Table 19: Description of links in signed digraph of above figure.

To	From	Comment
SupHab	Runoff	Degradation from sediment loads
SupHab	Turbid	Habitat degradation
SupHab	Dredgi	Habitat degradation
SupHab	Ports	Habitat degradation
TurDug	SupHab	Critical habitat & resource for turtles and dugongs
FisSto	SupHab	Critical habitat & resource for turtles and dugongs
FisSto	StoDis	Enhances productivity following storms
TurDug	CoFiPr	Mortality from encounters with fishing gear
CoFiPr	FisSto	Fishing pressure increases with catch
FisSto	CoFiPr	Harvest mortality
CoFiPr	BooEco	Labour shortage on fishing vessels from competition with mining jobs
ReFiPr	BooEco	Disposable income invested in high-end vessels, which increases fishing power
BooEco	MinSec	Boom economy driven by mining sector
MinSec	Ports	Mining sector depends on ports
Ports	MinSec	Ports depend on mining sector
Turbid	Ports	Ports contribute to near shore turbidity
Turbid	Shippi	Shipping contributes to near shore turbidity
AgrSec	MinSec	Mining sector suppresses agriculture
UrbSec	MinSec	Mining sector drives urban growth
AgrSec	UrbSec	Urban sector suppresses agriculture
Dredgi	Ports	Ports increase dredging activity
Turbid	Runoff	Runoff increases turbidity
Runoff	AgrSec	Source of runoff
Runoff	UrbSec	Source of runoff
KnoEdu	Runoff	Knowledge and education works to reduce runoff from urban and agriculture sectors

8.3.1.2 BURDEKIN LMAC REFERENCE GROUP

The first of two meetings were held with the Burdekin LMAC RG on May 14, 2013 and produced a list of key assets to the region and a barramundi model.

Attendees: CSIRO, GBRMPA, LMAC members, Burdekin Council

Asset
Wetlands - Habitat for migratory birds (subset of wetlands) - Riparian vegetation
Land use - Ownership, stewardship - Economic and social - Infrastructure
Fish resources (barramundi, mud crabs)

River
Inshore coral
Seagrass
Mangroves
Water resources - surface - subsurface - Ocean
Wildlife

Model 1. Barramundi model (i)

A life-stage model of barramundi was developed to describe the inter-relationships of various impacts, including commercial and recreational fishing, changes to stream flow, habitat and water quality, and the influence of fish stocking programs (see Figure and Table below). The model includes the influence of a black market for recreationally caught barramundi, which acts to increase effort in the recreational fishery and suppress the commercial fishery. Included also is life stage-specific protandrous hermaphroditism, in which younger (and smaller) adults are all males prior to maturing into females, and also cannibalism, where barramundi consume individuals of the previous (smaller) life stage.

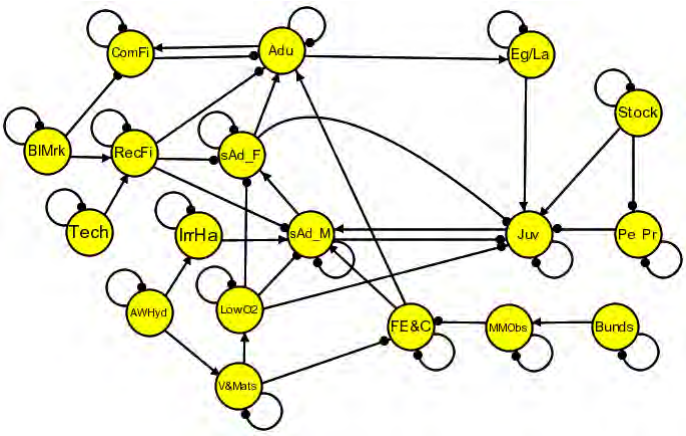

Figure 21: Barramundi model from the Burdekin LMAG reference group. Adu: adult barramundi, AWHyd: altered wetland hydrology, BlMrk: black market for recreationally-caught fish, Bunds: bunds (small dams), ComFi: commercial fishing, Eg/La: barramundi egg and larvae, FE&C: flow events and stream channel connectivity, IrrHa: irrigation-based habitat, Juv: juvenile barramundi, LowO2: low dissolved oxygen, MMObs: man-made obstructions, Pe Pr: pest and predator species, RecFi: recreational fishing, sAd_F: subadult female barramundi, sAd_M: subadult male barramundi, Stock: stocking of juvenile barramundi, Tech: fishing and sport equipment technology, V&Mats: vegetation and mats.

Table 20: Description of links in signed digraph of above figure.

To	From	Comment

To	From	Comment
Eg/La	Adu	Fecundity & reproduction
Juv	Eg/La	Life stage development
sAd_M	Juv	Life stage development
sAd_F	sAd_M	Life stage development
Adu	sAd_F	Life stage development & maturation
Juv	Stock	Stocking of hatchery reared juvenile barramundi
Pe Pr	Stock	consumption of pest and predator species by stocked barramundi
Juv	Pe Pr	Suppression of juvenile barramundi by pest and predator species
FE&C	MMObs	Changes to hydrology and stream connectivity from man-made obstructions to stream flow
sAd_M **Adu**	FE&C	Life-cycle requirements dependent on stream migration natural flow regimes
FE&C	V&Mats	Obstruction of stream flow by vegetative mats
LowO2	V&Mats	Reduction in dissolved oxygen from biological oxygen demand of decaying vegetation and reduced stream flow
Juv **sAd_M** **sAD_F**	Low O2	Low levels of dissolved oxygen suppresses growth and survival of barramundi life stages
ComFi **RecFi**	BlMark	Black market for recreationally-caught barramundi suppresses commercial fishery and increases recreational fishery
sAd_M	IrrHa	Irrigation channels provide rearing habitat for subadults
Adu **sAd_F** **sAd_M**	RecFi	Fishing mortality to barramundi life stages
Adu	ComFi	Fishing mortality to adult barramundi
IrrHab **V&Mats**	AWHyd	Alteredwetland hydrology contributes to irrigation-based habitat and also vegetation and mats
Juv	sAd_M sAd_F	Cannibalism-based mortality of juvenile barramundi
RecFi	Tech	Increased catchability from increased availability of fishing technology and sports equipment
ComFi	Adu	Commerical fishing effort sensitive to relative abundance of adult barramunidi

The second meeting in Burdekin was held on the July 2, 2013.

Attendees: CSIRO, GBRMPA, LMAC, Burdekin Council

Model 2. Social value of fishing and governance

A model was developed to describe the social values, and the personal, family and community dynamics associated with fishing or harvest activities (see Figure and Table below). The principle driver of harvest was described as an appreciation of the interaction with the natural environment. This sentiment is itself driven by the relative abundance of the natural resource and a basic respect for the environment. The appreciation of the natural environment is an important driver of a sense of community, which in the presence of role models, provides the basis of education for

the next generation of fishers, thus leading back to and enhancing respect for the environment. The level of harvest activity depends on the having sufficient access to the fishing grounds, which can be limited by a lack of available time for the activity or by crowding. Crowding can also act to diminish the relative amount of solitude, which is an important factor in the appreciation of the interaction with the natural environment. Natural disturbances and anthropogenic pressures can act to diminish the abundance of the natural resource.

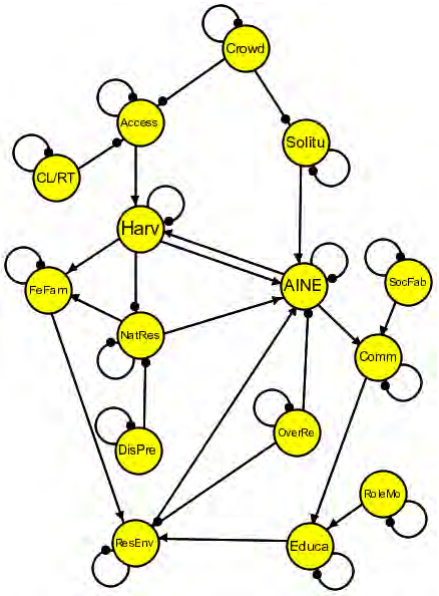

Figure 22: Social values of fishing and other resource activities. Access: access to fishing grounds, AINE: appreciation of interaction with natural environment, CL/RT: increased cost of living and decreased recreation time, Comm: sense of community, Crowd: crowding, DisPre: natural disturbances and anthropogenic pressures, Educa: education of younger generation of fishers, FeFam: feeding family, Harv: fisheries harvest & catch, NatRes: natural resource, OverRe: over regulation of fishing, ResEnv: respect for the environment, RoleMo: role models, SocFab: social fabric, Solitu: solitude.

Table 21: Description of links in signed digraph of above figure.

To	From	Comment
Harv	AINE	Fish harvest activity contributes to appreciation of interaction with natural environment
AINE	Harv	Appreciation of interaction with natural environment contributes to harvest activity
FeFam	Harv	Harvest activity leads to feeding of family
ResEnv	FeFam	Feeding of family leads to respect for environment
AINE	ResEnv	Respect for environment increases appreciation of interaction with natural environment
AINE	Solitu	Solitude enhances the experience of interacting with natural environment, leading to increased appreciation
NatRes	Harv	Harvest leads to reduced levels of natural resource
FeFam	NatRes	Abundant natural resources result in increased catch levels

To	From	Comment
AINE	NatRes	Abundant natural resources result in increased appreciation of interaction with natural environment
Harv	Access	Access to fishing grounds facilitates harvest activity
CL/RT	Access	Access to fishing grounds limited by lack of available time
Access **Solitud**	Crowd	Crowding diminishes experience of solitude and interferes with access to fishing grounds
NatRes	DisPre	Natural disturbances and anthropogenic pressures reduce abundance of natural resources
AINE **ResENv**	OverRe	Over regulation of fishing activites suppresses appreciation of interaction with natural environment and respect for the environment
Comm	AINE SocFab	Strong social fabric and appreciation of interaction with natural environment contributes to an increased sense of community
Comm	Educa RoleMo	Strong sense of community and availability of role models facilitates education of younger generation of fishers
ResEnv	Educa	Education leads to increased respect for the environment

8.3.1.3 BRISBANE

Two sets of meetings took place in Brisbane – the first on the August 6, 2012.

Attendees: CSIRO, DERM, DAFF, DSEWPAC, DEHP

Model 1. Sea Turtle (i): Cumulative Impacts

This model depicts a general life history of sea turtles through four life stages, including egg, hatchling, sub-adult and adult (see Figure and Table below). Each of these life stages flow into the next through the process of maturation or reproduction. The focus of this model was to highlight the principle sources of natural and anthropogenic mortality and their interrelationships. Key resource variable for sea turtles include seagrass beds and nesting habitat, with the principle human-caused threats to the system coming from coastal development, dredging, and agricultural runoff. Natural disturbances include river flow cycles (i.e., storm flows) and cyclones.

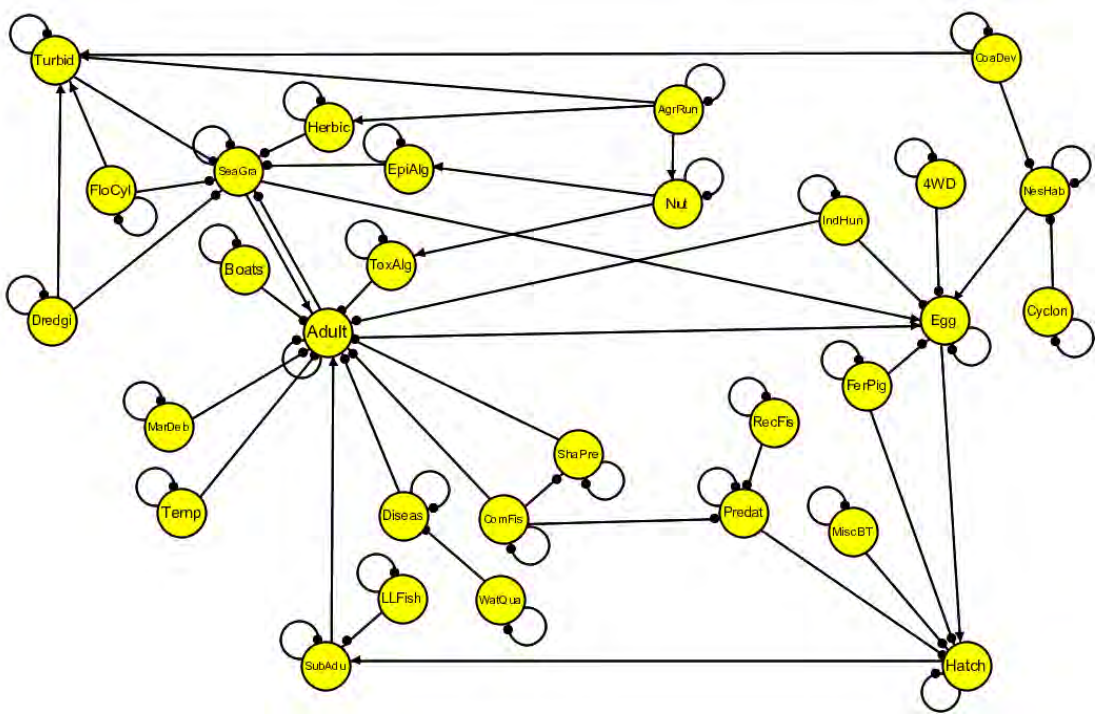

Figure 23: Sea Turtle (i): Cumulative Impacts model. 4WD: off-road vehicle traffic over nest sites, Adult: turtle adult, AgrRun: agricultural runoff, Boats: boat strike and disturbances, CoaDev: coastal development, ComFis: commercial fishing, Cyclon: cyclone, Diseas: disease, Dredgi: dredging, Egg: turtle egg, SubAdu: turtle subadult, EpiAlg: epiphytic algae, FerPig: feral pigs, FloCyl: river flow cycle, Hatch: turtle hatchling, Herbic: herbicide, IndHun: indigenous hunting, LLFish: long line fishing, MarDeb: marine debris, MiscBT: miscellaneous beach threats (e.g., foxes, native predators, night lights). NesHab: turtule nesting habitat, Nut: nutrients, Predat: predators, RecFis: recreational fishing, SeaGra: seagrass, ShaPre: shark predation, Temp: temperature, ToxAlg: toxic algae, Turbid: turbidity, WatQua: water quality.

Table 22: Description of links in signed digraph of above figure.

To	From	Comment
Adult	Boats	Boat strikes and disturbance of turtle feeding activity
Adult	SeaGra	Nutrition that reduces mortality from starvation
Adult	ToxAlg	Mortality
Adult	IndHun	Harvest mortality
Adult	ShaPre	Shark predation mortality
Adult	ComFis	Mortality from encounters with commercial fishing gear
Adult	Diseas	Disease mortality
Adult	Temp	Increases in temperature affects sex ratio and possibly success of hatchlings
Adult	MarDeb	Mortality from encounters and ingestion of marine debris
Egg	IndHun	Harvest mortality
Egg	4WD	Destruction of nests from vehicles on beaches
Egg	FerPig	Predation mortality from feral pigs

To	From	Comment
Egg	SeaGra	Increased fecundity from nutrition
Hatchling	MiscBT	Various threats to hatchlings, including predation from foxes and native predators, and disorientation from night lights
Hatchling	FerPig	Predation mortality
Hatchling	Predat	Mortality from fish predators
SubAdu	LLFish	Mortality from encounter with long line fishing gear
SeaGr	Dregi	Direct removal of seagrass beds from dredging
SeaGr	FloCyl	Natural impacts to seagrass beds from storms flows
SeaGr	Turbid	Smothering of seagrass beds from turbidity
SeaGr	Herbi	Mortality or decline in growth from herbicide
SeaGr	EpiAlg	Loss of growth from shading by epiphytes
SeaGr	Turtles	Grazing from turtles
Turbid	AgrRun	Contribution of turbidity from agricultural land use
Herbic	AgrRun	Contribution of herbicide from agricultural land use
ToxAlg	Nut	Toxic algal blooms from nutrients
EpiAlg	Nut	Increase growth from enrichment
Nut	Agr	Contribution of nutrients from agricultural land use
Turbid	CoaDev	Contribution of turbidity from land use run off
Turbid	Dredgi	Increased turbidity from dredging
Turbid	FloCyc	Natural contribution of turbidity
NestHab	CoaDev	Destruction of nesting habitat
NestHab	Cyclone	Destruction of nesting habitat
Disease	WatQual	Poor water quality inducing increase in disease of adult turtles
Predat	ComFis	Harvest mortality
Predat	RecFis	Harvest mortality
ShaPre	ComFis	Harvest mortality
Adult	SubAd	Life-stage transition
SubAd	Hatch	Life-stage transition
Hatch	Egg	Life-stage transition
Egg	Adult	Life-stage transition

Model 2. Sea Turtle (ii): Fishery Impacts & Regulation

This model describes interaction between turtles, fisheries and management agencies (see Figure and Table below). Here the focus is on the regulation of commercial (inshore net, inshore trawl, crab potting) and recreational fisheries for the purpose of limiting encounters of turtles with fishing gear. DAFF observer and logbook programs provide information on fishery-turtle interactions that are acted upon by DAFF by such measures as regulation of fishing gear (e.g., turtle excluding device) spatial closures, and effort reduction. There is a possible link to the observer program from recreational fishers, but it was judged to be weak and was not included in the model. The observer information also enhances public perceptions, which motivates the industry association to limit the impact of fishing on turtles (via gear modifications).

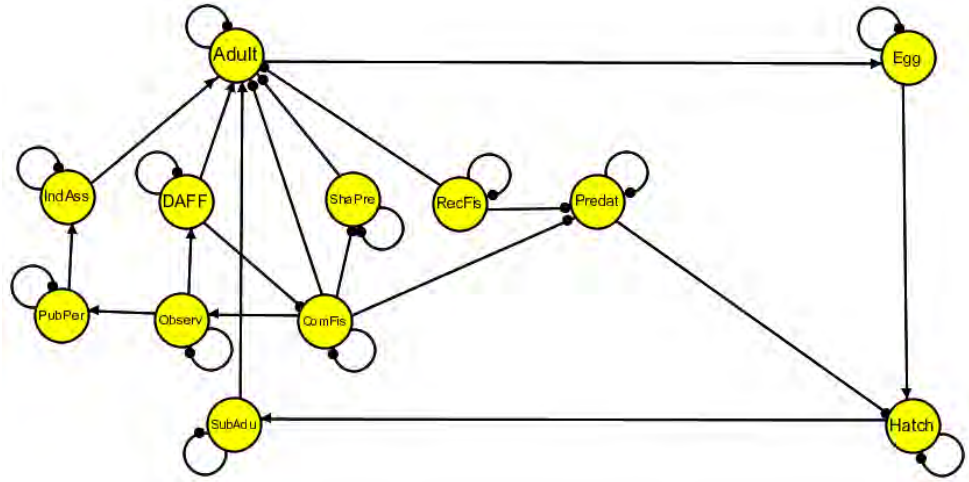

Figure 24: Sea Turtle (ii): Fishery Impacts & Regulation model. Adult: adult turtle, ComFis: commercial fishing, DAFF: Dept. Agriculture, Egg: turtle egg, Fisheries & Forestry, Hatch: turtle hatchling, IndAss: industry associations., Observ: observer program, Predat: predators, PubPer: public perception, RecFis: recreational fishing, ShaPre: shark predators, SubAdu: turtle subadult.

Table 23: Description of links in signed digraph of above figure.

To	From	Comment
Adult	ShaPre	Shark predation mortality
Adult	RecFis	Mortality from encounter with fishing gear
Adult	ComFis	Mortality from encounter with fishing gear
ComFis	DAFF	Regulation of fishing effort
Adult	DAFF	Reduction of encounters fisheries
Observ	ComFis	Information on encounters of turtles with fishing gear
DAFF	Observ	Information on encounters of turtles with fishing gear
PubPer	Observ	Information on encounters of turtles with fishing gear
IndAss	PubPer	Influence of public perception of encounters of turtles with fishing gear
Adult	IndAss	Reduction of encounters fisheries
Hatch	Predat	Predation mortality
Predat	ComFis	Harvest mortality
Predat	RecFis	Harvest mortality
ShaPre	ComFis	Harvest mortality
Adult	SubAd	Life-stage transition
SubAd	Hatch	Life-stage transition
Hatch	Egg	Life-stage transition
Egg	Adult	Life-stage transition

Model 3. Seagrass (i): Water Quality and Regulation

This model focuses on seagrass as affected by agricultural runoff through diminished water quality, and also the role of water quality monitoring and regulation (see Figure and Table below). Seagrass beds are affected by the natural cycle of river flows, which create erosion of seagrass beds and turbidity; seagrass growth can also be limited naturally by epiphytic algae. Anthropogenic effects include direct removal or covering of beds from dredging and coastal development, and increases to turbidity, herbicides and nutrients. These latter effects are driven by commercial interests, but are also observed and reported in water quality monitoring programs. This reporting feeds back on the system in the form of regulation and influence on public opinion, albeit these pathways for feedback are largely compromised by weak influence.

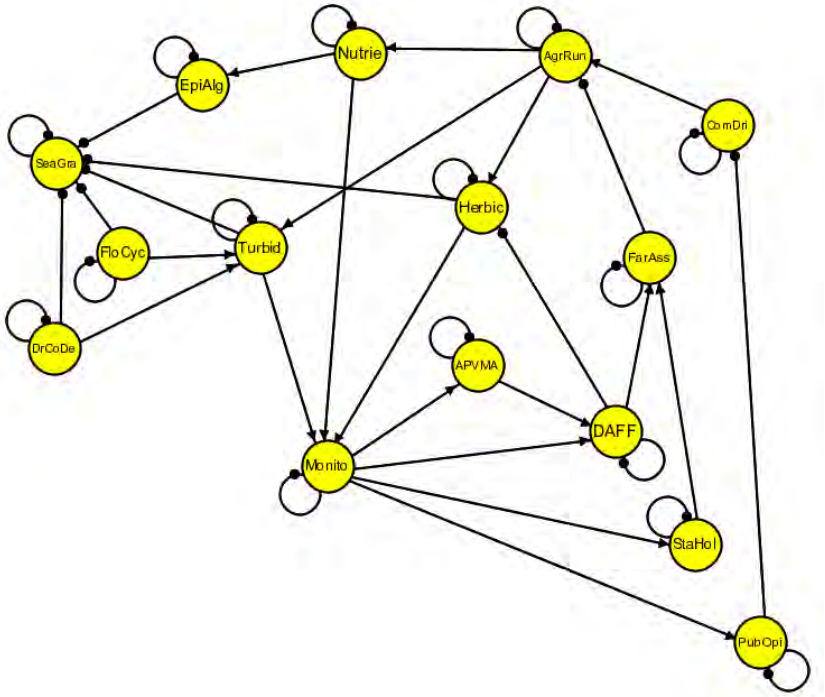

Figure 25: Seagrass (i): Water Quality and Regulation model. AgrRun: agricultural runoff, APVMA: Australian Pesticides and Veterinary Medicines Authority (with DSEWPaC), ComDri: commercial drivers, DAFF: Dept. Agriculture, Fisheries & Forestry, DrCoDe: dredging & coastal development, EpiAlg: epiphytic algae, FarAss: Farming associations, FloCyc: river flow cycle, Herbic: herbicides, Monito: monitoring program, Nutrie: nutrients, PubOpi: public opinion to protect or improve water quality, SeaGra: seagrass, StaHol: stake holders, Turbid: turbidity.

Table 24: Description of links in signed digraph of above figure.

To	From	Comment
SeaGr	EpiAlg	Diminished growth from shading
SeaGr	FloCyc	Disturbance to seagrass beds from high flows
SeaGr	DrCoDe	Removal/destruction of seagrass beds

To	From	Comment
SeaGr	Turbid	Suppression of growth from turbidity or mortality from smothering
SeaGr	Herbic	Mortality or suppression of growth from herbicides
AgrRun	ComDri	Commercial pressure to engage in land use practices that lead to increased runoff
Nutrie	AgrRun	Increased nutrients in runoff
Turbid	AgrRun	Increased turbidity in runoff
Herbic	AgrRun	Increased herbicide in runoff
EpiAlg	Nutrie	Increased growth from enrichment
Monito	Nutrie	Monitoring of nutrients in runoff
Monito	Herbic	Monitoring of herbicides in runoff
Monitor	Turbid	Monitoring of turbidity
APVMA	Monitor	Water quality reporting
DAFF	Monitor	Water quality reporting
StaHol	Monitor	Water quality reporting
PubOpi	Monitor	Water quality reporting
APVMA	DAFF	Setting of regulatory rules and targets
Herbici	DAFF	Suppression of agricultural runoff
FarAss	DAFF	Regulatory motivation to reduce agricultural runoff (critical but weak link)
FarAss	StakHo	Regulatory motivation to reduce agricultural runoff (critical but weak link)
ComDri	PubOpi	Motivation to reduce agricultural runoff
Turbid	FloCyc	Natural contributions to turbidity from seasonal flow cycle

Model 4. Seagrass (ii): Coastal Development

A second model for seagrass was developed that focused on the impacts of coastal development (see Figure and Table below). Here seagrass beds are directly removed or covered by dredging and reclamation projects. Such activities can be managed by Department of Industries as an area of special development, which has the potential to reduce the impact of dredging on seagrass beds and turbidity. Increasing the urban footprint of mining-associated communities also leads to increased dredging, turbidity and nutrients. Regulation of this latter pressure is the responsibility of regional planning authorities.

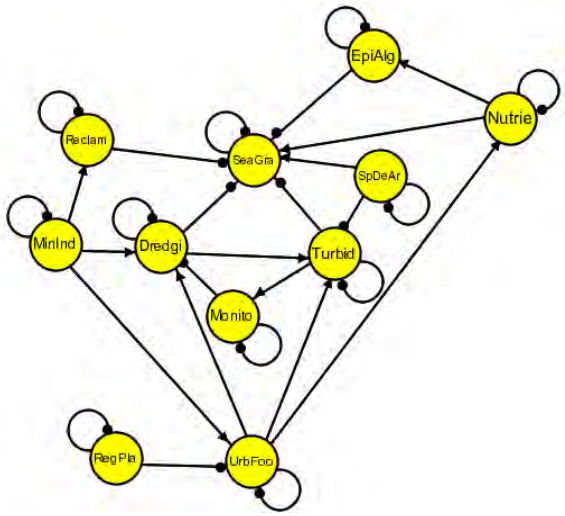

Figure 26: Seagrass (ii): Coastal Development model. Dredgi: dredging, EpiAlg: epiphytic algae, MinInd: mining industry, Monito: monitoring, Nutrie: nutrients, Reclam: reclamation, RegPla: regional planning, SeaGra: seagrass, SpDeAr: special development areas, Turbid: turbidity, UrbFoo: urban footprint.

Table 25: Description of links in signed digraph of above figure.

To	From	Comment
SeaGra	Reclaim	Destruction of seagrass beds
SeaGra	Dredgi	Destruction of seagrass beds
SeaGra	Turbid	Smothering of seagrass beds
SeaGra	EpiAlg	Reduced growth of seagrass from shading
SeaGra	Nutri	Increased growth of seagrass from enrichment
Reclaim	MinInd	Increased reclamation from mining associated projects
Dredgi	MinInd	Increased dredging from mining associated projects
Turbid	Dredgi	Increased turbidity from dredging operations
UrbFoo	MinInd	Increase in urban areas and growth from mining associated communities
Dredgi	UrbFoo	Increase in dredging from urban developments
Turbid	UrbFoo	Increased turbidity from urban runoff
UrbFoo	RegPla	Restriction of spatial extent and impact of urban growth
Nutrie	UrbFoo	Increased nutrient runoff from urban growth and foot print
EpiAlg	Nutrie	Increased growth from enrichment
Monito	Turbid	Water quality monitoring
Dredgi	Monitor	Regulation of dredging activities based on water quality reporting
SeaGra	SpDeAr	Limitation of dredging impacts by Dept of Industry regulation.
Turbid	SpDeAr	Limitation of dredging impacts by Dept of Industry regulation.

Model 5. Barramundi (ii): Cumulative Impacts

A second life-stage model of barramundi was developed to describe the inter-relationships of various impacts, including commercial and recreational fishing, migration barriers, loss of coastal wetlands, water quality and riparian vegetation, and the effects of introduced species such as tilapia and feral pigs (see Figure and Table below). The model included monitoring of water quality, fish populations and riparian vegetation, and a number of management activities. The model includes stage include hermaphroditism as a life history feature, and also consumption of previous (smaller) life stage through cannibalism.

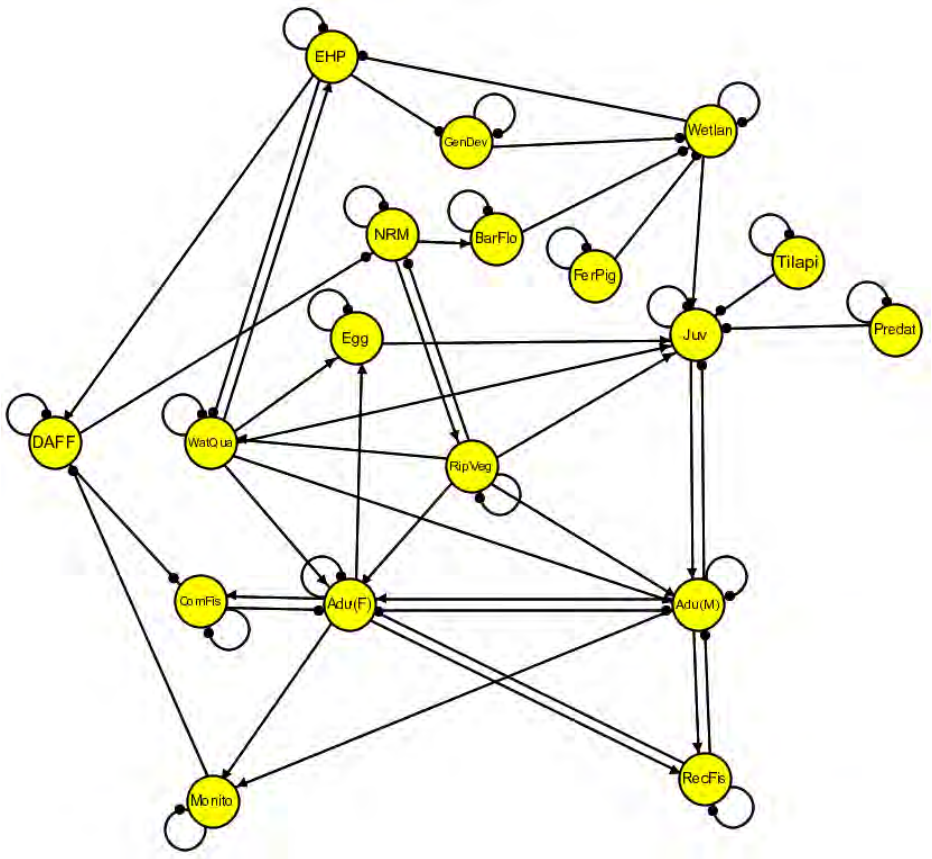

Figure 27: Barramundi (i): Cumulative Impacts model. Adu(F): barramundi adult females, Adu(M): barramundi adult males, ComFis: commercial fishing, DAFF: Dept. Agriculture, Fisheries & Forestry, Egg: barramundi eggs, EHP: Ecosystem Health Monitoring Program, FerPig: feral pigs, GenDev: general development, Juv: barramundi juveniles, Monito: monitoring, NRM: QLD Regional Natural Resource Management, Predat: predators, RecFis: recreational fishing, RipVeg: riparian vegetation, BarFlo: barriers & flow extraction, Tilapi: tilapia, WatQua: water quality, Wetlan: wetlands.

Table 26: Description of links in signed digraph of above figure.

To	From	Comment
Adu(F)	Adu(M)	Maturation
Adu(M)	Adu(F)	Mortality from cannibalism

To	From	Comment
Adu(M)	Juv	Maturation
Juv	Adu(M)	Mortality from cannibalism
Juv	Egg	Development
Egg	Adu(F)	Reproduction
Adu(F)	RipVeg	Critical habitat (i.e., ambush)
Adu(M)	RipVeg	Critical habitat (i.e., ambush)
Juv	RipVeg	Critical habitat (i.e., ambush)
WatQua	RipVeg	Filtration and shade
Egg	WatQua	Critical requirement
Juv	WatQua	Critical requirement
Adu(M)	WatQua	Critical requirement
Adu(F)	WatQua	Critical requirement
Juv	Wetlan	Critical habitat (i.e., provides shelter from predation and cannibalism)
Juv	Tilapia	Degrades wetlands benefit to juvenile barramundi
Juv	Predat	Predation mortality
Wetlan	FerPig	Degradation of wetlands
Wetlan	BarFlo	Degradation of wetlands
Wetlan	GenDev	Degradation of wetlands
Adu(F)	ComFis	Fishery harvest mortality
ComFis	Adu(F)	Catch-driven fishing effort
Adu(F)	RecFis	Fishery harvest mortality
RecFis	Adu(F)	Catch-driven fishing effort
Adu(M)	RecFis	Fishery harvest mortality
RecFis	Adu(M)	Catch-driven fishing effort
Monito	Adu(F)	Populaiton monitoring (weak link)
Monito	Adu(M)	Populaiton monitoring (weak link)
DAFF	Monito	Reporting of population monitoring
ComFis	DAFF	Effort control of fishery
DAFF	EHP	Reporting of habitat monitoring
NRM	DAFF	Advises on water barriers
NRM	RipVeg	Monitoring of riparian vegetation, if good need for NRM decreases
RipVeg	NRM	
WatQua	EHP	
EHP	WatQua	Water quality monitoring
EHP	Wetlan	Habitat monitoring, if quality high then no need to protect
GenDev	EHP	Regulation of development to protect-maintain habitat quality
BarFlo	NRM	Protection of critical flow and connectivity (weak link)

A second meeting was held on the September 25, 2012 in Brisbane to more directly address governance within the coastal zone.

Attendees: CSIRO, AIMS, JCU, Griffiths University

Model 6. General Governance of Natural Assets

A general model was developed to describe the main feedback associated with regulation of natural assets of coastal marine environments (see Figure and Table below). Natural assets are formed and maintained by supporting natural processes, both of which can be degraded or compromised by activities associated with various sectors of the economy. The activities of economic sectors can be limited by regulations to protect the environment, which derived their motivation from management agencies and political action. Environmental non-governmental organizations and public concern for the environment both react to the status of the natural asset, mutually support each other, and act to increase political actions for the environment. Lobbyists for economic sectors, on the other hand, act to weaken political action for environmental protection.

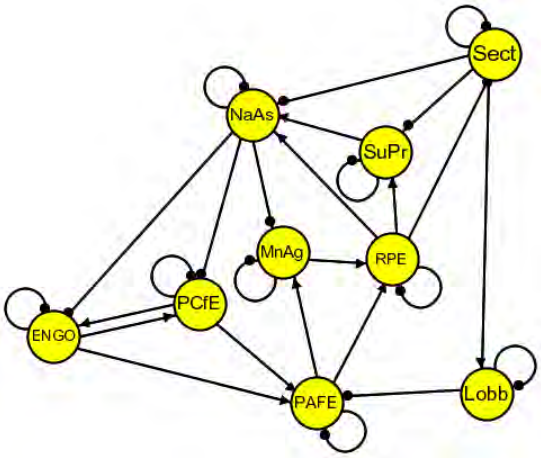

Figure 28: General Governance of Natural Assets model. ENGO: environmental non-governmental organization, Lobb: lobbyist, MnAg: management agency, NaAs: natural asset, PAFE: political actions for environment, PCfE: public concern for environment, RPE: regulations to protect environment, Sect: sector of economy, SuPr: supporting processes.

Table 27: Description of links in signed digraph of above figure.

To	From	Comment
NaAs	Sect	Degradation of asset by activity of economic sector
NaAs	SuPr	Supporting process of natural environment or ecosystem
NaAs	RPE	Regulations that limit impacts of economic sector benefit or maintain natural assets
SuPr	RPE	Regulations that limit impacts of economic sector benefit or maintain natural processes
Sect	RPE	Limitation of activity of economic sector
MnAg	NaAs	Status of natural asset provided motivation for management
RPE	MnAg	High motivation for management increases regulations to protect environment
ENGO	NaAs	Low asset status increases activity of non-governmental organizations

To	From	Comment
PCfE	NaAs	Low asset status increases activity of political action for environment
ENGO	PCfE	Activity by ENGO increases public concern
PCfE	ENGO	Public concern increases activity by ENGO
PAFE	PCfE	Public concern leads to increased political action to protect environment
PAFE	ENGO	ENGO activity increase political action to protect environment
MnAg	PAFE	Political actions for the environment increases strength of management agency
PAFE	RPE	Political action strengthens regulations
Lobb	Sect	Economic sectors support lobbying
PAFE	Lobb	Lobbying suppresses political actions for environment

Model 7. Coastal Wetlands

A model for coastal wetlands considers the influence of bunds (or flow blockages) and associated land use in coastal wetlands on a number of natural assets (see Figure and Table below). A natural flow regime maintains fish populations (i.e., barramundi, mangrove jack, giant herring, milk fish and tarpon), but is compromised by bunds, weed growth and an extended dry cycle (i.e., El Nino). Bunds create semi-permanent freshwater swamps, which increase agricultural land and wading bird habitat, but also weed growth. Weed growth in turn suppresses the natural flow regime and habitat for juvenile fish. A natural flow regime is critical for settlement of fish larvae. Bunds also suppress tidal swamps with are important habitat for juvenile fish and mangroves. The model examines other impacts of an extended dry cycle as well as sea level rise.

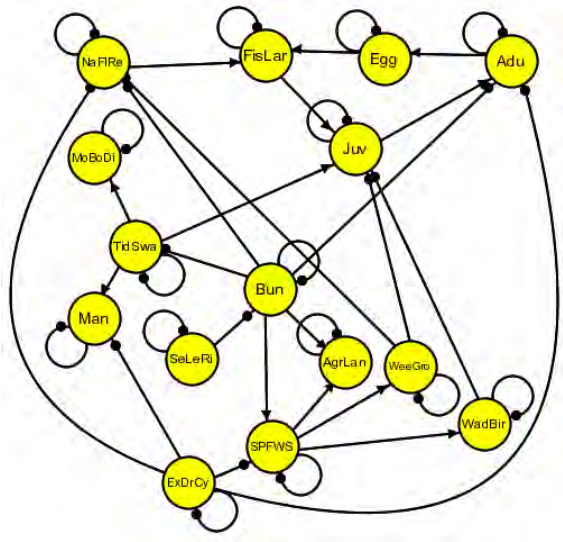

Figure 29: Coastal Wetlands model. Adu: adult fish, AgrLan: agricultural lands, Bun: bunds (or flow blockages), Egg: Fish eggs, ExDrCy: extended dry cycle (El Nino), FisLar: fish larvae, Juv: juvenile fish, Man: mangroves, MoBoDi: mosquito-borne disease, NaFlRe: natural flow regime,

SeLeRi: sea level rise, SPFWS: semi-permanent freshwater swamps, TidSwa: tidal swamps, WadBir: wading birds, WeeGro: weed growth.

Table 28: Description of links in signed digraph of above figure.

To	From	Comment
FisLar	Egg	Maturation
Juv	FisLar	Maturation
Adu	Juv	Maturation
Egg	Adu	Reproduction
NaRIRe	FisLar	Successful settlement of fish larvae flow dependent
Adu	ExDrCy	Dry cycle limits juvenile-to-adult survival
Adu	Bun	Bunds suppress juvenile-to-adult survival by blocking access to key habitats
NaFIRe	ExDrCy	Natural flows diminished in extended dry cycle
NaFIRe	WeeGr	Weeds suppress natural flow regime
NaFIRe	Bun	Bunds suppress natural flow regime
Juv	TidSwa	Tidal swamps critical habitat for juvenile fishes
Juv	WeeGro	Weed growth degrades juvenile habitats
Juv	WadBir	Predation mortality
WadBir	SPFWS	Supporting habitat for wading birds
WeeGro	SPFWS	Favourable to weed growth
AgrLan	SPFWS	Favourable to agricultural landuse
SPFWS	Bun	Bunds create semi-permanent freshwater swamps
TidSwa	Bun	Bunds eliminate tidal swamps
Mag	TidSwa	Mangroves require tidal swamps
Mag	ExDrCy	Mangroves diminished by extended dry cycle
MoBoDi	TiSwa	Tidal swamps for mosquito-borne disease
Bun	SeLeRi	Sea level rise will diminish bunds
SPFWS	ExDrCy	Extended dry cycle diminishes semi-permanent freshwater swamps

8.3.1.4TOWNSVILLE

Attendees: CSIRO, GBMRPA, JCU, DEHP

Model 1. Seagrass (iii): Dynamics & Cumulative Impacts

A model of seagrass dynamics was developed that distinguished between what were termed colonizing and climax growth forms and species and seagrasses (see Figure and Table below). In the absence of agents of disturbance, the climax seagrass will outcompete colonizing seagrass, but where there is grazing by dugongs or storms of intermediate intensity then the balance is shifted in favour of colonizing seagrass. This model also addressed the influence of impacts via land use runoff, ocean acidification and increases in extreme temperature events.

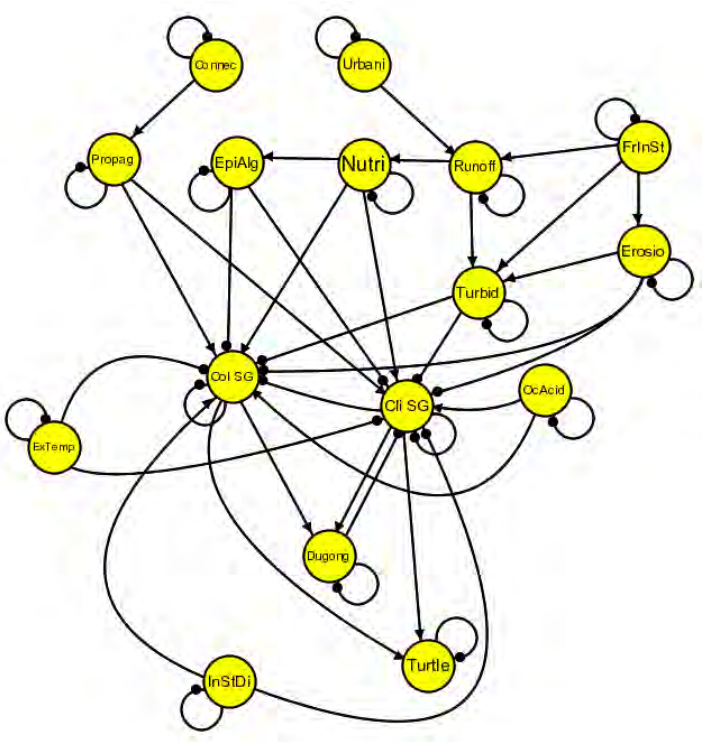

Figure 30: Seagrass (iii): Dynamics & Cumulative Impacts. Cli SG: climax seagrass,Col SG: colonizing seagrass, Connec: connectivity, Dugong: dugong populations, EpiAlg: epiphytic algae, Erosion: wave erosion, ExTemp: extreme temperatures., FrInSt: frequency of intense storms, InStDi: intermediate (intensity) storm disturbances, Nutri: nutrients, OcAcid: ocean acidification, Propag: propagules, Runoff: land use runoff, Turbid: turbidity, Turtle: turtle populations, Urbani: urbanization.

Table 29: Description of links in signed digraph of above figure.

To	From	Comment
CliSG	Dugong	Destructive grazing
ColSG	CliSG	Competitive dominance
Dugong	CliSG	Consumption of resource
Dugong	CliSG	Consumption of resource
ColSG	ExTemp	Mortality from extreme temperature
CliSG	ExTemp	Mortality from extreme temperature
ColSG	InStDi	Intermediate disturbance that favours colonizing seagrasses
CliSG	InStDi	Intermediate disturbance that suppresses climax seagrasses
Turtle	CliSG	Resource consumption
Turtle	ColSG	Resource consumption
ColSG	OcAcid	Shift to more favourable pH
CliSG	OcAcid	Shift to more favourable pH
CliSG	Propag	Recruitment from distant seagrass beds
ColSG	Propag	Recruitment from distant seagrass beds
Propag	Conne	Connectivity of source-sink populations (distance betw een beds, current flow and direction)

To	From	Comment
ColSG	EpiAlg	Reduced growth from shading
CliSG	EpiAlg	Reduced growth from shading
ColSG	Nutri	Increased growth from enrichment
CliSG	Nutri	Increased growth from enrichment
EpiAlg	Nutri	Increased growth from enrichment
ColSG	Erosio	Destruction of seagrass bed
CliSG	Erosio	Destruction of seagrass bed
ColSG	Turbid	Smothering of seagrass bed
CliSG	Turbid	Smothering of seagrass bed
Turbid	Erosio	Increased movement of sediments in near shore waters
Runoff	FrInSt	Increased sediments from storms
Erosion	FrInSt	Increased wave energy from storms
Turbid	FrInSt	Re-suspension of sediments in near shore waters
Runoff	Urbani	Increased delivery of sediments to runoff
Nutri	Runoff	Increased delivery of nutrients
Turbid	Runoff	Delivery of sediments to near shore waters

Model 2. Water Quality Monitoring, Regulation & Governance

This model focused on the monitoring, regulation and governance of water quality in near shore waters (see Figure and Table below). Water quality (sediment, toxins and nutrients) is impacted by coastal development and monitored via the reef water quality protection plan, with monitoring reports informing actions of the Queensland environmentally relevant activities (QLD ERA), the world heritage status. Disease and mortality events are driven by water quality, but also natural events, and influences public concern for the environment, which is a driver for more restrictive regulation of coastal development by QLD ERA. This restriction, however, is strongly countered by lobbying pressure from economic interests. Economic interests drive coastal development, but also can affect the relative demographics of transient versus long-term communities, which has the effect of eroding proportion of the public that is concerned for the environment. Commonwealth legislation and policies are seen to be sensitive world heritage status, public concern, and the QLD ERA, but can also be influenced by lobbying for economic interests. A major concern of this model was that most of the links required to achieve effective environmental monitoring, reporting, and regulation were weak, and those associated with economic interests were overwhelmingly strong.

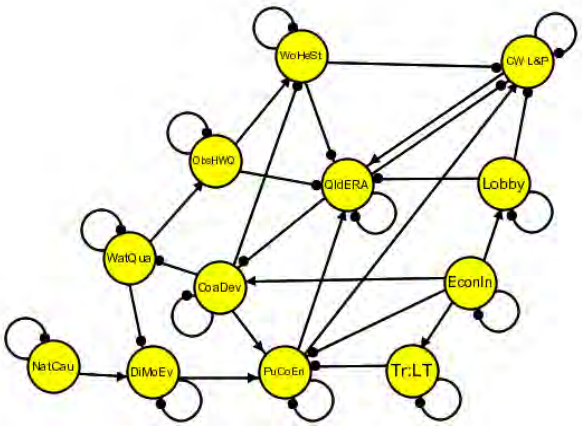

Figure 31: Water Quality Monitoring, Regulation & Governance model. CoaDev: coastal development, CW L&P: commonwealth legislation and policies, DiMoEv: disease & mortality events, EconIn: economic interests, Lobby: political lobbying for economic interests, NatCau: natural causes of disease & mortality, ObsHWQ: observed water quality, PuCoEn: public concern for the environment, QldERA: QLD Environmentally Relevant Activities, Tr:LT: transient versus long-term community, WatQua: water quality, WoHeSt: World Heritage Status.

Table 30: Description of links in signed digraph of above figure.

To	From	Comment
WatQual	CoaDev	Degradation of water quality
DiMoEv	WatQua	Sever impact to observable species
ObsHWQ	WatQual	High water quality leads to favourable monitoring results (described as weak link)
WoHeSt	ObsHWQ	Favourable monitoring results leads to higher status
QldERA	WoHESt	High status reduces motivation to protect environment (described as weak link)
QldERA	ObsHWQ	Unfavourable monitoring results increases motivation to protect environment (described as weak link)
WoHeSt	CoaDev	High levels of development diminishes status
CoaDev	QldERA	High motivation to protect environment suppresses coastal development (described as weak link)
PuCoEn	CoaDev	High levels of development increases concern for environment (described as weak link)
DiMoEv	NatCau	Natural causes lead to noticeable disease and mortality events
PuCoEn	DiMoEv	Disease and mortality events raise public concern (described as weak link)
QldERA	PuCoEn	Public concern raises motivation to protect environment
PuCoEn	Tr:LT	High proportion of transient community diminishes level of concern for environment
PuCoEn	EconIn	Economic interests erode concern for environment
CoaDev	EconIn	Economic interests main driver of coastal development
Tr:LT	EconIn	Economic interests diminish long-term populous and promotes transient community
QldERA	Lobby	Lobby for economic interests suppress motivation to

To	From	Comment
		protect environment
Lobby	EconIn	Economic interests increase strength of lobbying
CW L&P	Lobby	Lobby suppresses motivation of commonwealth to protect environment
CW L&P	PuCoEn	Public concern strengthens motivation for commonwealth to protect environment (described as weak link)
CW L&P	QldERA	Strong state motivation to protect environment diminishes motivation of commonwealth
QldERA	CW L&P	High motivation of commonwealth to protect environment stimulates motivation of the state
CW L&P	WoHeSt	Low status stimulates motivation of commonwealth to protect environment

Model 3. Barramundi (iii): Supporting Habitats and Seasonal Flows

A third model for barramundi focused on the importance of supporting habitats and seasonal flows for six different life stages, but did not include hermaphroditism as a life history feature (see Figure and Table below). Seasonal flows play a critical role in life stage transitions, primarily through flow-based habitat connectivity. Supporting habitats are also critical for providing refuge from predation and cannibalism. Restocking of barramundi juveniles, while it is seen to increase juveniles, ultimately suppresses egg production through degradation of the genetic fitness of the population.

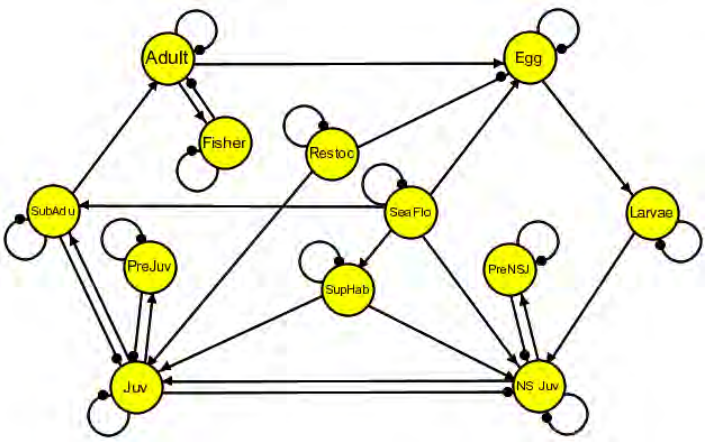

Figure 32: Qualitative model of Barramundi supporting habitats and seasonal flows. Adult: barramundi adult, Egg: barramundi egg, Fishery: commercial and recreational fisheries, Juv: barramundi juveniles, Larvae: barramundi larvae, NS Juv: newly settled barramundi juveniles, PreJuv: predators of juvenile barramundi, PreNSJ: predators of newly settled juvenile barramundi, Restoc: barramundi restocking, SeaFlo: seasonal flows, SubAdu: barramundi subadults, SupHab: supporting habitats.

Table 31: Description of links in signed digraph of above figure.

To	From	Comment
Larvae	Egg	Maturation

To	From	Comment
NS Juv	Larvae	Maturation
Juv	NS Juv	Maturation
SubAdu	Juv	Maturation
Adult	SubAdu	Maturation
Egg	Adult	Maturation
NS Juv	Juv	Mortality from cannibalism
Juv	SubAdu	Mortality from cannibalism
NS Juv	SupHab	Suppression of cannibalism and predation
Juv	SupHab	Suppression of cannibalism and predation
NS Juv	PreNSJ	Predation mortality
PreNSJ	NS Juv	Consumption of prey
PreJuv	Juv	Consumption of prey
Egg	SeaFlo	Flow triggers spawning
NS Juv	SeaFlo	Natural flows allow juveniles to settle in critical wetland habitats
SupHab	SeaFlo	Natural flows critical to habitat quality
SubAdu	SeaFlo	Natural flows required for juvenile survival
Juv	Restoc	Restocking of juveniles increases juvenile population
Egg	Restoc	Restocking degrades genetic fitness of barramundi populations
Adult	Fisher	Fishing mortality
Fisher	Adult	Fishing pressure increases with catch

8.4 Discussion

Looking across the range of models developed in this work, there appears to be a consistent theme of how coastal development and land use interact with assets of near-shore Great Barrier Reef. The chief modes of impact include runoff associated with urban and agricultural runoff, and commercial activities or footprints from industrial operations. Regulation and management of these impacts, especially those related with water quality were described as being hampered by relatively weak links associated with effective environmental monitoring, reporting and regulation, while those associated with economic interests were considered to be comparatively stronger.

Impacts from fishing (both recreational and commercial) played a key role in the species specific models, but by comparison, had stronger and more effective controls and regulations in place than those for management of water flows, water quality and wetland habitats. However, a "boom economy" from mining was perceived as having a dramatic and problematic effect on fishing power, as well as undermining the effectiveness and strength of community-based protection of environmental assets.

The collective understanding embedded within the above the qualitative models were used to subsequently engage with each Reference Group to develop objectives and strategies for the management of inshore biodiversity. Objectives identified from subsequent stakeholder elicitations (Section 7) broadly encompass the elements, causal processes and dynamics identified through the qualitative modelling workshops, and can be generally described as strengthening the model

connections associated with community cohesion and the monitoring and management of water flows, water quality and aquatic and riparian habitats, and curtailing the influx of pollutants into runoff leading to freshwater and near-shore environments.

9 Available information

9.1 Introduction

In order to allow for an informed discussion about the fisheries within Mackay and the Bowen-Burdekin region some relevant region specific information was provided. These were mainly used in Mackay and made available during the fisheries discussions of Section 10.

9.2 Methods

A review of available information was undertaken. The bulk of the review concentrated on distribution maps of the key environmental assets of Mackay, as this is a key information source for the RG to use as input into the management strategies discussion. Given that fisheries information is a key topic of interest to the group a detailed data analysis was also undertaken by DAFF.

9.3 Mackay regional inshore fisheries profile

Authors: Malcolm Dunning, Julia Davies and Anna Garland
Fisheries Queensland, Brisbane

9.3.1 INTRODUCTION

For the purposes of this study, the Mackay region is defined as extending from 20.5°S to 22.5°S and offshore approximately 30 nautical miles from Repulse Bay in the north to Broad Sound in the south. It includes grids N24, O24, O25, P25, O26, P26, O27 and P27 of the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) commercial fisheries logbook grid system (DAFF, 2012a). This area represents most of the coastal Cape Clinton to Gloucester Head fishing region as defined for the statewide recreational fishing survey (that includes the Whitsundays). In terms of participation by recreational fishers, this region falls within the Mackay area of residence for the DAFF telephone surveys—however it is important to note that the Mackay residential area is much larger than the area shown in Figure 33. It is possible that the recreational participation rate would be higher than the estimate provided due to the close proximity of these grids to the coast (DAFF, 2012a).

There are extensive commercial fisheries closures in the region imposed by Greet Barrier Reef and Queensland marine parks zoning (Marine National Park and Conservation Park zones) and Dugong Protection Areas declared under the Fisheries Act 1994 (Figure 33). Trawling is further restricted to General Use zones in the region while recreational fishers are only restricted by Marine National Park zones.

To capture recent interannual variability, information for the last four years, 2010 to 2013 are presented in the following sections. In section *Trends in Regional*

Commercial fisheries information is presented back to 2005. Catchability, catch and catch rate of inshore species will be impacted by recent environmental conditions including summer flooding and cyclone Yasi in early 2011.

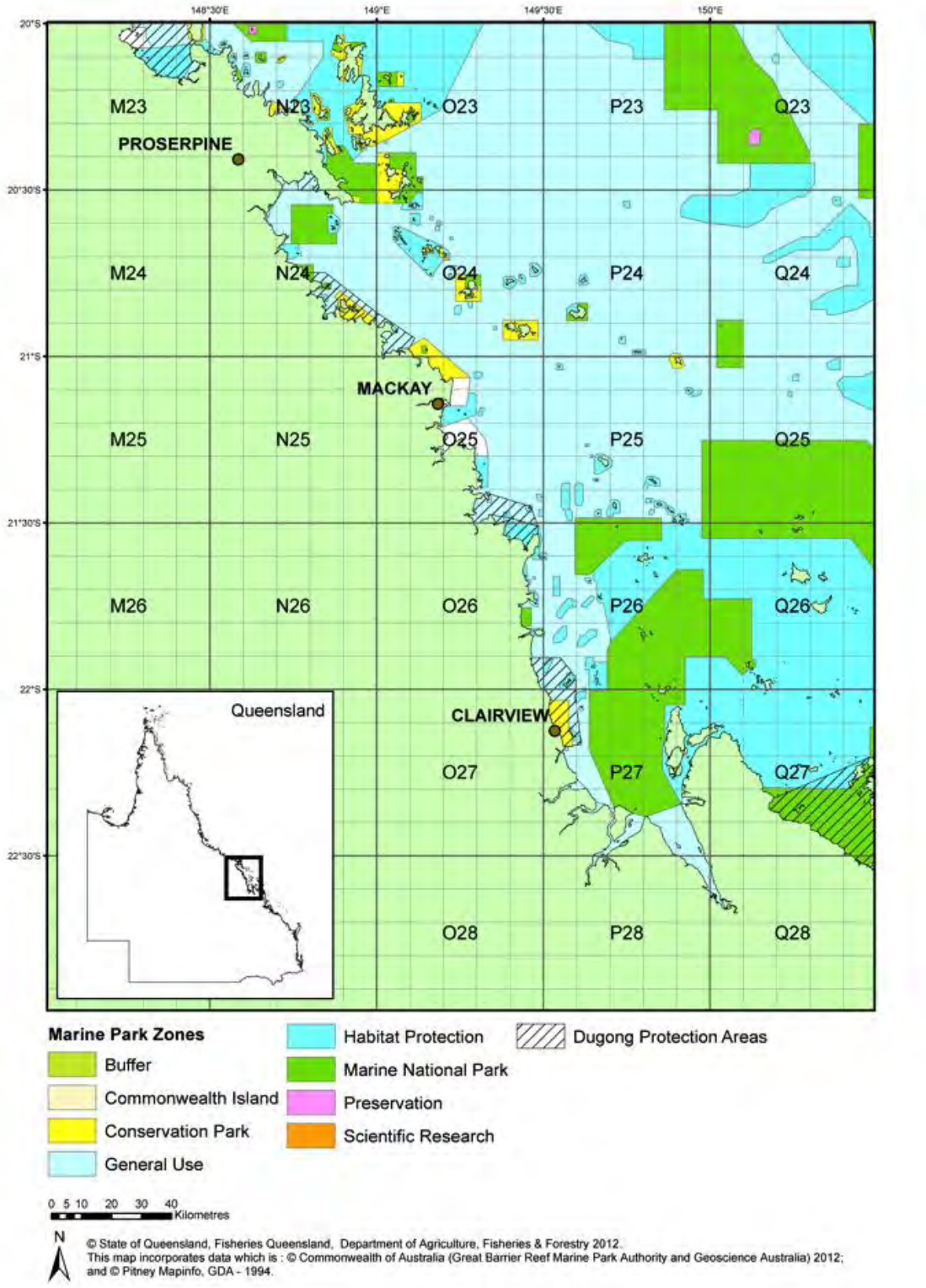

Figure 33: Mackay region showing Dugong Protection Areas and Marine Parks zoning.

9.3.2 COMMERCIAL FISHING OPERATIONS

Most commercial fishing operations have multiple endorsements which allow them to switch fishing apparatus and target different fisheries resources. In addition some fishing operations, especially otter trawlers, are mobile and may shift their fishing operation to adjacent areas to maximise their profits. Consequently, the number of commercial fishers operating in an area will change from year to year.

In 2010, there were 111 active commercial fishing licences in the Mackay region. In 2011 and 2012, this number dropped to 87 and 99 respectively. In 2013 logbook data reported a return to 2010 levels with 109 commercial fishing licences submitting returns.

Fluctuating levels of active fishing licences in the Mackay region are largely attributed to the annual variability in the number of otter trawlers (Figure 34). Between 2010 and 2013 all licences which reported otter trawling did not undertake any other method of fishing. In 2010 there were 42 otter trawlers - which then reduced by more than 40% to 22 and 24 in 2011 and 2012 respectively. During 2013 an increase in the number of otter trawlers was recorded which saw numbers rise to 35. The largest constituent of active commercial fishing licences in the Mackay region utilise pot and net apparatus in combination to fish for crab and inshore fin fish species. Between 2010 and 2013 the number of licences fishing in the net and pot fisheries increased. In 2010, 46 fishers went pot fishing and 44 fishers undertook net fishing - of these 27 partook in both. In 2011, 44 and 42 fishers submitted logbooks for pot and net fishing activities. In 2012, 47 pot fishers and 45 net fishers submitted logbook returns - of which 26 used a combination of the two fishing methods. The highest number of active commercial fishing licences reporting fishing activity in the net and pot fisheries was in 2013, 47 licences went net fishing and 53 licences went pot fishing, of these 31 engaged in both during the year.

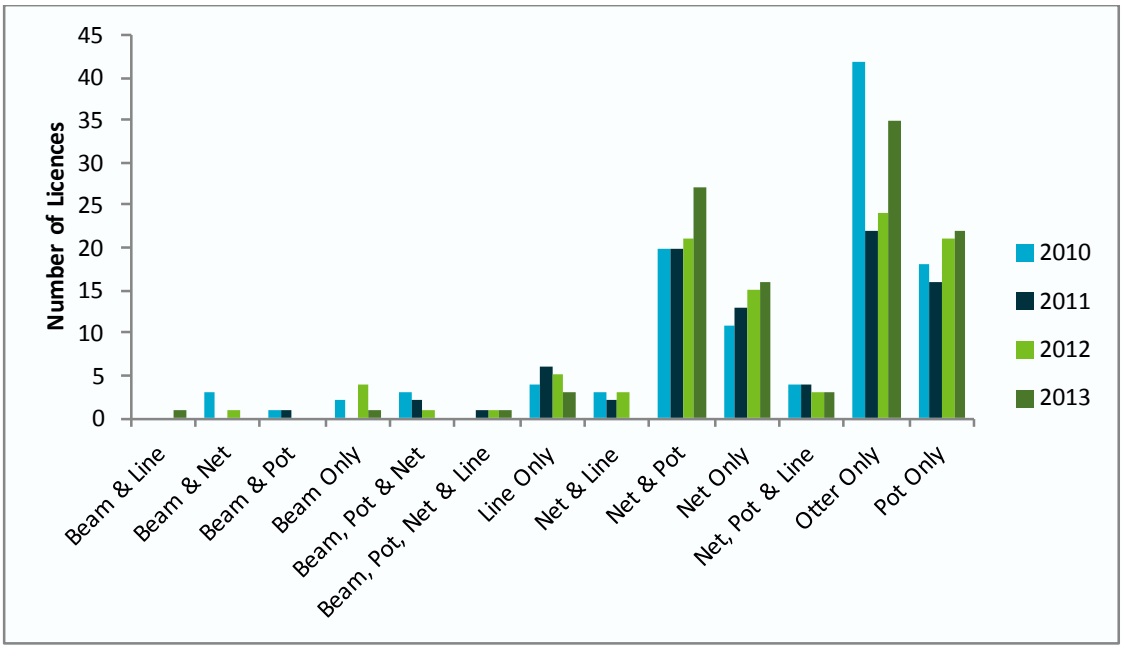

Figure 34: Count of licences against fishing operations by fishing method for the Mackay region.

In Mackay, line fishing is the second smallest fishery by count of active fishing licences - the smallest is beam trawl. In 2010 there were 11 line fishers, shortly thereafter licence numbers peaked at 13 and 12 in 2011 and 2012 respectively before dropping to a total of eight fishers in 2013. More than 50% of commercial line fishers in the Mackay region participate in other fisheries - predominantly net and pot.

The majority of beam trawlers in the Mackay region operate in multiple fisheries. In 2010, nine beam trawlers reported catch in the Mackay region. In 2011 this number was reduced to less than half, logbooks were received for only four operators - 2012 saw an increase to seven operators. Beam trawler numbers reduced to their lowest in 2013, where only three operators submitted logbook returns.

Every year, between 2010 and 2013, approximately 30% to 35% of the operators in the Mackay region participate in multiple fisheries - the majority operate solely in one fishery using one type of fishing method. In 2010, the Mackay region produced a total of 543 tonnes of seafood - in 2011 a decreased to 500 tonnes was recorded. Yield from commercial fisheries in the region have increased in the last two years with 563 tonnes and 635 tonnes being reported in 2012 and 2013 respectively.

9.3.3 INSHORE COMMERCIAL TRAWL FISHERIES

The inshore waters of the Mackay region support both beam and otter trawling. In 2010, 42 otter trawlers retained 252.7 tonnes. In 2011 and 2012, 112.2 and 133.9 tonnes were recorded through logbook returns; the downturn in catch directly proportional to the decrease in active commercial licences during the same period. An increase to 247.4 tonnes was recorded in 2013. Banana and blue leg king prawns

are the dominant retained species contributing between 80% and 95% of the yearly catch.

Nine beam trawlers retained 4.1 tonnes in 2010. Catch decreased to 2.6 tonnes in 2011, increased to 3.8 tonnes in 2012 and most recently decreased to 3.5 tonnes in 2013. Banana and greasy prawns were the only species reported by beam trawl fishers in the Mackay region - banana prawns dominated catch statistics with a minimum of 97% of the annual harvest.

A total of 29 taxa, including 13 prawn taxa, were reported by the trawl fisheries between 2010 and 2013. Otter trawl species composition is largely dominated by a handful of species (as detailed above) with the remaining retained species contributing less than 1% to the total catch by weight. The top species by weight for 2010, 2011, 2012 and 2013 are shown in Figure 35.

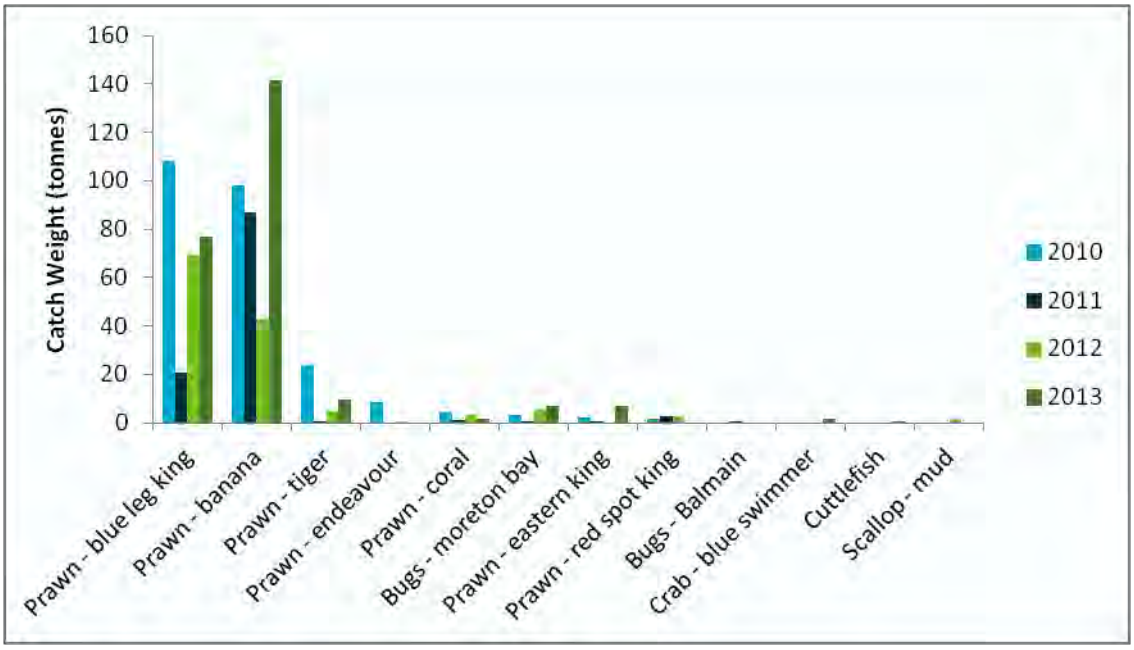

Figure 35: Top annual otter trawl species by weight (tonnes) for the Mackay region in 2010, 2011, 2012 and 2013.

9.3.4 INSHORE COMMERCIAL NET FISHERIES

The top five taxa harvested in the inshore net fishery represent approximately 70% of the harvest by weight (barramundi, king threadfin, blue threadfin, mullet and grey mackerel), with a further 98 taxa retained as by-product. Included in the count are 20 shark taxa with whaler species the most abundant. Figure 36 shows the catch in tonnes of the top annual species for 2010, 2011, 2012 and 2013.

In 2010, the total catch for the region from 1202 fishing days was 158.7 tonnes - the lowest catch per effort yield during the four year time period. In 2011, active fishing licences decreased to 42, the number of fishing effort days increased to 1272 and the total reported weight was 193.9 tonnes. Effort and catch continued to increase in

2012 with 45 boats reporting 249 tonnes of catch. In 2013, 47 licences fished for 1378 days with logbooks returns totalling 207.3 tonnes.

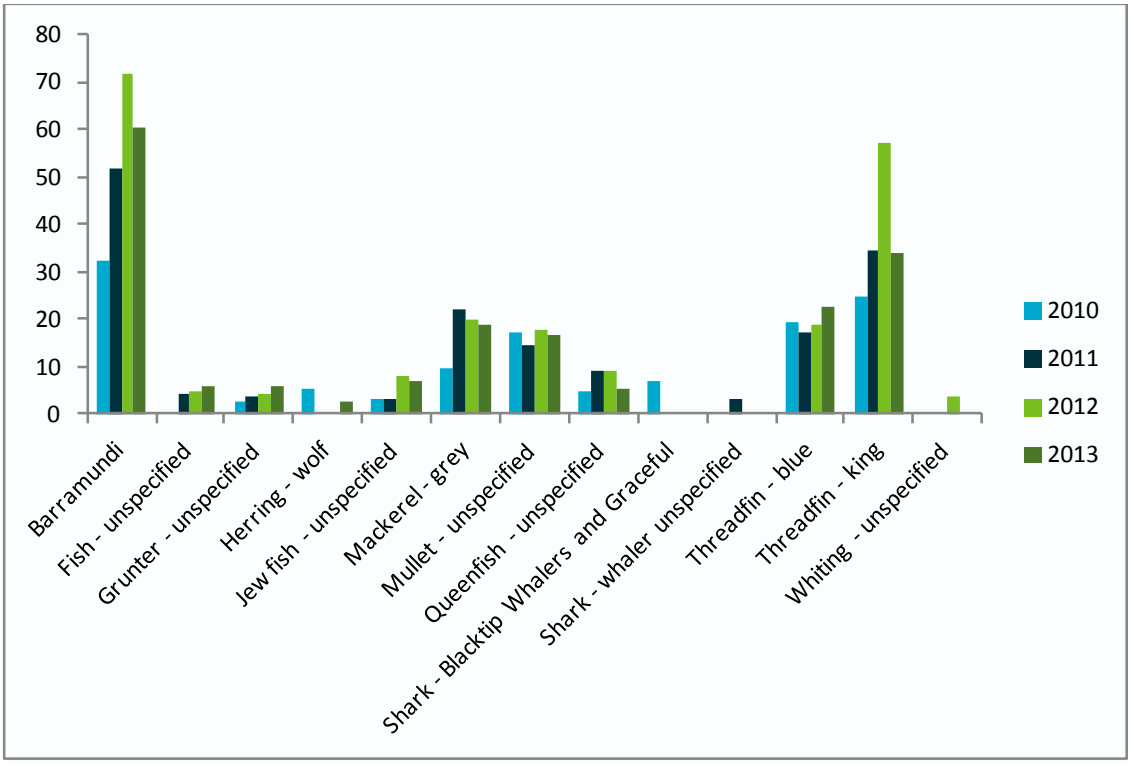

Figure 36: Top annual species by commercial net fishers between 2010 and 2013 for the Mackay region. Catches are in tonnes.

9.3.5 INSHORE COMMERCIAL POT FISHERIES

Mud crabs represented over 99% of the retained catch from the pot fishery—blue swimmer crabs, crabs - unspecified, baitfish, barramundi and mullet were also retained albeit in very small quantities as by-product.

Catch and effort attributed to pot fishing in the region has increased over the time period. In 2010, 46 licences recorded 3620 days of effort which yielded a total of 142.7 tonnes. In 2011, these figures increased to 44, 4312 ad 186.5 tonnes for licences, fishing effort days and retained weight respectively. Fishing effort continued to increase with 2012 reporting 47 licences and 4425 days of fishing effort and 2013 reporting 53 licences and 4971 days of fishing effort. Both years yielded a total of 173 tonnes - overall 2012 averaged a slightly higher catch per unit of effort.

9.3.6 INSHORE COMMERCIAL LINE FISHERIES

The commercial line fishery contributes the smallest amount of product by weight in comparison with other fishing method types in the Mackay region. Between 2010 and 2013 a total of 28 licences utilised line apparatus with a total reported catch of 13.8 tonnes. Line catch included 44 taxa - high catch species were Spanish

mackerel, silver jewfish and coral trout as shown in Figure 37. The presence and reported weight of line caught species differ quite significantly between years, unlike other fishing method types; this suggests that line fishing in the area doesn't target a set list of key species.

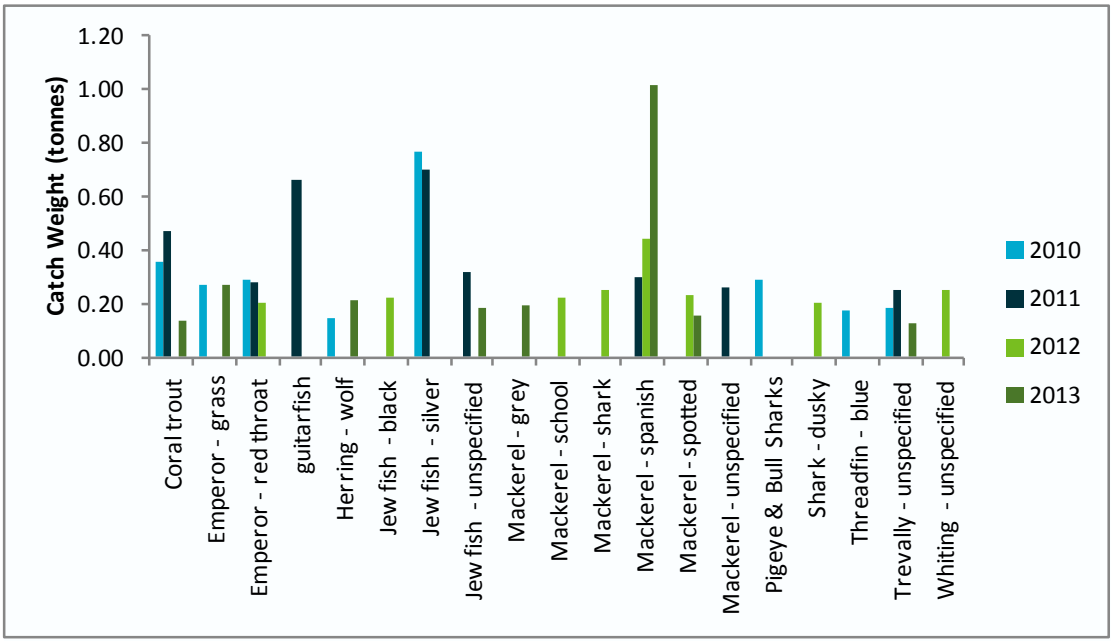

Figure 37: Highest line caught species by weight (tonnes) for the period 2010 to 2013 in the Mackay region.

Despite the very low catch in comparison with adjacent areas, Mackay is the most important port for the landing of line caught quota fish species in the east coast finfish fishery. The average annual landing of quota caught reef finfish and Spanish mackerel between 2010 and 2013 was approximately 330 tonnes.

Between 2010 and 2013, 22 charter vessels reported fishing in the Mackay region. Calculations from logbook data estimate that charter operators retained 5.1 tonnes of inshore species and discarded an additional 2.6 tonnes.

9.3.7 INTERACTIONS WITH PROTECTED SPECIES

Between 2010 and 2013, only one interaction with a Species of Conservation Interest was reported. This interaction occurred in 2012 and involved the net fishery and a saltwater crocodile, which was released alive.

9.3.8 TRENDS IN REGIONAL COMMERCIAL FISHERIES

When considering a larger time period, 2005 to 2013, it becomes evident that there has been a slight downward trend in the number of fishers operating in the Mackay region (Figure 38).

The number of otter trawlers operating in the region is highly variable annually but has declined from 69 in 2005 to only 35 in 2013. All other fisheries appear relatively

stable over the time period. Examining the trends in more detail shows active pot licences increasing slightly - most recently between 2011 and 2013 but both beam trawl and line licences decreasing to their lowest or below their lowest active licences since 2005. Oppositely, the total number of days fished across all sectors shows an increasing trend.

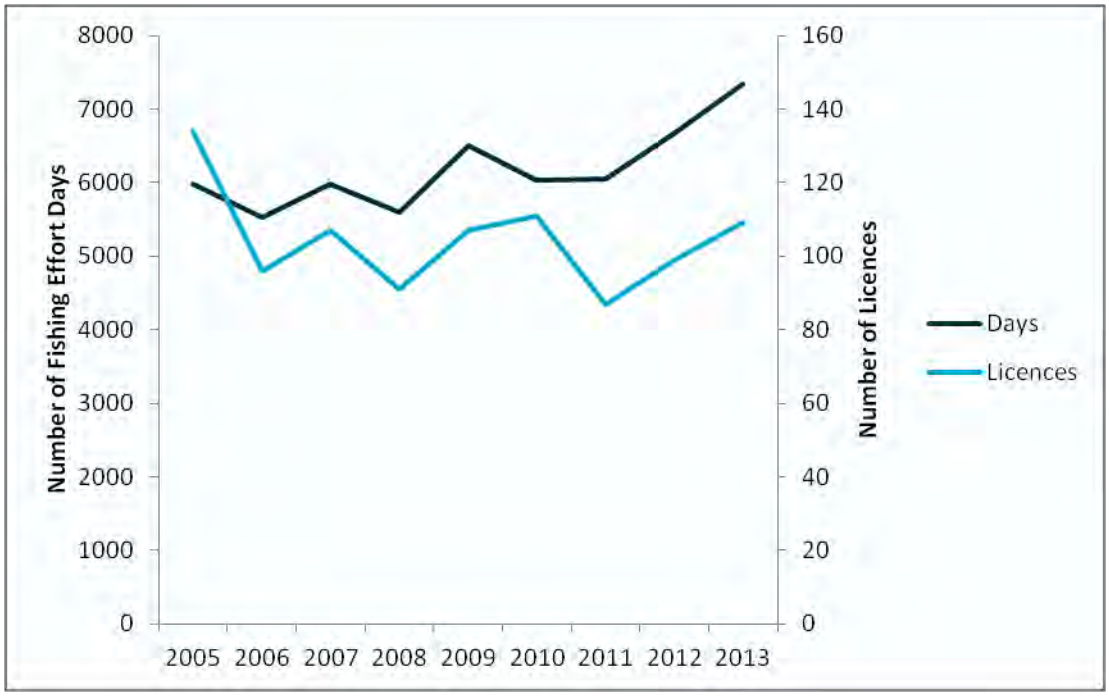

Figure 38: Overall fishery participation and effort information, 2005–2013.

Catches from the pot fishery have shown an increase over time in association with an increasing number of days fished. Net fishing days have remained relatively steady with a very slight overall decrease, on closer inspection an initial increase in catch was reported between 2005 and 2009 but declined shortly thereafter paralleling trends in days fished in that sector.

Beam trawl statistics for the time period have remained relatively stable with the exception of 2011 and 2013 where active licences, days fished and catch were at their lowest since 2005. Overall the line fishery has shown a small decline in commercial participation and catch in the region since 2005.

Otter trawl fishing effort days and catch followed a similar overall decreasing trend - with high and low fluctuations exaggerated by the catch data.

9.3.9 RECREATIONAL FISHING IN THE REGION

The Mackay region in the state wide recreational fishing survey includes Bowen, Mackay, Proserpine and the Whitsunday islands. Fishers in the region have access to excellent marine fishing environments which is reflected in their catches. Information included in this section describes the recreational fishing activities of residents of the Mackay region. Residents of the Mackay region did most of their fishing where they

lived but some ventured south to the Fraser Coastal waters and the south-eastern catchment.

The Mackay region showed the highest recreational fishing participation rate of all Queensland regions according to the 2010 DAFF telephone survey. It was estimated that 28% of residents fished at least once recreationally in the twelve months prior to July 2010 - much higher than the state wide average of 17% - a total of 45 322 fishers (+/- 3478 se) which was 8493 fishers more than in 2000.

Fishers were distributed across all age groups with the 30–44 year olds making up the bulk of recreational fishers. As with the rest of Queensland more males than females participated in recreational fishing.

More days were spent fishing from boats (Figure 39) than the shore and most of this was done in marine waters. People go fishing throughout the year but peaks in fishing activity were recorded in April and September, coinciding with school holidays.

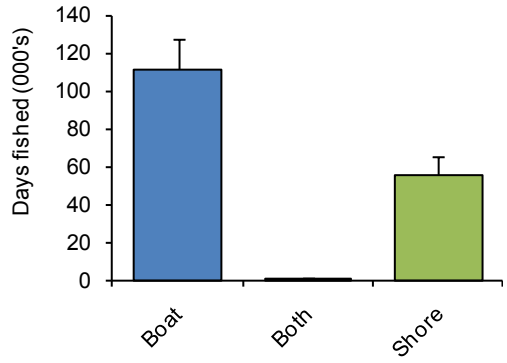

Figure 39: Number of recreational days fished from a boat or the shore.

Residents of the Mackay region caught over 200,000 mud crabs. Marine cod and pikey bream were also commonly caught species. Approximately 70,000 marine cod were caught with 85% of them released. Approximately 25,000 barramundi were caught and 75% of those were released (see Figure 40).

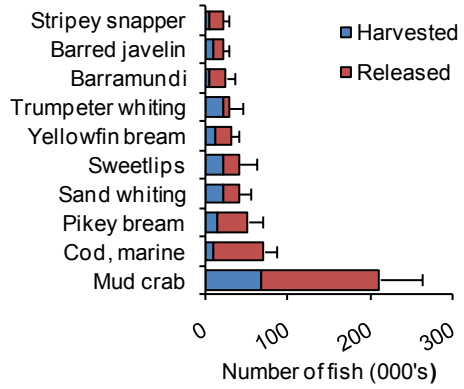

Figure 40: Top ten recreational species caught by number.

Although redthroat emperor was not one of the top ten species caught by residents of the Mackay region, they did take approximately 25% of Queensland's recreational harvest of this species. They also took more than 20% of Queensland's harvest of silver javelin and stripey snapper.

9.3.10 REFERENCES

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Data on recreational fishing from the DAFF recreational fishing survey 2010-11.

9.4 Burdekin regional inshore fisheries profile

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9.4.1 INTRODUCTION

Fisheries Queensland defines the Burdekin region as extending from 19°S just north of Herald Island to 20.5°S encompassing Edgecumbe Bay and waters approximately 30 nautical miles from the coastline. For the purpose of this report the Burdekin region includes grids J21, K21, K22, L21, L22, M22 and M23 of the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) commercial fisheries logbook grid system (DAFF, 2012a). This area represents a small portion of both the Cape Clinton to Gloucester Head (including the Whitsundays) fishing region and Edgecumbe Bay to Lucinda Point fishing region as defined in the statewide recreational fishing survey. In terms of participation by recreational fishers, the Burdekin grids fall within both the Mackay and Northern area of residence for the DAFF telephone surveys - it is important to note that the Mackay and Northern residential areas are far larger than the area shown in Figure 41. It is possible that the recreational participation rate would be higher than the estimate provided due to the close proximity of these grids to the coast (DAFF, 2012a).

There are extensive commercial fishery closures in the region imposed by Great Barrier Reef and Queensland marine parks zoning (Marine National Park and

Conservation Park zones) and Dugong Protection Areas declared under the Fisheries Act 1994 (Figure 41). Trawling is further restricted to General Use zones in the region while recreational fishers are only restricted by Marine National Park zones.

To capture recent interannual variability, information for the last four years, 2010 to 2013 are presented in the following sections. In section *Trends in Regional Commercial fisheries* information is presented back to 2005. Catchability, catch and catch rate of inshore species will be impacted by recent environmental conditions including summer flooding and cyclone Yasi in early 2011.

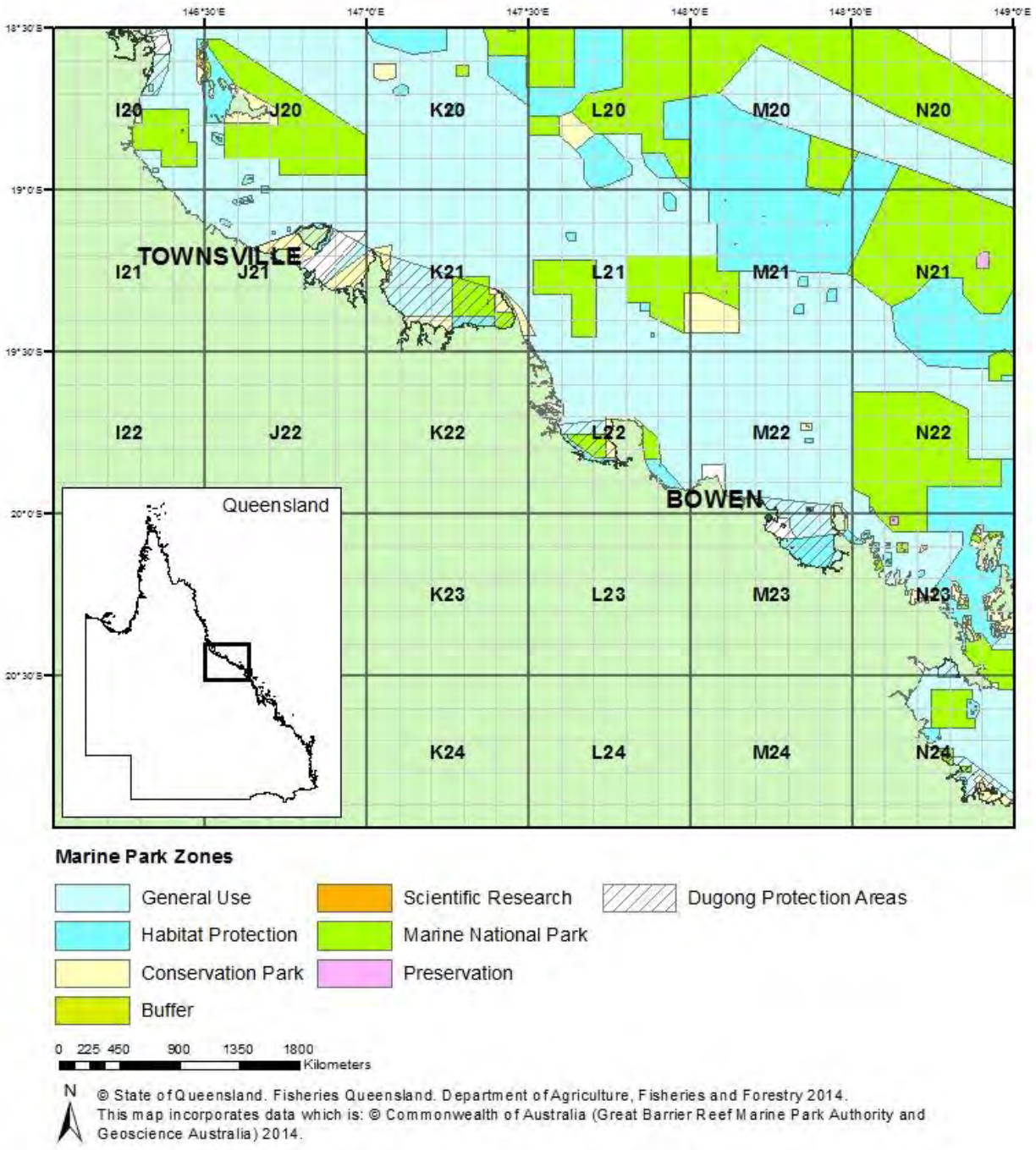

Figure 41: Burdekin region showing Dugong Protection Areas and Marine Parks zoning.

9.4.2 COMMERCIAL FISHING OPERATIONS

Most commercial fishing operations have multiple endorsements, which allow them to switch fishing apparatus and target different fisheries resources. In addition some fishing operations, especially otter trawlers, are mobile and may shift their fishing operation to adjacent areas to maximise their profits. Consequently, the number of commercial fishers operating in an area will change from year to year.

In 2010, there were a total of 134 active commercial fishing licences in the Burdekin region (Figure 42). In 2011 and 2012 fisher numbers decreased to 117 and 106 respectively. Most recently in 2013, 123 operators reported the catch of inshore species via logbook returns.

Similarly to the Mackay region, fluctuating levels of active fishing licences in the Burdekin region can be attributed to the variability in the number of otter trawlers and to a smaller extent in recent years, the line fishers. In 2010 there were 55 otter trawlers operating within the defined Burdekin region; this number dropped to 34 and 31 in 2011 and 2012 respectively. An increase to 39 operators was recorded in 2013. During this time period there were approximately three otter trawlers annually participating in alternative fisheries - predominately gillnetting.

A 45% drop in the number of active line fishers between 2011 and 2012 combined with the declining number of otter trawlers, resulted in the noticeable drop in the total number of active fishers, particularly in 2012. In 2010, the number of active line fishers was 31 - in 2012 this number peaked to 33. Thereafter, the activity of line fishers decreased to 22 in 2012 and rose slightly again to 27 in 2013. Annually between 35% and 55% of line fishers in the Burdekin region participate in other fisheries - 70% of the multiple endorsed operators fish in the net and pot fisheries.

In recent years the pot and net fisheries have reported the largest number of active commercial licences - since 2010 the net fishery has been the greatest source of inshore finfish catch in the Burdekin region. In 2010, 57 fishers reported net catch and 40 fishers reported pot catch - of these, five fished solely in the pot fishery, 19 fished using net apparatus only and 23 used a combination of both methods. Between 2011 and 2013 net fishers remained reasonably constant, ranging from 56 to 59 operators. The pot fishery displayed an initial decrease from 45 in 2011 to 42 operators in 2012 followed by a return to 2011 levels in 2013. Between 2011 and 2013 the number of exclusive net fishers and the number of combination fishers remained relatively stable, however operators solely undertaking pot fishing have steadily increased and in 2013 were at 150% of 2010 levels. Fishers that engage in net and pot fishing also fish using otter trawl, beam trawl and line apparatus.

In the Burdekin region the least number of operators - out of all commercial fishing method types - fish using beam trawl equipment. In 2010, three operators submitted beam trawl logbook returns. This number then dropped to a single operator in 2011 and remained stable at two fishers during 2012 and 2013. It is evident through logbook data that in 2010, 2011 and 2013, with the exception of 2012, beam trawl operators fished in combination with other fishing method types.

Every year, between 2010 and 2013, approximately 30% to 40% of the operators in the Burdekin region participate in multiple fisheries - the majority operate solely in one fishery using one type of fishing method. Between 2010 and 2013 the Burdekin region displayed increases and decreases in catch weight. In 2010, the region retained 661 tonnes of product which then increased to 733 tonnes in 2011. Commercial seafood production in 2012 decreased, recording levels similar to that in 2010 with a reported 627 tonnes of catch - figures increased in 2013 to 708 tonnes.

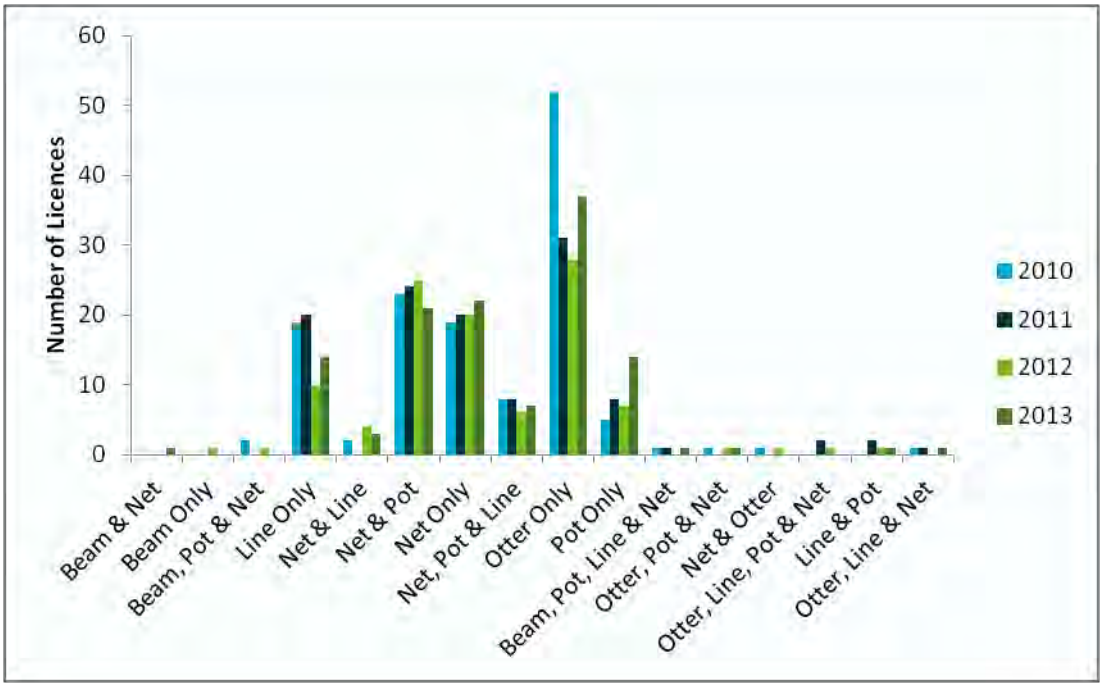

Figure 42: Number of licences participating in the different fishing method type combinations in the Burdekin region.

9.4.3 INSHORE COMMERCIAL TRAWL FISHERIES

Of the two types of commercial trawling available to fishers in the Burdekin region, otter trawling is the predominant trawling method - otter trawling is second to net fishing in its total production of inshore species by weight. In 2010, 55 operators, fished for a total of 930 days to retain 145.7 tonnes of seafood. Numbers of operators fishing using otter trawling equipment decreased to 34 in 2011 along with the number of fishing effort days to 850, inversely, catch weight increased to 155.3 tonnes. In 2012, otter trawl effort and catch fell to its lowest during the time period, 31operators, 446 fishing days - 50% of that recorded in 2011 - and 104.7 tonnes of total catch. Fishing effort and catch increased in 2013 to 39 operators, 1329 days and 241.1 tonnes.

Several species are identified in the Burdekin region as being the highest caught, however the 'species list' changes on a yearly basis. Only two species are caught consistently at a slightly higher weight than all other species - Moreton Bay bugs and red spot king prawn. Moreton Bay bugs feature as a top caught species between 2010 and 2013 where they contributed between 12% and 40% to the total weight. During the time period red spot king prawn, in all years apart from 2012, also features as a dominant species with catches contributing between 20% and 30% to the annual total otter trawl production. In 2011, banana prawns contributed an astounding 68% to the total recorded weight. Similarly, peaks in mud scallop during 2012 contributed more than 40% of the total catch and tiger prawns contributed 20% during 2013.

Three beam trawlers retained 1.6 tonnes of catch in 2010. Since then catch has fallen well below one tonne. Banana prawns are the dominant species in the beam trawl fishery with very miniscule quantities of greasy prawns reported in some years.

A total of 29 taxa, of which 12 are prawns, were reported by the trawl fisheries between 2010 and 2013. The majority of the otter trawl catch weight consists of a handful of species; the remaining retained species contributed approximately two to three percent to the total catch by weight. The highest caught species by weight for 2010, 2011, 2012 and 2013 are shown in Figure 43.

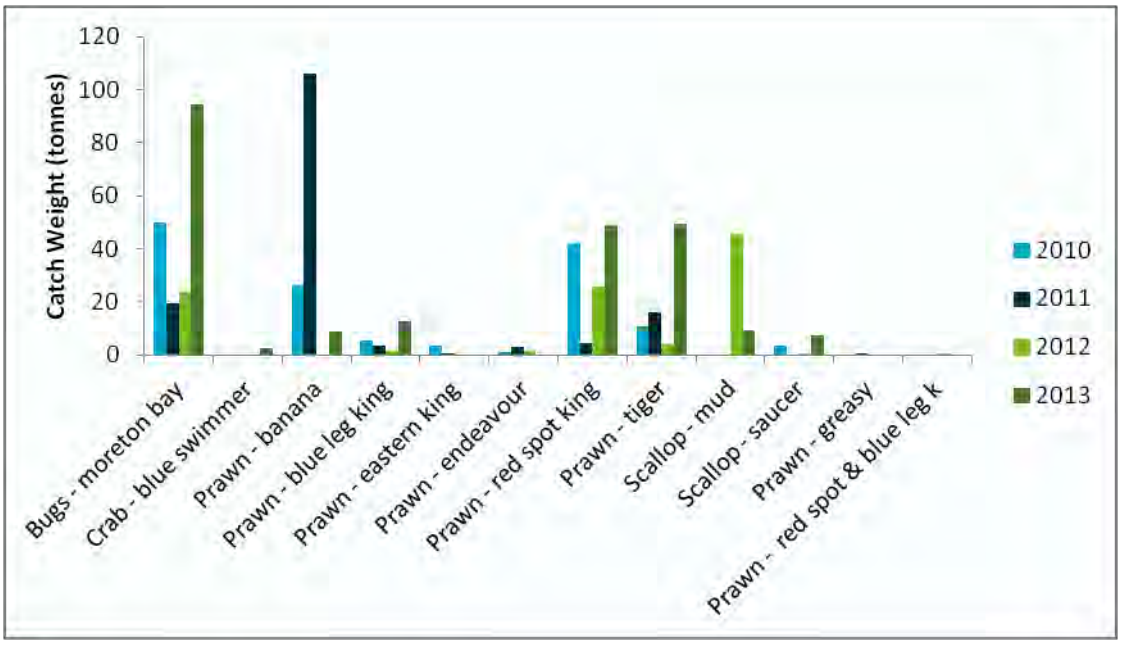

Figure 43: Top annual otter trawl species by weight (tonnes) for the Burdekin region in 2010, 2011, 2012 and 2013.

9.4.4 INSHORE COMMERCIAL NET FISHERIES

The top five taxa in the inshore net fishery differ slightly from those caught in the neighbouring Mackay region. In the Burdekin region the top five species contribute on average 70% by weight to the total annual fishery harvest - these species are barramundi, grey mackerel, mullet, queenfish, blacktip whalers and graceful sharks (complex) and blue threadfin. An additional 87 taxa are reported but retained in smaller by-product quantities. Of the reported taxa, 23 are sharks with the blacktip and graceful shark complex reported as the most abundant. The catch in tonnes of the top annual net species for the period 2010 to 2013 is illustrated in Figure 44.

In 2010, the total net catch for 2165 days of fishing was 366.3 tonnes. The yield of catch per unit of effort increased in 2011, with 2245 fishing effort days reported and total retained weight increasing to 410.3 tonnes. In 2012, active net fishers increased to 59, the number of fishing effort days decreased to 2115 and total weight declined

by 45 tonnes from 2011 to 364.8 tonnes. Fishing effort days and catch weight continued to decrease in 2013 with fishers catching 363.3 tonnes in 1998 days.

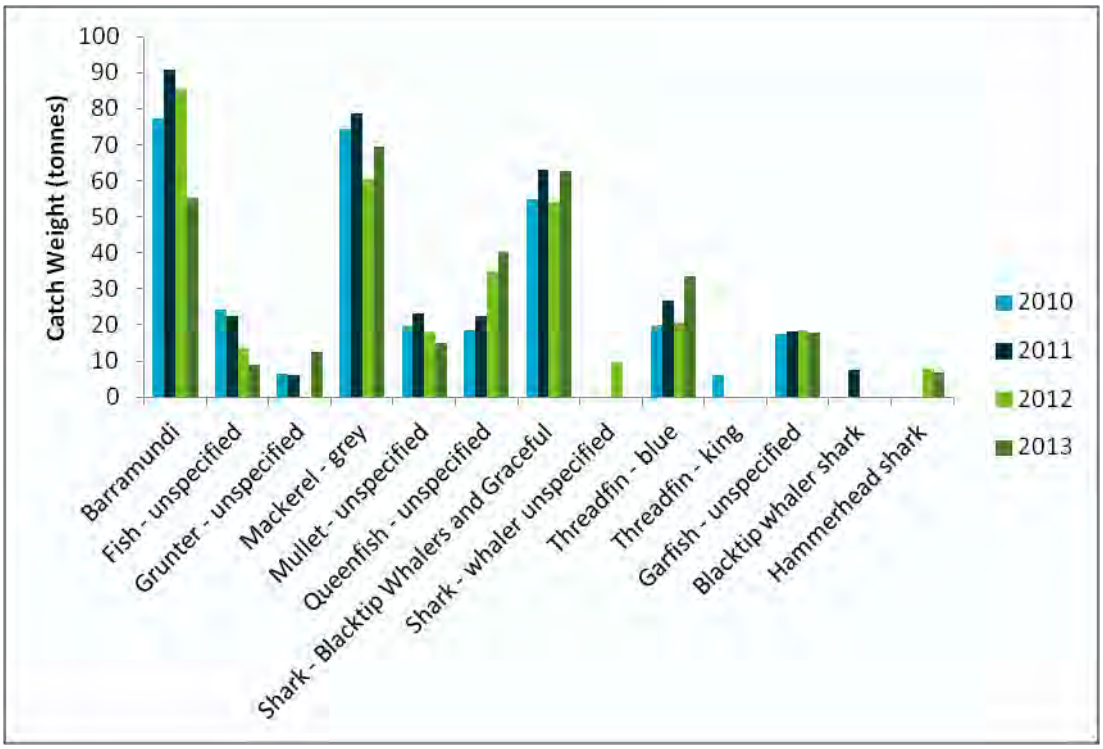

Figure 44: Top annual species by commercial net fishers between 2010 and 2013 for the Burdekin region. Catches are in tonnes.

9.4.5 INSHORE COMMERCIAL POT FISHERIES

Catch and effort in the Burdekin pot fishery has fluctuated over time - it is apparent that the numbers of operators, number of fishing effort days and total catch do not increase or decrease in direct proportion. In 2010, 40 pot operators submitted logbooks, which reported 3602 days of fishing effort and the harvest of 104.6 tonnes of crustaceans and inshore finfish. The highest yield per unit of effort for the fishery was recorded in 2011 when 45 operators went fishing for a total of 4155 days and retained 138.9 tonnes of catch. The following two years, 2012 and 2013, recorded large decreases in catch levels to 122 tonnes and 81.4 tonnes respectively.

Mud crabs represented over 98% of the retained catch from the pot fishery in the Burdekin region - blue swimmer crabs were also retained but in small quantities. Species of bream, mullet, grunter, threadfin and cod were also retained as by-product in quantities smaller than 200 kilograms.

9.4.6 INSHORE COMMERCIAL LINE FISHERIES

The commercial line fishery contributes the second smallest amount of product by weight in comparison with other fishing method types in the Burdekin region. The number of annual fishing effort days in the line fishery decreased from 316 in 2010 to

196 in 2013. In 2010, 43 tonnes of inshore finfish species were harvested, this figure decreased in 2011 to 28.1 tonnes. Although the number of operators and fishing effort days decreased in 2012 catch weights increased to 35.2 tonnes. In 2013, retained catch reached its lowest point during the time period - a total of 21.9 tonnes was reported via logbook returns.

Line catch statistics include a total of 66 taxa - Spanish mackerel was the highest contributing species by weight. Other dominant line species (although not in the same quantities as Spanish mackerel) were coral trout, grey mackerel, unspecified mackerel and spotted mackerel (Figure 45).

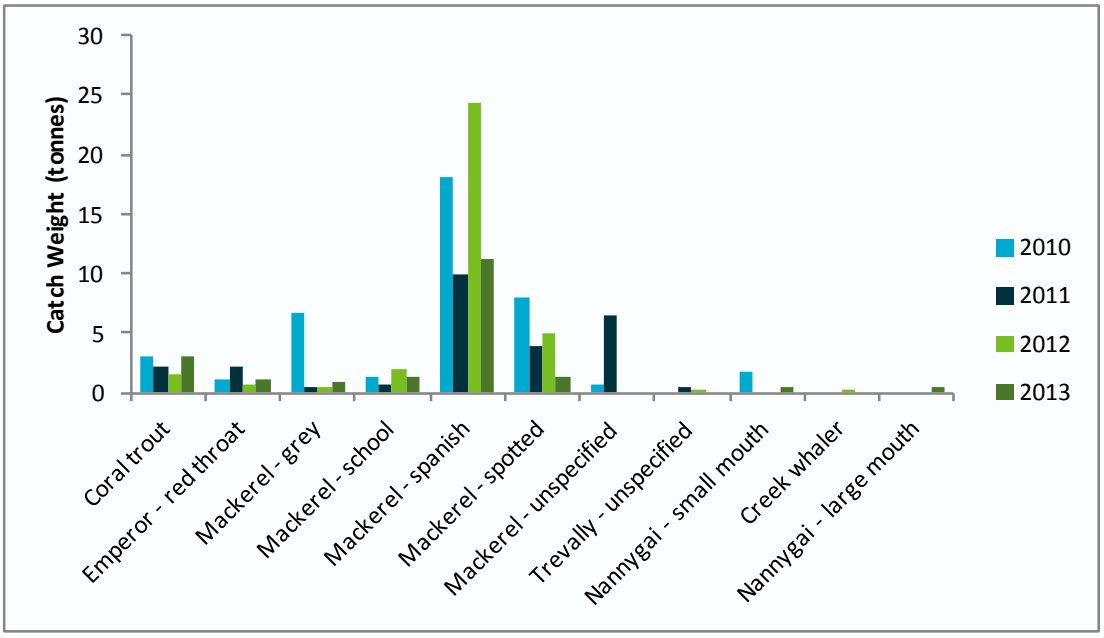

Figure 45: Highest line caught species by weight (tonnes) for the period 2010 to 2013 in the Mackay region.

Despite lower catch weights than other areas, the Burdekin is an important port for the landing of line caught quota fish species in the east coast finfish fishery. The average annual landing of quota caught reef finfish and Spanish mackerel between 2010 and 2013 was approximately 260 tonnes.

Between 2010 and 2013, 27 charter vessels reportedly spent 910 days fishing in the Burdekin region. Logbook data estimate charter operators retained 11.2 tonnes of inshore species and discarded an additional 11 tonnes over the time period.

9.4.7 INTERACTIONS WITH PROTECTED SPECIES

Between 2010 and 2013, multiple interactions with Species of Conservation Interest were reported. In 2010, the net fishery interacted with five loggerhead turtles and a saltwater crocodile, all were released alive. During the same year the trawl fishery interacted with a seahorse which as released alive and a total of 393 sea snakes, of which six were injured, seven were released dead and 380 were released alive. Interactions in 2012 decreased significantly to one fatal interaction between a net

and an offshore bottlenose dolphin and 27 sea snake interactions with the trawl fishery - all survived with the exception of one which was released dead. In 2012 and 2013 combined the net fishery interacted with four hawksbill turtles which were all released alive.

9.4.8 TRENDS IN REGIONAL COMMERCIAL FISHERIES

Over the last nine years the Burdekin region has illustrated a decreasing trend in the number of operators - fishing effort appears relatively stable through time apart from a small peak in 2008 (Figure 46).

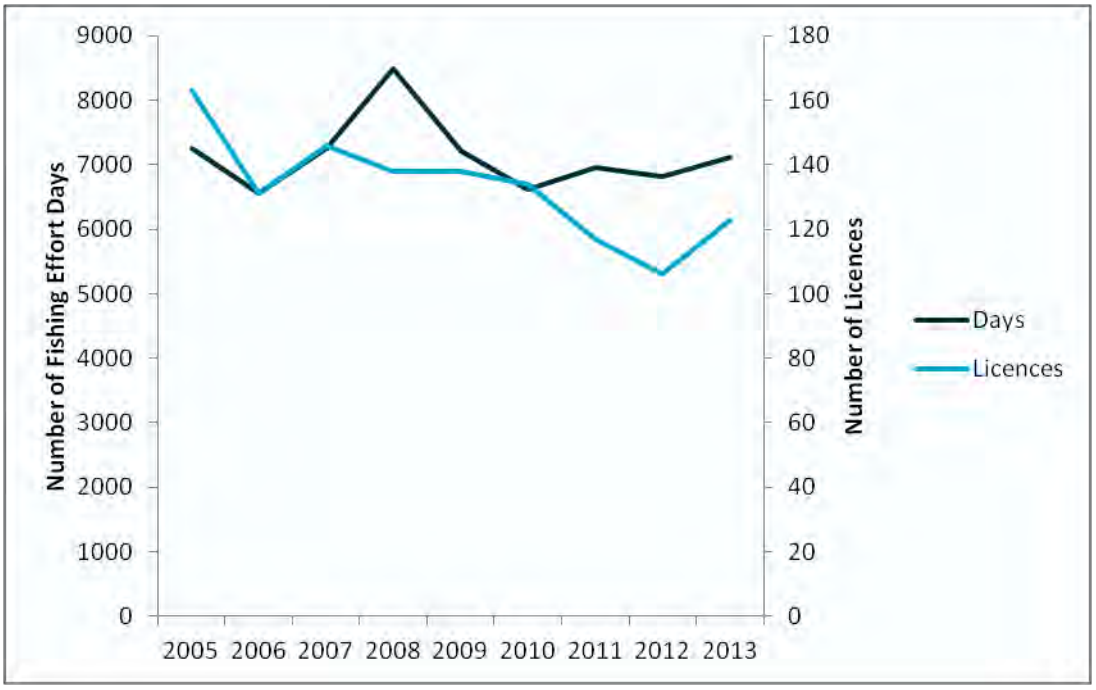

Figure 46: Overall fishery participation and effort information, 2005–2013.

Figure 47 illustrates the most noticeable decline in the number of operators in the otter trawl fishery. Operator numbers decreased from 92 in 2005 to 39 in 2013. Between 2005 and 2013 all other fishing method types exhibited relatively steady trends in active fishers - close observation shows very slight increases in the pot and net fisheries and a small decrease in the line fishery.

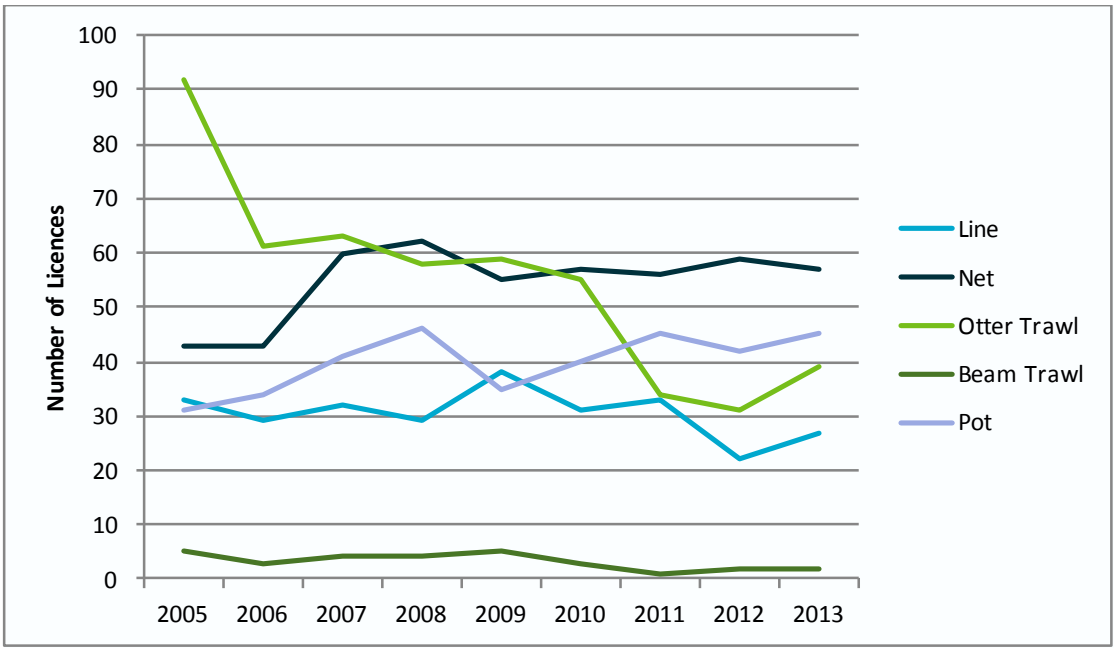

Figure 47: Number of active fishing licences by fishing method type, 2005–2013.

Over time, fishing effort days in the net, line and beam trawl fisheries appear relatively stable - pot and otter trawl fisheries fishing days appear proportional to increases or decreases in operator numbers. Otter trawl fishing effort days and catch followed an overall decreasing trend - with high and low fluctuations exaggerated by the catch data (Figure 48). The overall trend in the pot fishery illustrates an increase in the number of fishing effort days and catch - catch weights began increasing in 2008 and peaked in 2011 but have since decreased, although to levels higher than in 2005.

Whilst operator numbers and fishing days have remained fairly stable, fluctuations in net catches have been recorded throughout the time period, 2005 to 2013. Peaks in catch were recorded in 2005, 2008, 2009 and 2011, with the remaining years consistently reporting in the mid to high 300 tonnes.

Line fishery catch weights appear relatively stable in Figure 48 with data suggesting that after peaking in 2009 and 2010 the line fishery is decreasing slightly. Oppositely, catch yield per day of fishing effort has increased over time period with the exception of the most recent year 2013.

At its highest, in 2005, the beam trawl fishery retained 5.1 tonnes of catch in the Burdekin region, since then beam trawl catch statistics have decreased over time. In 2013, a mere 220 kilograms of inshore fin fish species were reportedly retained - the lowest reported during the time period.

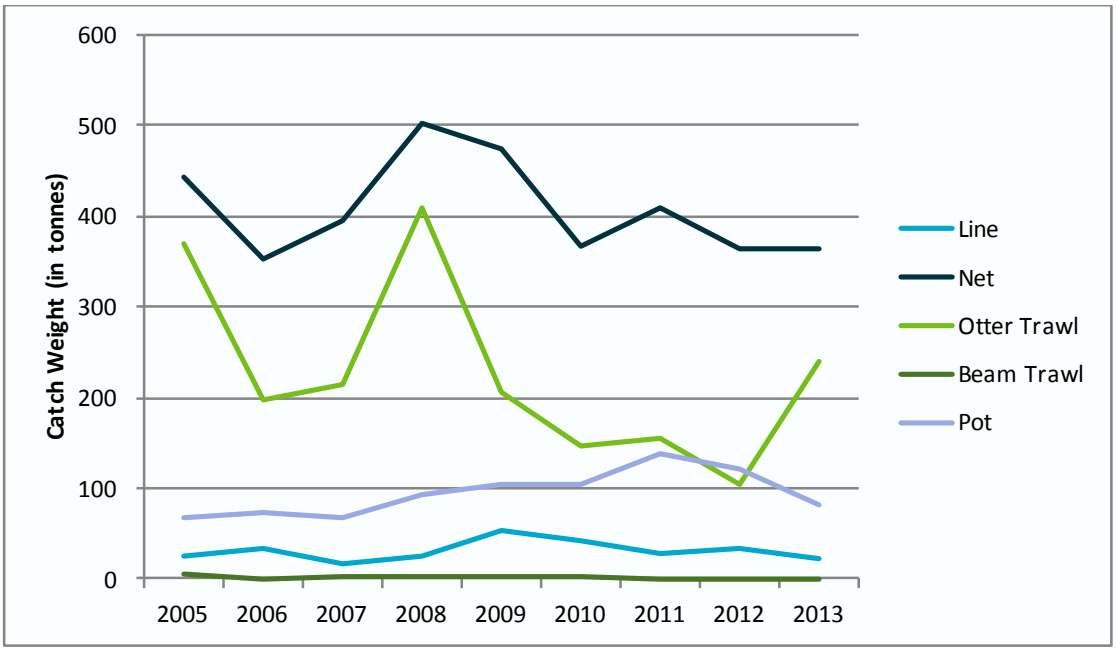

Figure 48: Catch weight (in tonnes) by fishing method type, 2005–2013.

9.4.9 RECREATIONAL FISHING IN THE REGION

The Mackay residential region in the statewide recreational fishing survey includes Bowen, Mackay, Proserpine and the Whitsunday islands. Fishers in the region have access to excellent marine fishing environments which is reflected in their catches. Residents of the Mackay region did most of their fishing where they lived but some ventured south to the Fraser Coastal waters and the south-eastern catchment.

The Northern residential region includes Townsville and Ingham and provides access to fish habitats such as the mangrove lined Hinchinbrook channel and the Great Barrier. Northern residents mainly fish close to where they live in the central coast catchment and the Cairns and Townsville coastal waters but some also ventured north and fishing in Cooktown's coastal waters.

The Burdekin grids allocated for this report fall inside both the Mackay and Northern residential regions of the recreational fishing survey. This report presents a simple average of the two residential regions to present effort and catch based information for the Burdekin region. Information included in this section describes the recreational fishing activities of residents of the Mackay and Northern residential regions.

Approximately 24% of Burdekin residents aged five years or above went fishing in the 12 months prior to the survey. This was much higher than the statewide average of 17%.

For the combined region fishers were distributed across all age groups with the 30-44 year olds making up the bulk of recreational fishers. As with the rest of Queensland more males than females went recreational fishing.

More days were spent fishing from boats (Figure 49) than the shore and most of this was done in marine waters. People go fishing throughout the year but peaks in

fishing activity were recorded in April and September, coinciding with school holidays.

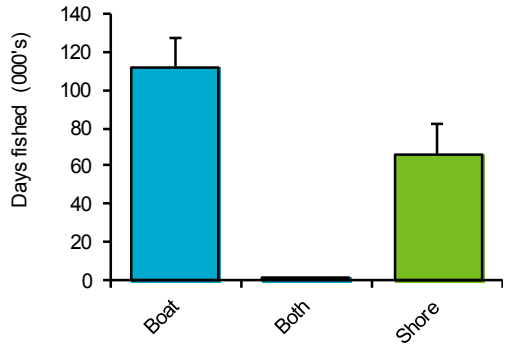

Figure 49: Number of recreational days fished from a boat or the shore (average of Mackay and Northern Residential areas).

Residents of the Burdekin region caught more mud crabs than other species, with marine cod, barramundi and pikey bream also featuring as commonly caught species (Figure 50).

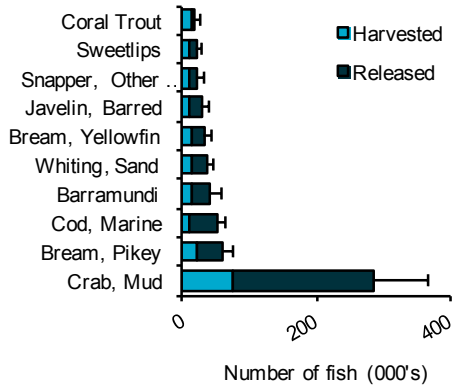

Figure 50: Top ten recreational species caught by number (average of Mackay and Northern Residential areas).

9.4.10 REFERENCES

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Data from the DAFF commercial fishery logbook database: 12 May 2014.

Data on recreational fishing from the DAFF recreational fishing survey 2010-11.

10 Management options and their relative importance in Mackay

10.1 Introduction

The coastal zones of the world, especially those associated with estuaries, are environmentally, economically and socially complex (91). These zones support many important industries (e.g. fisheries, ports, tourism), key habitats (e.g. wetlands, salt marshes, seagrass, mangroves), and iconic or threatened species (e.g. dugongs, inshore dolphins, water birds). The coastal zone and associated estuaries are one of the most impacted ecosystems (1, 92), often experiencing cumulative impacts of more than 15 human-induced stressors (1). Land and catchments adjacent to the Great Barrier Reef (GBR) region in Australia can be a source of nutrients, sediments and contaminants to the reef (2). On the other hand, estuaries provide nursery habitats to reef biodiversity (93, 94).

Stakeholder input (aka. a partnership approach) is seen as essential for good management in many industry sectors (13, 95). For example, the Australian commonwealth manages fisheries with the input from a series of committees with industry, scientists, managers and the conservation sector represented to provide technical (Resource Assessment Groups) and management advice (Management Advisory Committees) (13). However, these fisheries structures tend to focus on industry and conservation as their stakeholders, while local communities are not often directly involved. The Australian forestry sector has attempted to engage the general community although at times highly contentious and seemingly irresolvable issues were shown to be difficult to resolve due to outside, non local influences and interest groups (96). It could be argued that the coastal zone has developed a form of community engagement through the use of report cards produced and used by, for instance, regional Natural Resource Managers (NRMs) that explicitly provide environmental health status. Examples of these report cards can be found in many parts of the world (e.g. Chesapeake Bay http://ian.umces.edu/ecocheck/report-cards/chesapeake-bay/2013/) including the GBR (http://www.reefplan.qld.gov.au/measuring-success/report-cards/assets/report-card-2012-2013.pdf) and South-east Queensland (http://www.health-e-waterways.org/reportcard).

An important component of regional management is mechanisms for stakeholder and community input local management (97, 98) and to also consider these inputs in management decisions. Engagement mechanisms provide a two-way flow of communication between stakeholders (including communities, industry and government) and managers who are able to ground truth and further develop possible management actions with locals. By actively participating in the decision process and having inputs into decisions, communities are also able to obtain relevant information and better appreciate and understand trade-offs associated with different decisions. This gives community members a greater sense of ownership through participation. The concept of citizen participation in management has a long (although intermittent) history in Australia (99). In the coastal zone this engagement is not trivial as the issues and management structures are inherently complex. However, often the engagement with the community has been somewhat linear and aimed at addressing singular issues and possible management responses

(e.g. Pressey, Cowling and Rouget (37)). Few have undertaken a structured approach as described in the adaptive management loop (100, 101).

Adaptive management follows control theory (6, 102) and includes the steps of firstly reviewing knowledge, then determining management objectives, developing management actions, establishing monitoring program, and lastly implementing management actions (Figure 51).

Figure 51: Adaptive management loops steps (Redrawn from (103))

In this section, a structured approach, following the adaptive management loop, was adapted from a method used in a trawl fishery in Queensland (104) and applied to a coastal case study. The purpose was to test the method in a multiple-use coastal setting using a community group (as opposed to a stakeholder representative group) and managers. The research was applied in a coastal case study city in rural Queensland (Australia) to investigate the articulation of management options and their relative importance with regards to coastal fisheries and inshore biodiversity.

10.2 Methods

10.2.1 MANAGEMENT STRATEGIES

The LMAC RG was used as a representative of a community group in Mackay. It consists of a group of interested residents and relevant agencies (as part of the project). A key aspect of the process is to provide the RG access to many of the relevant management agencies to the coastal zone and information relevant to the topic. Of importance is that the management options elicitation process came after a lengthy deliberation of their objectives and relative weights, and developing

qualitative models of key assets in the region. A transitional meeting leading the RG from the objectives weighting to the management options was undertaken, showing existing management being undertaken by the different agencies and NGOs.

The process of management options elicitation followed a standard process, with only minor refinements in each session: an initial discussion about which topic in the coastal zone would be the subject of management discussions, and then for each topic one or two presentations from an expert in the field asked to concentrate on information relevant to Mackay, the development of an issues register, and the production of two classes of management options and the related relevant agency to which it relates. The RG was asked to produce two classes of management options for each issue – direct and indirect options. The former was seen as working directly with the relevant management agency e.g. the local council whereas the indirect was seen as working in an influencing manner to potentially achieve the same or a similar outcome (although the degree and effectiveness may differ). This was seen as important by the project team, to ensure people do not get unrealistic expectations that a government action is achievable and needed as the only option.

Apart from the presentations, the RG were provided printouts of the qualitative models they produced (when applicable), a distribution map of the topic, the water quality Outlook results for Mackay. The map was used as way of geo-locating any issues and the RG were provided with post-it notes, one for each issue, so that they could place on the maps.

Initially, due to perceived time constraints, the presentation and issues register was undertaken as a separate session to developing management option. This was viewed by the group as unnecessary and also means people forgot what was discussed between sessions. There were also practical considerations such as trying to keep the same groups between two meetings when there was not always a consistent membership. The next options were to undertake the topic in the same meetings as a series of presentation, issues register and management options discussions. However, after one session in this format, the group naturally completed the process as presentation with subsequent discussion on issues and management options at the same time. This process seemed more intuitive to people. The project team observed that the groups still produced a reasonably comprehensive list of issues and completed at least two management options for each issue.

Existing management measures: setting the scene

A series of presentations were provided as a transitional meeting between the objectives weighting and management options sessions:

- An overview of the catchment to coast framework concentrating on the Reef Catchment Plan;
- Upper and middle catchment statistics, issues, plans and existing management measures;
- Coastal statistics, issues, plans and existing management measures;

- Biodiversity statistics, issues, plans and existing management measures; and
- Fisheries statistics, issues, plans and existing management measures.

Issues register

Seven topics were chosen that were relevant to the coastal zone and of interest to the group:

- Coastal water quality;
- Seagrass and associated ecosystem;
- Mangroves and associated megafauna;
- Inshore corals;
- Urban development;
- Port development; and
- Fisheries.

Since upper catchment water quality was out of scope in the project, the RG decided to bundle coastal water quality and seagrass into a single session. The two were seen as very interrelated.

Management Strategies elicitation

Elicitation of management options from stakeholders is a key component of this project. The elicitation of management options is aimed at maintaining the balance between practical, cost-effective options and creative ideas to address inshore biodiversity and fisheries issues in the Mackay region. The project team combined management solutions from the community with ideas from Queensland management organisations on how to best implement them.

From June 2013 to March 2014 the GBR NERP project team met with the Mackay reference group (RG) almost monthly to discuss issues and management options for the Mackay inshore region. The RG is a sub-committee formed from the Mackay Local Marine Advisory Committee and consists of local Mackay residents that are, amongst others, local farmers, fishers, conservation group members, employees from council and Qld Bulk Ports.

The outcomes of these meetings were discussed in a 3-day project team workshop to develop management strategies and discuss the best ways of implementing them. The objective of the meeting was to provide a first cut at combining these management options into practical grouped management strategies that could be garnered from over 300 options mentioned by the group. The United Nations Environment Program (UNEP) assessment framework was used as a basis for this process.

This list of management strategies and associated description were then discussed and changed (if needed) to reflect the views of the RG. The objective of this report was to present and discuss the list of management strategies of the RG to managers and other interested parties that could help move these ideas towards implementation. It was the main seed document to the workshop that was held at the end of May 2014. At this meeting these management strategies were discussed

in the context of a) what is currently being done in the context of each management strategy, b) what more can be done, c) what would this extra work cost and d) what the social, economic and ecological impact of undertaking this work would be.

In order to distil the resultant large number of management options into a more practical, combined set of management strategies, the project team spent three days reviewing each of the management options elicited from the RG. There was always someone at the meeting that was at the table when an option was discussed and this memory and notes taken were very useful as some of the options were often written in short hand. In order to articulate the pathway of combining management options, the project team used the well-known United Nations Environment Program risk assessment framework known as DPSIR (Drivers, Pressures, States, Impacts and Response) as a basis for their thought processes. This framework first started in a more simplified form of Pressure-State-Response – this basic version was used here.

The management options from the RG were grouped into management strategies, following a process of naming management strategies via aggregation, addition, exclusion and re-wording of the original management options. Each strategy is a response to address the pressures affecting the inshore GBR, which are expected to influence the ecological, social or economic states. An Access and a GIS database have been created also allowing one to follow each management option, its spatial location (if provided) and which management strategy it was placed in. No management option has been ignored or deleted in the process. This work was then edited and changed by the RG to reflect the views of the group rather than only the project team. The final list below is therefore the result of 2 years of work by the RG to provide local views of the issues and the potential management strategies to address these.

The resultant management strategies were discussed and reviewed with the Mackay reference group on May 14, 2014. The agreed management strategies were presented to managers and other interested parties that could help move these ideas towards implementation in a workshop Mackay on May 28, 2014. Managers were defined as people whom either directly or indirectly influence management decisions. The below are the resultant management strategies that went to this management meeting.

10.2.2 IMPACT ASSESSMENT

Two phases of impact assessment were undertaken – the first was before the management workshop and undertaken by the RG members only. The second was during the management workshop by all participants based on any suggestions made within the workshop of possible management actions. By nature of the process, the latter list of management options will be a smaller more implementable list than that brought to the management workshop.

The method of obtaining the impact assessments were different to the two steps in that the first were against the full list of objectives, whereas the second was against the goals "social" "economic", "ecological" and "governance". The scoring scale was unchanged. For both, they also scored their uncertainty ("confidence") of their answers against each objective.

The aim of the two assessment surveys was to determine how the thirteen different management strategies compare to the current system. The time horizon was 10 years i.e. the changes that would occur over a 10-year horizon if the strategy were to be implemented over that period. The idea was to identify strengths and weaknesses of each strategy, and also if they will have different effects on the different management objectives for the Mackay region.

To complete the survey participants placed a value ranging from -3 (considerably worse than the current system) to 3 (considerably better than the current system) against a) management objectives in the case of the pre-management workshop impact assessment undertaken by the RG and b) during the management workshop but at the goal level (both RG and managers).

Table 32 summarises the meaning of each score. Participants were also asked to provide their confidence score from 1 to 5 (Table 33) as to their confidence in providing the answer relating to each objective, with 1 indicating very unsure and 5 indicating certain.

The impact assessment form for the pre-management workshop is shown in Table 38 and that for the management workshop in Table 42. The preambles (details of respondent, ethical statement, introduction and instructions – including Table 34 to Table 36) for each meeting are provided before these two tables respectively.

Table 32: Details of scores on how participants think each strategy performs against each objective.

Scale	Meaning
3	Considerably better than current situation
2	Moderately better than current situation
1	Slightly better than current situation
0	Same as current situation
-1	Slightly worse than current situation
-2	Moderately worse than current situation
-3	Considerably worse than current situation

Table 33: Details of scores on how confident participants were about the way they scored against each objective.

Confidence

Scale	Meaning
1	Very unsure
2	Fairly uncertain
3	Moderately certain
4	Fairly certain
5	Certain

Pre-management workshop impact assessment form

Your details

Name: _____

Email: _____

Please choose the group that you mostly associate with by checking (✓) the appropriate stakeholder group

Stakeholder groups	Tick one
Commercial Fishing	
Charter Fishing	
Commercial seafood processing	
Recreational Fishing	
Diving	
Tourism	
Fisheries Management	
Fisheries Compliance	
Tackleshops, Recreational Service Industry	
Marine Services Industry	
Mining	
Port Authority	
Farmer	
Grazier	
Conservation organisation	
Great Barrier Reef Marine Park Authority	
Queensland Parks and Wildlife Service	
NRM group	
Local Government	
State Government	
Aboriginal & Torres Strait Islander	
Local Resident	
Scientists	
Student - High School	
Student - Tertiary	
Other	

Please indicate the region where you are located

Region	Please ✓
Torres Strait to Cairns	
South of Cairns to Bowen	
South of Bowen to Repulse Bay	
Repulse Bay to Clairview (Mackay)	
South of Yeppoon to Baffle Creek	
South of Baffle Creek to Double Island Point	
South of Double Island Point to Caloundra	
Caloundra to the NSW Border	
Other	

Instructions

This survey is being undertaken as part of the project 'Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)'. It is currently limited to members of the Mackay LMAC reference group.

The aim of the survey is to determine how the fourteen different management strategies presented earlier compare to the current system. The time horizon is 10 years i.e. the changes that would occur over a 10-year horizon if the strategy were to be implemented over that period. The idea is to identify strengths and weaknesses of each strategy, and also if they will have different effects on the different management objectives for the Mackay region.

To complete the survey, please place a value ranging from -3 (considerably worse than the current system) to 3 (considerably better than the current system) in each of the boxes on the tab 'Mackay_Obj and MgtStrat' in the Excel spreadsheet or in the attached hard copy. The table below summarises the meaning of each score. Please also provide your confidence score from 1 to 5 as to your confidence in providing the answer relating to each objective, with 1 indicating very unsure and 5 indicating certain (see 'confidence score' table below for details).

Details about management objectives elicited in an initial stage of the project are provided below. The description of each management strategy and information on how they were constructed is provided in a separate document.

Information you provide will only be used for the purposes of aggregate analysis, and individual responses will be kept confidential. We ensure your confidentiality by not making public the individual content of the information you provided both verbally and also on the Excel and paper spreadsheets. The information will be used for research purposes only, without reference to specific facts or events. For any reporting your individual information will not be presented - all information will be presented in summarised form based on collating all spreadsheet data.

After use, the recorded material you provide will be kept at a secure location on the CSIRO network only accessible to a core team of people until Dec 2014. Before that date, participants will be able to access, upon request, the material corresponding to their own spreadsheet. After that date, all recorded material will be securely deleted.

It is your right to withdraw from the workshop at any time if you wish to do so. Also, if you do not wish the project team to use the data you provided you will have 30 days from today (14 May 2014) to advise the project team.

Thank you for your participation!

Cathy Dichmont

Table 34. Details of scores on how you think each strategy performs against each objective.

Scale	Meaning
3	Considerably better than current situation
2	Moderately better than current situation
1	Slightly better than current situation
0	Same as current situation
-1	Slightly worse than current situation
-2	Moderately worse than current situation
-3	Considerably worse than current situation

Table 35. Details of scores on how confident you are about the way you scored against each objective.

Confidence

Scale	Meaning
1	Very unsure
2	Fairly uncertain
3	Moderately certain
4	Fairly certain
5	Certain

Table 36. Example of how to give your relative score (-3 to 3) of how you think each of the management strategies will perform against each management objectives.

Objectives	Address littering through education, legislation and operating procedures	Develop and implement weed and pest management plans for regions	Confidence (score 1-5)
1.1.1 Reduce direct impacts of infrastructure and development	1	0	3
1.1.2 Minimise human induced changes in water flow regimes	2	3	5
1.2.1 Ensure Reef Plan water quality targets are met	0	0	2

Explanation about management objectives for the Mackay region

Table 37. Objective hierarchy showing levels (branches of the tree) and descriptors of the objectives presented in Figure 1.

Level	Objective	Descriptor
1	Protect and restore inshore environmental assets	Overarching environmental objective for the region
1.1	Improve ecosystem connectivity	Connectivity between catchment, fresh- and salt-water habitats
1.1.1	Reduce direct impacts of infrastructure and development	Minimise the negative impacts to biodiversity associated with the strong development currently occurring in the region
1.1.2	Minimise human induced changes in water flow regimes	Maintain water flow regimes to allow for catchment to coast connectivity
1.2	Improve water quality	Reduce sediment and nutrient runoff into waterways and reefs
1.2.1	Ensure Reef Plan water quality targets are met	Meet regional water quality targets
1.2.2	Increase feral animal control and environmental friendly weed control strategies	Control invasive species to improve water quality. When possible weed control should avoid/minimise the use of chemicals
1.2.3	Reduce influx of pollutants	Reduce the use of chemicals used in agriculture and industry and its disposal in waterways. Also involves reduction of sediment and nutrient runoff
1.3	Conserve inshore living resources	Ensure long-term conservation of the inshore living resources and their support systems
1.3.1	Sustainable human use of marine resources	Ensure sustainable harvesting of living resources; Reduce waste and human footprint of extractive activities, and improve re-use of by-products
1.3.2	Maintain habitat function and structure	Maintain/restore habitats for their biodiversity values
1.3.3	Reduce impacts on Threatened, Endangered, Protected (TEP) species	Minimise accidental strikes and kills of fauna and flora (e.g. dugongs, turtles, quolls)
Level	**Objective**	**Descriptor**
2	Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity)	Improve leadership, institutions, rules and decision-making processes involving government, citizens, public associations, private businesses, and non-governmental organisation, for the management of inshore biodiversity and its uses
2.1	Increase management effectiveness	Increase the effectiveness of management systems by removing barriers to flexibility
2.1.1	Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)	Remove regulatory barriers that impede creativity in the development of alternative techniques to harvest natural resources, to increase flexibility in zoning arrangements and remove regulatory barriers that impede the diversification of the economy
2.1.2	Increase compliance with environmental and resource use regulations	Discourage illegal, unreported and unregulated activities, and encourage compliance with existing regulations
2.2	Increase management support	Increase support towards inshore biodiversity management systems through increased management acceptability, increased stakeholder engagement, ensuring that management costs are sustainable and increase compliance with environmental and resource use regulations

Level	Objective	Descriptor
2.2.1	Increase management acceptability	Increase management acceptability through rational and proportional legislation, and increased information dissemination
2.2.2	Increase stakeholder engagement and community ownership/stewardship	Increase stakeholder engagement through involvement of private developers / corporate responsibility and community involvement in management to foster community ownership/stewardship
2.2.3	Sustainable financial costs	Minimise industry compliance costs and government enforcement costs, including recoverable and non-recoverable total management costs and infrastructure costs
2.3	Increase management integration	Improve the integration of management systems in policy, regulation and implementation, across Local, State and Commonwealth levels
2.3.1	Increase policy integration	Coherent and integrated policies across Local, State and Commonwealth levels
2.3.2	Increase regulatory integration	Coherent and integrated regulations across Local, State and Commonwealth levels
2.3.3	Increase implementation integration	Coherent and integrated management implementation across Local, State and Commonwealth levels
Level	**Objective**	**Descriptor**
3	Improve regional economic and social well-being	Improve the long-term well-being of the region's people by promoting economic growth, increasing social cohesion and increasing social capital
3.1	Increase economic growth	Promotion of regional economic development, including natural resource based industries, to maintain or improve family livelihoods
3.1.1	Improve regional economic development and industry diversity	Increase the flow of human and financial resources into the Mackay region, develop efficient and integrated infrastructure, increase the local market opportunities for locally produced foods
3.1.2	Improve family livelihoods in the region	Enhancement of quality of life via increasing employment opportunities and family income
3.1.3	Ensure that natural resource based industries are profitable and sustainable	Maximise industry value, economic profits and productivity, and minimise price variability
3.2	Increase social cohesion	Increase social cohesion of the regional communities through minimising conflicts between stakeholders, conserving traditional activities and cultures and ensuring equitable access to inshore areas and resources
3.2.1	Minimise conflicts between stakeholders	Minimise conflicts between different users of the inshore marine area and resources
3.2.2	Conserve traditional activities and cultures	Preserve the traditional and cultural relationships between natural resources and areas and local human cultures (aboriginal and non-aboriginal)
3.2.3	Ensure community equity	Ensure equitable access to inshore areas and resources
3.3	Increase social capacity	Increase social capacity to act, through health improvement and investment in social capital development
3.3.1	Improve workplace and family health and safety in the region	Improve safety in the workplaces, as well as physical and mental family health and safety in the region

Level	Objective	Descriptor
3.3.2	Improve education, training, social infrastructure and networks	Improve the social capital at both individual level (education, training, ...) and collective level (physical infrastructure – hospitals, schools, ... - as well as networks and community groups) providing the regional community with the capacity to address development challenges and take advantage of emerging opportunities

Table 38. Impact assessment form at the objective level undertaken by RG members.

Objectives															**Confidence (score 1-5)**
1.1.1 Reduce direct impacts of infrastructure and development															
1.1.2 Minimise human induced changes in water flow regimes															
1.2.1 Ensure Reef Plan water quality targets are met															
1.2.2 Increase feral animal control and environmental friendly weed control strategies															
1.2.3 Reduce influx of pollutants															
1.3.1 Sustainable human use of marine resources															
1.3.2 Maintain habitat function and structure															
1.3.3 Reduce impacts on Threatened, Endangered,															

Objectives															**Confidence (score 1-5)**
Protected (TEP) species															
2.1.1 Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)															
2.1.2 Increase compliance with environmental and resource use regulations															
2.2.1 Increase management acceptability															
2.2.2. Increase stakeholder engagement and community ownership/stewardship															
2.2.3 Sustainable financial costs															
2.3.1 Increase policy integration															
2.3.2. Increase regulatory integration															
2.3.3 Increase															

Objectives															Confidence (score 1-5)
implementation integration															
3.1.1 Improve regional economic development and industry diversity															
3.1.2 Improve family livelihoods in the region															
3.1.3 Ensure that natural resource based industries are profitable and sustainable															
3.2.1 Minimise conflicts between stakeholders															
3.2.2 Conserve traditional activities and cultures															
3.2.3 Ensure community equity															
3.3.1 Improve workplace and family health and safety in the region															
3.3.2 Improve education, training, social infrastructure and networks															

Scale	-3: Considerably worse than current situation	-2: Moderately worse than current situation	-1: Slightly worse than current situation	0: Same as current situation	1: Slightly better than current situation	2: Moderately better than current situation	3: Considerably better than current situation

Confidence score (1-5)	1: Very unsure	2: Fairly uncertain	3: Moderately certain	4: Fairly certain	5: Certain

Management workshop impact assessment form

Your details

Name: _____

Email: _____

Please choose the group that you mostly associate with by checking (✓) the appropriate stakeholder group

Stakeholder groups	Tick one
Commercial Fishing	
Charter Fishing	
Commercial seafood processing	
Recreational Fishing	
Diving	
Tourism	
Fisheries Management	
Fisheries Compliance	
Tackleshops, Recreational Service Industry	
Marine Services Industry	
Mining	
Port Authority	
Farmer	
Grazier	
Conservation organisation	
Great Barrier Reef Marine Park Authority	
Queensland Parks and Wildlife Service	
NRM group	
Local Government	
State Government	
Aboriginal & Torres Strait Islander	
Local Resident	
Scientists	
Student - High School	
Student - Tertiary	
Other	

Please indicate the region where you are located

Region	Please ✓
Torres Strait to Cairns	
South of Cairns to Bowen	
South of Bowen to Repulse Bay	
Repulse Bay to Clairview (Mackay)	
South of Yeppoon to Baffle Creek	
South of Baffle Creek to Double Island Point	
South of Double Island Point to Caloundra	
Caloundra to the NSW Border	
Other	

Instructions

This survey is being undertaken as part of the project 'Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)'. It is currently limited to members of the Mackay LMAC reference group.

The aim of the survey is to determine how the fourteen different management strategies presented earlier compare to the current system. The time horizon is 10 years i.e. the changes that would occur over a 10-year horizon if the strategy were to be implemented over that period. The idea is to identify strengths and weaknesses of each strategy, and also if they will have different effects on the different management objectives for the Mackay region.

To complete the survey, please place a value ranging from -3 (considerably worse than the current system) to 3 (considerably better than the current system) in each of the boxes in the attached hard copy. The table below summarises the meaning of each score. Please also provide your confidence score from 1 to 5 as to your confidence in providing the answer relating to each objective, with 1 indicating very unsure and 5 indicating certain (see 'confidence score' table below for details).

Information you provide will only be used for the purposes of aggregate analysis, and individual responses will be kept confidential. We ensure your confidentiality by not making public the individual content of the information you provided both verbally and written. The information will be used for research purposes only, without reference to specific facts or events. For any reporting your individual information will not be presented - all information will be presented in summarised form based on collating all spreadsheet data.

After use, the recorded material you provide will be kept at a secure location on the CSIRO network only accessible to a core team of people until Dec 2014. Before that date, participants will be able to access, upon request, the material corresponding to their own spreadsheet. After that date, all recorded material will be securely deleted.

It is your right to withdraw from the workshop at any time if you wish to do so. Also, if you do not wish the project team to use the data you provided you will have 30 days from today (28 May 2014) to advise the project team.

Thank you for your participation!

Cathy Dichmont

Table 39: Details of scores on how you think each strategy performs against each objective.

Scale	Meaning
3	Considerably better than current situation
2	Moderately better than current situation
1	Slightly better than current situation
0	Same as current situation
-1	Slightly worse than current situation
-2	Moderately worse than current situation
-3	Considerably worse than current situation

Table 40: Details of scores on how confident you are about the way you scored against each objective.

Confidence

Scale	Meaning
1	Very unsure
2	Fairly uncertain
3	Moderately certain
4	Fairly certain
5	Certain

Table 41: Example of how to give your relative score (-3 to 3) of how you think each of the management strategies will perform against each management objectives.

Objectives	Ecological	Governance	Social	Economic
Address littering through education, legislation and operating procedures	3	2	1	0
Develop and implement weed and pest management plans for regions	2	3	0	2
Confidence (score 1-5)	5	4	3	1

Table 42: Impact assessment form used during management workshop.

Management Strategies	Ecological	Governance	Social	Economic
1. Address littering through education, legislation and operating procedures				
2. Develop and implement weed and pest management plans for regions				
3. Education - best development practices				
4. Education – on farm best practices				
5. Education - fishery campaign				
6. Education - improving governance				
7. Improve compliance by obtaining local stakeholder input				
8. Improve resource management through better planning, assessment and regulation				
9. Legislation changes to allocation and sustainability of fishery issues				
10. Management for protected species				
11. Reduce impacts of dredging				
12. Support, facilitate and coordinate basic research				
13. Transparent (to public) and coordinated monitoring reporting				
Confidence (score 1-5)				

Scale	-3: Considerably worse than current situation	-2: Moderately worse than current situation	-1: Slightly worse than current situation	0: Same as current situation	1: Slightly better than current situation	2: Moderately better than current situation	3: Considerably better than current situation

Confidence score (1-5)	1: Very unsure	2: Fairly uncertain	3: Moderately certain	4: Fairly certain	5: Certain

Impact assessment analyses

The relative impact of each management strategy was analysed as per the fisheries case described in Dichmont, *et al.* (105). The output of the relative impact assessment is an impact matrix $I^{s}_{i,j}$ where s is the management strategy, i is the number of objectives and j is the number of workshop participants. The confidence

scores, $C^s_{i,j}$ were applied to the impact matrix by adding the impact matrix to the average (over *j*) of the confidence scores, i.e. $(I^s_{i,j} * C^s_{i,j}) / \overline{C^s_i}$ as the elements of the matrix $I^{'}$. This results in a higher weight being applied to strategies (s) where respondent (*j*) scores were more certain. The relative weights per respondent for each objective were combined into a single relative weight matrix, $W^g_{i,r}$ by stakeholder group, *g*, where *r* is the number of respondents to the survey (which is a larger number than *j*). The overall results can therefore be combined, $\overline{W^g_i} * \overline{I^{'s}_i}$ for each stakeholder group and management strategy.

Where the sums of all the objectives are a positive score, an overall positive score contribution is indicated. A negative score indicates that the overall result is negative relative to the current situation. The scale of the confidence score indicated the degree of confidence in whether the positive or negative effect is likely to eventuate. In the RG workshop, the impact assessment was undertaken at the objective level on the lowest part of the objective hierarchy (i.e. 24 objectives), whereas the managers' workshop only assessed against 4 high level goals (environment, governance, economic, social). Participants were divided into "Government", "Resource users" or "Other" (Table 43).

Table 43: Stakeholders and stakeholder groups

Stakeholder	Stakeholder group
Aboriginal and Torres Strait Islander	Others
Charter Fishing	Resource users
Commercial Fishing	Resource users
Commercial seafood processing	Resource users
Conservation Organisation	Others
Diving	Resource users
Farmer	Resource users
Fisheries Compliance	Government
Fisheries Management	Government
Grazier	Resource users
Great Barrier Reef Marine Park Authority	Government
Local Government Councillors	Government
Local Resident	Others
Marine Services Industry	Resource users
Mining	Resource users
NRM Group	Others
Other	Others
Port Authority	Resource users
Queensland Parks and Wildlife Service	Government
Recreational Fishing	Resource users
Scientists	Others
State Government	Government
Student - High School	Others
Student - Tertiary	Others
Tackleshops or Chandleries	Resource users

Tourism	Resource users

The analyses are undertaken in R (106) and the default settings are used for the box and whisker plots. This means that the box shows the median (second quarter: Q2) and the first and third Quartile (Q1 and Q3). The upper whisker is the $\min\left[\max(\mathbf{x}); Q3 + 1.5(Q3 - Q1)\right]$ of the data vector x and the lower whisker is $\max\left[\min(\mathbf{x}); Q1 - 1.5(Q3 - Q1)\right]$. Any values outside these whiskers are shown as outliers.

The level of group coherence was tested and indicates the degree to which members of the above stakeholder group have similar or dissimilar objective preferences. A measure of group coherence can be given by:

$$\overline{\rho} = \left\langle v_i \bullet v_j \right\rangle \quad i \neq j$$

where v_i and v_j are vectors that compromise the square root of the objective weights of individuals i and j; • indicate the dot product between the two vectors and $\langle\ \rangle$ indicates the average of the set of dot products (107). The closer the value is to one, the greater the average agreement in opinion of the individuals. There is not accepted critical value though some authors have adopted 90%, 95% or 99% as their critical measures.

10.3 Results and Discussion

10.3.1 QUALITATIVE MODELS

RG members were very quick (within the first session) to understand the qualitative modelling method once it was explained to them. Visualising their perceptions on a whiteboard as they described the system was the most effective means of learning the method. Four different qualitative models were developed i) creek habitats with emphasis on cumulative impacts; ii) seagrass with emphasis on coastal development; iii) a generalised model on coastal development that includes most coastal space users; and iv) a coastal model that investigated the management feedback loop of water quality monitoring and public opinion.

It was interesting that although several assets were included, such as turtles and dugongs, seagrass, mud flats, mangroves and creeks, the models tended to show the same cumulative impacts as coastal development. Although these models can be used to inform management strategies and the models were provided to RG, these were not used by the RG to develop management actions or understand feedback loops. Therefore this is one part of the process that could be discretionary in order to save time.

10.3.2 GOALS AND OBJECTIVES

Each of the goals (first level) contains additional (second level) sub-goals and (third level) objectives (Table 44). The full list of goals (top), sub-goals (mid) and objectives (lower level) in a hierarchical format are shown in Appendix B Figure S.1 and described in more detail in Dutra, *et al.* (108). The objectives are used in the impact analyses for the RG results (Table 44).

The overarching goals selected by the RG differ from the usual triple-bottom line objectives (environmental, social and economic) often found in the literature (34, 109). The three goals developed here included a) environment, b) governance and c) conjoined economic and social goal of "well-being". This highlights the importance of governance goals in the hierarchy.

Although governance was also given prominence in a Queensland fisheries example (110), there were four goal levels being "Environment", "Management", "Economic" and "Social". Interestingly, in this example the word "Governance" was not liked and replaced by "Management". In this section, the term was also much discussed, but when the RG tried to find a more adequate replacement they retained its use. The RG preferred instead to further define the meaning of governance in the name of the goal: "Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity)".

Table 44: Objectives used in the Research Group (RG) workshop – numbers show their lineage in the hierarchy where the first number is the goal, the second is the sub-goal and the final number is the objective itself. The management strategies were provided for the impact assessment to RG and managers' workshop. The order in which they appear does not reflect their importance

Environmental objectives	**Governance objectives**	**Well-being objectives**
1.1.1 Reduce direct impacts of infrastructure and development	2.1.1 Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)	3.1.1 Improve regional economic development and industry diversity
1.1.2 Minimise human induced changes in water flow regimes	2.1.2 Increase compliance with environmental and resource use regulations	3.1.2 Improve family livelihoods in the region
1.2.1 Ensure ReefPlan water quality targets are met	2.2.1 Increase management acceptability	3.1.3 Ensure that natural resource based industries are profitable and sustainable
1.2.2 Increase feral animal control and environmental friendly weed control strategies	2.2.2. Increase stakeholder engagement and community ownership/stewardship	3.2.1 Minimise conflicts between stakeholders
1.2.3 Reduce influx of pollutants	2.2.3 Sustainable financial costs	3.2.2 Conserve traditional activities and cultures
1.3.1 Sustainable human use of marine resources	2.3.1 Increase policy integration	3.2.3 Ensure community equity
1.3.2 Maintain habitat function and structure	2.3.2. Increase regulatory integration	3.3.1 Improve workplace and family health and safety in the region
1.3.3 Reduce impacts on Threatened, Endangered, Protected (TEP) species	2.3.3 Increase implementation integration	3.3.2 Improve education, training, social infrastructure and networks

10.3.3 RELATIVE WEIGHTING

When the goal and objective weightings were analysed for all respondents, the median of the environmental goal had the highest weighting, followed by governance and then well-being, although the latter two were closely scored (Figure 52). The variance of the scoring, especially the environmental goal, was high, but there were also obvious outliers in the other two goals.

In Pascoe, Mary Dichmont, Brooks, Pears and Jebreen (42) fisheries example, "Management" was the third most important goal either after "Environment", and "Economic" or "Social". However, in this paper, there is a much more diffuse management environment where there are multiple responsible agencies at all three tiers of government and non-government agencies with many disparate resource users. It could therefore be argued that the respondent groups are quite different even though they fall within the "Resource User" group as these included recreational and commercial fishers, and ports; the same applied to the "Government" group. This could explain the reasonably wide range of responses even within a group as shown by the coherency test Table 45.

Table 45 Average group coherence for goals and objectives by stakeholder group

Stakeholder group	Goals	Objectives
All	0.92	0.80
Government	0.92	0.73
Others	0.93	0.83
Resource users	0.90	0.79

The similarity of the goals by respondent group is remarkable given the diversity of stakeholders present. For instance, "Resource users" such as those from fisheries and ports may be expected to value the economic component of the well-being goal more than potentially the Government group (some of whom were not even resident in Mackay). Such similarity in the results indicates that, in terms of management goals and objectives for the Great Barrier Reef coastal zone, stakeholder perceptions converge and there is strong agreement on what they value as important. This finding is similar to what has been found in a study of a coastal port in Queensland (111), but contrasts to a fisheries case in Queensland where scientists and government were very similar whereas fishers rated economic values much higher (but still less than the environment) (110).

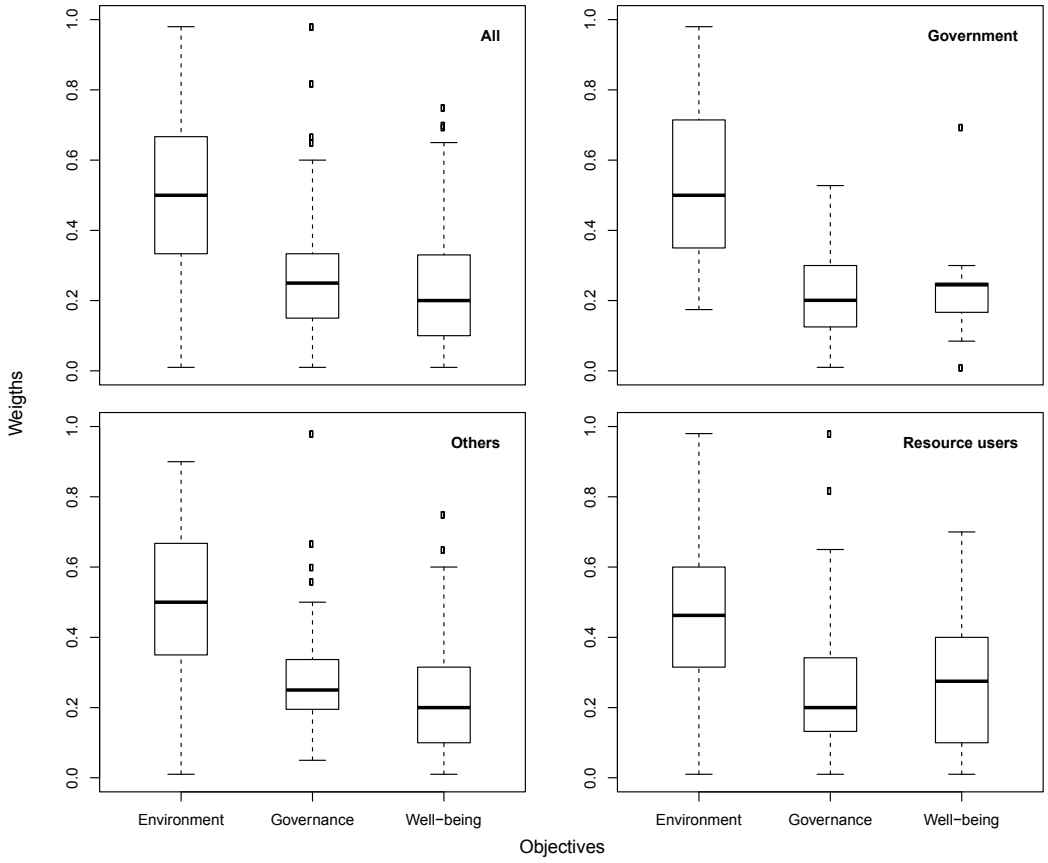


Figure 52: Goal weighting for all Mackay respondents combined ("all"), government agencies ("government"), resource users and others

When the objectives (as opposed to the goal) are considered, objectives 1.1.1 ("Reduce direct impacts of infrastructure and development") and 1.2.3 ("Reduce influx of pollutants") were the most important environmental objectives. The most important governance objective was 2.1.2 ("Increase compliance with environmental and resource use regulations"). The most important well-being objective was 3.3.2 ("Improve education, training, social infrastructure and networks") (Appendix B Fig S.2). Interestingly, the lower whiskers of the plot show that a zero rating is included in at least one of the respondent's answers in many of the goal and stakeholder combinations. Equally, the most highly weighted goal ("Environment") has the largest range. This highlights a diversity of opinion. If the outliers are included (Appendix B Fig S.3), there is a respondent that valued "Habitat" the highest, but this is clearly an outlier. The median score of the overall environmental goal consistently shows similar values for all the objectives within that goal, rather than the score being dominated by a single high or low score for an objectives i.e. people value all the objectives within the goal rather than only a few.

10.3.4 MANAGEMENT STRATEGIES

The RG selected seven topics relevant to coastal zone management. These were:

- Coastal water quality;
- Seagrass and associated ecosystem;
- Mangroves and associated megafauna;

- Inshore corals;
- Urban development;
- Port development; and
- Fisheries.

The topics are a combination of Pressures and State in the Pressure-State-Response framework (112). To the RG, combining pressures and states seemed a more natural way to categorise these topics than focussing specifically only on one or the other. Since upper catchment water quality was out of scope in the project, the RG decided to combine 'coastal water quality' and 'seagrass and associated megafauna' into a single topic. The two were seen as very interrelated.

From these six final topics, 357 non-unique management options were provided through the workshops, of which 230 fell within the category "Direct management options" and 127 as "Indirect management options". Unsurprisingly, since several groups were often working on the same topic and could mention the same "Issue" and "Management Options", there was much duplication. Identification of the "Responsible agency" produced 60 non-unique agency combinations (members may have listed several agencies for a specific action). On investigation with managers and the RG, this result demonstrated that often the RG did not know the exact jurisdiction and responsible management agencies, which resulted in misconceptions or false expectations about 'who' is supposed to manage coastal assets. The reason for this was likely to be two-fold based on discussions within the RG – members of RG did not know which agency was responsible but that there is a clear responsible agency or the responsible agency is not known given the nature of the solution. The latter was most noticeable for the options that included education campaigns.

Thirteen management strategies were derived from the 357 management options (A striking feature of this list is the breadth of impacts that are being addressed from littering – which negatively impacts biodiversity and fisheries – to incidents affecting protected species, such as boat strikes on dugongs and turtles.
Table 46). The management options are shown in Figure 53 where the outer top ring describes management strategies addressing a single impact, the inside top semi-circle represent the cross cutting management strategies, and the lower ring describes the educational campaign management. These latter strategies are aimed at integrating the outer and inner rings of the figure (the dominant indirect management option solution). In the impact analyses all the education campaigns were embedded within the 13 strategies so that their impacts were consistently addressed. The storylines that describe the background to the management strategy and the subsidiary management options are provided in Section 11.

A striking feature of this list is the breadth of impacts that are being addressed from littering – which negatively impacts biodiversity and fisheries – to incidents affecting protected species, such as boat strikes on dugongs and turtles.

Table 46: Management strategy names and their position in the conceptual diagram of Figure 53. There abbreviation used in figures are shown in brackets

Management Strategies	Position in the conceptual diagram
1. Address littering through education, legislation and operating procedures ("Littering")	Top outer ring: Littering
2. Develop and implement weed and pest management plans for regions ("PestMgt")	Top outer ring: Pests

3. Fishery campaign ("FishCampn")	Top outer ring: Fisheries
4. Legislation changes to allocation and sustainability of fishery issues ("Legislation")	Top outer ring: Fisheries
5. Management for protected species ("ProtectedSp")	Top outer ring: Protected species incidents
6. Reduce impacts of dredging ("Dredging")	Top outer ring: Dredging
7. On farm best practices ("BestFarmPrac")	Top outer ring: Farming
8. Best development practices ("BestDev")	Top outer ring: Development
9. Improving governance ("Governance")	Top semi-circle: Resources management
10. Improve resource management through better planning, assessment and regulation ("ImprvResMgmt")	Top semi-circle: Resources management
11. Improve compliance by obtaining local stakeholder input ("Compliance")	Top semi-circle: Compliance through stakeholder input
12. Transparent (to public) and coordinated monitoring reporting ("TransReport")	Top semi-circle: Transparent monitoring and reporting
13. Support, facilitate and coordinate basic research ("Research")	Top semi-circle: Basic research

The conceptual diagram was seen as a useful link between the management strategies developed by the RG and existing processes in management agencies. The project team presented the strategies to managers (decision makers that either make management decisions directly or influence the decision making indirectly) using the following steps:

1. selection of the specific impact (top outer ring) or cross-cutting topic (top semi-circle) in the conceptual diagram,
2. the list of 13 management strategies, and
3. the storylines.

Based on the strategies from the RG, individual summary documents with reference to specific assets and issues (e.g. fisheries, littering and coastal development) were also produced (not shown here). There results were specifically presented to Fisheries and Council agencies, as these were the most important target audience for the RG.

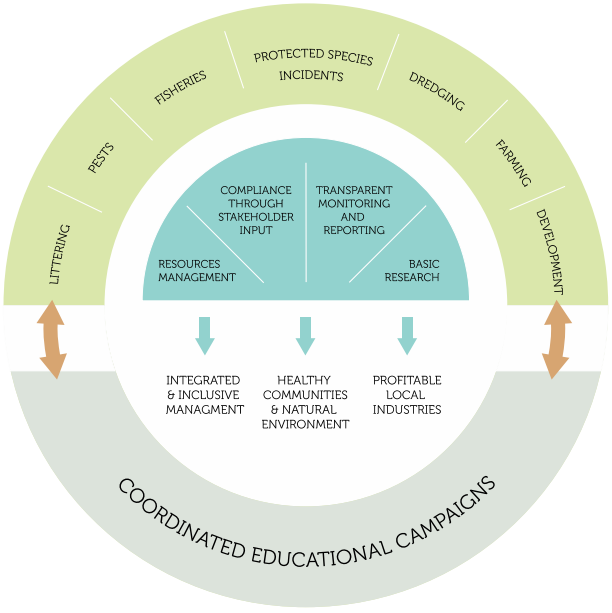


Figure 53: Conceptual diagram of the different management strategies and how they fit together

10.3.5 IMPACT ASSESSMENT FOR RELATIVE IMPORTANCE

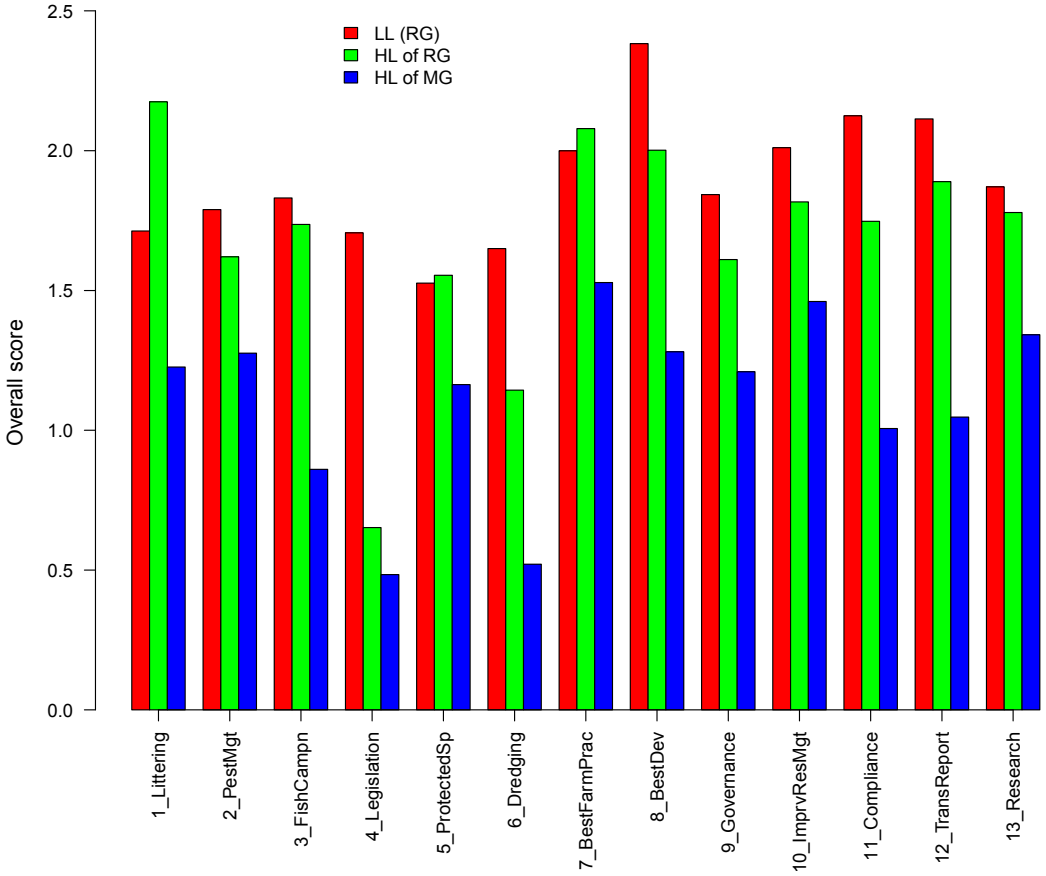


Figure 54: Average impact assessment scores (-3 to +3) without considering Confidence scores formed from i) the scores undertaken at the objective level (LL) prior to the management workshop by the RG, ii) the RG scores undertaken at the goal level (HL) at the management meeting, iii) HL scores of the managers at the management meeting.

Both the highest priority management strategy and the scale of the impact scores of the RG changed from earlier scores when they attended the Senior Managers Meeting (SMM) (although this may be confounded by the fact that they scored at the objective level prior and all participants scored at goal level at the SMM (Figure 54)). Members of the RG were contacted after the SMM to gather feedback and their overall impression was that the senior managers attending the meeting were either very negative or dismissive ("we are already doing this" or "we don't have the resources" was commonly heard). This could have influenced the perception of RG members about the effectiveness of management strategies to achieve objectives during the SMM (as opposed to their previous scoring without the managers) and thus the decrease in their impact score. The best development practice management strategy would require investment and commitment mainly by the local council representatives who were regarded by the RG as displaying the most negative attitudes. The Council members in contrast felt that RG members did not have enough knowledge of what work is being undertaken. Similarly, there is heavy investment in best farming practice in this region. Interestingly, the RG ranked littering

the highest strategy at the SMM, which is mainly managed by Council. Even though 'Council' is perceived by RG as being negative, they obviously saw that littering was a more 'tractable' strategy. Our results also indicate that the senior managers had a strong influence on the RG scores at the SMM. The managers' primary management strategy, which was of lesser importance to the RG prior to the meeting, became their second most important strategy in the course of the meeting. Of course, the method does not allow testing whether or not the RG influenced the managers, but the fact that some action, especially on fisheries compliance, was taken subsequently is indirect evidence that the engagement process between a local community group and managers also influenced managers' attitudes.

Similarly the impact assessment between the RG and managers was also quite different. Manager's impact scores were lower than that of the RG, thus managers consistently scored much less optimistically than the RG. Managers also valued different strategies to the RG. The highest (i) and second highest priority (ii), and lowest priority (iii) strategies, respectively were:

1. For managers at the goal level: i) best farming practice, ii) improved resource management, and iii) changes to legislation.
2. For the RG at goal level during SMM: i) littering, ii) best farming practice, and iii) changes to legislation, and
3. For the RG at the objective level prior to the SMM: i) best development practice, ii) increased compliance and iii) management of protected species.

Adding the confidence scores did not affect the results (Appendix B).

One of the strengths of this semi-quantitative method is that it creates a structured decision making framework that allows the evaluation of management strategies against often conflicting objectives (Hajkowicz, McDonald and Smith (113) and Dichmont, *et al.* (104)). In these two referenced cases, the trade-offs were usually identified. However, in this case neither managers nor RG members were able to identify trade-offs at the goal level at the SMM (Figure 55) and at the objective level at the RG meeting (Appendix B Fig S.5). This means that respondent were unable to identity trade-offs and felt that each management strategy would be of overall benefit against each objective. This contrasts to that found in Dichmont, *et al.* (104) which used a similar method, where people identified both negative, neutral and positive impacts for each management strategy. Although it is not clear exactly why this happened in this case study, one possibility is that the funding source for a strategy is not clear given the complex nature of coastal management. Similarly, the social impacts are unclear given the number of users in the area, but in this case study only one RG respondent provided negative impacts against some of the objectives (not provided for confidentiality reasons). Clarity on who should bear the cost and the trade-off are not easy to articulated, e.g. which Council activity would not happen if a strategy were adopted. This seems to be the case even for the managers.

Throughout the process it was observed that there is an implementation gap between what managers think they are achieving on the ground and what RG members perceive is actually happening. When this was discussed over several meetings with the RG, at the senior manager's meetings, and with managers separately, this gap seems to be due to both:

1. Community members not being fully aware of what activities are being undertaken in the area (and more subtly what activities are being rejected through approval processes), and
2. Observable issues, which are known by locals living in the area (and several of these were shown to the research team) but not necessarily known by managers. This was often due to lack of compliance and decreased investment in compliance spending.

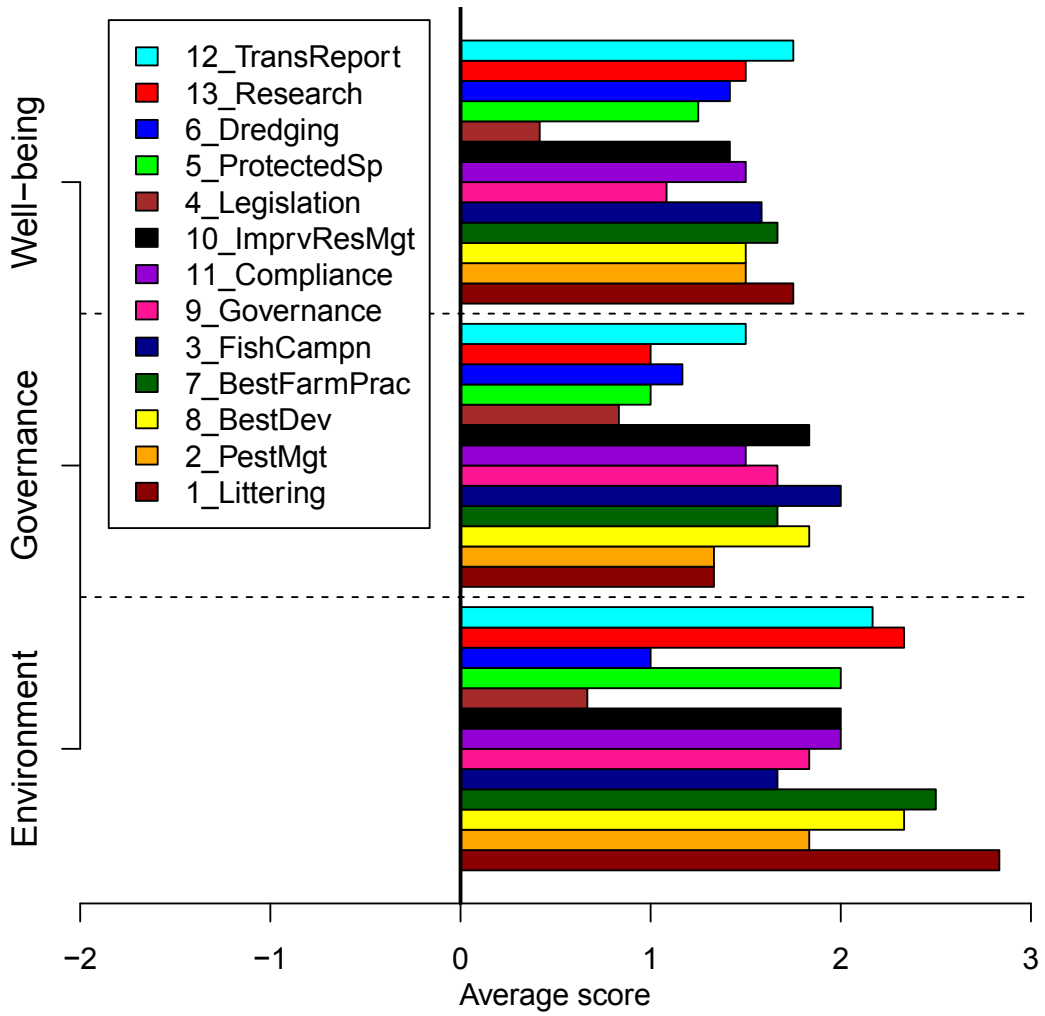


Figure 55: Average impact score of each management strategy for all participants that attended the senior manager's meeting against the three goals

10.4 Conclusions

When well informed, the results show that a community group can come up with realistic management strategies. Embedding managers in the process of developing management strategies is essential, but extending these strategies to senior managers should occur much earlier in the process to ensure greater take-up and acceptance of the output by senior managers. The RG volunteered more than 80 hours of their time per member to provide valuable local input to regional management. Providing the RG access to experts in the topic areas (also as

volunteers) meant that management strategies were well informed and thought out. Undertaking a structured process meant that overall objectives, and their relative importance were defined. Impact assessments of the management strategies also highlighted the relative priorities of different stakeholders. An added benefit of undertaking this approach was that the more controversial aspect of adaptive management, developing management strategies, occurred quite late in the process when the RG knew and trusted each other, and a clear articulation of the different values they might hold through the objective weighting process built greater mutual understanding and respect for others opinions. One weakness of this approach is that it did not articulate the trade-offs between different objectives and goals well – although this was discussed during the process, it was not resolved, even by senior managers. In contrast to single use examples, such as fisheries, defining costs are extremely difficult both in terms of scale and governance location. This seems to be a characteristic of complex socio-ecological systems such as the management of the coastal zone.

The gap between the RG and managers is important and demonstrates the need for a two-way communication approach for regional management – to obtain on-the-ground feedback from locals and to provide locals with some context of current activities. This is perhaps the most important value of this work. The approach used is very practical and produces a locally important outcome by following the adaptive management cycle with input from the community in a structured setting, especially while highlighting heterogeneity in stakeholder groups' perceptions and, through communication, achieving an agreed upon future direction.

11 Storylines for Management Strategies

11.1 Storyline 1. Address littering through education, legislation and operating procedures

In the Mackay region littering can be either through carelessness, such as plastic bags flying from boats on rough seas and security helmets and pieces of coal falling into the sea, or deliberate, such as discarding of plastic bottles, cigarette butts, and bags on land and in coastal waters.

Littering affects habitat amenity and impairment, and also leads to deaths of iconic species.

Littering occurs because of people's indifference about the effects of littering on the environment. Therefore behavioural changes are necessary to deal with littering in Mackay.

11.1.1 PROPOSED ACTIONS

Education program to change attitudes of society toward littering.

- Build from educational campaigns focusing on littering from organisations such as Mangrove Watch (http://www.mangrovewatch.org.au/) and Eco Barge Clean Seas (http://www.ecobargecleanseas.org.au/).
- Enhance and focus the Reef Guardian Program of GBRMPA to encourage littering educational campaigns at schools and with Council.
- Develop a regional report card system in the Mackay region that also includes littering as an indicator, which will be a valuable educational resource.
- Develop signage showing connection of rubbish impact on reef – stencils on drains, green waste signs.

Legislation changes.

- Establish higher fines for those caught littering.
- Incorporate retrofitting gross pollutant traps in planning and development frameworks.

Better design of industrial and government operational procedures.

- Make littering explicit in industrial management principles and design procedures to reduce littering during activities (e.g. security hats falling during works in the jetty of coal terminal).
- Implement procedures to manage littering found in the Water Quality Improvement Plan.

Increase resources for compliance.

- Increase funding to Marine Parks and police for compliance patrols to stay longer periods at sea for littering.

Implement waste management strategies.

- Enforce adequate signage on boats on the location of rubbish bins and responsible litter disposal.
- Encourage green waste recycling.
- Reduce plastic bag usage through education and campaigns.
- Undertake stormwater studies to identify priority areas for Gross Pollutant Traps (GPTs) retrofitting/installation and build into strategy.
- Develop an asset register of GPTs and WSUDs, and undertake an analysis of their efficacy.

Targeted campaign about adequate littering in fast food shops.

- Include message about importance of responsible disposal of packaging in fast food advertisements (social media, TV, radio, print media).
- Undertake TV/radio advertisement about responsible rubbish disposal and the usefulness of composting as an alternative, where applicable.

Custodianship.

- Continue promoting attendance at national clean-up days.
- Undertake regular beach clean-ups with volunteers and schools to remove litter/debris from the coast.
- Continue the GBRMPA Future Leader Eco Challenge program that encourages students to participate in projects about sustainable living and environmental protection.
- Promote programs such as 'adopt a beach', for roads, parks, and drains to encourage individuals or groups to regularly clean particular areas in the Mackay region.

Campaigns to report illegal littering.

- Undertake a 'Name and shame' campaign, where names of people caught in illegal littering are listed in local newspapers. Alternatively, the number of people caught (instead of names) can be provided to newspapers on a regular basis.
- Promote the DEHP website for reporting illegal dumping: http://www.ehp.qld.gov.au/waste/report-litter-illegal-dumping.html.

Produce education newsletters and editorials about adequate disposal of rubbish.

Assign a Council waste officer to go to schools and organise tours about how the Council manages littering. For example, display litter collected in gross pollutant traps and display information about how rubbish is recycled at the library.

11.2 Storyline 2. Develop and implement weed and pest management plans for regions

Introduced pests (weeds and animals) affect the abundance and composition of native species, which leads to ecosystem degradation resulting in habitat loss and impairment.

11.2.1 PROPOSED ACTIONS

Identify and agree on management options to deal with weeds and pests that is supported by cost/benefit analysis for options.

- Work with farmers or other land holders to understand how weeds can be managed on their property.

Establish pest surveys and monitoring programs.

- Undertake an analysis of which species occur locally, if they are spreading and to where, and how they are affecting the environment for more effective monitoring.

Develop and implement regional weed and pest management plans while learning from existing programs.

Improve soil health by re-using weeds.

- Replace present weed control with more environmentally friendly methods, for example weeds can be used to re-mineralise the soil (medium to long-term) as most weeds, especially water weeds, are a very beneficial addition to compost.

Decrease use of chemicals.

- Reduce the usage of pesticides/herbicides.
- Follow guidelines from Water Quality Improvement Plan.
- Burn the weeds to ashes (peppering) and use the ashes as a spray.
- Implement effective biological control, including micro-biotic control (not just bugs).
- Understand ecosystem impacts from pest management to identify unwanted flow on effects.

Follow established guidelines and management plans (NRM, GBRMPA).

- Targeted equipment for delivery.
- Big companies (AIMS) to work with business.
- Use a collaborative approach to control weeds: 'not point the finger'.

11.3 Storyline 3. Education – Best development practices

Coastal urban, industrial and aquaculture development are causing ecosystem degradation in the Mackay region through sediment runoff and reducing ecosystem connectivity. There are established and effective practices that can minimise effects of development on ecosystems, but in Mackay wide knowledge about these practices is limited.

It is necessary to change people's behaviour and attitudes about new development practices. Education about best development practices is therefore essential to change people behaviour and reduce impacts of development on inshore biodiversity and fisheries.

11.3.1 PROPOSED ACTIONS

Initiate education campaigns.

- Inform developers and fishers about existing legislation in place to deal with development impacts on inshore biodiversity and fisheries.
- Tell the population the importance of sustainable and nutritious sources of food.

Use social media (e.g. YouTube, Twitter, Flickr) in education campaigns.

- Demonstrate the effectiveness of using alternative transport for commuting and other purposes so as to reduce development pressures (e.g. roads, hard infrastructure),
- Demonstrate effectiveness of Parkland and drainage reserves to reduce impacts of development/runoff.

Improve knowledge feedback to 'improve' best practices over time.

- Understand whether and how practices and ideas from places with different climates could work in Mackay.
- Create conditions for groups to share data and knowledge and provide feedback to each other.
- Establish research programs based on better monitoring and sampling to identify whether or not management actions are effective. Consider linking with existing surface water quality monitoring program from NQBP.
- Identify State Planning Policy objectives that are relevant to the region and investigate how these could be implemented.

Commission flood studies to identify areas at risk and articulate to public for inclusion of local knowledge.

- Promote knowledge on the role that low lying flood prone areas play in both the management of flood impacts as well as their environmental importance in ecological productivity i.e. fishery spawning and recruitment.

- Consider using freeware tools easily accessible by the community, such as Google Maps and Google Earth, to show areas at risk from floods and inundation.

Undertake education campaigns within different sections of the Mackay Council and link to successful programs in other Councils.

- Educate Council staff about successful systems used elsewhere (e.g. Brisbane/Gold Coast), such as Water Sensitive Urban Design[1], keyline planning[2], wetlands bio-retention, sediment basin, grass swales, and vegetated drains to improve water quality. Mackay Council have established sediment control measures in Mackay as part of State Planning Policy and it would be beneficial to improve knowledge about other options available.

Develop an asset register for handover of infrastructure to Council from developers.

- Create an asset register of infrastructure passed on from developers to Council. Developers build infrastructure in new developments to reduce impacts on the environment. After a couple of years developer hand-over this infrastructure to Council who maintains them. At the moment the Council does not have the necessary information to know exactly which infrastructure was passed on from developers and the asset's condition.
- Investigate alternatives to maintain infrastructure built by developers and handed over to Council to minimise impacts on ecosystems. An asset register would be beneficial to assist Council to adequately budget to maintain such infrastructure.

Target Australian Government water quality initiative program to develop projects to enhance water quality in waterways of Mackay.

Use water quality offset contributions to mitigate pollution from developments.

[1] Water Sensitive Urban Design (WSUD) is about integrating water cycle management into urban planning and design. It looks to manage the impacts of stormwater from development.

[2] a technique for development of urban and rural landscapes that considers the topography to build infrastructure (hard or green) to maximise the beneficial use of water resources.

11.4 Storyline 4. Education – on farm best practices

In Mackay, coastal farming is important. Some farms in the lower catchments are even surrounded by suburbs as Mackay has grown in size. Sediment, nutrient, pollutant and chemical runoff from farms can affect fisheries and biodiversity in the reefs of the Mackay region. In recent years farming practices were improved in Mackay, which reduced runoff to coastal waters, but on-farm practices can still be improved.

The main causes of farm runoff are: a) the agriculture activity itself which requires land clearing and use of chemicals, and b) lack of knowledge about (i) dosage of chemicals and (ii) on-farm best practices to minimise runoff.

11.4.1 PROPOSED ACTIONS

Continue to provide individual farm and crop specific training to promote best farming practices.

- Promote information on target spraying of chemicals and/or bio-inputs (spray at the right time).
- Promote the use of cane trash blanketing and its conversion to humus.
- Establish buffer zones in crops to minimise spray drift and investigate the optimal design of such buffer zones, which includes minimal maintenance.
- Promote farm and crop specific tractor traffic management to reduce soil compaction.
- Promote nutrient management, which is a technique to manage application, timing and quantity of nutrients in crops.
- Provide written advice on the best local procedures and rates of chemical use (e.g. diuron).

Encourage farmers to learn from/through stories.

- Identify and promote 'champions' to increase community engagement, and collaboration between farmers, NRM and government to achieve water quality targets.
- Relay stories in magazines and forums about lessons learnt from using best farming practices (e.g. costs and effectiveness of practices used to reduce farm runoff).
- Use Reef Guardian program to encourage farmers to learn from each other.
- Identify or establish farms that use biological or other environmental friendly methods to highlight innovative agriculture.

Implement the Water Quality Improvement Plan (WQIP).

- Use the WQIP as an educational tool to farmers as it provides valuable and clear guidelines, measurements and targets to be achieved, and also potential actions that farmers can use to reduce farm runoff.

11.5 Storyline 5. Education – fishery campaign

In Mackay, high numbers of recreational fishers, driven by the mining sector, have increased fishing effort. This growth in number of fishers, combined with greed and disrespectful behaviour of some individuals, has led to unnecessary competition and conflicts between commercial and recreational fishers.

Existing behaviour of some fishers toward each other and the environment, in addition to a reduction in compliance presence, have also led to illegal activities by fishers, which affects fishery resources and sustainability in Mackay.

The present situation of narrow research funding focusing on iconic species (rather than the broader suite of species of interest to this sector) is also an important issue that needs to be addressed to maintain long-term sustainability of a range of important fishery resources in the region.

Changing behaviour of both commercial and recreational fishers through educational fishery campaigns is therefore paramount to reduce conflicts and competition between and within fishing sectors. It is expected that these campaigns will ultimately lead to improved fishery resources and sustainability.

11.5.1 PROPOSED ACTIONS

Promote a commercial fishery open day.

- Organise a day where the general public can see operations of commercial fishers (boats, shops) and the importance of the sector to the local community.

Educate public, especially youth, about the need for responsible resource allocation.

- Start education programs at schools about the importance of seafood and fishing (e.g. health and nutrition).
- Educate fishers and the broader community about the need for different allocation for different fishing sectors as a way of reducing competition for fish resources.
- Undertake school programs to expose students to both commercial and recreational fishing and their importance to society.

Educate the recreational sector and public about the commercial fishery.

- Use TV advertisements and other media campaigns to highlight:
    - Importance of commercial fishers to the community (e.g. health/nutrition).
    - Value of good behaviour of fishers.
    - Required clearance of 150m from commercial fishing boat.
    - The meaning of and reasons for restrictions in yellow zones.

    - Rules about illegal fishing, especially the consequences of buying from the black market.
- Educate recreational fishers about the extent of fishing controls in place for commercial fishers e.g. bans on commercial fishing on weekends as a way of minimising contact between commercial and recreational fishers and thus reducing conflicts.

Educate fishers about best fishing practices.

- Set up signs at boat ramps about good behaviour together with some local fishing information. Regularly maintain these signs as they are often vandalised.
- Use social media to present information about best fishing practices (species ID, season, sizes), but enhance to discuss respect of each other.
- Make up to date brochure/booklets with fishing rules more available and downloadable.
- Enhance the use of species ID cards with boating patrol.
- Enhance patrols to also educate commercial fishers so as to create a positive experience.
- Provide written communication to licence holders if management changes
- Promote FishWatch hotline 1800 017 116 to report illegal fishing activities.

Promote change in cultural attitude.

- Emphasise that recreational fishing is about enjoyment through, for example, the use fishing shows and the Reef Guardian program.
- Use regional radio for local stories about enjoyment in recreational fishing and importance of commercial fisheries.

Promote environmental branding to sell and market commercial products that are sustainably harvested.

Consistent communication campaigns.

- Re-emphasise existing communication campaigns directed towards more inshore and allocation issues using facts about Mackay, the reasons for recreation fishing (enjoyment) and the role of fisheries for the people and the economy.
- Link communication strategies between GBRMPA and QDAFF to send consistent and harmonised messages about regulation, management and best behaviour.
- Improve targeted advertising on the above fishing messages by getting local support through interviews of local fishers and other community members on local radio programs.
- Simplify ID discussions in web sites, etc.

Improve coordination between local fishers and managers.

- Create clear channels of communication.

Modify Illegal fishing and compliance risk assessment.

- Modify risk assessments so that it includes local knowledge and environmental characteristics (e.g. seasonality of fishing).
- Enhance the Fish-watch hotline so that it:
    - Links to local offices in time.
    - Enhances the DAFF compliance risk assessment in order for compliance activities to be better focused within their existing resources.

11.6 Storyline 6. Education – improve governance

Mackay is a growing city influenced by many different activities such as farming, fishing, shipping, mining tourism and recreation in its conservation areas. It has experienced significant expansion in the last 50 years and this is likely to continue in the future. The expansion from rural to urban and industrial sectors has created cumulative pressures on the region, through factors such as increased sediment runoff, construction and land- and resource-use. This requires governance that is cohesive and consistent between different management agencies. Although progress has been made, much improvement is still possible.

11.6.1 PROPOSED ACTIONS

Break down silos across the groups in Council

- Move the coordination of urban water runoff management around groups.
- Use better planning within existing staff.

Ensure development is well planned and infrastructure is well catered for.

- Take advantage of unfavourable economic conditions and low development pressure to better plan for development and infrastructure.
- Use existing network of roads to integrate new developments: recognise 'next door' 'down the road' development.
- Encourage the use of paths, walkways and alternative modes of transport to reduce traffic and the need to build new roads. Promote the use of Council online system for car polling (http://www.mackayregioncarpool.org/).

Ensure funding is available to support community groups to do on-ground work.

- Establish community-based programs to plant trees, maintain vegetation, and promote the use of green areas as part of the local lifestyle.

Encourage evidence-based decision-making process supported by monitoring programs and research.

- Secure long-term funding to establish a monitoring program to measure effectiveness of existing actions (e.g. artificial wetlands, gross pollutant traps) in place aimed at improving water quality.
- Establish research programs to investigate alternative solutions and their impacts on regional water quality.
- Establish partnerships between Mackay Regional Council and research organisations to reduce costs of monitoring and reporting.
- Pilot a project to demonstrate effectiveness of WSUD in developments.

Achieve holistic outcomes from actions (e.g. water quality, aesthetics, biodiversity).

Encourage regional learning.

- Identify and disseminate examples of cost-effective practices from around the GBR region that are known to improve environmental conditions.

Provide education material to students (e.g. engineering, planning, natural resources management) on existing understanding about downstream impacts of management actions and their consequences on natural systems.

11.7 Storyline 7. Improve compliance by obtaining local stakeholder input

Existing rules and legislation are effective to deal with fisheries resources and habitat loss associated with fisheries activities, and industrial and coastal development. However, these rules and legislations are not always enforced, which may increase illegal fishing, sale of products on the black market and increase runoff from developments. These illegal activities can affect fishery resources and sustainability, and degrade or impair coastal habitats.

The current small number of compliance staff within governments poses a big challenge to resource and habitat sustainability. For example, illegal fishers follow the movements of compliance staff and know where they are, so they can break the laws without being caught. It is necessary to improve compliance through local stakeholder input on risk areas so compliance efforts can be better planned and tailored to local conditions even within existing budgets.

11.7.1 PROPOSED ACTIONS

Encourage training of compliance staff.

- Promote education of compliance staff as they must be educated and diplomatic when dealing with the community to gain support. This is important because most people comply with legislation and courteous behaviour provides greater support of compliance activities.
- Improve compliance officer training in the legislation they are enforcing such as local species identification and gear specifications.
- Provide feedback to managers on how their compliance staff interact with the public.
- Balance compliance to local risk rather than centred on a specific sector e.g. commercial fishery.

Enforce existing rules/legislation.

- Ensure compliance risk assessments include local knowledge on key compliance priorities across all fisheries in the region.
- Identify how State and Council could better work together in terms of jurisdictions so that resources are optimised. For example, Council sometimes is better positioned to check compliance of State developments, but Council has no jurisdiction on State developments (e.g. roads).

Increase the number of compliance staff in State Government.

- Direct funds from other areas to increase number of compliance staff in State Government. In Queensland State it is not possible to have self-funded compliance staff positions as no incentive-based positions are allowed.

Establish and promote a community-based reporting system.

- Establish a reporting hotline for Council, similar to FishWatch, which could be used for reporting people that do not comply with legislation. The community reporting system can be done via advertisement of hot lines on the council website. This action needs to consider costs of an officer on call after hours (nights, weekends), plus costs associated with mobile phone and maintenance of website compared to the benefit of potentially increased compliance.
- Similar to already undertaken by some agencies, publish names of non-compliant people in the newspaper.

Increase resources for compliance as a whole, not only number of staff, but also boats, cars, etc. (people and resources).

11.8 Storyline 8. Improve resource management through better planning, assessment and regulation

Management processes and regulatory frameworks are disconnected and vary between Commonwealth, State and local governments in the Mackay region.

Disconnected and inconsistent management frameworks results in multiple and inconsistent approvals for activities, which reduces (i) environmental protection, (ii) fisheries resources and sustainability, (iii) habitat amenity, and (iv) species sustainability, and increases (i) habitat loss, degradation, and impairment, and (ii) death of iconic species.

11.8.1 PROPOSED ACTIONS

Maintain long-term master plans for Ports with public input to provide certainty.

- Identify areas for Port expansion/decline and focus management on these areas.

Improve existing public consultation processes to guide assessment of development applications for approval by encouraging people to participate.

- Understand where communities want to concentrate urban development.
- Provide clearer consultation and communication strategies for major processes such as the Coastal and Inland Flood Hazard Adaptation Study to be made public in 2015 as the study will affect insurance and bank loans for particular areas within Council.

Rather than create new legislation, enforce existing legislation.

- Enforce existing legislation within government and in the public especially those that deal with impacts of population growth, coastal development and aquaculture runoff on habitat loss.

Break down silos across the groups in Council.

- Create an environment within Council that promotes cultural changes via corporate values to break down existing silos, such as moving the coordination of urban water runoff management around groups.

Apply more widely existing urban design principles and soft solutions to reduce impacts of population growth/development on habitats.

- Further use the Internal WSUD (Water Sensitive Urban Design) working group in Council to identify problems and how they will be addressed to allow more to be done in terms of better understanding effectiveness of wetlands, bio-retention, sediment basin, grass swales, gross pollution traps (GPT), vegetated drains, and establishment of drainage reserves and how to implement these in the Mackay region.

Create an asset register for handed-over infrastructure from developers to Council.

- Provide training of this register as well as requirements regarding the ownership of and responsibility over the assets to Council departments.

Use existing policy instruments to protect high value areas that are of local environmental significance.

- Examples include the GBRMPA Emergency Special Management Area (SMA), which can be used to protect specific areas within existing zoning. The SMA can use feedback from local people, maps, and measurements to provide for the closure of a specific area, such as the seagrass meadow at Hilborough identified by the RG.

Improve connectivity within the Mackay catchment.

- Identify the type of bund walls and the need to improve connectivity through fish passages using basin assessments.
- Use offsets to address lack of connectivity due to construction of bund walls
- Maintain mangrove community links to improve connectivity along the coastal and estuarine fringe.

Create an across Commonwealth to local governments integrated 'one stop shop' for applications of permits and assessments.

- Develop an on-line application tool that is hierarchical depending on risk. This should enable self-assessment prior to lodging development/approval applications. It should be a mechanism to deal with regulatory burden and minimise duplication and inconsistency of approval processes. This approval process should still uphold legislative, societal and environmental and values.

Improve decision-making process.

- Use fact-based decision-making.
    - Fund the implementation a monitoring program to measure effectiveness of management actions (e.g. installation of artificial wetlands) aimed at improving, for example, water quality. This will allow management agencies to justify further investments.
    - Fund and undertake research about alternative solutions to improve water quality and their impacts to support decisions.
- Consider local knowledge in decision-making.
- Apply lessons learnt from elsewhere such as examples of cost-effective practices from around the GBR that have been known to improve environmental conditions.
- Achieve holistic outcomes from actions by considering cumulative impacts (e.g. water quality, aesthetics, biodiversity, economic).
- Improve coast-wide understanding of cumulative impacts related to multiple dredging and seasonal river runoff in the Mackay area.
- Move towards a code of practice that can be either regulatory or non-regulatory.
- Pilot project to demonstrate benefits of WSUD in developments and justify further investments.

Investigate institutional instruments to protect the specific seagrass meadow identified by the RG.

- Investigate the GBRMPA Emergency Special Management Area (SMA) instrument to protect specific seagrass meadow in Hillborough Channel as it can use feedback from local people, maps, and measurements of extent of seagrass meadows to provide for the closure of a specific area. Local groups, such as LMAC can provide the evidence of the importance of the seagrass meadow to GBRMPA who will then investigate and make the decision about the closure of the area.

Establish partnerships and secure funding to improve connectivity.

- Use existing studies to identify, prioritise, and budget for construction of fish passages in the Mackay region. Council and Reef Catchments are working together to establish fish passages in areas identified in the Fish Barrier (Culvert) report. Needs further funding to speed up the process as priority areas were already identified. The Partnership between Reef Catchments and Council is a good example on how to act together towards a common goal.

Establish partnerships with research organisations to reduce costs of monitoring and reporting.

- Council can establish partnerships with research organisations such as CSIRO, Universities and AIMS in a collective effort to get financial and human resources to support monitoring programs.

11.9 Storyline 9. Legislation changes to allocation and sustainability of fishery issues

Management controls on some species are through size and bag limits for recreational fisheries, and gear and catch restrictions for the commercial fishery. In addition to these controls, spatial and temporal restrictions are also used to protect biodiversity, restrict gear types in certain habitats, protect spawning species and allocate effort between the different sectors. Some of the existing legislation is inadequate for the appropriate control of some species and habitats, which in combination with illegal fishing activities, increases effort on fishery resources (with negative long-term consequences on fishery resources and sustainability) and degrades coastal habitats in the Mackay region.

11.9.1 PROPOSED ACTIONS

Revisit bag and size limits

- Tighten and simplify bag limits especially slot limits for iconic target species in similar groups (e.g. flathead an grunter).
- Apply bag limits to the boat not just individuals; for example having a boat limit that is twice the individual limit.
- Reduce upper slot size limits especially for king salmon and barramundi.

Tackle illegal fishing.

- Increase the recreational fishery use fund (RUF) to enforce good rules (e.g. enforcement of legislation against illegal fishing activities).
- Increase value of fines for illegal fishing so as to create a disincentive to fish illegaly.

Promote flexibility in management to incorporate regional changes in permits, legislation, and zoning for trawling.

- Move the existing seagrass closure within Hillsborough channel to a nearby site as the seagrass bed has relocated.
- Provide input to the Queensland fishery review to promote the importance of local input and regional management in fisheries.

11.10 Storyline 10. Management for protected species

Mackay is well endowed with a large number of iconic species, many of which are also declared as threatened, endangered and protected species. Every year protected species such as dugongs, turtles and dolphins are killed. They can be accidentally caught in fishnets, illegally fished, or stricken by boats, causing loss of biodiversity in the Mackay region.

Indigenous fishing of protected species requires further investigation given issues related to (i) non-indigenous people claiming to be indigenous and therefore illegally fishing indigenous resources, and (ii) potential impacts of traditional fishing on stocks. However, since there was no indigenous representative in the group there were no management actions formally addressing this topic.

11.10.1 PROPOSED ACTIONS

Review the use of offshore gillnet use in Dugong Protected Area B.

- Especially with respect to bottom set nets and the use of mechanical reels allowing for shorter soak times.

Trial dugong friendly nets in Dugong Protected Area B.

- Conduct trials of dugong friendly nets that can inform industry about their use specific to the local situations.
- Investigate and collate existing industry changes to fishing gear that may already reduce capture of dugongs.
- Use Reef Guardian Program to help improve net practices with industry.
- Identify champion in local area to trial new gears to reduce deaths of protected species to see what works.

Use lead core rope and refine float line loop to reduce entanglement potential.

Trial new propeller designs to protect protected species.

- Trial folding up propellers (soft plastic propeller designed not to cut animals/people in accidents – won invention of the year prize).
- Trial other methods of modification to the propeller to reduce turtle strikes.

Create education campaigns to reduce accidental deaths of protected species.

- Use Reef Guardian program to facilitate education campaign about focusing on improved fishing practices to minimise accidental deaths of protected species.
- Educate population about new type of propellers to minimise injury/deaths from boat strikes – Develop a funding program to test the kit.

11.11 Storyline 11. Reduce impacts of dredging

Dredging is an important activity to maintain access to Ports, which benefits the regional economy. Dredging directly removes species, and destroys or impairs habitats. It also re-suspends sediments, which increases turbidity, reduces light penetration and smother benthic organisms (e.g. corals, sponges). Sedimentation and turbidity affect species composition and abundance and may also alter habitats such as coral reefs.

Impacts of dredging can be reduced to improve environmental protection and minimise habitat loss.

11.11.1 PROPOSED ACTIONS

Thorough and transparent assessments on locations for dumping spoil.

- Decision on disposal sites (inshore versus offshore) needs to be transparent to the public and thoroughly investigated.
- Use dredge spoil to create artificial islands/reef (e.g. Dubai).
- Time dredge operations to make sure it doesn't coincide with other dredging operations nearby.

Avoid the need for dredging.

- Investigate options to avoid/minimise dredging.
- Use a barge to transport the coal to the boat off shore.
- Consider costs, location, environment, logistics of alternatives to dredging, such as barge to transport coal to ships.

Apply strategic management control systems to dredge when water clarity is low.

- Identify a trigger to control how long dredging can run – monitor turbidity while dredging is underway and use data to identify such trigger points.

Research in land options for dredge spoil (although local options are limited)

- Use modelling and cost benefit analysis to investigate options for depositing dredge spoil on land not in water (e.g. industrial estate in Mackay Harbour).
- Investigate the use of spoil to back fill holes from the mines – train is empty on return.

Undertake an education and information program targeted at the local community to explain the activities of the Port and how these are being managed.

- Provide greater transparency to the community by providing greater access to information and data collected by the Port.
- Undertake a science program that uses the monitoring data for modelling to investigate Port and cumulative impacts.

Remove the existing window for dredge spoil dumping timing and investigate the optimal window time design that fits the local conditions adaptively but also consider the Port, environment and other users' needs.

11.12 Storyline 12. Support, facilitate and coordinate basic research

Predicted population growth in Mackay and associated expansion of fish markets (more people buying fish) could threaten fishery resources and sustainability. More coordinated basic research is therefore needed to increase fishery sustainability, but this is particularly challenging because current funding for research is small, highly competitive, and focuses mainly on iconic and high profile species. Basic research on non-iconic species is also important because these may become important in the future.

11.12.1 PROPOSED ACTIONS

Undertake more basic research on:

- Fish aggregation areas (e.g. king salmon).
- Species that aren't presently iconic or high profile as these are increasingly targeted and little is known about their biology, distribution and the fisheries' catch and effort. These species may become important in the future (e.g. abalone in WA, grunter).

Fund research to support decisions about how to allocate resources to different sectors and how to realistically apply it.

Look into stocking of marine species and evaluate the role of existing stocking contributions to catch.

Better understand spawning size of the grunter species as they are heavily targeted in North QLD.

Facilitate a process where local input could be obtained to influence research priorities of the QLD Fisheries Research Advisory Board (FRAB), which needs to consider local views:

- Write up a submissions for next FRAB call, which incorporates local views from Mackay, focusing on the following legislation changes.

Revisit bag and size limits:

- Tighten and simplify bag limits especially slot limits for iconic target species in similar groups (e.g. flathead an grunter).
- Apply bag limits to the boat not just individuals; for example having a boat limit that is twice the individual limit.
- Reduce upper slot size limits especially for king salmon and barramundi.

Tackle illegal fishing:

- Increase the recreational fishery use fund (RUF) to enforce good rules (e.g. enforcement of legislation against illegal fishing activities).
- Increase value of fines for illegal fishing so as to create a disincentive to fish illegally.

Promote flexibility in management to incorporate regional changes in permits, legislation, and zoning for trawling:

- Move the existing seagrass closure within Hillsborough channel to a nearby site as the seagrass bed has relocated.
- Provide input to the Queensland fishery review to promote the importance of local input and regional management in fisheries.

11.13 Storyline 13. Transparent (to public) and coordinated monitoring reporting

There are several programs collecting data in the inshore coastal zone of Mackay as part of environmental licences (e.g. air quality and marine data for Port activities) and research. Collecting data is expensive and therefore often subject to IP and commercial-in-confidence contracts, which hinders data sharing between organisations and the general public. Developers are cautious in making data publicly available because it can get 'twisted' or misinterpreted depending on who is doing the analysis.

Most data and information from existing monitoring programs in the Mackay region is not easily accessible by the general public, which causes perception problems about the actual impacts of development in general.

The public needs transparent and coordinated access to monitoring reporting as a way of understanding what the issues really are and their magnitude. This is important in dealing with issues related to multiple and inconsistent approval processes, public perception and misconception, and cumulative impacts.

11.13.1 *PROPOSED* ACTIONS

Establish a report card system for water quality.

- Use a report card system with clear and consistent methods to support more transparent dissemination of information to the public.

Understand expectations and public perceptions about coastal issues.

- Run surveys with the broader community to understand their perceptions and expectations about the coast, for example with regards to the perception of communities in relation to risks of shipping in the GBR.

Promote information and data sharing with public.

- Facilitate information and data sharing between industries and with the public so as to improve management of the inshore GBR, to influence perceptions related to development and to support a more evidence-based decision making process. Knowledge sharing should be mandatory and independently managed.
- Make data sharing conditional to approval processes. The big problem involved in accessing and sharing data/information from Environmental Impact Assessments and Consultancies is related to IP and commercial in-confidence contracts.

12 Can locals affect regional management? A generic method of engagement from two case studies

Although this section has a lot of overlap with earlier sections, it is kept together here for completeness as this could also be a stand alone product.

12.1 Introduction

The ecological pressure on the coastal zone has increased with time due to population growth and the social and economic importance of these areas (1). However, successful management of this zone is important as they also contain many iconic and threatened species (such as dugongs, water birds, turtles) and also key habitats (wetlands, seagrass, mangroves). In the Great Barrier Reef in Australia, this region like most coastal zones, experience the impacts of cumulative effects, most notably nutrient, sediment and contaminants from rural and urban land sources (2). However, managing cumulative impacts can be seen as a "wicked" problem because interactions within and among the social, economic and ecological systems are highly complex, non-linear and mostly unknown, which has often led to management failure (3, 4) Science is seen as having been developed to solve "tame" problems (4).

Two solutions have been put forward to address this issue. Adaptive management involves iterative decision making, evaluating the outcomes from the previous decisions and adjusting subsequent actions on the basis of this evaluation (5, 6). If undertaken in combination with effective stakeholder engagement, these two processes form essential platforms to achieving effective environmental management, being through good information, identity, institutions and incentives (7).

In the coastal zone, governance is complex with many institutions designated to manage the system (local, regional and national) and many forms of ownership (government, semi-government, public open access, private). To some the solution is to create boundary organisations either through a non-government organisation (NGO) or a union of scientists and government institutions. Boundary organisations cross the boundary between science and government as a network by drawing on both sides to facilitate evidence based decisions (8). These organisations attempt to solve problems by meeting three criteria and providing a) the opportunity and incentives for boundary products, b) participation of actors from different sides of the boundary and c) links between politics and science (amongst others). Examples of these boundary organisations can be seen in the health sector (9) and waterways (10).

Whether attempting management with or without these boundary organisations, stakeholder or community engagement is seen as crucial to success (11, 12). Similarly the scale of management should include local input into regional management rather than only distant high level and scale management (12). Stakeholder engagement has been successfully applied in many single use applications such as fisheries. Often engagements have been through technical and management boundary organisation (13) or various forms of devolved management such as

through Territorial User Rights (14). However, moving from stakeholder engagement to community engagement has been generally not been undertaken as many scholars have presumed that these users could not self organise nor be representative (15). In this review of "self-organised regimes" their findings supported Ostrom's eight design principles of local stable common pool resource management (15).

The Great Barrier Reef World Heritage Area (GBRWHA) includes the world's largest coral reef system, the Great Barrier Reef (GBR), stretching over 2,300 km of the coastline of Queensland, Australia (Figure 56). Much of the reef is managed by the Australian Commonwealth's Great Barrier Reef Marine Park Authority (GBRMPA). Although it manages the biodiversity assets and most activities therein, fisheries and much of the coastal zone inshore of 3nm are managed by various other agencies such as the Queensland State Department of Agriculture, Forestry and Fisheries (DAFF), and local councils. There is growing interest and success in engaging local coastal communities to achieve reef management goals. NGOs have played a key role through engaging especially with the farm community (http://reefcatchments.com.au/). Although these NGOs are in many aspects boundary organisations, they have until recently only concentrated on a few impacts areas. In the coastal zone of the GBR, the community values the GBR highly (16) and as such there is a great wish to be involved in local management. It is understood that a) it is difficult to regulate all impacts that affect the GBR coast and reef so stakeholder support is essential and b) given the size of the area and its complexity, it is not possible to have both regional and local knowledge without local input. In a perfect world this would generate voluntary compliance and regulation.

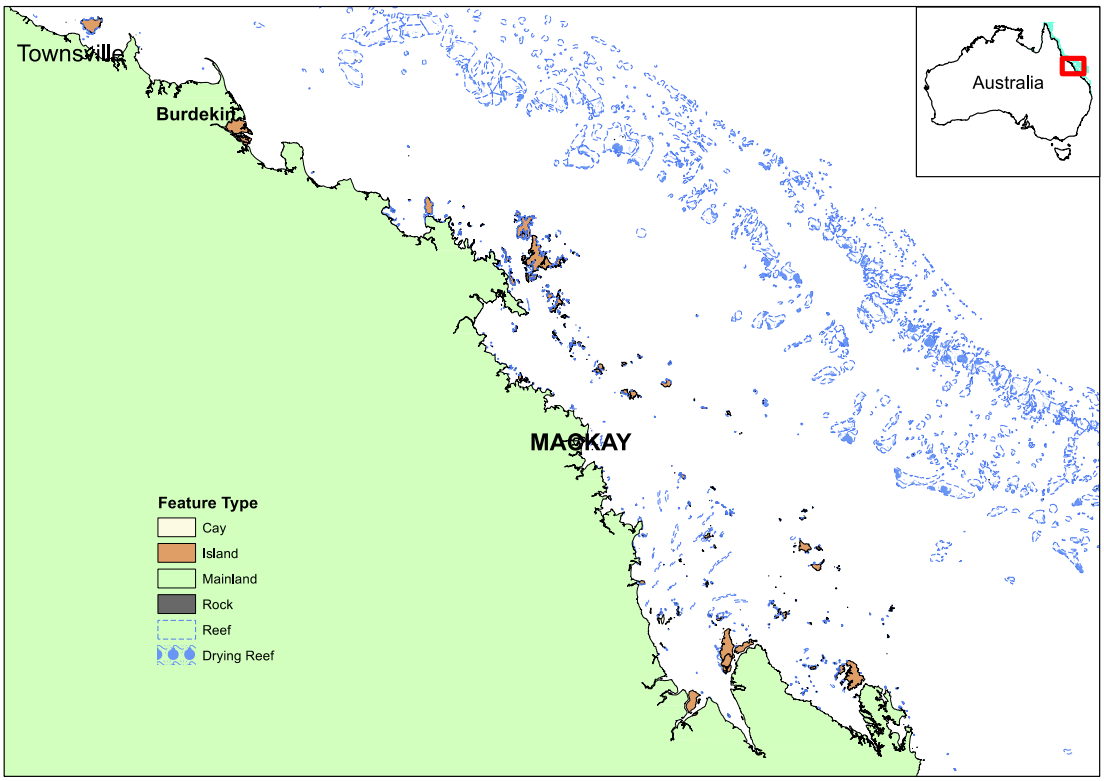


Figure 56: Case studies shown in the context of the Great Barrier Reef in Queensland, Australia.

However, the challenge is how to effectively link decisions made in the catchment by multiple management authorities with objectives that determine outcomes for marine biodiversity and fisheries productivity while including community input. In an increasingly connected community in Queensland, social media has become an increasingly useful medium to focus public opinion (for example the 2014 GetUp campaign against a port development – https://www.getup.org.au/campaigns/great-barrier-reef--3/protect-our-reef/protect-our-reef). However, these are seen as not engaging science, management and community in a non adversarial long-term framework as described in Cox, Arnold and Tomás (15). There are several case studies and suggestions of what constitutes successful engagement. A successful case study was Arsland and Cahantimur (2011) in Turkey which was based on the idea that community intelligence could be influential to the decision making process, but demonstrated that there are practical considerations with the continued community engagement including scheduling and other time commitments. Many emphasise the importance of gaining trust and respect (17), and models of engagement (18) and moving beyond simple models of linked socio-ecological systems and the perception that most resource users are the same (the "panacea") (19).

12.2 Method

12.2.1 CASE STUDIES

Two coastal regions within the GBRWHA area were chosen as case studies.

Mackay was chosen as it represented a growing city of about 167,000 people (25) and a large associated Fly in and Fly out (FIFO) community due to the local mining industry. It also has an active port, Hay Point, just south of Mackay with the main export being coal. Another major economic driver and employer in the region is sugar cane, where the cane is locally grown and refined into sugar. In terms of natural assets it has a national park, many beaches, offshore islands, inshore and offshore reefs that are part of the Great Barrier Reef. The environment is tropical with the marine environment characterised by very large tidal ranges, key habitats such as mangroves and seagrass, and threatened, endangered and protected (TEP) species groups such as dugongs, turtles and inshore dolphins.

The Bowen-Burdekin Shire has a population of about 26,000 people (25) and is approximately 60 km south of a major city Townsville (and north of Mackay) with Ayr and Home Hill as its main towns. It is a region characterised as being mainly rural with sugar cane farming its major source of economic development and employment.

These two case studies were chosen for what they have in common and also what separates them. Both case studies have in common that the rural area is mostly farming for which accelerated management activity has been directed to reduce the amount of sediment and nutrient runoff to the GBR. However, the two regions' ports are distinct in that, during the study period, a major proposed port upgrade with associated dredging in the Abbott Point area (just south of the Burdekin) was a source of conflict in the region and great controversy within Australia. Whereas the Mackay ports were well established and are presently not as controversial. The population size is also very different with Mackay having a far larger urban footprint with a growing city although this may have slowed down in recent years due to the general downturn in mining activity.

12.2.2 ENGAGEMENT PROCESS

A hierarchical system of engagement was attempted in both regions. At the highest level, a community group, the Local Marine Advisory Committee (LMAC) run by GBRMPA was already established in the region. Its charter is to advise GBRMPA on local management issues (http://www.gbrmpa.gov.au/about-us/local-marine-advisory-committees). Although the chair is elected and paid a nominal fee, the members are volunteers sourced from the community. LMACs have a 3-year term and calls for nominations are made normally to stakeholder groups, although a nominee can be an independent. There is some vetting based on what GBRMPA (or a referee) knows about an individual and their ability to contribute constructively. Membership of the LMACs in our case studies included representatives from GRBMPA, local Port and Council employees. The LMACs aim is balanced representation, although this is not always achieved. The quality of participation and 'team' output is highly variable.

Since the LMACs met every quarter with a full agenda, a sub-committee was formed and called the LMAC Reference Group (RG). This was made up of LMAC members who volunteered for the group and additional members that would cover a broader skill set from people who were previously on the LMAC. The project lead facilitated the RG meetings, with a member elected as the RG chair.

The project team included "managers" (defined as people that either directly or indirectly influence management decisions) from QDAFF and GBRMPA, and social,

economic, mathematical and environmental scientists from both State and Commonwealth agencies.

Within a few months of project engagement in the Bowen-Burdekin area, the Abbott point port controversy meant that participation was minimal. An alternative approach was undertaken described in detail in van Putten, *et al.* (114), but generally meant engaging with individuals directly and separately. Interactions between the different RG and LMAC members were minimal. In Mackay, the RG was very successful and was used throughout the process. However, the indigenous member resigned from the group due to circumstances external to the RG.

At various stages in the process (described further below) community and senior level managers' input was sought. All documentation was kept in a traceable format, i.e. iterations of all steps could be backtracked through the various meetings to its original source.

A local Mackay GBRMPA person spent enormous support and engagement time in between meetings. This support was essential and provided local continuity.

A sequence of steps were undertaken – see Dichmont, *et al.* (115) for more details:

1. Qualitative modelling (116, 117) of the Mackay coastal system was carried out (118) (both case studies). The RG was asked to list assets of importance to them in the region and the impacts on these assets. They were then asked to select their priority asset and these were modelled. An introduction on terminology and how the method works were also provided (see Dichmont, *et al.* (118));
2. A review of existing objectives from government organisations, NGOs and NRM bodies that were directly or indirectly relevant to the region was undertaken (both case studies). This was then combined into a hierarchical tree format using input from a series of workshops attended by the RG and LMAC van (108, 114); After this stage, the Bowen-Burdekin case study was dropped given the controversy around the Port development.
3. A survey of the RG, LMAC and Mackay public was undertaken to ascertain the relative importance of different objectives. Dutra, *et al.* (108) describe the analysis details and survey methods in detail but two approaches were undertaken – the recommended Analytical Hierarchical Process (42, 119) and a new Point Allocation method at each level of the objective tree and called the Hierarchical Point Allocation method (108);
4. Managers gave presentations to the RG about existing management actions that were being undertaken in the Mackay coastal zone so that they could subsequently discuss any remaining management actions that needed to be addressed for the different assets;
5. Topics relevant to the focal question of management of biodiversity and fisheries in the coastal zone were developed in session. These described both key assets (such as mangroves and seagrass) and key issues (such as development).
6. Over a period of just over 12 months, the RG undertook a series of workshops that discussed management options for these topics. Each workshop included:
    a. Presentation by an expert of background information pertinent to Mackay about the specific topic being discussed at the workshop,
    b. The RG, project team and invited expert workshopped an issues register, direct and indirect management options, and responsible

agencies for each issue (115). The discussions were held either in small groups or as a whole group, depending on the number of workshop participants. Direct management options were defined as a management action that is undertaken directly by the agency responsible for managing the issue and could include proposing legislative changes, whereas indirect management options were those that could have the same impact as the direct option, but undertaken indirectly through a non-responsible agency or the community. Issues or management options could be geo-located using a Google™ map of the study region. Relevant qualitative models were also made available.

   c. Initially, the issues list was developed separately from the management actions, but this was seen as inefficient. The meeting length was increased to half a day and all aspects of a topic were covered together as described above.
   d. The topic sequence was generally down the catchment, but most of the contentious topics (port and urban development, fisheries) were left for last.

7. The project team combined all the management options into management strategies, which were presented to the RG and subsequently modified over two workshops. In order to articulate the pathway of combining management options, the project team used the well-known United Nations Environment Program risk assessment framework known as DPSIR (Drivers, Pressures, States, Impacts and Response) (120, 121). This framework first started in a more simplified form of Pressure-State-Response – this basic version was ultimately used. The results were presented with an associated storyline for each Management Strategy that provided background and a list of the relevant management options.
8. An impact assessment was undertaken in two phases (with the analysis method described in Dichmont, *et al.* (115):
   a. The RG was asked to rate each management strategy from -3 (''considerably worse than current situation'') to +3 (''considerably better than current situation'') against the low level objectives,
   b. They were also asked to score their level of confidence in their ability to answer question a) for each objective from a score of 1 ("very unsure") to 5 ("certain") (see Supplementary material Table S.3).
   c. A subsequent workshop was then held where the RG, Mackay coastal managers and NRMs were asked to undertake the same impact assessment scoring. However, due to time constraints scores were made during the meeting against the high level goals only (although well-being was split into social and economic goals).
9. The overall priority list and final set of management strategies were provided to the RG for comment, and thereafter to the management workshop.
10. Storylines of each report card were developed that described the management strategies and actions for use by RG and LMAC members. These were made available online for the community.
11. Letters to the two management agencies most affected were also written, but drafted in language more appropriate for this target audience.
12. All documentation was always approved by RG members before release.

A review of the successes and failures of the two case studies by the project team were undertaken through questionnaires to the Mackay RG and managers. A final framework was developed for future engagement.

12.3 Results and Discussion

12.3.1 COMPARING THE CASE STUDIES

The progress of the different case studies was heavily impacted by external factors, in this case a contentious Port development proposal. The level of distrust and at times acrimony divided the volunteers from the Bowen-Burdekin RG and LMAC such that the case study did not complete the process in the area. In that context, however, it was still possible to complete the objective review and hierarchy through individual or smaller group interactions that produced a useful product. In contrast, the RG in Mackay was highly functional and delivered more than 150 hours of volunteer time (above that of the project team). Given the time and energy they put in, ownership of the output by the Mackay RG increased over the time with members controlling the final product (in terms of both content and detailed wording), which was not the case in the Bowen-Burdekin where the project team was more influential on the final product. However, despite these differences in approach the final objective trees from each case study were quite similar which allowed generic objectives to be developed.

A further issue with the Bowen-Burdekin was stakeholder fatigue in that previous studies have used several of the members for other strategy discussions especially on fisheries. There had been intensive progress in developing regional management strategies, which then led to complete breakdown and acrimony with state-wide condemnation of their product orchestrated by a particular stakeholder group with strong influence but not resident to the area. This meant that some of the members felt the new process was repeating previous work and were also worried that the end result would be the same. In reality, the Mackay case demonstrated that the result need not always end in conflict. It is argued that a rigorous semi-quantitative sequential approach is an important aspect of this success.

As the Mackay RG increased in confidence of their own value and knowledge due to access to experts, the link between the RG and LMAC became more tenuous. RG members expressed their frustration with the LMAC being perceived to discuss small-scale issues compared to RG discussion.

The successes were that:

- There was a large and highly dedicated local volunteer force within the community, scientific community and managers. The scientific input was of excellent standard with well-pitched presentations – although verbal or written communications about what was needed had been provided. Of key importance was the dedication to provide mostly local content. These presentations were very motivational to RG members and valued, and certainly influenced the way they understand both management and biophysical processes.
- There were strong links established between managers and RG members. Discussions about contentious issues did happen but debates happened in a climate of mutual respect and understanding. They also gained immense

local knowledge through visits to local examples of good and bad management practices.

However, senior management support for the uptake of the final management strategies was variable. Lack of perceived uptake by some agencies were due to:

- The RG had no broad official mandate to represent Mackay, as they were not elected which makes management action perceived as being more risky. This is related to the conundrum that there was basic resistance to change and lack of enthusiasm to undertake the effort that would be required to effect any change – the managers needed to be open and or empathetic to a different form of input given that a community group by nature cannot be representative of a large region.
- Managers' perception of what was happening on the ground was widely different from that of the RG. This was due to a mixture of managers not being aware of local issues and RG members not being aware of what work management agencies were undertaking (or not).
- The final management strategies were seen as "wishy washy" and not radical, and also already implemented. However, this highlighted a great implementation divide as evidence of bad and good practices were shown to the project team and some of the managers. However, these outputs had great significance to the RG members.

The process was seen as very extensive and comprehensive, but required large volunteer input. Some of this time commitment was explained by the test case nature of the work where several approaches were trialled by RG members. A shorter, less time consuming version is suggested below.

12.3.2 REVIEW OF PROCESS

The qualitative modelling was used as an introduction for the members to discuss their present knowledge of the area, to show that their view was valued and to inform the project team on key issues and assets to address. Although the project team provided these at the time of management strategy development, the models were not used by the RG members. Since the whole process was extensive – partly because different methods were trialled – this is one step that could be removed from the process or needs to be enhanced by a Bayesian Belief Network (122) which may be perceived as more useful (from a management strategy point of view).

Undertaking the objective development process before discussing management options was essential to encourage group cohesion and trust. The review was surprisingly quick and easy (given the online nature of many of the agencies) and the Mackay RG process of developing the hierarchy formed cohesion and was enjoyed. However, success was also achieved through a more individual approach although perhaps with not as much attachment to the final product. Since there were no winners and losers in this stage, conflict was low.

Several approaches were trialled when developing the management strategies. Group input in the process highlighted that discussing the assets-issue combinations as topics at the start and covering each per meeting worked best. At each meeting access to an expert with local knowledge was essential. Undertaking the Issues Register, and listing direct and indirect management options at the same time was most productive and produced a more cohesive product. Given the complex

nature of the governance system, the responsible agency was not accurately identified by the RG or was too generic and not used in the analyses. The topic sequence was roughly down the length of the catchment, which seemed to make sense and reduced overlap. It also highlighted the connectivity of the system. The most controversial topics were at the end of the process so the group was very familiar with each other's view and therefore more open to opposing management actions.

Traceability about where the objectives and management options came from was an essential component that maintained trust. The RG feedback emphasised this point and that they felt their view was listened to.

Relative importance of objectives helped highlight that there was quite a lot of consistency in the group's view and the relative importance of each goal. In session discussion of the results allowed general articulation of RG member's values and opinions in a more factual manner.

By embedding managers in the project team and RG an extremely important component of linking the community with the management system was successful. However, connection to the more senior management and thought leaders, which has been shown to be very influential in other studies for example Dutra, *et al.* (123), was weak in the process partly due to the work load on the project team. Ensuring greater connections throughout the process rather than at the end meant that getting traction was harder. However, senior managers were approached at the early stages of the process and the project team was told to wait until the end when there was more substance. The final managers meeting was destructive for some RG members even though the project team warned the RG that some negative response from managers would be expected. As a result a balance between the RG and managers' needs should be used where more regular contact is made rather than using the manager's approach of connecting towards the end.

The impact assessment was the most useful to managers. This provided relative priorities of each management strategy for funding purposes. It also uncovered an expected conundrum that does challenge the effectiveness of management: there was a significant gap between what managers thought was happening or resulting from their actions and the perception of the community as to the effectiveness (and wisdom) of these management action(s).

After the managers meeting, the final set of management strategies was separated into products for specific to the two major agencies relevant to the coastal zone (fisheries and council) and these were much more successful. These two letters were also socialised behind the scenes by key members of the project team and were more clearly put in the language of this agency rather than those of the RG. Both products are needed for the process as there was a demonstrated disconnect between local and manager's views.

12.4 Generic process

A local person that is within the project team is a huge advantage. This person can be a conduit for out of session conversations.

The process can be simplified into four steps (Figure 57) of i) developing the engagement process, ii) defining objectives (which includes the review, creating the hierarchy and obtaining their relative importance), iii) developing the management

strategies (provide information, define issues and develop actions) and set the priorities through a relative impact assessment.

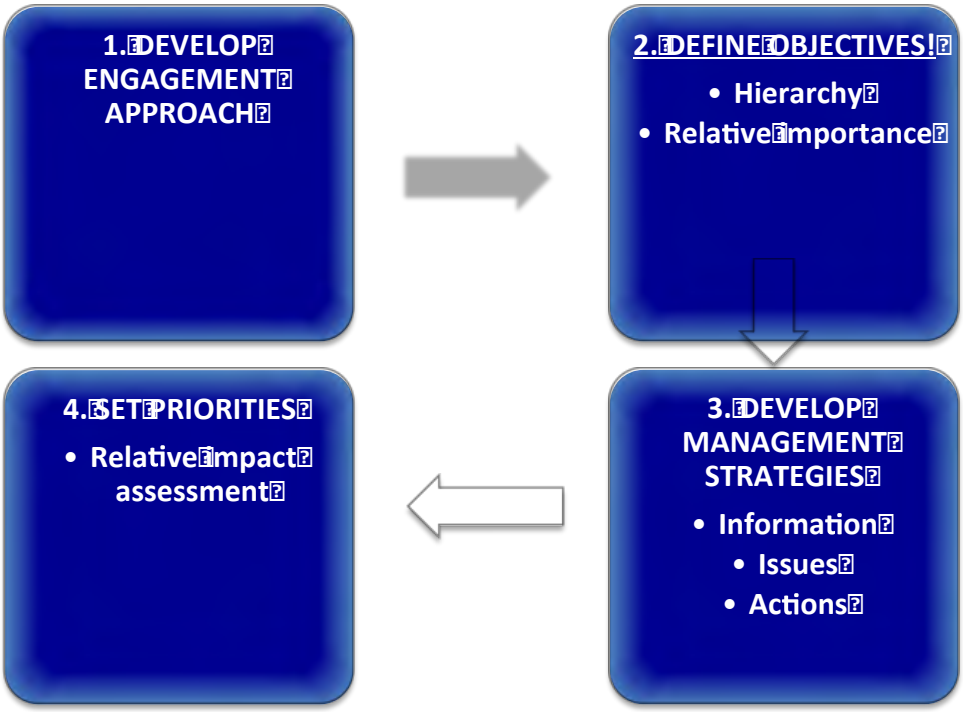


Figure 57: Generic process of developing management strategies using local community input

The engagement system should be similar to that of the Mackay RG but with much more enhanced LMAC (generically called the header group) involvement where they preferably act as a header group giving direction through defining the RGs tasks and timelines (Figure 58). The header group should meet less frequently than the RG. Managers should be embedded in the RG. The header group should preferably have some authority and representativeness, whereas the RG membership should maintain some representation but mainly consists of volunteers willing to provide their time generously. Important influencers should be identified at an early stage in the process. The RG chair should be elected from the RG membership but facilitation should be provided by the project team member to allow all RG members equal access to the discussion, but also for the chair to be able to contribute to the discussion.

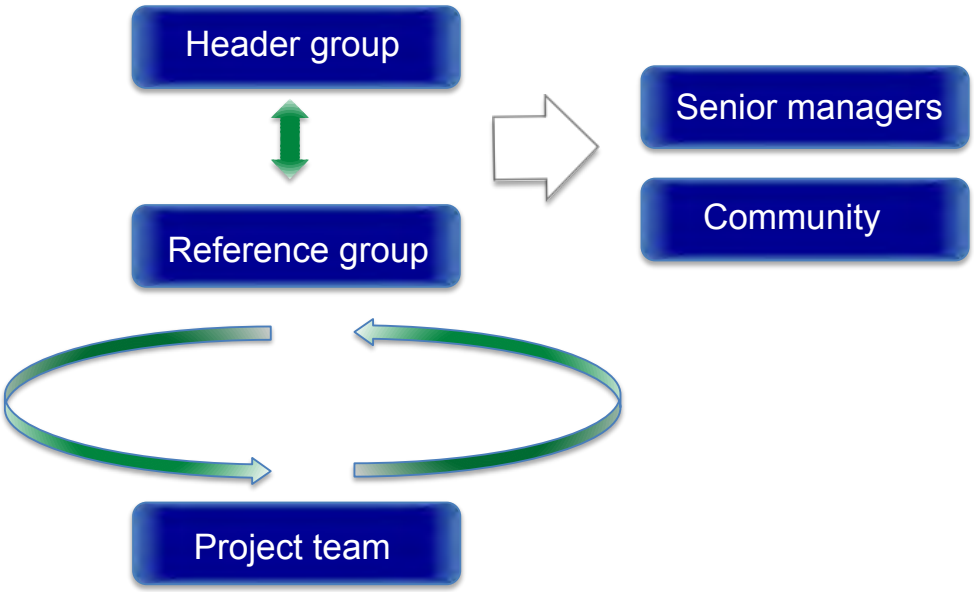


Figure 58: Generic engagement process

The objectives review should maintain links to source documents and also keep track of versions as the RG and header group input is obtained. To speed up the process if needed, a generic objective tree to develop management strategies for coastal zone fisheries and biodiversity can be used and the lower level (the objectives) can be subsequently added for more local content (Figure 59).

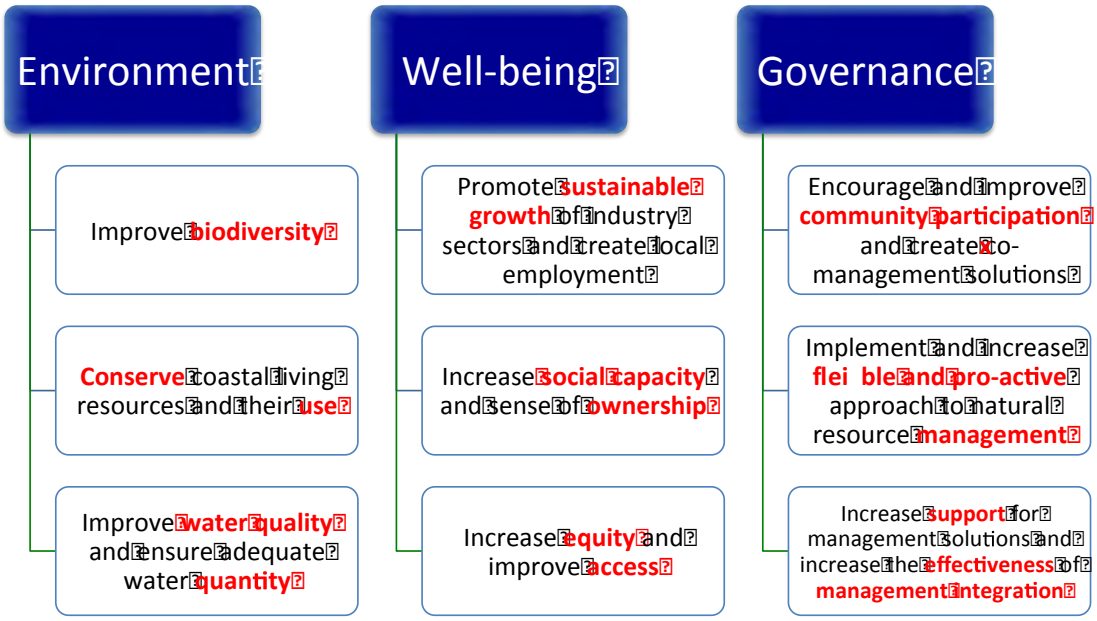


Figure 59: Generic objectives hierarchy for the management of the coastal zone fisheries and biodiversity

The objective relative weighting can be kept within the header group and RG (rather than going to the community as well), as this is more influential to the task at hand. However, if the community views can be obtained, the approach that worked best was doing local radio interviews linking to online surveys. A paper backup with a local office is also needed. A new method of obtaining these relative weights should be used rather than the more confusing and controversial approached such as the

AHP as described in Dutra, *et al.* (108). An example survey is provided using the generic objectives (Appendix C).

Management strategies should start with a meeting between managers and the RG and header group describing existing management measures. The management strategy question should be divided into topics that could be a combination of key assets and issues. The topic sequence should allow for connectivity in the system to be highlighted but controversial topics should be raised at the end. For each topic an expert with local knowledge on that topic should attend. Using the simpler Pressure-State-Response framework (Figure 60) – the precursor to the Driver-Pressure-State-Impact-Response approach (120, 121) – an issues register can be developed with direct and indirect management actions (Table 47). Some flexibility on the day is needed in term of small or whole group discussions. The project team should collate these using a database and provide these to the RG for input. The final product should be supported by the header group.

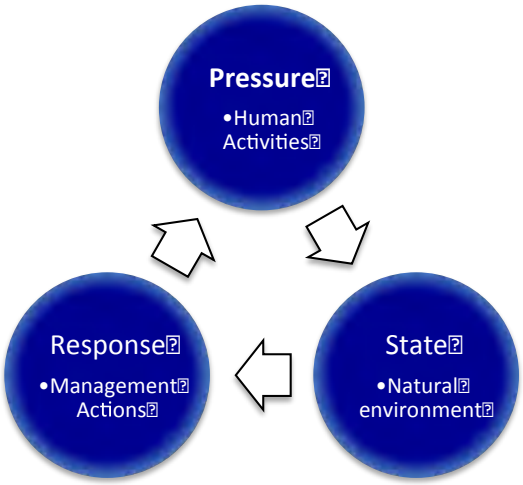


Figure 60: A drawing that could be provided to explain the Pressure-State-Response framework

Table 47: Generic management action table for use in RG discussions

Topic		
Issue	**Direct management action**	**Indirect management action**
Issue 1	Action 1	Action 1
Issue 2	Action 1 Action 2	Action 1 Action 2

The impact assessment should be undertaken at the highest level of the objectives tree by both the RG and the header group prior to the key managers meeting. It can be repeated in session at the managers meeting to obtain information on influence – see example tables in Dichmont, *et al.* (115). This is a good tool to highlight relative priorities and the difference between managers and members. The analysis method is provided in Dichmont, *et al.* (104) and Dichmont, *et al.* (115).

At least one managers meeting between senior managers, embedded managers, the header and RG should be undertaken. Follow up meetings with managers are essential and documents specific to their needs and communication style should be produced.

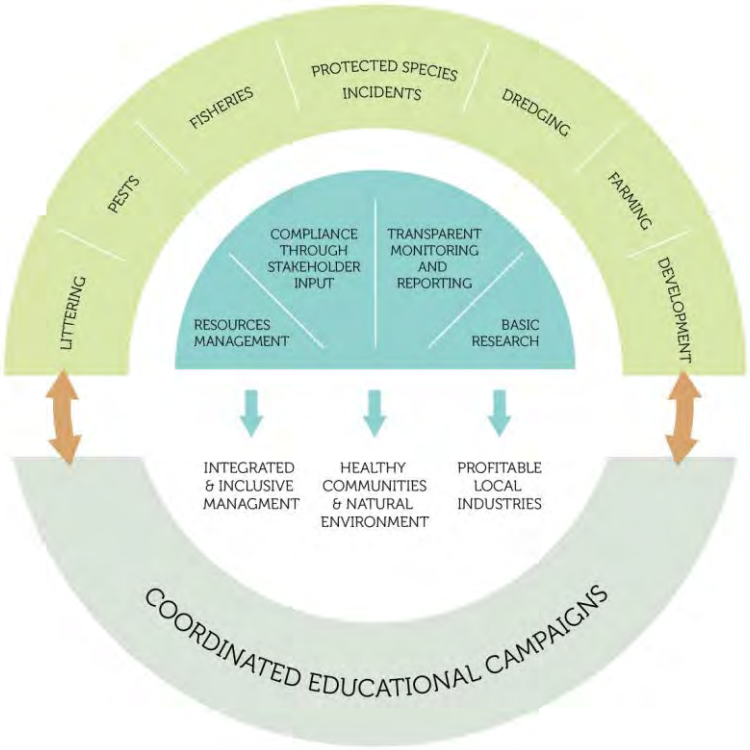


Figure 61: Generic classes of management strategies as a communication tool with which to explain the management strategies

A generic strategy communication tool (Figure 61) for the different management strategies to ensure that all bases are covered can be used. A key underlying theme of the figure is that all management actions can result from either direct actions on individual impacts, such as reducing littering and runoff from farms and development (outer ring at top) or through responses by means of resource management, added compliance, and basic research (inner top semi-circle). Coordinated educational campaigns targeted at both the local community, industries and government agencies (bottom ring) are a key action that can help influence positive behaviour and attitudes towards inshore resources in the Mackay region. The final outcomes expected from the management strategies are:

1. Healthy communities and natural environment
2. Integrated and inclusive management
3. Profitable local industries.

12.5 Conclusions

A generic approach is developed from the two case studies. These highlight that embedding managers within the process and having a local person is essential to successful implementation. In addition, senior managers and thought leaders should be brought along during the process rather than only at the end when a more tangible but less controversial product is available. High volunteer time to support the process showed the wish for local scientists and community members to be part of regional management. Several steps are needed to ensure reduced risk of conflict,

but the most important is to discuss objective prior to management strategies to allow for the group to value and understand each other.

13 Communication products and project impact

13.1 Introduction and Methods

The project undertook a series of different communication forms during the life of the project. The type of and audience for the communication changed as the project stepped through its process (Figure 2). Much of the communication was aimed at Mackay where the process was less controversial and well supported by the project partners, the Mackay LMAC and RG. The project started with Fact Sheet (Figure 62), which was available for general use but also used to introduce the project in Mackay and Bowen-Burdekin. The project also produced a Poster for use at a Conference and also explains the project to a scientific and general audience (Figure 63).

An intense communication period followed to entice the Mackay public to undertake a survey of the relative importance of coastal management objectives. The following methods of communication the project survey:

- A newspaper advertisement for a 3-day in person survey session with the project team at Mercy College (Figure 64);
- Twitter and Facebook campaigns (Figure 65);
- Web page with survey link (Figure 66);
- Flyer made available at major public centres such as the Council and library; (Figure 67)
- Radio interview mentioning a 3-day in person survey session with the project team at Mercy College (Figure 68);
- Radio interviews enticing people to undertake an online survey (initially in SurveyMonkey™ and then hosted on CSIROs web site – Figure 69)
- A paper survey available at the Mackay GBRMPA office (Section 0);

After the management strategy development phase several key products were produced (see Sections within 0):

- A letter on behalf of the Mackay RG for official submission to the Queensland Minister's fisheries management review (https://www.daff.qld.gov.au/fisheries/consultations-and-legislation/reviews-surveys-and-consultations/fisheries-management-review)
- A letter to the CEO of the Mackay Council
- A series of "what actions can you take" cards for use by the Mackay public and the Mackay RG. Printed versions will be available in the Mackay GRBMPA offices.

13.2 Communication products

13.2.1 PROJECT OVERVIEW

Project fact sheet

NERP Tropical Ecosystems Hub Project Factsheet

Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore

Project leader: Dr Cathy Dichmont (CSIRO)

Project summary

This project will develop a Management Strategy Evaluation (MSE) framework to build understanding of the key human uses and drivers of change in the inshore Great Barrier Reef (GBR), and to inform GBR stakeholders of the likely consequences, costs and benefits of particular management decisions that aim to minimise the impacts on biodiversity, particularly from inshore multi-species fisheries.

Photos: State of Queensland, Department of Agriculture, Fisheries and Forestry; CSIRO.

Why this research is needed

The participatory approach used in the development of the MSE framework will build a common understanding of how the socio-economic and ecological components of the inshore GBR system function and interact, and will assist stakeholders to formulate management objectives. The resulting MSE framework will be used to identify which policies and practices have the potential to meet the stated objectives of stakeholders and to assess trade-offs between social, economic and environmental outcomes.

Research-user focus

The project will deliver outcomes that are useful to a range of stakeholder organisations including local, state and federal government bodies, the fishing and other sectors, and conservation planners/managers. These organisations include the Great Barrier Reef Marine Park Authority, DSEWPaC, the Queensland Departments of Environment and Heritage Protection and Agriculture, Fisheries and Forestry and the Queensland Seafood Industry Association.

Outcomes

- An understanding of the relative importance of different social, ecological, economic and governance objectives of each stakeholder group and for all stakeholders combined within the inshore GBR region.
- A qualitative model built using stakeholder input to develop a common understanding of the interactions between the various components of the inshore GBR system.
- Stakeholder driven development of alternative strategies for the management of the inshore GBR region.
- An assessment of the relative impacts of different management strategies compared with present management systems to provide clear direction about the pros and cons of different management strategies for the inshore region and their impacts on different stakeholder objectives.
- Management options aimed at biodiversity outcomes, focusing on inshore multi-species fisheries management.

Project Partners:

CSIRO

JAMES COOK UNIVERSITY AUSTRALIA

Australian Government
Great Barrier Reef Marine Park Authority

Queensland Government

Find this project at www.nerptropical.edu.au
Theme 3: Managing for resilient tropical systems
Program 9: Decision support systems for GBR managers
Project: 9.2

For more information about this project, contact:
Dr Cathy Dichmont (CSIRO)
cathy.dichmont@csiro.au

National Environmental Research Program

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

Reef & Rainforest RESEARCH CENTRE

Figure 62: Project fact sheet developed at the beginning of the project

Project poster

National Environmental Research Program

TROPICAL ECOSYSTEMS hub

Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore

PROJECT LEADER: Dr Cathy Dichmont

PROJECT TEAM: CSIRO, Great Barrier Reef Marine Mark Authority, Department of Agriculture, Fisheries and Forestry, Department of Environment and Heritage Protection, Department of Science, Information Technology, Innovation and the Arts, James Cook University

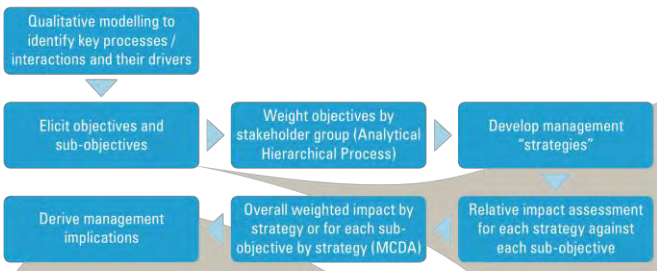
A Management Strategy Evaluation (MSE) framework is being developed to help understand the key human uses and drivers of change in the inshore Great Barrier Reef (GBR).

The framework will demonstrate the likely consequences, costs and benefits of management decisions that aim to minimise the impacts on biodiversity, particularly from inshore multi-species fisheries.

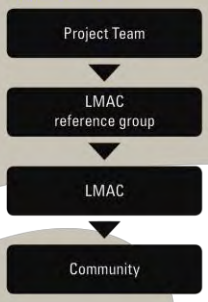
Extensive consultation with stakeholders at Mackay and the Burdekin is an important feature of the project which aims to:

1. Develop qualitative models to understand key interactions in the region, and underlying processes and drivers.
2. Identify social, ecological, economic and governance objectives of stakeholders for the inshore GBR region.
3. Identify alternative strategies for managing the inshore region, using a stakeholder-driven approach.
4. Assess the impacts of the management strategies against objectives using a semi-quantitative approach.
5. Develop management options (with end users) aimed at biodiversity outcomes, focusing on inshore multi-species fisheries management.

PROJECT PROCESS



STAKEHOLDER ENGAGEMENT



PATHWAY TO IMPACT

The project will engage local groups and key government departments linked to regional management.

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

CSIRO

Australian Government
Great Barrier Reef Marine Park Authority

Queensland Government

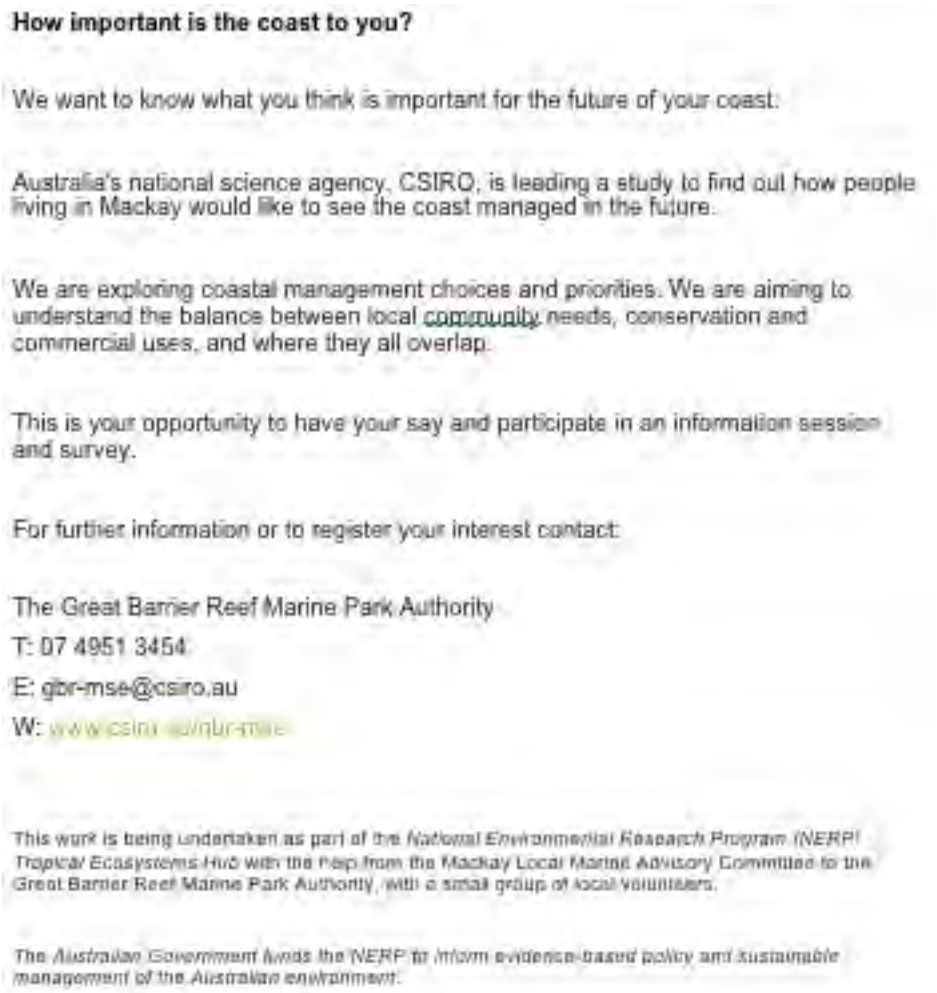
JAMES COOK UNIVERSITY AUSTRALIA

Photos: Jetty and trawler – State of Queensland, Department of Agriculture, Fisheries and Forestry; Seagrass – CSIRO; Mangroves – Louise Bell; Hawksbill Turtle – Mat Vanderklift, CSIRO

Figure 63: Project poster presented at NERP Conference , Cairns 2013.

13.2.2 OBJECTIVES WEIGHTING IN MACKAY

Daily Mercury advertisement text



How important is the coast to you?

We want to know what you think is important for the future of your coast.

Australia's national science agency, CSIRO, is leading a study to find out how people living in Mackay would like to see the coast managed in the future.

We are exploring coastal management choices and priorities. We are aiming to understand the balance between local community needs, conservation and commercial uses, and where they all overlap.

This is your opportunity to have your say and participate in an information session and survey.

For further information or to register your interest contact:

The Great Barrier Reef Marine Park Authority
T: 07 4951 3454
E: gbr-mse@csiro.au
W: www.csiro.au/gbr-mse

This work is being undertaken as part of the *National Environmental Research Program (NERP) Tropical Ecosystems Hub* with the help from the Mackay Local Marine Advisory Committee to the Great Barrier Reef Marine Park Authority, with a small group of local volunteers.

The Australian Government funds the NERP to inform evidence-based policy and sustainable management of the Australian environment.

Figure 64: Daily Mercury advertisement text June 2013

Twitter and facebook

Sample tweets sent from https://twitter.com/CSIROnews (21,679 followers)

Figure 65: Sample tweets sent to CSIROnews

Project web page hosted by CSIRO

Balancing coastal use and community values with management options

CSIRO is leading a study to learn more about how the community is using the coastal area near Mackay and the Burdekin in northern Queensland.

11 June 2013 | Updated 3 February 2014

Hawksbill turtle swimming over coral reef

Project summary

IN THIS ARTICLE

1. **Project summary**
2. Project partners

Holidaymakers launching boats to go fishing

Balancing coastal use and community values with management choices that support the conservation of diverse marine life and protect commercial interests is important for long-term sustainability.

To develop considerations required to meet the variety of activities undertaken along the coastal area near Mackay and the Burdekin, this project aims to identify the demands on the coast and which aspects are most valued by those who use it, and then incorporate these priorities with different options to help improve management of this region.

The results of the project will demonstrate the likely consequences, advantages and limitations of management decisions that aim to minimise the impacts on biodiversity from recreational and commercial activities.

Extensive consultation with stakeholders at Mackay and the Burdekin is an important feature of this project.

With input from the local community, industry, key government departments linked to regional management the project will direct the development of alternative strategies for the biodiversity management of the coastal and inshore Great Barrier Reef region.

Learn more about research by Wealth from Oceans.

Fast Facts

- It is critical to balance coastal use and community values with management choices that support the conservation of diverse marine life and protect commercial interests.
- This project aims to identify the demands on the coast, the areas valued by the local community, and deliver an assessment of the impacts of different potential management strategies compared with present management systems.

Contact Information

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Related Links

Our resilient coastal Australia

Dr Cathy Dichmont: leading fisheries and ecosystems research

Online survey for Mackay residents *(external link)*

NERP Tropical Ecosystems Hub *(external link)*

Great Barrier Reef Marine Park Authority