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The National Marine Science Centre, Coffs Harbour: a review of the first ten years of research

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Abstract

The National Marine Science Centre (NMSC) opened in 2002. At that time the establishment of the centre was a joint exercise of two universities – Southern Cross University (SCU) and the University of New England (UNE). By mutual agreement and with a financial payment to UNE, Southern Cross University took over sole operation of the centre in 2010. This review outlines the directions and outcomes of the NMSC over those ten years, in the achievements in research and the communication of that research. Research themes were established and maintained in marine ecology and biodiversity, reproductive ecology and regeneration in marine communities, human impacts and their management, fisheries management, and aquaculture. Later additions included responses of marine organisms to climate change, economics and governance of fisheries, and in an avenue of terrestrial ecology. The research outputs are grouped according to these themes and to the occurrence across the years. Personnel involved and the highlights of some of this research are presented.

Keywords: marine, ecology, invertebrates, corals, fisheries, aquaculture

Introduction

At the start, a prime function of the National Marine Science Centre (NMSC) was to establish undergraduate third year courses in marine science that would be suitable for the students of two universities. Much time and energy were spent on that goal and on the accompanying administrative procedures for both the teaching and the centre itself. Although the original concept of the subject matter for the undergraduate courses remains largely the same, the courses were continually appraised and revised to meet the needs of undergraduate training in marine science. In 2012 the NMSC offers eight third year units for the Southern Cross University (SCU) degree programs; with extra work the units can also be taken at Masters level.

In 2002, research began with inputs from two sources: 1) staff from the universities who were assigned to the centre or who had involvement with the supervision of postgraduate students at the centre and 2) staff from the Conservation Technology Unit of NSW Fisheries (now part of the NSW Department of Primary Industries). The Fisheries Conservation Technology Unit was based at the centre at the very beginning of the centre's operation in an agreement with NSW Fisheries, an arrangement that has continued as a prominent feature of the research activities.

Research themes in marine science were established for implementation at the outset and these included: biology, ecology and biodiversity; reproductive ecology and regeneration in threatened communities; management and human impacts; regional aquaculture and fisheries. The NMSC has been under the stewardship of three Directors over the ten years: Prof. Rod Simpson, Prof. Alistair McIlgorm, and Prof. Les Christidis. Each of these brought their own influence in relation to research themes, funding, and postgraduate training. Other marked influences on these three key components were personnel who had been stationed at the NMSC from its inception: Assoc. Prof. Steve Smith, and from NSW Fisheries: Dr Matt Broadhurst and Dr Paul Butcher. Other personnel have joined the centre since its beginnings, some have come and gone, and some staff gained their postgraduate qualifications while at the centre. Work within the initial themes has continued and been expanded to the present day and some themes have been added.

Research

Following the research activity over the ten years provides an outline of how these research themes developed, how emphases changed, and some significant highlights and features across that research

Table 1 gives the publications in refereed journals from the NMSC, grouped according to research themes. Table 2 lists these same publications in their categories as a numerical time sequence. Areas of particular strengths in research are indicated by the following summaries of refereed journal publications. Work in these areas was also augmented by numerous reports for commissioned research and by conference presentations, the numbers for which are listed in Table 3. To achieve these research outputs, extensive research grants from many funding sources have been obtained.

Marine Biology and Ecology – Invertebrates

Antarctic benthic ecology

One of the earliest topics of research, Antarctic benthic ecology, was brought to the NMSC by personnel transferred there. The work involved the ecology of benthic organisms and assemblages, the effects of human impacts on these organisms and assemblages, and the distribution of coastal species in the southern ocean (Smith 2002; Smith and Simpson 2002; Stark et al 2003, 2004; Lewis et al 2005; Simpson 2007). These research interests continued through to more recent work on trophic structures (Gillies et al 2012a, b).

Biology, patterns and processes, marine parks, tourism and conservation

Processes and patterns in coastal benthic ecology became a feature of the research at the NMSC. The work was often coupled with the measurement, monitoring and management of marine biodiversity. However, to allow this coupling much foundation work is required on basic ecology and patterns within and between benthic communities to provide the baseline studies on which to assess possible effects of different types of human impact on a range of marine biota (Smith and Rule 2002; Smith and Simpson 2002; Edwards and Smith 2005; Rule and Smith 2005, 2007; Hastie and Smith 2006; Smith et al 2008; Harrison and Smith 2012). The documentation of impacts and their effects is used as an essential stepping stone to effective management, and in assisting policy decisions through the provision of sound scientific data. Such work

Theme					
Marine biology and ecology – Invertebrates, seaweed	Corals and associated organisms	Biology, patterns and processes	Marine parks, tourism conservation	Antarctic ecology	Taxonomy, Chemistry
	Scott and Harrison 2005; Dalton and Godwin 2006; Scott and Francisco 2006; Dalton and Smith 2006; Carroll et al 2006; Scott and Harrison 2007a,b, 2008, 2009; Adjeroud et al 2007, 2010; Smith and Hattori 2008; Baird et al 2010; Purcell and Cheng 2010; Dalton et al 2010a,b; Harrison et al 2011; Smith 2011a,b; Dalton and Carroll 2011; Penin et al 2011; Bridge et al 2012; Hill and Scott 2012.	Smith and Rule 2002; Smith 2003, 2005, 2008; Edwards and Smith 2005; Rule and Smith 2005, 2007; Hastie and Smith 2006; Hacking 2007; Jones et al 2007; Townsend et al 2008; Malcolm et al 2010a; Purcell 2010b; Burns and Smith 2011; Harrison and Smith 2012.	Malcolm et al 2007, 2010b,c, 2011a,b, 2012; Smith et al 2008; Malcolm and Smith 2010; Scott et al 2011; Hammerton et al 2012; Smith 2012	Smith 2002; Smith and Simpson 2002; Stark et al 2003; Stark et al 2004; Hughes et al 2005; Lewis et al 2005; Simpson 2007; Gillies et al 2012a,b.	Peart 2006, 2007a,b; Hughes and Lowry 2006; Amaral et al 2008; Yerman and Krapp-Schickel 2008; Yerman 2009; Yerman and Coleman 2009; Liu et al 2012; Peters et al 2012

Table 1: Research Outputs (refereed – journals, chapters, books) from the SCU National Marine Science Centre.

Birds and Mammals	Biology and ecology of seabirds, marine mammals	Terrestrial ecology and evolution			
	Clancy 2005a,b; Oxley and McKay 2005; Totterman and Harrison 2007; Franklin et al 2011	Christidis et al 2010, 2011; Jønsson et al 2010, 2011; Alström et al 2011; Williamson et al 2011; Letnic and Dworjanyn 2011; Driskell et al 2011; McBride et al 2012; Prober et al 2012			
Aquaculture and climate change* * Marine Environment	Aquaculture – invertebrates	Aquaculture – fish	Climate change		
	Liu et al 2004a,b,c, 2006, 2009; Troup et al 2005; Dworjanyn et al 2007; Byrne et al 2008; Dworjanyn and Pirozzi 2008; Mos et al 2011; Scott 2012; Swanson et al 2012	Black and Pankhurst 2009; Guy et al 2009; Rushworth et al 2011	Byrne et al 2009, 2010a,b, 2011; Sheppard et al 2010; McIlgorm et al 2010; Beger et al 2011; Doo et al 2012; Durrant et al 2012; Foo et al 2012; Prober et al 2012		

Table 1(cont'd…): Research Outputs (refereed – journals, chapters, books) from the SCU National Marine Science Centre.

Fisheries biology and management *refers to "unaccounted" mortality	Reviews and identification of fishing *mortality and reproduction	Modifications of existing gear to mitigate fishing *mortality	Modifications beyond existing gear to mitigate fishing *mortality	Modifications to operational, post-handling practices to mitigate fishing *mortality	Analysis of stocks in fisheries, fisheries organisation and economics
	Kennelly and Broadhurst 2002; Gray et al 2004, 2005b 2006; Broadhurst et al 2005b, 2006a,b, 2007a,b, 2011, 2012a,d,e; Butcher et al 2006, 2008a, 2010a,b, 2011a,b, 2012b; Pinhero et al 2006; Fischer et al 2007; McShane et al 2007; Hazin et al 2008; Hall et al 2009a,b, 2012; Uhlmann et al 2009; Dowling et al 2010; Roach et al 2011; Roberts et al 2011; Zagaglia et al 2011; Leland et al 2012	Broadhurst et al 2002a, 2003, 2004a,b, 2007c, 2012a,b; Macbeth et al 2004, 2005a,b,c; Gray et al 2005a,c; Rotherham et al 2006; Butcher et al 2008b; Graham et al 2009; McGrath et al 2011a,b	Broadhurst et al 2002b, 2004c, 2006c, 2009c, 2010, 2012a,c; Millar et al 2004, 2005; Scandol et al 2006; Macbeth et al 2007; Rotherham et al 2008; Broadhurst and Millar 2009, 2011; Silva et al 2011, 2012a,c	Macbeth et al 2006; Broadhurst et al 2005a, 2007, 2008a,b, 2009a,b, 2012b,c; Broadhurst and Uhlmann 2007; Butcher et al 2007, 2012a; Uhlmann and Broadhurst 2007; McGrath et al 2009; Reynolds et al 2009; Leland et al 2012	McIlgorm and Sykes 2008; Grafton and McIlgorm 2009; Kildow and McIlgorm 2010; Purcell 2010a; Purcell et al 2011; Purcell and Samya 2012

Table 1(concl.): Research Outputs (refereed – journals, chapters, books) from the SCU National Marine Science Centre.

THEME	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 (AUG)	OVERALL TOTALS
Marine Biology and Ecology – Invertebrates and Vertebrates	3	2	1	9	7	11	7	3	10	11	10	74
Fisheries Biology, Management, Economics	3	1	6	9	9	9	7	11	5	9	12	81
Aquaculture and Climate Change			3	1	1	1	2	4	4	4	5	25
Terrestrial Ecology and Evolution									2	6	2	10
Yearly Totals	6	3	10	19	17	21	16	18	21	30	29	190

Table 2: Numbers of refereed publications (journals, chapters, books) from the NMSC across the years, grouped by broad themes.

	Time Period											
	2002		2003		2004		2005		2006		2007	
	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs
Marine Biology and Ecology - Invertebrates and Vertebrates		4		16	1	7	3	8	4	19	9	10
Fisheries Biology and Management				1	1	4	6	1	3	6	4	3
Aquaculture and Climate Change		1		2		1				1		1
Overall Yearly Totals		**5**		**19**	**2**	**12**	**9**	**9**	**7**	**25**	**13**	**14**

Table 3: Numbers of scientific and technical reports (Rpts) and conference presentations (Cfs) from the NMSC across the years, grouped by broad themes.

	Time Period											
	2008		2009		2010		2011		2012 (August)		Overall Totals	
	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs	Rpts	Cfs
Marine Biology and Ecology - Invertebrates and Vertebrates	3	9	2	1	3		4	2		2	30	78
Fisheries Biology and Management	5	4	2	3		3		2			21	27
Aquaculture and Climate Change	1				1	2	1		5		8	8
Overall Yearly Totals	**9**	**13**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**2**	**59**	**113**

TABLE 3 (cont'd…): Numbers of scientific and technical reports (Rpts) and conference presentations (Cfs) from the NMSC across the years, grouped by broad themes.

was applied to management of the coastal zone in NSW, but the main application has been in conservation planning for marine parks. The research has involved collaboration with external parties, primarily involving Assoc. Prof. Steve Smith. Often, owing to the objectives of the work, team members are from government agencies, from local to federal. The fostering of these collaborations had the additional benefit of ensuring connections to contemporary issues, relevant to concerns across marine parks, tourism, and conservation. Significant works include: (1) marine park management (Smith 2005, 2008; Malcolm et al 2010c; Malcolm et al 2011a,b; Malcolm et al 2012; Malcolm and Smith 2010) and (2) marine debris and conservation (Smith and Hattori 2008; Smith et al 2008; Smith 2008, 2012)

Taxonomy, chemistry

Collaboration with the Crustacean section of the Australian Museum resulted in significant contributions to taxonomy within the amphipod group (Hughes and Lowry 2006; Peart 2006; Peart 2007a, 2007b; Yerman and Krapp-Schickel 2008; Yerman 2009; Yerman and Coleman 2009)

Recently, there has been participation in research in the chemical properties of marine organisms. Liu et al (2012) undertook a comprehensive review of the bioactive compounds in Sargassum seaweed and the implications for Chinese medicine. Peters et al (2012) investigated the properties of bacterial communities on the surface of molluscan egg cases, in relation to their protective value.

Corals and associated organisms

The NMSC is ideally located at a marine transitional zone where warmer waters from the north meet cooler southern waters from the south. The offshore region has many tropical species that reach their southernmost distribution. This transitional feature in the offshore marine environment was one of the main components of the rationale to establish the Solitary Islands Marine Park. It followed that the biology and ecology of corals and associated organisms became another prime feature of the research at the NMSC, with a foundation provided by Prof. Peter Harrison, Dr Anna Scott and Dr Andrew Carroll, encompassing the reproductive and regeneration theme. This has included some highly innovative research on the spawning times, larval development, settlement and metamorphosis of two species of sea anemone that provide essential habitat for anemonefishes (Scott and Harrison 2005; 2007a, b; 2008; 2009). Within that research work a novel biopsy sampling method outlined in Scott and Harrison (2009) provides an opportunity to gain a more thorough understanding of the gametogenic cycles and sexual patterns of host sea anemones throughout their distribution. Work is now being done on developing optimal methods for the culture of host sea anemones in captivity (Scott 2012), and other aspects of the anemone/anemonefish symbiosis are being investigated (Scott et al 2011, Bridge et al 2012, Hill and Scott 2012). Research on the corals of Polynesia has also been undertaken in collaboration with French scientists (Carroll et al 2006; Adjeroud et al 2007, 2010; Penin et al 2011). Investigation into coral reef organisms was also extended to the effects of thermal stress on corals, and to diseases of corals by Dr Steve Dalton. An infectious disease was identified that was temperature dependent and this formed an important component in the assessment of impacts on hard corals in a sub-tropical environment (Dalton and Smith 2006; Dalton et al 2010a,b; Dalton and Carroll 2011). Work has also been undertaken on the

management of coral reefs (Purcell and Cheng 2010; Beger et al 2011).

Aquaculture and climate change

Facilities for aquaculture were set up from the start and the initial research was via collaboration between Prof. Simpson and postgraduate students stationed either at NSW Fisheries or at private enterprises. The work covered abalone, oysters, bream, and the freshwater silver perch (Liu et al 2004a,b,c; Liu et al 2006; Liu et al 2009; Troup et al 2005; Black and Pankhurst 2009; Guy et al 2009). Results were also often reported to funding bodies (Table 3). Aquaculture continued on organisms such as sea urchins, fish, aquarium species and seaweed with Dr Symon Dworjanyn, Dr Jeff Guy, Dr Ken Cowden, and Dr Steve Purcell joining the NMSC (Dworjanyn et al 2007; Dworjanyn and Pirozzi 2008; Byrne et al 2008; Mos et al 2011; Rushworth et al 2011; Scott 2012; Swanson et al 2012). Again, much work has also been presented as reports (Table 3).

In 2009 the NMSC aquaculture infrastructure was used in the establishment of an ocean acidification and warming facility. In this facility future ocean conditions can be simulated using flow-through seawater, allowing tests of the physiology and adaptive capacity of marine organisms in response to consequences of predicted climate change. Work from this facility has shown how ocean warming and acidification might interact to impact on the early development and larval phases of sea urchins (Byrne et al 2009; Byrne et al 2010a,b; Sheppard et al 2010; Byrne et al 2011; Doo et al 2012). It appears that very early development of invertebrates may be more affected by warming; at later calcified larval stages warming may mitigate the negative effects of acidification until a thermal threshold is reached after which there are additive negative effects of both these stressors. In recent work it has been shown that some sea urchin larvae exhibit genetic variation to both warming and acidification (Foo et al 2012). The facilities for aquaculture and climate change work have been further upgraded in 2011-2012, ready for increased targeted research in this area, particularly on adaptations shown by sea urchins and on species interactions.

Birds and mammals

Seabirds and marine mammals

Work on seabirds and mammals came about from postgraduate students either assigned to the centre or supervised by staff or associated personnel (Clancy 2005a, b; Oxley and McKay 2005; Totterman and Harrison 2007; Franklin et al 2011). Although such research is distant from the core themes of the centre, this illustrates another facet in the centre's operations; in that it provides associated personnel and excellent facilities for projects that may be one-off or directed towards regional topics.

Terrestrial ecology and evolution

When Prof. Les Christidis joined the centre, he established a research program in the terrestrial sphere as applied to birds, focussing on a newly emerging area of conservation biogeography. The research emphasizes the importance of conserving the ecological and evolutionary processes that will generate future diversity; a research topic that extends the greater concentration of conservation work on extant biodiversity (Christidis et al 2010; Jønsson et al 2010, 2011; Alstrom et al 2011; Christidis et al 2011; Driskell et al 2011; Williamson et al 2011; McBride et al 2012; Prober et al 2012).

Fisheries Biology and Management

NSW Department of Primary Industries

The Fisheries Technology Conservation Unit of the DPI has been the mainstay of the fisheries biology and management research at the NMSC. Personnel stationed at the NMSC include Dr Matt Broadhurst (head of the unit), Dr Paul Butcher, and Dr Karina Hall, and they also collaborate with other national and international researchers in this field. The research of the unit is focussed on fishing mortality for both commercial and recreational fisheries, particularly for New South Wales, and is applied to fish and prawns. The work is centred on unaccounted mortality, that is, the mortality from fishing apart from what is reported as landed catch. There are a number of possible causes for unaccounted mortality and the research of the unit at the NMSC involves four stages in an investigation of the principal causes. Some key papers across those stages are cited here and a full list is given in Table 1. These stages are: (1) reviews and identification of the potential for problematic unaccounted fishing mortality (Kennelly and Broadhurst 2002; Gray et al 2004; Broadhurst et al 2005, 2006a, 2007b, 2012a; Butcher et al 2006, Butcher et al 2008a, Hall et al 2009b, 2012; Butcher et al 2010b, Butcher et al 2011b) (2) modifications of existing gear to mitigate fishing unaccounted mortality (Broadhurst et al 2002a, 2003, 2004b, 2007c; Macbeth et al 2005a,c; Rotherham et al 2006; McGrath et al 2011b; Butcher et al 2012) (3) modifications beyond existing gear to mitigate fishing unaccounted mortality (Broadhurst et al 2002b, 2004c, 2005, 2010, 2012c; Millar et al 2004; Broadhurst and Millar 2011; Rotherham et al 2008; Silva et al 2011) and (4) modifications to operational and post-handling practices to mitigate fishing unaccounted mortality (Macbeth et al 2006; Broadhurst et al 2007a, 2008b, 2009a; Butcher et al 2007, 2012a; McGrath et al 2009; Leland et al 2012). These four stages represent a well-developed application of fisheries science to address a sequence of what is known, how can existing methods be improved, what new methods might be suitable, and how to improve actual practices. The findings not only appear in the scientific literature (Table 1) but are also applied to newsletters, handbooks, and reports for the use by the fishing industries and these are enumerated in Table 3.

Other fisheries work

Research on sea-cucumber fisheries was introduced to the NMSC by Dr Steve Purcell. Although, much of the work applied to the Pacific region, analysis has also been applied to the sea-cucumber fisheries globally (Purcell et al 2011). The first comprehensive book on managing sea-cucumber fisheries was produced for the UN's Food and Agricultural Organisation (Purcell 2010).

During his term as Director, Prof. Alistair McIlgorm brought a new field of research expertise to the NMSC – economics and governance in the fishing industry (Grafton and McIlgorm 2009; McIlgorm and Sykes 2009; Kildow and McIlgorm 2010; McIlgorm et al 2010). The work gained international recognition on the importance of measuring the marine economy (Kildow and McIlgorm 2010) and on the challenges from governance and climate change in fisheries management (McIlgorm et al 2010). The research also produced many reports on the economics behind the control of marine resources and the care of the marine environment for government institutions and the Asia-Pacific region.

Postgraduate projects

Training the researchers of the future through postgraduate programs has been a prominent feature of the activities at the NMSC since its inception. Table 4 lists the completed research degrees (MSc (10) and PhD (21)) across the years and according to the research themes at the NMSC. Also, there have been 25 honours students, each with an investigative project, over that time. The apparent anomaly in the high number of completed PhDs in the 2005-2007 time slot can be explained by the high number of honours and postgraduate students brought to, and attracted to, the centre by Prof. Rod Simpson and Assoc. Prof. Steve Smith in the first years.

Research outside of the scientific literature and engagement with professional bodies

Personnel at the NMSC have been actively engaged in conducting research for a number of organisations, primarily for governmental bodies. Over all, the topics fall within the same areas of expertise as illustrated by the publications in the scientific literature. There are numerous reports from such work and the numbers are shown in Table 3, grouped according to the research themes. Many of these reports are extensive with peer review scrutiny. Also in Table 3, the numbers of conference presentations are similarly grouped in the research themes. Among the conference presentations there have been five keynote addresses. As to be expected, the numbers of conference presentations in any

Theme	**Time Period**									
	2002-2004		**2005-2007**		**2008-2010**		**2011-**		**Overall Totals**	
	MSc	**PhD**	**MSc**	**PhD**	**MSc**	**PhD**	**MSc**	**PhD**	**MSc**	**PhD**
Marine Biology and Ecology - Invertebrates and Vertebrates	1	2	1	8		3		2	2	15
Fisheries Biology and Management	1		1	2	2	1	2	1	6	4
Aquaculture	1		1	1		1			2	2
Overall Totals for Time Periods	**3**	**2**	**3**	**11**	**2**	**5**	**2**	**3**	**10**	**21**

Table 4: Completed Research Postgraduate Awards with supervision at NMSC.

year tend to be related to the occurrence of conferences dealing with the research themes.

Research personnel of the NMSC have been active in many professional societies and advisory committees over the ten years. This involvement has ranged across all the research themes and has included participation in environmental management groups that were formed to address specific concerns. Some notable examples of the latter are: Assoc. Prof. Steve Smith (advisory groups for estuarine and nearshore ecological health); Dr Anna Scott (organisational roles for the Coral Reef Society); Prof. Alistair McIlgorm, Dr Steve Purcell (working groups for the Asia Pacific region).

Communication of research findings to the general community

There has been wide-ranging communication of research work at the NMSC to the general community, via public talks at the centre, local and national media interviews, presentations to a wide selection of clubs and societies, and newspaper and magazine articles. In particular, researchers in the Conservation Technology Unit working on recreational fisheries make regular contributions to a number of fishing magazines, alerting the fishing world to relevant findings.

The aquarium at the NMSC had modest beginnings with two central tanks for viewing by the public. From 2006, the aquarium facilities have been greatly expanded to allow an entrance fee display for the public. It also provides an educational role by displaying research projects and findings as well as information and films about the marine environment and its resources. For schools, there are educational activities for class participation.

Summary

The NMSC has had a very successful first ten years. Although its physical establishment was made possible by way of a grant from the federal government, the operation and the concomitant financial support of the centre were the responsibilities of two universities at the outset and, later, solely that of SCU. The progress of activities at the NMSC in the early years always had difficulties through the differing agendas of two universities. After UNE retreated to its inland rural base, the NMSC has received increased support for the facilities and staffing via the more marine orientated SCU which now had a better focus with definite ownership.

The outputs and involvement in research have been very impressive for such a small number of research staff located at the NMSC, which was four at the beginning, increased to twelve by 2009 and stands at seventeen (including four adjunct appointments) in 2012.

With the opening of new facilities in 2012, the NMSC is poised for increases in personnel and for further advances in productivity in the established research themes across regional, national and international spheres.

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