selection.

Though considered an improvement to mass selection, hatchery production of SROs can be a costly and high-risk activity for the breeding program and industry. This has been exacerbated by factors such as reliance on hatchery conditioning, low fertilisation success using strip-spawned gametes, extended larval rearing period compared to Pacific Oysters, and variable settlement rates.

In 2016, Australian Seafood Pty Ltd along with a number of other partners were granted $3 million under the Australian Government's Cooperative Research Centres Projects (CRC-P) Grant program for a project known as the Future Oysters CRC-P. The Future Oysters CRC-P investment planned to conduct research that would accelerate the breeding of disease resistant oysters, improve disease management, increase productivity and profitability, and diversify risks to allow the Australian oyster aquaculture industry to grow both domestically and globally (Australian Government, 2022).

Rationale for Project 2016-803

FRDC Project 2016-803 was funded as part of the Future Oysters CRC- P and was developed through discussions with the Australian SRO industry hatchery sector to target hatchery production challenges. The project was to address four fundamental components:

1) Production of tetraploid SROs for triploid hatchery production,
2) Decreasing the time frame and increasing the reliability of hatchery conditioning,
3) Producing a spawn inducing factor(s)/pheromone to trigger natural release of gametes, and
4) Physiological process that occurs following oocyte release to extend the duration of viability through the use of benchtop storage media.

Project Details

Summary

Project Code: 2016-803
Title: *Future Oysters CRC-P: New Technologies to Improve Sydney Rock Oyster Breeding and Production*
Research Organisation: New South Wales Department of Primary Industries (NSW DPI)
Principal Investigator: Michael Dove, Research Scientist
Period of Funding: April 2017 to August 2019
FRDC Program Allocation: Industry 100%

Objectives

The specific objectives of the project were to:

1. Achieve 20% of industry with access to triploid SRO.
2. Reduce complete hatchery operation costs by 15% through a reduction in time for oyster conditioning.
3. Increase SRO breeding program reliability.

Logical Framework

Table 1: Logical Framework for FRDC Project 2016-803

<table>
<tr><td>Activities</td><td>Optimised protocols for tetraploid SRO production
• The production of triploids has become increasingly important to the oyster industry worldwide. Triploid oysters have superior growth and can be marketed outside the normal windows of sale compared to diploid counterparts.
• NSW DPI investigated triploid and tetraploidy induction of SROs in the 1990s. However, this research was unsuccessful due to low numbers of tetraploid larvae surviving through to metamorphosis and no tetraploids found in batches where metamorphosis and settlement did occur.
• Through related research in Pacific Oysters, the technology has progressed and been refined significantly over the years to the point that practitioners were far more confident of success in SRO.
• Tetraploid inductions were performed by Southern Cross Shellfish (SCS) and NSW DPI.
• Two main techniques were used for the production of triploid oysters:
(1) direct chemical induction using cytochalasin B (CB), or
(2) 6-dimethylaminopurine (6-DMAP)
• Tetraploid oyster production involved finding a fertile triploid female oyster, strip-spawning the oocytes, fertilising the oocytes with a diploid male and blocking expulsion of polar body I using CB or 6-DMAP.

Neuropeptide induction of sexual maturation in SRO
• The peak reproductive period for SROs generally occurs from late November through to early April throughout NSW.
• Obtaining ripe, ready-to-spawn broodstock outside of this period is a challenge for hatcheries producing SROs. Hatchery reproductive conditioning can be used to perform out-of-season breeding runs but is expensive due to the time and resources required.</td></tr>
</table>

- Reducing the duration of the hatchery conditioning period and improving hatchery conditioning success with respect to producing ready-to-spawn animals reduces the financial impost for SRO hatcheries.
- Neuropeptides (NPs) are peptides that are synthesized and released by modified neurons, called neurosecretory cells. NPs play important roles in neuroendocrine control of many physiological activities, for example, growth, reproduction and stress responses.
- Previous research had shown that buccalin and APGWamide are the most potent NPs that help stimulate gonad conditioning in SROs.
- Trials were undertaken to investigate the effect of administering the individual forms of buccalin and APGWamide in assays to observe stimulation of gonad conditioning in SROs.
- Three gonad maturation assays were performed, and iterative changes were made to the method for each subsequent assay based on the results from the previous assay.
- In addition, the experiments also were used to investigate different methods for effective delivery of peptides to SROs.

Spawning induction in SRO

- Oysters are broadcast spawners, that is, eggs and sperm are released into the water where fertilisation occurs externally. SROs have a seasonal reproductive pattern where oysters are generally highly fecund and serially spawn though the months of November to April throughout most of their growing range.
- Commercial production of SROs in hatcheries uses two spawning techniques:
  (i) Natural spawning - oysters are placed in tanks and temperature and salinity is manipulated to induce gamete release.
  (ii) Strip-spawning - oysters are sacrificed to physically remove gametes from the gonad using a scalpel or pipette.
- Strip-spawning is necessary for the SRO BP to manage matings between a single male and female to create families however only 27% of the matings performed produced a family for ongoing assessment.
- A study was undertaken to identify the spawning inducing pheromones or factors in the sperm of the SRO.

SRO gamete storage protocols

- Commercial hatchery production of SROs is more difficult compared to other species such as Pacific oysters and Eastern Oysters.
- More challenges are encountered when producing single pair mated SRO families using strip-spawned gametes due to fertilisation deficiency in certain crosses, low rates of success when fertilisation occurs and low levels of larval development in the 24-hour period post fertilisation.
- This compares poorly with very high fertilisation and development rates in the initial 24-hour period when natural SRO gametes are used.
- Although holding periods for male gametes (sperm) after manual stripping are potentially in the order of many days during which the gametes may retain fertilising capacity, the holding period for female gametes (ova) is short.
- Ova removed by manual stripping and held in storage media rapidly lose viability and fertilising capacity over a period of 6-9 hours.
- Experiments were undertaken to develop a better understanding of the causes of oocyte degradation and to improve storage protocols for oocytes that would extend the holding period *in vitro* after manual stripping.
- Oocytes were tested for fertilisation differences when stored in different media to determine whether the contents of the environment contributed to lowered fertilisation.

	• InstantOcean® (a commercial salt mix targeted to mimicking seawater) as a media was compared at varying concentrations (30, 60, 100, and 125%). • Physiological properties of the gonad were then determined to compare against the properties of the storage media to assess if the characteristics of the gonad were different to the storage media. It was thought that these differences could be adopted in a modified media for extended holding of cells.
Outputs	• Eleven attempts at tetraploid induction. However, inductions were not successful in producing a batch of tetraploid SRO that could be made available for commercial hatchery production of triploids using tetraploid male and triploid female crosses. • The major challenges encountered was low egg numbers, asynchronous embryonic development in strip-spawned oocytes after fertilisation, poor development, and poor larval survival. A very small number of spat were successfully settled from 2 trials, however, no tetraploids were found in these batches when oysters had reached a size where tissue could be taken to determine ploidy level. • The results of the three independent NP trials indicated that administering the individual forms of buccalin and APGWamide showed a stimulation of gonad conditioning in SRO. • Comparing the stimulatory effect of two different forms of APGWamide, APGWa and RPGWa, the study found that the APGWa form was more potent than the RPGWa form. • For buccalin, the buccalin-G form showed a better performance than the buccalin-A form in most of reproductive activities assessed. • Considering the stimulatory effects of APGWa and buccalin-G on SRO conditioning, the research showed that their stimulatory effects appeared to be comparable. Hence, the study team proposed that either APGWa or buccalin-G could be applied to large-scale breeding programs for SRO. • Considering the method of peptide delivery, the NP study found that the use of cocoa butter to allow a slow release of peptide was not appropriate as it caused high mortality in SRO. • Injection of peptides was therefore preferable, and it was expected that multiple injections would help in maintaining the level of the peptides in the oyster's circulatory system to successfully control gonad conditioning. • However, delivery of peptide by injection was relatively difficult and uncontrollable since different individual oysters could receive a different amount of the NP per injection. To overcome this problem, the research team recommended that delivery using other techniques, such as oral delivery by using peptide-encapsulated algae, should be considered and tested in the future. • Results of the spawning study found that inducers including the natural sperm, sperm cells, sperm membrane proteins and sperm cytoplasmic contents, could induce spawning in SROs. This suggested that the sperm membrane proteins are involved in the spawning induction. • The study further showed that the extrinsic sperm membrane proteins, but not the intrinsic sperm membrane proteins, could effectively induce spawning activity. • Further analysis showed that eight proteins were present, and therefore it was concluded that one or more of those proteins may play a critical role in stimulating spawning of the SRO. • Further research is required to identify the protein(s) and how to optimise spawning induction. • Results from the gamete storage experiments indicated that fertilisation was the most successful in the 100% InstantOcean®. • Further, alterations to the holding media led to increased vitality determined after a period of 24 hours.

	• After 24 hours, the treatments had at least a 50% increase in live cells compared to media without any alterations. This was an improvement where the oocytes typically decrease in vitality at an exponential rate in unaltered media. • However, further tests are required on larger sample sizes to determine whether this trend is generally reproducible and to determine the variability of the response between oysters across lines. • The findings of the research were extended directly to the SRO breeding program and hatcheries producing SROs.
Outcomes	• Research is ongoing for tetraploidy induction techniques (SCS), neuropeptide delivery to broodstock (University of the Sunshine Coast; USC), spawn inducing factors (USC) and oocyte storage for SROs (University of Newcastle; UoN). • Further research will be required to incorporate all findings from this research into routine operations of the SRO breeding program. • However, outcomes from this work have already provided benefits for the breeding program. • Findings associated with conditioning and strip-spawning that improve these processes have been incorporated into the SRO breeding program manual and improvements to conditioning and strip-spawning were used in the most recent SRO breeding run to produce the 2019-year class. • Specifically, technical improvements to the fertilisation process have increased family production success from 27% to 45%. • This is relevant for the SRO breeding program and commercial hatcheries as it will reduce the time it takes to create families and the numbers of broodstock required for a breeding or commercial hatchery run. • The project also contributed through interaction with other Future Oyster CRC-P projects that have improved the reliability of SRO breeding and increased disease resistance. • The knowledge gained and the improvements to SRO breeding achieved within the project and the broader Future Oysters CRC-P have been synthesised into a new plan for SRO research that aims to reduce the annual cost of breeding by one third. • For the SRO breeding program, annual breeding, and progeny testing costs $350,000 and evaluations have started in order to lower this operational cost to below $250,000.
Impacts	• Contribution to increased productivity and/or profitability for the Australian SRO industry through increased effectiveness of the SRO breeding program and hatchery production. • Contribution to increased effectiveness and/or efficiency of resource allocation for SRO RD&E through the creation of new knowledge and methods relevant to SRO breeding and production. • Some contribution to future reductions in annual breeding and progeny testing costs for the SRO breeding program. • Contribution to increased scientific knowledge and research capacity associated with SRO breeding and production. • Potentially, some contribution to improved regional community wellbeing through spillover benefits from a more productive and profitable SRO industry.

Source: FRDC project documentation

Nominal Investment

Table 2 shows the total annual investment made in project 2016-803 by FRDC and the CSIRO.

Table 2: Total Investment in FRDC Project 2016-803
(nominal dollar terms)

Year ended 30 June	FRDC ($)	Others[(a)] ($)	Total ($)
2017	0	50,000	50,000
2018	0	50,000	50,000
2019	148,640	32,000	180,640
2020	55,427	0	55,427
Totals	**204,067**	**132,000**	**336,067**

Source: FRDC project 2016-803 project agreement and financial acquittal
(a) Other funding partners included the University of Newcastle, University of the Sunshine Coast, and Select Oyster Company Pty Ltd.

Management and Administration Costs

For the FRDC investment, the cost of managing the FRDC funding was added to the FRDC contribution for the project via a management cost multiplier (1.179). This multiplier was estimated based on a five-year average of the ratio of total FRDC cash expenditure to project expenditure reported in the FRDC's Cash Flow Statement (FRDC Annual Reports, 2017-2021). This multiplier then was applied to the nominal investment by FRDC shown in Table 2.

For the other contributors to project 2016-803, it was assumed that any management and administration costs were already included in the cost data presented in Table 2. A multiplier of 1.0 was applied to the nominal investment by others shown in Table 2.

Real Investment and Extension Costs

For the purposes of the impact analysis, the investment costs of all parties were expressed in 2020/21-dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020).

No additional costs of extension were included as the findings of the research were extended directly to the SRO breeding program and hatcheries producing SROs.

Impacts

Table 3 provides a summary of the principal types of potential impacts from Project 2016-803. Impacts have been taken, and potentially expanded, from those listed in Table 1 and categorised using a triple bottom line framework into economic, environmental and social impact types.

Table 3: Principal Potential Impact Types from Investment in FRDC Project 2016-803

Economic	• Contribution to increased productivity and/or profitability for the Australian SRO industry through increased effectiveness of the SRO breeding program and hatchery production contributing to increased rates of genetic gain that improve SRO growth performance and disease resistance. • Contribution to increased effectiveness and/or efficiency of resource allocation for SRO RD&E through the creation of new knowledge and methods relevant to SRO breeding and production (for example, tetraploid induction) • Some contribution to future reductions in annual breeding and progeny testing costs for the SRO breeding program through improved fertilisation rates and storage of SRO gametes.
Environmental	• Nil.
Social	• Contribution to increased scientific knowledge and research capacity associated with SRO breeding and production. • Potentially, some contribution to improved regional community wellbeing through spillover benefits from a more productive and profitable SRO industry.

Public versus Private Impacts

The potential impacts from Project 2016-803 were primarily private impacts. Private impacts will be delivered through chiefly increased SRO industry productivity/profitability from a more effective breeding program and reduced breeding and progeny testing costs for commercial hatcheries.

Some public impacts also may be delivered and would occur through increased effectiveness/efficiency of public resource allocation on SRO breeding RD&E, increased scientific capacity, and longer-term improvements in regional community wellbeing for regions associated with SRO production.

Distribution of Private Impacts

Any private impacts from the investment in Project 2016-803 will primarily accrue to Australian SRO producers driven by improved growth performance and disease resistance achieved from a more effective breeding program.

Impacts on other Australian industries

The technical research elements were very specifically focused on SRO and were targeted at closing breeding and productivity gaps between SRO and other oyster types produced in Australia. Thus, no direct impacts to other Australian industries were identified. However, other aquaculture industries could benefit in the longer-term from increased scientific knowledge and research capacity spillovers.

Impacts Overseas

No direct impacts to overseas parties were identified.

Match with National Priorities

Australian Agriculture, Science, and Research Priorities

The Australian Government's National Science and Research Priorities and Agricultural Innovation Priorities are reproduced in Table 4. Project 2016-803 has contributed to National Science and Research Priority 1. Further, the RD&E investment is likely to contribute indirectly to Agricultural Innovation Priority 1 and 3 because of increased rates of genetic gain and improved SRO performance and disease resistance.

Table 4: Australian R&D Priorities

Australian Government	
National Science and Research Priorities[1]	**National Agricultural Innovation Priorities**[2]
1. Food – optimising food and fibre production and processing; agricultural productivity and supply chains within Australia and global markets. **2. Soil and Water** – improving the use of soils and water resources, both terrestrial and marine. **3. Transport** – boosting Australian transportation: securing capability and capacity to move essential commodities; alternative fuels; lowering emissions. **4. Cybersecurity** – improving cybersecurity for individuals, businesses, government, and national infrastructure. **5. Energy and Resources** – supporting the development of reliable, low cost, sustainable energy supplies and enhancing the long-term viability of Australia's resources industries. **6. Manufacturing** – supporting the development of high value and innovative manufacturing industries in Australia. **7. Environmental Change** – mitigating, managing, or adapting to changes in the environment. **8. Health** – improving the health outcomes for all Australians.	On 11 October 2021, the National Agricultural Innovation Policy Statement was released. It highlights four long-term priorities for Australia's agricultural innovation system to address by 2030. These priorities replace the Australian Government's Rural Research, Development and Extension Priorities which were published in the 2015 Agricultural Competitiveness White Paper. **1.** Australia is a trusted exporter of premium food and agricultural products by 2030. **2.** Australia will champion climate resilience to increase the productivity, profitability, and sustainability of the agricultural sector by 2030. **3.** Australia is a world leader in preventing and rapidly responding to significant incursions of pests and diseases through futureproofing our biosecurity system by 2030. **4.** Australia is a mature adopter, developer, and exporter of digital agriculture by 2030.

[1] Source: 2015 Australian Government *Science and Research Priorities*. https://www.industry.gov.au/data-and-publications/science-and-research-priorities.
[2] Source: 2021 National Agriculture Innovation Policy Statement. https://www.awe.gov.au/agriculture-land/farm-food-drought/innovation/research_and_development_corporations_and_companies#government-priorities-for-investment.

FRDC National RD&E Priorities

Through extensive consultation, the FRDC 2015-2020 RD&E Plan identified three national RD&E priorities to focus and direct FRDC investments. The three FRDC national RD&E priorities were:

1. Ensuring that Australian fishing and aquaculture products are sustainable and acknowledged to be so.
2. Improving productivity and profitability of fishing and aquaculture.
3. Developing new and emerging aquaculture growth opportunities.

Project 2016-803 primarily addressed FRDC national RD&E priority 2 through a contribution to a more effective and efficient SRO breeding program leading to increased rates of genetic gain and improved SRO performance and disease resistance.

Valuation of Impacts

The valuation of impacts generally focused on the most important and direct impacts of the investment in project 2016-803. The decision to value any of the impacts identified in Table 3 was based on:

- Data availability and information necessary to form credible valuation assumptions,
- The complexity of the relevant valuation methods applicable given project resources,
- The likely magnitude of the impact and/or the expected relative value of the impact compared to other impacts identified, and
- The strength of the linkages between the RD&E investment and the impact identified.

Impacts Valued

One impact was valued for the assessment of Project 2016-803. The impact valued was:

- Contribution to increased productivity and/or profitability for the Australian SRO industry through increased effectiveness of the SRO breeding program and hatchery production contributing to increased rates of genetic gain that improve SRO growth performance and disease resistance.

Valuation of Impact 1: Increased productivity for the NSW SRO Industry

The major industries for edible oysters in Australia are based on production of native SRO (*Saccostrea glomerata*) and introduced Pacific oysters (*Crassostrea gigas*). The major areas of production, are NSW (predominantly SRO but with 5% of total value from Pacific oysters), South Australia (almost all Pacific oysters) and Tasmania (almost all as Pacific oysters) (Maguire & Nell, 2019). Therefore, NSW SRO production makes up the vast majority of Australian SRO production. The total production and value of NSW SRO for the period 2012 to 2021 are shown in Table 5 and Figure 1 below.

It was assumed that the investment in Project 2016-803 has contributed to improved growth performance and disease resistance for SRO producers through the project's contribution to the SRO breeding program. Specifically, the project contributed to technical improvements to the fertilisation process that increased family production success from 27% to 45%. This, in turn, will increase the rate of genetic gain for the SRO breeding program and contribute to long-term productivity improvements for the industry.

Hatcheries are estimated to be providing up to 20% of the stock used by the SRO industry. The proportion of this stock derived from selective breeding is increasing and is expected to form the majority of hatchery seed supply in forthcoming seasons (Project 2016-803 final report).

Further, given strong domestic demand, there has been little incentive for the industry to export significant volumes of product in recent years and only about 1% of national oyster production is currently exported. As further evidence of the strength of domestic market, since 2015 Australia has been a net importer of oysters, with most of this product coming in frozen from New Zealand (Oysters Australia, 2020). Therefore, it was assumed that any production increase in SRO would predominantly serve the domestic market and would generally replace other imported shellfish/seafood with Australian consumers.

Specific assumptions for the valuation of Impact 1 are reported in Table 6.

Table 5: NSW Sydney Rock Oyster Production 2012-2021

Year (ended 30 June)	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**10yr Avg.**
Production (dozens)	4,558,873	4,675,770	4,786,802	5,152,964	5,273,919	5,517,866	5,989,101	6,224,789	5,613,140	5,368,601	5,316,183
Value ($m)	28.25	29.88	31.84	34.77	36.87	40.68	48.74	53.65	50.79	49.07	40.46

Source: NSW DPI Aquaculture production reports - https://www.dpi.nsw.gov.au/fishing/aquaculture/publications/aquaculture-production-reports (NSW DPI, n.d.)

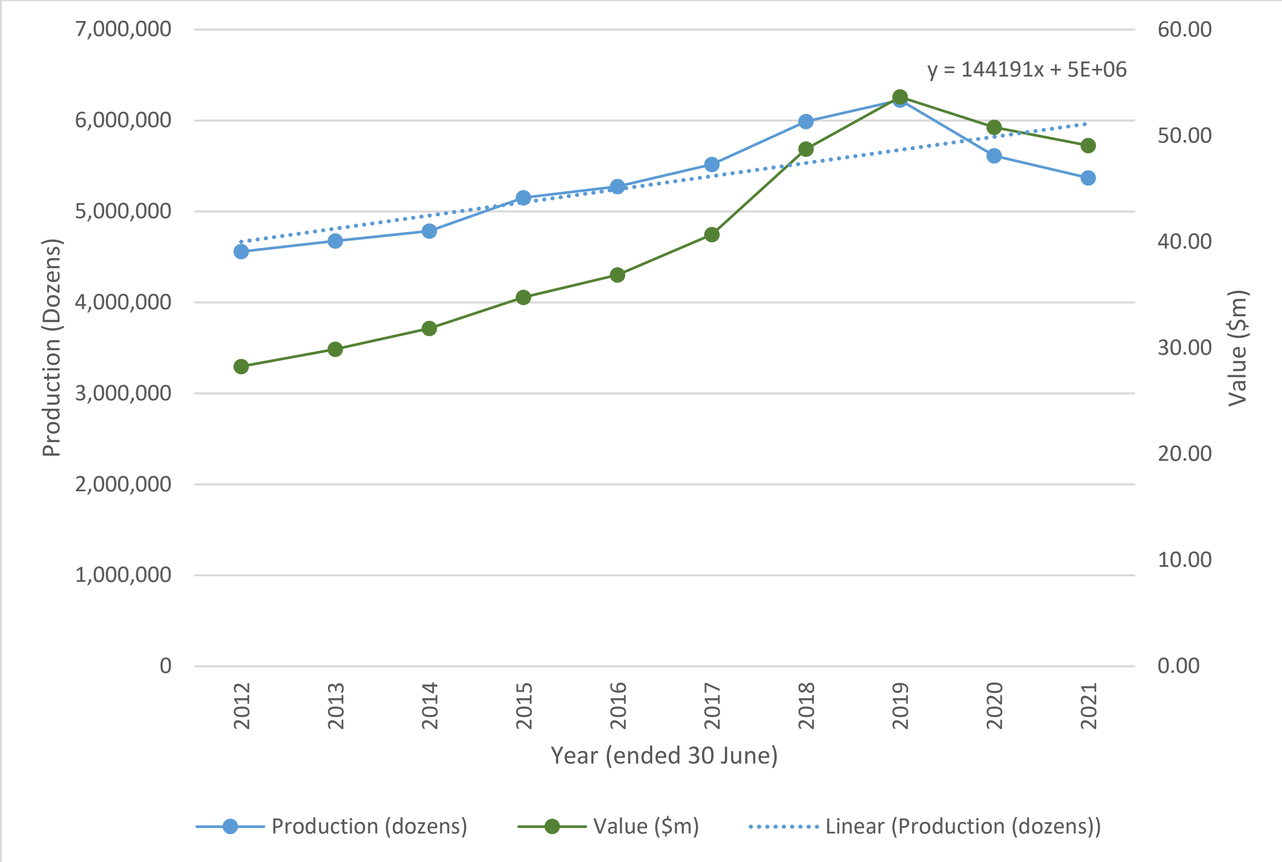

Figure 1: NSW Sydney Rock Oyster Production and Value 2012-2021
Source: Derived from NSW DPI aquaculture statistics (NSW DPI, n.d.)

Attribution

Project 2016-803 was one of two Future Oysters CRC-P investments targeted at improving breeding and production specifically for the SRO industry (Oysters Australia, 2018). The Future Oysters CRC-P projects also built on previous foundational SRO breeding and production research. It was assumed that 25% of the total estimated expected net benefits were attributable to the specific investment in Project 2016-803.

Counterfactual

It was assumed that, without the investment in FRDC Project 2016-803, Oysters Australia and other key stakeholders such as NSW DPI would likely have made investments in SRO breeding and production. However, such investments would likely have been smaller and may have been less effective or efficient. Thus, it was assumed that 50% of the total estimated expected net benefits would have occurred without the Project 2016-803 investment.

Impacts Not Valued

The impacts not valued included:

- Contribution to increased effectiveness and/or efficiency of resource allocation for SRO RD&E through the creation of new knowledge and methods relevant to SRO breeding and production (for example, tetraploid induction). This impact was not valued because data for the specific current and likely future annual investment in SRO breeding and production RD&E were not available.
- Some contribution to future reductions in annual breeding and progeny testing costs for the SRO breeding program through improved fertilisation rates and storage of SRO gametes. This impact was not valued because of uncertainty regarding the pathways to impact and a lack of evidence of actual cost reductions attributable to the investment in Project 2016-803.
- Contribution to increased scientific knowledge and research capacity associated with SRO breeding and production. This impact was not valued due to the complexity of assigning monetary values to changes in knowledge and research capacity.
- Potentially, some contribution to improved regional community wellbeing through spillover benefits from a more productive and profitable SRO industry. This impact was not valued because of uncertainty around the pathways to impact and a lack of data on which to base credible assumptions.

Summary of Assumptions

The following tables present the specific assumptions used in the valuation of Impact 1.

Table 6: Summary of Assumptions for the Valuation of Impact 1

Impact 1: Increased productivity for the NSW SRO Industry		
Variable	**Assumption**	**Source**
WITHOUT investment in Project 2016-803		
Average annual production of SRO	5.3 million (dozens)	10-year average, derived from NSW DPI aquaculture production statistics (NSW DPI, n.d.) – See Table 5.
Weighted average SRO domestic farm gate price	$9.14 per dozen	Weighted average for 2020/21 derived from SRO average price per dozen from NSW DPI aquaculture production statistics (NSW DPI, n.d.) Large SRO (>70mm length or >50g whole weight) = $11.63/dozen (1,278,558 dozen or 23.8% 2020/21 total volume) Medium (55-70mm length or 30-50g whole weight) = $9.39/dozen (2,365,176 dozen or 44.1% 2020/21 volume)

Impact 1: Increased productivity for the NSW SRO Industry		
Variable	**Assumption**	**Source**
		Small (<55mm length or <30g whole weight) = $6.95/dozen (1,724,867 dozen or 32.1% 2020/21 total volume)
Expected production growth rate from 2020/21	2.7% per annum	Based on linear growth trend derived in Figure 1. Estimating an additional 144,000 dozen SRO per annum and an average total production of 5.3 million dozen (144,000 / 5,300,000 = ~2.7%)
WITH investment in Project 2016-803		
Expected production growth rate from 2020/21	4.3% or 227,900 dozen SRO per annum	Based on a 60% improvement in productivity through increased effectiveness of the SRO breeding program. Evidenced by data showing that the project contributed to technical improvements to the fertilisation process that increased family production success from 27% to 45%.
Current proportion of SRO industry experiencing increased productivity by procuring spat from hatcheries benefitting from the improved SRO breeding program	20%	2016-803 reported that hatcheries are estimated to be providing up to 20% of the stock used by the SRO industry.
Maximum proportion of SRO industry experiencing increased productivity by procuring spat from hatcheries benefiting from the improved SRO breeding program	50%	2016-803 reported that the proportion of hatchery supplied stock derived from selective breeding is increasing and is expected to form the majority of hatchery seed supply in forthcoming seasons.
First year of impact	2021/22	Based on evidence that improved fertilisation processes had led to improvements in family production success in 2019/20 and noting constraints brought about by the impact of COVID-19 in 2019/20 and 2020/21.
Year of maximum adoption of hatchery supplied stock	2025/26	Five years after first year of impact
Maximum potential SRO production (production ceiling)	Double current production (10.6 million dozen SRO per annum)	Analyst assumption to prevent unrealistic industry growth estimates over the long-term
Risk Factors		
Probability of output	100%	Based on successful completion of Project 2016-803 and evidence of new and improved fisheries education resources being accessed and adopted
Probability of outcome	100%	The probability of outcome refers to the likelihood that the project outputs are adopted/implemented at the level assumed. Based on evidence of adoption of improved fertilisation processes by the SRO breeding program.

Impact 1: Increased productivity for the NSW SRO Industry		
Variable	**Assumption**	**Source**
Probability of impact	80%	Refers to the probability that, given adoption (outcome), the impact as estimated will be realised. This allows for exogenous factors that may affect the estimated benefits being achieved (e.g. biosecurity incursion, climate change, etc.)
Attribution of benefits to investment in Project 2016-803	20%	See valuation of impact 1 description reported previously.
Counterfactual	50% of the estimated benefits would have occurred without the Project 2016-803 investment.	

Results

All past costs and benefits were expressed in 2020/21-dollar terms. All costs and benefits were discounted to 2021/22 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the modified internal rate of return (MIRR). The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2019/20) to the final year of benefits assumed.

Investment Criteria

Tables 7 and 8 show the investment criteria estimated for different periods of benefits for the total investment and FRDC investment respectively. The present value of benefits (PVB) for the FRDC investment was estimated by multiplying the total PVB cash flow by the proportion of FRDC investment in real, undiscounted dollar terms (64.4%).

Table 7: Investment Criteria for Total Investment in Project 2016-803

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.21	0.58	0.92	1.22	1.49	1.54
Present value of costs ($m)	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Net present value ($m)	-0.50	-0.29	0.09	0.42	0.72	0.99	1.04
Benefit-cost ratio	0.00	0.42	1.17	1.85	2.46	3.00	3.10
Internal rate of return (%)	negative	negative	2.1	6.5	8.2	9.0	9.1
MIRR (%)	negative	negative	6.2	8.5	9.0	9.1	8.6

Table 8: Investment Criteria for FRDC Investment in Project 2016-803

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.13	0.37	0.59	0.78	0.96	0.99
Present value of costs ($m)	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Net present value ($m)	-0.31	-0.18	0.06	0.28	0.47	0.65	0.68
Benefit-cost ratio	0.00	0.43	1.20	1.90	2.52	3.07	3.18
Internal rate of return (%)	negative	negative	2.6	7.3	9.0	9.7	9.8
MIRR (%)	negative	negative	6.4	8.6	9.1	9.1	8.6

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period plus 30 years from the last year of investment are shown in Figure 2.

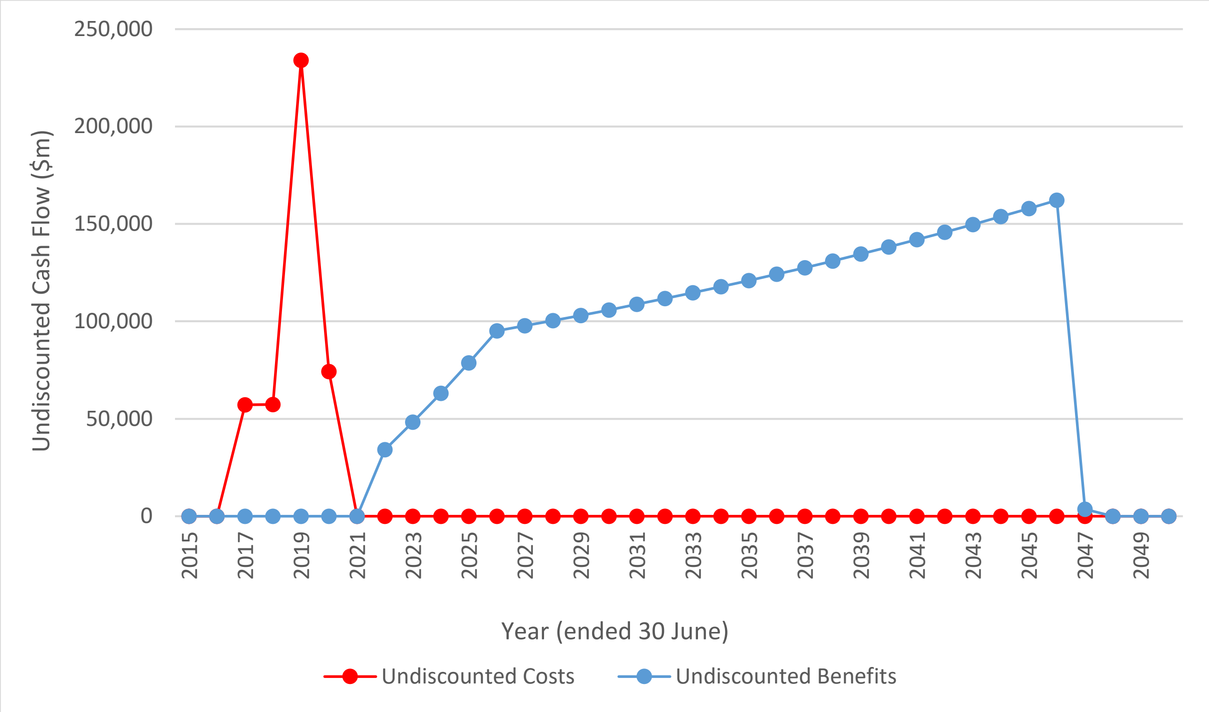

Figure 2: Annual Cash Flow of Undiscounted Total Expected Benefits and Total Costs

Sensitivity Analyses

Sensitivity analyses were performed for variable that were considered (a) key drivers of the investment criteria, and/or (b) uncertain. Each sensitivity analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values.

A sensitivity analysis was carried out on the discount rate. The results, shown in Table 9, showed a moderate sensitivity to the discount rate. This was largely due to the benefit cash flows occurring over the medium- to long-term after the last year of investment in the project and therefore being subject to relatively more severe discounting.

Table 9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	2.87	1.54	0.94
Present value of costs ($m)	0.42	0.50	0.58
Net present value ($m)	2.45	1.04	0.36
Benefit-cost ratio	6.79	3.10	1.62

A sensitivity analysis then was carried out on annual productivity growth rate with the investment as this was considered a key driver of the investment criteria. Table 10 shows the results. The investment criteria showed a low sensitivity to the productivity growth rate with the investment. This was likely because of the attribution of benefits to the investment and the counterfactual assumption.

Table 10: Sensitivity to the Rate of Productivity Growth with the Investment
(Total investment, 5% discount rate, 30 years)

Investment Criteria	**Productivity Growth Rate with the Investment**		
	3.0%	**4.3% (base)**	**5.4%**
Present value of benefits ($m)	1.07	1.54	1.93
Present value of costs ($m)	0.50	0.50	0.50
Net present value ($m)	0.58	1.04	1.43
Benefit-cost ratio	2.16	3.10	3.89

A final sensitivity analysis was undertaken on the assumed attribution of the benefits to the specific investment in Project 2016-803. The results, presented in Table 11, showed a high sensitivity to the attribution of benefits to the investment. This was expected as the assumed attribution of benefits was purposefully conservative given previous investment in SRO breeding and other related projects within FRDC and the Future Oyster CRC-P.

Table 11: Sensitivity to the Attribution of Benefits to Project 2016-803
(Total investment, 5% discount rate, 30 years)

Investment Criteria	**Attribution of Benefits to Project 2016-803**		
	20% (base)	**50%**	**90%**
Present value of benefits ($m)	1.54	3.84	6.91
Present value of costs ($m)	0.50	0.50	0.50
Net present value ($m)	1.04	3.35	6.42
Benefit-cost ratio	3.10	7.75	13.96

Confidence Rating and Other Findings

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 12). The rating categories used are High, Medium and Low, where:

- High: denotes a good coverage of benefits or reasonable confidence in the assumptions made
- Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
- Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 12: Confidence in Analysis of Investment

Coverage of Benefits	**Confidence in Assumptions**
Medium	Low-Medium

The coverage of benefits was assessed as Medium. Only one impact was value; however, the impact valued was deemed to be the most important and likely to be generate the greatest benefits relative to the other impacts identified.

Confidence in assumptions was rated as Low-Medium. The valuation was underpinned by credible data, expert opinion and published research. However, a number of the key variables, such as the likely increase in productivity growth that may occur through improved SRO breeding, were uncertain.

Conclusions

The investment in Project 2016-803 produced useful knowledge that has contributed to ongoing research to improve tetraploidy induction techniques, neuropeptide delivery to broodstock, spawn inducing factors, and oocyte storage for SRO breeding. Findings from the project associated with improved SRO conditioning and strip-spawning already have been incorporated into the SRO breeding program manual. These technical improvements to SRO fertilisation processes have increased family production success from 27% to 45%.

The knowledge gained and the improvements to SRO breeding achieved within the project and the broader Future Oysters CRC-P have been synthesised into a new plan for SRO research that aims to reduce the annual cost of breeding by one third.

Investment in Project 2016-803 is likely to have contributed to a number of positive impacts including:

- Increased productivity and/or profitability for the Australian SRO industry through increased effectiveness of the SRO breeding program and hatchery production.
- Increased effectiveness and/or efficiency of resource allocation for SRO RD&E through the creation of new knowledge and methods relevant to SRO breeding and production.
- Future reductions in annual breeding and progeny testing costs for the SRO breeding program.

Total funding for the Project was $0.50 million (present value terms). One impact was valued within the scope of the assessment. The impact valued was increased productivity for the SRO industry through improved growth performance and disease resistance. The impact generated estimated total expected net benefits of $1.54 million (present value terms). This produced an estimated net present value of $1.04 million, a benefit-cost ratio of 3.10 to 1, an internal rate of return of 9.1%, and a MIRR of 8.6% (over 30 years, using a 5% discount rate and 5% finance rate).

Given the conservative assumptions made and the fact that a range of economic and social impacts were not valued in monetary terms, the investment criteria reported are likely to be an underestimate of the true performance of the investment in Project 2016-803. The positive results should be viewed favourable by FRDC, the Australian Government, industry, and other RD&E stakeholders.

Glossary of Economics Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.

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