Marine and Coastal

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FINAL REPORT

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Assessing changes in black rockcod abundance and size

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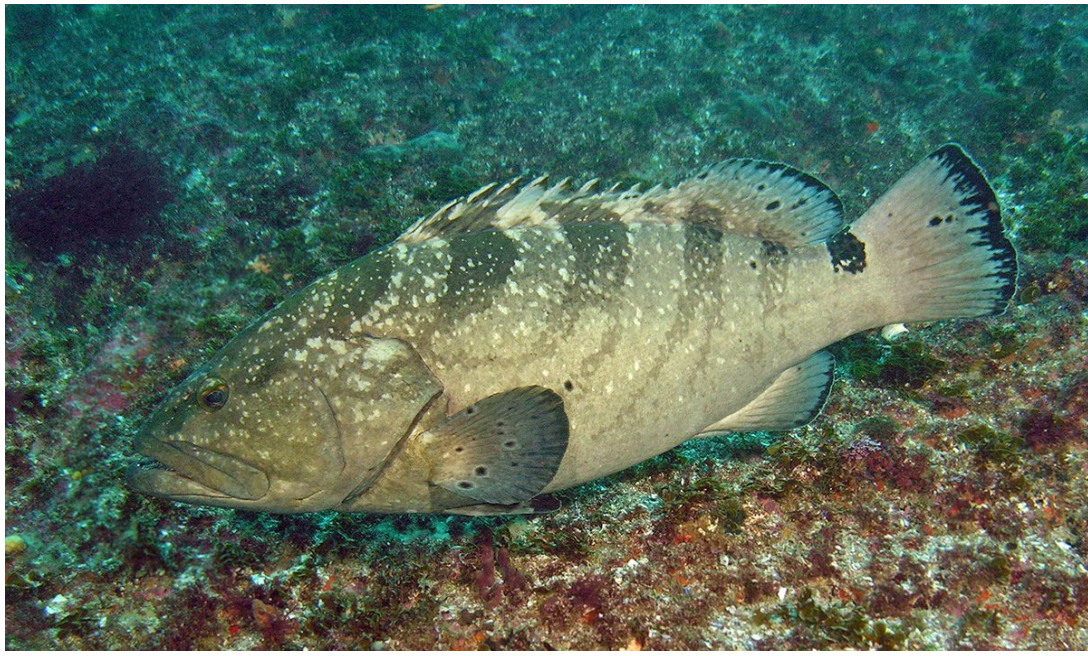

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Executive summary

The Black rockcod also known as Black cod (*Epinephelus daemelii)*, is a threatened species listed as 'Vulnerable' under both the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* and the *NSW Fisheries Management Act 1994*. The species has been protected in NSW since 1983; its protection resulting from concerns of population declines across its range. In 2012, the NSW Government released a recovery plan for the species that outlined actions that need to be implemented to assist with the species recovery. Research activities such as determining the abundance and distribution of Black rockcod and investigating the biology and ecology of Black rockcod are assigned a high priority in the recovery plan.

This slow-growing long-lived fish is known to occur on rocky reefs and offshore islands along the NSW coast, including Lord Howe Island. Broadscale surveys of Black rockcod were first conducted in 2009-11 that involved sampling 83 sites from Port Stephens to Cook Island in far north NSW, including the waters of Lord Howe Island. These initial broadscale surveys were undertaken using timed diver swims of up to 45 minutes duration to search and record the abundance and associated lengths of encountered Black rockcod. These initial surveys recorded a total of 117 Black rockcod at 34 different sites (of 83 sites surveyed in total). As part of this NESP project, the broadscale survey sites were resurveyed in 2023 with a total of 67 Black rockcod observed at 27 of the 83 original sites. An additional 2 Black rockcod were also recorded at the Cod Grounds Marine Park site in 2023 that was not surveyed in the initial broadscale survey.

These surveys found a reduction of 43% in the relative abundance of black rockcod at the broadscale survey sites over the past 15 years. There was also a reduction in the proportion of sites where Black rockcod were observed (40% of sites reduced to 32% of the original 83 sites).

Based on the surveys of the broadscale survey sites in 2009-11, a subset of 19 key Black rockcod survey sites along mainland NSW were established to be used in a long-term monitoring program to help assess the species recovery. Key sites were also established at Lord Howe Island, based on initial surveys at this location in 2011. For this NESP project, these key Black rockcod sites were surveyed in both 2023 (37 sites in total) and 2024 (33 sites in total – Balls Pyramid sites and Julian Rock sites not surveyed in 2024) across northern NSW and Lord Howe Island.

Surveys of the key sites in 2023 recorded a total of 57 Black rockcod with more being observed at the key sites in 2024 (n= 69 Black rockcod). Black rockcod were observed at 62% of key sites surveyed in 2023 (23 of 37 sites) and at 51% in 2024 (17 of 33 sites).

There were some positive indicators of Black rockcod recovery with increased length structure of the monitored population. The average length of fish observed increased over time in all locations surveyed. There was an increase in the overall proportion of larger fish from the first (2009-11) to the second (2023) broadscale survey. The length class with the most individuals in 2009-11 was 60 to 70 cm, which are sub-adult. In 2023, the length class with most individuals was 90 -100 cm, a length class of large mature females.

Indicators of recovery can include increasing abundance, broadening distribution, larger sizes classes, and increased abundance of mature fish. Although we do not have benchmark data from 1983, when Black rockcod became protected in NSW, and therefore do not know their recovery trajectory from that time, we do have an indication of the species recovery since 2010. Monitoring over the past 15-years shows a combination of negative and positive indicators, with fewer fish seen at fewer sites, although fish are getting bigger with more mature individuals at the key sites.

The existing legislative protection as a threatened species does not yet appear to have greatly improved recovery of this species over the past 15 years. Although they are protected from fishing, it does not stop them being accidentally caught by anglers where they can suffer harm from barotrauma and hook injuries that can cause death. As the Black rockcod is slow growing, late to mature and still in low abundances across NSW, ongoing future recovery of this species will take time, even if all the threats from incidental fishing pressure were eliminated.

1. Introduction

Black rockcod (*Epinephelus daemelii*) is listed as a 'Vulnerable' species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the (NSW) *Fisheries Management Act 1994*. The listing as a threatened species commenced in NSW in 1983. Under the threatened species listing, they are fully protected from being taken from the wild and it is illegal to possess or harm them. Yet a lack of baseline and benchmark data at the time of protection and no information until ~25 years after protection commenced, mean that the true effectiveness of this protection is not actually known. Although they are a protected species, they are still caught (although legally they must be immediately released), can die post-release from embolism, and are occasionally illegally taken by fishers (from NSW DPI compliance data). Long-term monitoring of the population abundance was identified as a high priority by the NSW Black rockcod recovery plan and the NSW Fisheries Scientific Committee.

Black rockcod have a life history that constrains their recovery. It is a large (>1.5 m) and long-lived (60+ year) reef-dwelling rockcod/grouper species in the family Serranidae. It has a restricted distribution, being endemic to the subtropical to warm temperate southwest Pacific: New South Wales (NSW) southern Queensland, Lord Howe Island (LHI), Elizabeth-Middleton Reefs, the Kermadec Islands, and northern New Zealand/Aotearoa. They are a protogynous hermaphrodite that change sex from female to male at about 100 - 110 cm. Females become sexually mature at about 70 cm. Spawning and fertilisation of eggs is external in the water column, with a pelagic larval transport phase.

Black rockcod were once widespread in NSW (Roughley 1916). However, from the 1950s through to the late 1970s, spearfishers at various locations along the NSW mainland coastline heavily targeted this species (Andrewartha et al, 1968) as it is considered an excellent eating fish. They were also caught by line-fishing, including at LHI. Concentrated spearfishing effort combined with line fishing impacts led to a noticeable decline in Black rockcod numbers within NSW. As a result, NSW Fisheries were approached by concerned divers to protect the species in the late 1970s. Even though there was limited information on Black rockcod available at the time, it was recognised as being under threat, and the species was afforded total protection in NSW in 1983.

The recovery and conservation status of this threatened species is Commonwealth responsibility within Australian Commonwealth waters, including the Lord Howe Marine Park (Commonwealth) (both at Elizabeth and Middleton Reefs and Lord Howe shelf waters). Any decline in abundance and other metrics of recovery within the Commonwealth, or adjacent State marine park, has implications for the overall Black rockcod population in Australia.

The species is known to occur in Commonwealth waters at Pimpernel Rock in the Solitary Islands Marine Park and the Cod Grounds Marine Park off northern NSW. Whilst the species is known to occur in Queensland waters, its occurrence in that state is considered rare based on very infrequent sightings.

This project assesses the relative abundance and size of Black rockcod to inform how the species is responding to the conservation and management actions being implemented to protect the species. In 2009-2011, a broadscale survey (83 sites) was undertaken in northern NSW and Lord Howe Island, followed by subsequent surveys of a subset of these sites (19 sites) approximately every 1 to 3 years in mainland Australia and less frequently (18 sites) at Lord Howe Island. This project repeats the surveys of the initial 83 baseline sites to assess how protection measures, particularly the listing and protection as a threatened species, is assisting in recovery of Black rockcod.

There are various benefits that can arise from this research project. Black rockcod will benefit through threatened species recovery planning and actions informed by this research. It is a critical input to enable marine park and threatened species managers to make decisions informed by research. The broader community will also benefit from the research findings being communicated, as well as more select marine user groups, such as divers and Indigenous groups. The Community Group Green Heroes, with strong Bunjalung ties, have conservation objectives and strong Sea Country connection to Jungarra Gnarrian / Cook Island and are helping assess Black rockcod and sea turtles at this special place to them. More frequent community monitoring at Jungarra Gnarrian provides an extra temporal layer of insight that can be incorporated into the overall NSW DPI Black rockcod monitoring program.

Overall, this NESP project and the overall Black rockcod monitoring program being conducted by NSW DPI - Fisheries Research, provides a 15-year time series (2009 to 2024) that can help indicate if Black rockcod are increasing in abundance, getting larger, and/or becoming more widespread; all indicators that can be used to assess if the management actions being implemented in NSW are effective.

The primary aims of this project were:

- to assess if Black rockcod have increased in abundance since 2009-2011 at 83 broadscale surveys sites;
- to assess if Black rockcod have increased in overall size compared with size estimates from 2009-2011;
- to determine if Black rockcod are becoming more widely spread on rocky reefs in northern NSW and Lord Howe Island; and
- to assess if Black rockcod have increased in abundance and size at key sites surveyed multiple years (n=11 years) from 2009 to 2024.

2. Methods

The overall Black rockcod long-term monitoring program that this current NESP project builds on and contributes to, was originally established in 2009 in response to knowledge gaps identified by threatened species recovery planning in NSW. This long-term monitoring program monitors the relative abundance and lengths of Black rockcod to inform on species recovery and the effectiveness of management actions. Below are the details of the methodology and locations of surveys sites.

1.1 Sites and locations

The initial broadscale survey of 83 sites was undertaken during 2009 to 2011 in northern NSW (Port Stephens to Cook Island) and Lord Howe Island (LHI). Surveys were originally undertaken in the Port Stephens-Great Lakes Marine Park (PSGLMP) in 2009 (Harasti, 2009), in the Solitary Island Marine Park (SIMP) and other northern NSW sites in 2010 (Malcolm & Harasti, 2010) and in Lord Howe Island in 2011 (Harasti et al, 2011). These initial broadscale survey sites were resurveyed in 2023, plus eight additional sites, as part of the NESP project reported here with the full list of sites surveyed shown in Appendix A.

Based on the initial broadscale survey results in 2009-2011, a total of 19 key sites in northern NSW were selected for ongoing monitoring. These 19 key sites have been monitored annually most years (11 out of 15 years) between 2009 and 2024. These years were: 2010, 2011, 2012, 2013, 2014, 2018, 2019, 2020, 2021, 2023, and 2024 (Appendix B).

These key sites include two sites in the Cape Byron Marine Park (CBMP), five sites in the SIMP, two sites at SW Rocks (Fish Rock) and ten sites in the PSGLMP. Lord Howe Island has 18 key sites that have been sampled on four separate occasions (2011, 2019, 2023, 2024), though not all sites have been able to be sampled in all years (e.g. two sites at Balls Pyramid in 2024 due to weather constraints).

Overall, this provides a 15-year time series (2009 – 2024) with a broadscale survey towards either end of this time-period. From these survey data, various comparisons at different temporal and spatial scales can be used to assess if black rockcod are increasing in abundance, are getting larger, and/or are becoming more widespread, which are all indicators of the species recovery. Alternatively, this monitoring can also indicate if the population is remaining stable or declining.

Refer to Appendix A and Appendix B for tables of Black rockcod survey sites (broadscale sites and key sites).

1.2 Roving diver timed count

Surveys involved two divers (DH, HM) swimming along each site for up to 45 minutes searching for black rockcod and recording any individuals, as well as estimating their length, the habitat they were found in, the depth range surveyed, the depth that individual Black rockcod were found at, and if the fish sighting was cryptic (i.e. hidden from initial view or camouflaged) (See: Harasti and Malcolm, 2013). For some of the deeper sites (25+ metres), the timed swim was limited to approx. 30 minutes to prevent divers from undertaking decompression dives.

The Underwater Visual Census (UVC) technique of diver roving timed counts is a widely adopted method for fish surveys (Kingsford, 1998) and has been more fully described as a successful method for Black rockcod (Harasti and Malcolm 2013). It is a useful method in diving depths where a species is rare and unlikely to be detected using belt-transect UVC methods. The habitat where each fish was recorded was described based on topographic structure and this included categories such as: cave, overhang, coral, swim-through, wreck, gutter and boulders. Divers followed the topography of the reef to a maximum depth of 30 m and searched any caves or overhangs that they came across on the dive. Divers carried a dive torch to search in caves and overhangs for any hiding Black rockcod. For the sites at Lord Howe Island, any other serranid species that were encountered during the timed survey were also identified and recorded.

The timed swim method has proven to be much more practical for Black rockcod surveys, compared to transects and baited remote underwater videos (BRUVs), as it allows divers to thoroughly search key habitats such as caves and overhangs. Notably, the same divers (DH and HM) have undertaken all the surveys from 2009 – 2024, thus reducing any potential observer bias between surveys. Additionally, as it has been the same divers for the surveys, the general search ‘route’ for each site has been consistent to ensure the same areas of reef were surveyed each time.

1.3 Diver stereo-video

For each black rockcod sighting, the length of the fish was visually estimated (by both DH and HM where possible) in centimetres. Where possible, the fish was also filmed using a diver stereo system (SeaGIS Pty. Ltd) to obtain an exact length measurement as per Harasti and Malcolm (2013). The diver stereo-video system used in 2023 consisted of two GoPro Hero 6 cameras on a base bar that had been calibrated, as per standard operating procedures (Langlois et al 2018, 2020). Measuring individual fish using the diver stereo system was only possible where a side profile was videoed with the fish stretched straight and the full image of the fish appearing simultaneously in both cameras. In most cases, this was not possible due to fish being within constrained habitat (such as a cave or crevice) and maintaining a head-on profile to the diver, or due to the fish taking off when observed before effective video was taken. Stereo measurements taken from the stereo camera were compared with those of the two observer divers (HM and DH) with the diver estimates being reasonably similar. This provides confidence for Black rockcod lengths where only visual estimates were able to be obtained.

1.4 Data analyses

Data analyses were predominantly descriptive due to the low abundance of this species, with many sites surveyed having zero counts of Black rockcod.

Analysis of Variance was used to compare ‘Total Length’ of Black rockcod between the initial broadscale survey in 2009-11 and the survey conducted in 2023. Differences in length distributions between the first and second set of broadscale surveys were compared using the Kolmogorov-Smirnov test. This test calculates the maximum distance between two cumulative distributions (test statistic D) and determines a corresponding P value with significant P values (<0.05) indicating differences in their relative cumulative length distributions.

Comparison of fished and ‘no take’ sites for the two broadscale surveys was carried out using PERMANOVA in PRIMER, where Management Type (fished and ‘no take’ sanctuary zone) was fixed and Period (Period 1: 2009-11, Period 2: 2023) was treated as fixed. In 2009-11, there were 43 sites in ‘no take’ sanctuary zone and 40 sites in areas that could be fished. In 2023, there were 46 sites in ‘no take’ sanctuary zone and 45 sites in areas that could be fished. The broadscale surveys were undertaken temporally at either end of our overall 15-year monitoring study. Data were square-root transformed and analysed using a Bray-Curtis resemblance matrix with a dummy variable added to avoid undefined resemblances between samples.

3. Results

3.1 Relative abundances and lengths in 2023 and 2024 NESP surveys at broadscale and key sites.

Black rockcod surveys undertaken in 2023 and 2024 were funded through this NESP study. A total of 69 Black rockcod were recorded (including sites at LHIMP) in 2023 (Table 1). Of these fish, 57 Black rockcod were recorded at key long-term monitoring sites. More Black rockcod (69 individual fish) were recorded in 2024 at the key long-term monitoring sites (Table 2), although fewer key sites were surveyed in 2024 (37 key sites in 2023 versus 33 key sites in 2024).

Table 1: Observations of Black rockcod in 2023 broadscale survey with length, depth, habitat, and fish detectability recorded.

Fish	Location	Date	Length (cm)	Depth	Sighting type	Habitat
1	South Solitary north end	1/23/2023	85.5	15	cryptic	overhang
2	South Solitary north end	1/23/2023	78.7	12	cryptic	canyon
3	South Solitary north end	1/23/2023	90	12	cryptic	canyon
4	South Solitary north end	1/23/2023	85	12	cryptic	canyon
5	South Solitary north end	1/23/2023	65	12.5	obvious	open water
6	South Solitary north end	1/23/2023	80	14	cryptic	cave
7	South Solitary north end	1/23/2023	100	13	cryptic	overhang
8	South Solitary north end	1/23/2023	116	13	cryptic	overhang
9	South Solitary north end	1/23/2023	87	13	cryptic	overhang
10	South Solitary north end	1/23/2023	65	15	obvious	open water
11	South Solitary west side	1/23/2023	100	18	cryptic	overhang
12	South Solitary west side	1/23/2023	90	14	cryptic	overhang
13	South Solitary west side	1/23/2023	71	13	cryptic	overhang
14	South Solitary west side	1/23/2023	100	7	cryptic	overhang
15	North Solitary Anemone Bay	2/1/2023	120	15	cryptic	overhang
16	North Solitary Anemone Bay	2/1/2023	104	8.5	obvious	open water
17	Split Solitary north east	2/2/2023	100	14	cryptic	cave
18	North Solitary Elbow Cave	2/7/2023	140	12	cryptic	cave
19	North Solitary Elbow Cave	2/7/2023	122	12	cryptic	overhang
20	North Solitary Elbow Cave	2/7/2023	105	12	cryptic	overhang
21	North Solitary Bubble Cave	2/7/2023	99	16	cryptic	cave
22	40 Acres	2/16/2023	85	17	cryptic	cave
23	40 Acres	2/16/2023	108	12	cryptic	rock
24	Split Bommie	2/16/2023	105	16	cryptic	overhang
25	Pimpernel Rock	5/25/2023	130	30	cryptic	cave
26	Pimpernel Rock	5/25/2023	100	30	cryptic	crack
27	Pimpernel Rock	5/25/2023	120	30	cryptic	gutter

28	Pimpernel Rock	5/25/2023	100	30	cryptic	cave
29	NW Solitary Eastern side	5/31/2023	70	10	cryptic	overhang
30	NW Rock Fish Soup	6/12/2023	120	11	cryptic	cave
31	NW Rock Fish Soup	6/12/2023	120	12	obvious	open
32	NW Rock Fish Soup	6/12/2023	100	14	cryptic	cave
33	NW Rock Fish Soup	6/12/2023	120	14	obvious	gutter
34	NW Rock Fish Soup	6/12/2023	125	13	obvious	open
35	NW Rock Fish Soup	6/12/2023	110	12	obvious	slope
36	NW Rock Fish Soup	6/12/2023	100	10	obvious	slope
37	NW Rock Fish Soup	6/12/2023	90	10	obvious	gutter
38	Surgeons	6/12/2023	89	10	cryptic	cave
39	Surgeons	6/12/2023	77	8	cryptic	cave
40	Surgeons	6/12/2023	108	12	cryptic	gutter
41	Julian Rocks northern side	6/14/2023	83	18	obvious	open
42	Julian Rocks northern side	6/14/2023	99	18	obvious	open
43	Julian Rocks southern side	6/14/2023	128	14	cryptic	open
44	Fish Rock Cave	6/19/2023	130	27	cryptic	boulders
45	Fish Rock Cave	6/19/2023	100	16	cryptic	cave
46	Fish Rock Land of Giants	6/19/2023	70	23	obvious	wall
47	Fish Rock Land of Giants	6/19/2023	100	20	obvious	wall
48	Cod Ground	9/8/2023	83	26	obvious	gutter
49	Cod Ground	9/8/2023	105	28	obvious	boulders
50	Looking Glass	2/22/2023	55	12	cryptic	cave
51	Boondelbah Island - South	3/29/2023	50	18	cryptic	boulders
52	Outer Edith Breaker	7/12/2023	110	23	obvious	gutter
53	Outer Edith Breaker	7/12/2023	80	23	obvious	gutter
54	Outer Edith Breaker	7/12/2023	70	23	obvious	boulders
55	Inner Edith Breaker	4/27/2023	55	15	obvious	boulders
56	Little Seal Rock	6/2/2023	100	15	cryptic	cave
57	Little Seal Rock	6/2/2023	90	15	cryptic	cave
58	Little Seal Rock	6/2/2023	80	16	obvious	boulders
59	Little Seal Rock	6/2/2023	55	16	obvious	boulders
60	Forster - Pinnacle	6/6/2023	100	32	obvious	boulders
61	Forster - Pinnacle	6/6/2023	60	30	obvious	boulders
62	Sylphs Hole	2/28/2023	18	2	cryptic	coral
63	Shiprock	2/28/2023	35	1.5	cryptic	overhang
64	North Bay	3/2/2023	35	1.5	cryptic	wreck
65	North Bay	3/2/2023	48	1.5	cryptic	wreck
66	Dave’s Cave (Old Gulch)	3/2/2023	71	8	cryptic	cave
67	Yellow Rock	3/2/2023	70	8	cryptic	overhang
68	North Rock	3/3/2023	85	30	cryptic	cave
69	North Rock	3/6/2023	100	30	cryptic	cave

Table 2: Observations of Black rockcod in 2024 key site surveys with length, depth, habitat, and fish detectability recorded.

Fish	Location	Date	Length (cm)	Depth (m)	Sighting type	Habitat
1	South Solitary Is north end	17/04/2024	110	17	obvious	open
2	South Solitary Is north end	17/04/2024	105	13	obvious	gutter
3	South Solitary Is north end	17/04/2024	66	11	cryptic	cave
4	South Solitary Is north end	17/04/2024	118	12	cryptic	gutter
5	South Solitary Is north end	17/04/2024	70	10	cryptic	gutter
6	South Solitary Is north end	17/04/2024	106	11	obvious	gutter
7	South Solitary Is north end	17/04/2024	80	13	cryptic	underhang
8	South Solitary Is north end	17/04/2024	75	11	cryptic	boulders
9	South Solitary Is north end	17/04/2024	100	11	cryptic	boulders
10	South Solitary Is north end	17/04/2024	122	14	cryptic	boulders
11	South Solitary Is north end	17/04/2024	100	15	cryptic	boulders
12	South Solitary Is north end	17/04/2024	73	11	cryptic	boulders
13	South Solitary west side	17/04/2024	90	17	cryptic	boulders
14	South Solitary west side	17/04/2024	90	20	cryptic	boulders
15	South Solitary west side	17/04/2024	75	17	cryptic	boulders
16	South Solitary west side	17/04/2024	130	17	cryptic	boulders
17	South Solitary west side	17/04/2024	68	11	cryptic	boulders
18	South Solitary west side	17/04/2024	80	12	obvious	open
19	South Solitary west side	17/04/2024	75	7	obvious	open
20	Pimpernel Rock	30/04/2024	82	30	cryptic	wall
21	Pimpernel Rock	30/04/2024	87	35	cryptic	cave
22	Pimpernel Rock	30/04/2024	110	35	cryptic	cave
23	Pimpernel Rock	30/04/2024	67	28	cryptic	open
24	Pimpernel Rock	30/04/2024	86	30	obvious	open
25	North Solitary Anemone Bay	30/05/2024	111	16	cryptic	open
26	North Solitary Anemone Bay	30/05/2024	108	16	cryptic	open
27	North Solitary Anemone Bay	30/05/2024	80	15	cryptic	underhang
28	North Solitary Anemone Bay	30/05/2024	123	16	obvious	open
29	North Solitary Anemone Bay	30/05/2024	85	16	obvious	open
30	NW Rock Fish Soup	30/05/2024	95	12	cryptic	underhang
31	NW Rock Fish Soup	30/05/2024	110	13	obvious	underhang
32	NW Rock Fish Soup	30/05/2024	95	13	obvious	underhang
33	NW Rock Fish Soup	30/05/2024	75	14	obvious	open
34	NW Rock Fish Soup	30/05/2024	70	13	obvious	open
35	NW Rock Fish Soup	30/05/2024	60	13	obvious	open
36	NW Rock Fish Soup	30/05/2024	90	9	obvious	open
37	Fish Rock Land of Giants	27/05/2024	130	28	obvious	open
38	Fish Rock Land of Giants	27/05/2024	140	28	obvious	open
39	Fish Rock Land of Giants	27/05/2024	90	20	obvious	open
40	Fish Rock Land of Giants	27/05/2024	140	20	obvious	open
41	Fish Rock Cave	27/05/2024	100	12	cryptic	cave
42	Fish Rock Cave	27/05/2024	70	12	cryptic	cave
43	Fish Rock Cave	27/05/2024	50	12	cryptic	cave

44	Little Seal Rock	25/03/2024	90	18	Open	Gutter
45	Little Seal Rock	25/03/2024	65	15	Open	Boulders
46	Little Seal Rock	25/03/2024	80	14	Open	Boulders
47	Outer Edith Breaker	26/03/2024	70	12	Open	Boulders
48	Outer Edith Breaker	26/03/2024	100	16	Open	Boulders
49	Outer Edith Breaker	26/03/2024	60	23	Open	Cave
50	Outer Edith Breaker	26/03/2024	130	28	Open	Cave
51	Outer Edith Breaker	26/03/2024	70	28	Open	Gutter
52	Outer Edith Breaker	26/03/2024	50	28	Hidden	Cave
53	Forster Pinnacle	27/03/2024	80	28	Open	Boulders
54	Forster Pinnacle	27/03/2024	55	28	Hidden	Cave
55	Forster Pinnacle	27/03/2024	135	30	Open	Boulders
56	North Rock	2/04/2024	110	30	cryptic	in cave swim-through
57	North Rock	2/04/2024	140	32	cryptic	in cave swim-through
58	10th June	2/04/2024	100	23	obvious	open gravel
59	10th June	2/04/2024	130	23	obvious	open gravel
60	Old Gulch - Daves Cave	2/04/2024	50	12	cryptic	bommie
61	Old Gulch - Daves Cave	2/04/2024	80	12	cryptic	bommie
62	Trevally Hole	3/04/2024	60	13	cryptic	cave
63	Trevally Hole	3/04/2024	50	13	cryptic	cave
64	Trevally Hole	3/04/2024	40	10	cryptic	cave
65	Trevally Hole	3/04/2024	120	7	obvious	open water
66	Yellow Rock	3/04/2024	50	7	cryptic	underhang
67	Sylphs Hole	4/04/2024	25	1	cryptic	reef hole
68	North Bay	8/04/2024	50	1.5	cryptic	in wreck
69	North Passage south	9/04/2024	25	3	cryptic	under coral table Acropora

3.2 Key sites – temporal pattern (2010–2024)

Through time, the abundance of Black rockcod observed at the overall key survey sites in northern NSW has remained relatively consistent (Figure 1). Within the SIMP, the mean number of observed Black rockcod for each survey period is 37.6 ± 2.0 S.E compared with 13.4 ± 1.0 for PSGLMP and 7.8 ± 1.1 for Fish Rock.

Figure 1: Total number of Black rockcod observed at key survey sites in the SIMP (including Pimpernel Rock), PSGLMP and Fish Rock (SW Rocks) from 2010 – 2024.

Of the 19 key sites in northern NSW, a subset of these sites (n=12) (Table 3) have been sampled in all survey years (11 years of the 15-year period from 2010 to 2024). These 12 sites enable a temporal comparison of counts that indicate a trend in relative abundance at important Black rockcod sites (Figure 2). Relative abundance was stable across years until 2021, when it showed a slight decrease with the lowest abundance recorded in total at these 12 sites. Numbers have started to increase again since the low record of 2021 with more in 2024 than 2023; however, still less than was recorded in counts at these sites between 2010 and 2020 (Figure 2). A PERMANOVA test comparing years was not significant overall. Most years did not differ. The noticeable drop in 2021 (Table 3, Figure 2) did not cause a significant change in relative abundance over the 15-year period.

Table 3: Observations of Black rockcod across all surveys at 12 key sites.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
North Sol Anemone Bay	8	7	5	6	3	ns	ns	ns	9	4	9	2	Ns	2	5
NW Rock	11	13	18	13	13	ns	ns	ns	16	11	14	9	Ns	8	7
South Sol west	4	8	8	9	13	ns	ns	ns	6	1	4	6	Ns	4	7
South Sol north end	10	6	10	8	12	ns	ns	ns	17	19	15	4	Ns	10	12
Fish Rock SW	14	8	9	6	5	ns	ns	ns	8	5	6	2	Ns	2	3
Latitude Rock	2	2	4	3	6	ns	ns	ns	0	0	0	0	Ns	2	0
Big Seal Rock	1	0	0	0	0	ns	ns	ns	1	1	1	0	Ns	3	0
Little Seal Rock	2	3	3	5	2	ns	ns	ns	6	6	6	4	Ns	1	3
Edith Breaker - Outer	2	2	2	1	2	ns	ns	ns	3	4	ns	3	Ns	3	6
Fingal Island - North	2	1	2	0	0	ns	ns	ns	1	0	ns	0	Ns	1	0
Little Broughton SG	0	1	1	1	1	ns	ns	ns	1	0	0	0	Ns	2	0
Looking Glass	0	0	0	0	0	ns	ns	ns	0	0	0	0	Ns	1	0
SUM	56	51	62	52	57				68	51	55	30		39	43

ns =not sampled

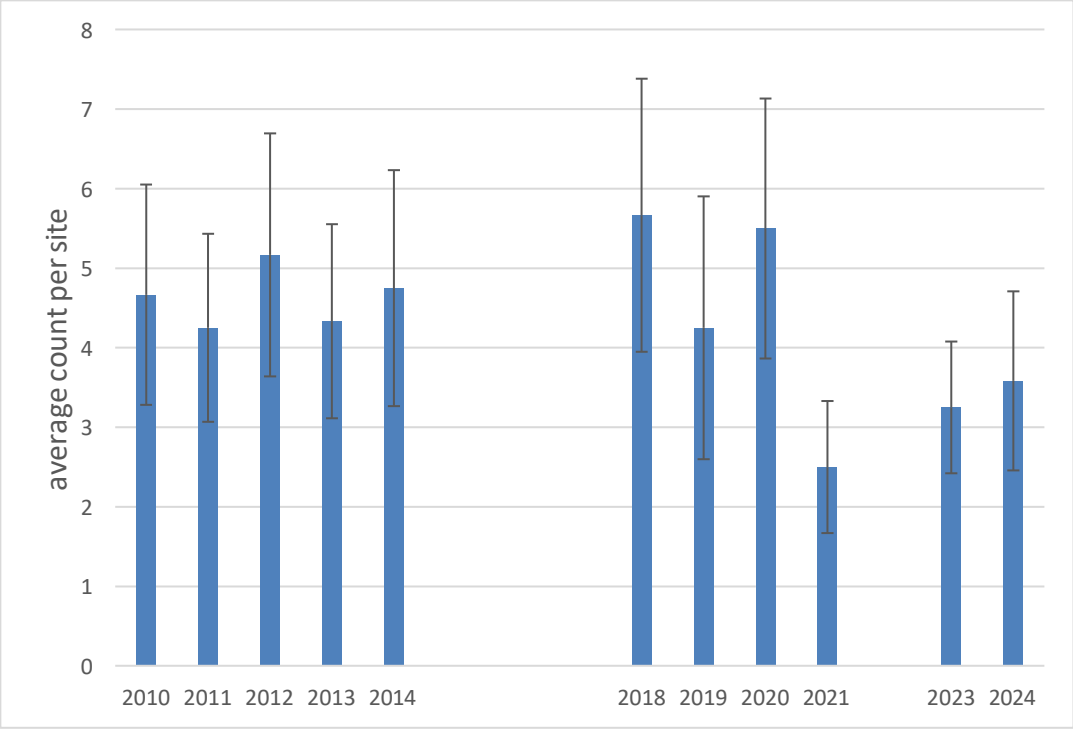

Figure 2: Comparative average count (+/- SE) of Black rockcod observed at 12 key survey sites sampled in 11 years spanning the 15-year period 2010 – 2024.

Lord Howe Island key sites have been surveyed in four years spanning the 15-year period and initially declined in both 2019 and 2023 following the benchmark survey in 2011 (Figure 3). However, the highest number of Black rockcod were recorded in the most recent survey in 2024. These results are expanded on in more detail in a report to the Lord Howe Island Marine Park (See Appendix C).

Figure 3: Length frequency counts for Black rockcod observed at Lord Howe Island Marine Park during the four surveys undertaken.

Overall, we have 765 Black rockcod observations during our key site monitoring program from 2010 to 2024 (for a single count per site per year). The length frequency histogram based on all 765 lengths indicates the size structure at these key sites over that 15-year period (Figure 4). Our surveys have predominantly detected more adults (>75 cm) and sub-adults (>60 cm) than juveniles (Figure 4). We have detected few juveniles <40 cm with only five individual fish recorded less than 30 cm. The largest individual we recorded during all surveys was 142 cm (the only individual larger than 140 cm) and the smallest was 18 cm.

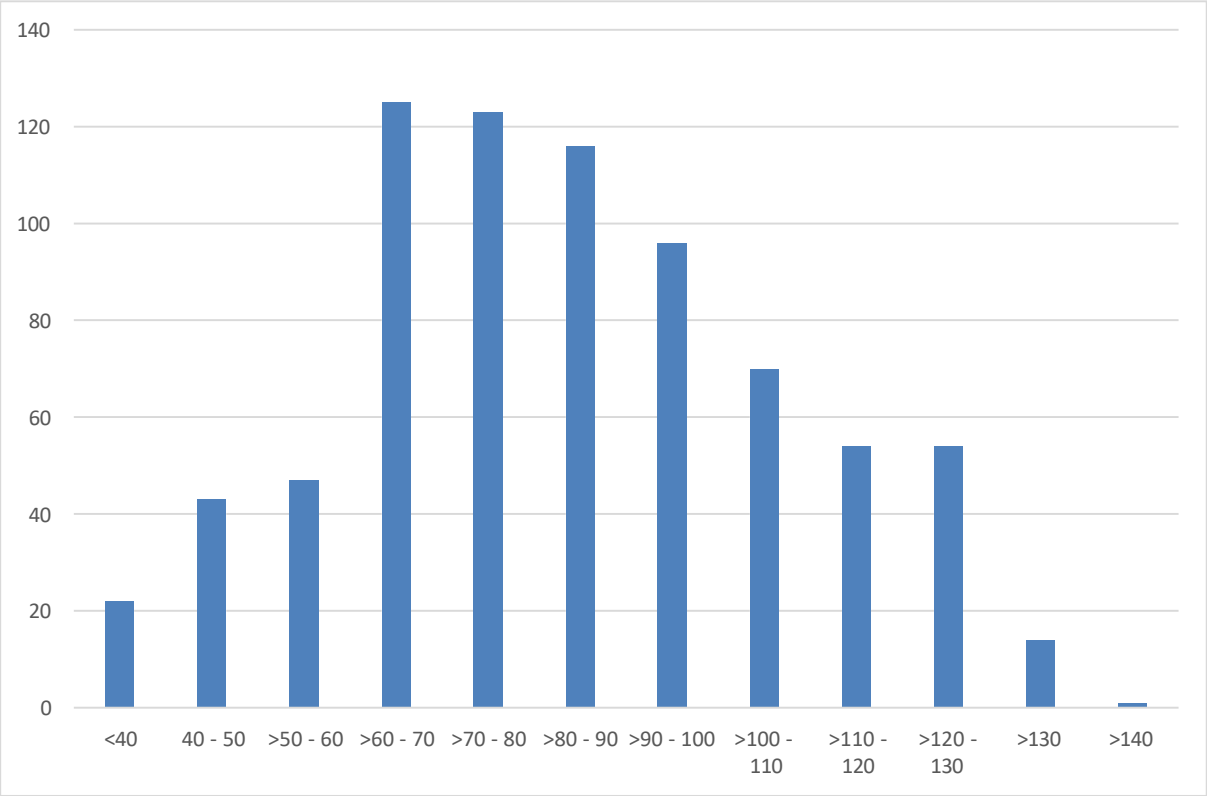

Figure 4: Length frequency counts for Black rockcod observed for all key site observations over 15 years.

When length frequencies for the key sites for each surveyed year are compared, we found similar length frequencies. In 10 of the 11 years, the highest number of lengths recorded was in either the >60 to 70 cm length bin or the >70 to 80 cm length bin, although in 2023, it was in the >90 to 100 cm bin (Figure 5).

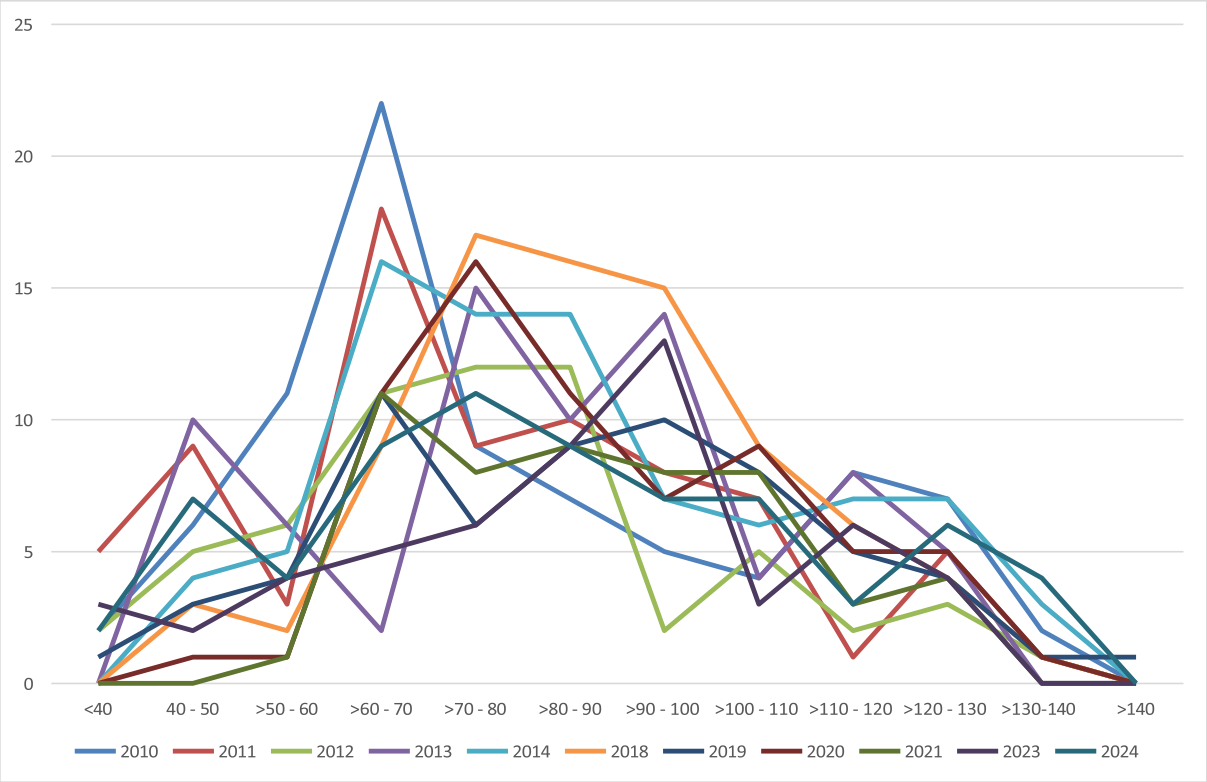

Figure 5: Overall length frequency by Year – number of individuals within 10 cm length class bins for all fish observed at key sites in each year from 2010 to 2024.

3.3 Broadscale survey comparison 2010–11 versus 2023

The initial broadscale surveys conducted in 2009-2011, recorded a total of 117 Black rockcod occurring at 34 of the 83 sites (41% of sites) surveyed (Harasti and Malcolm, 2013). The broadscale survey sites were resurveyed in 2023 with a total of 67 Black rockcod observed at 27 of the 83 original sites (32% of sites). An additional 2 Black rockcod were recorded at one site in 2023 that were not surveyed in the initial broadscale survey: Cod Grounds, however, these extra 2 fish are not included in the comparisons.

There has been a recorded reduction of 43% in the relative abundance of Black rockcod at the broadscale survey sites over the past 15 years. There was also an 8% reduction in the proportion of sites where Black rockcod were observed (40% of sites reduced to 32% of the original 83 Sites). Abundance of black cod was seen to decline across most locations over the past 15 years. The declines are most evident in the PSGLMP and at Fish Rock (Figure 6).

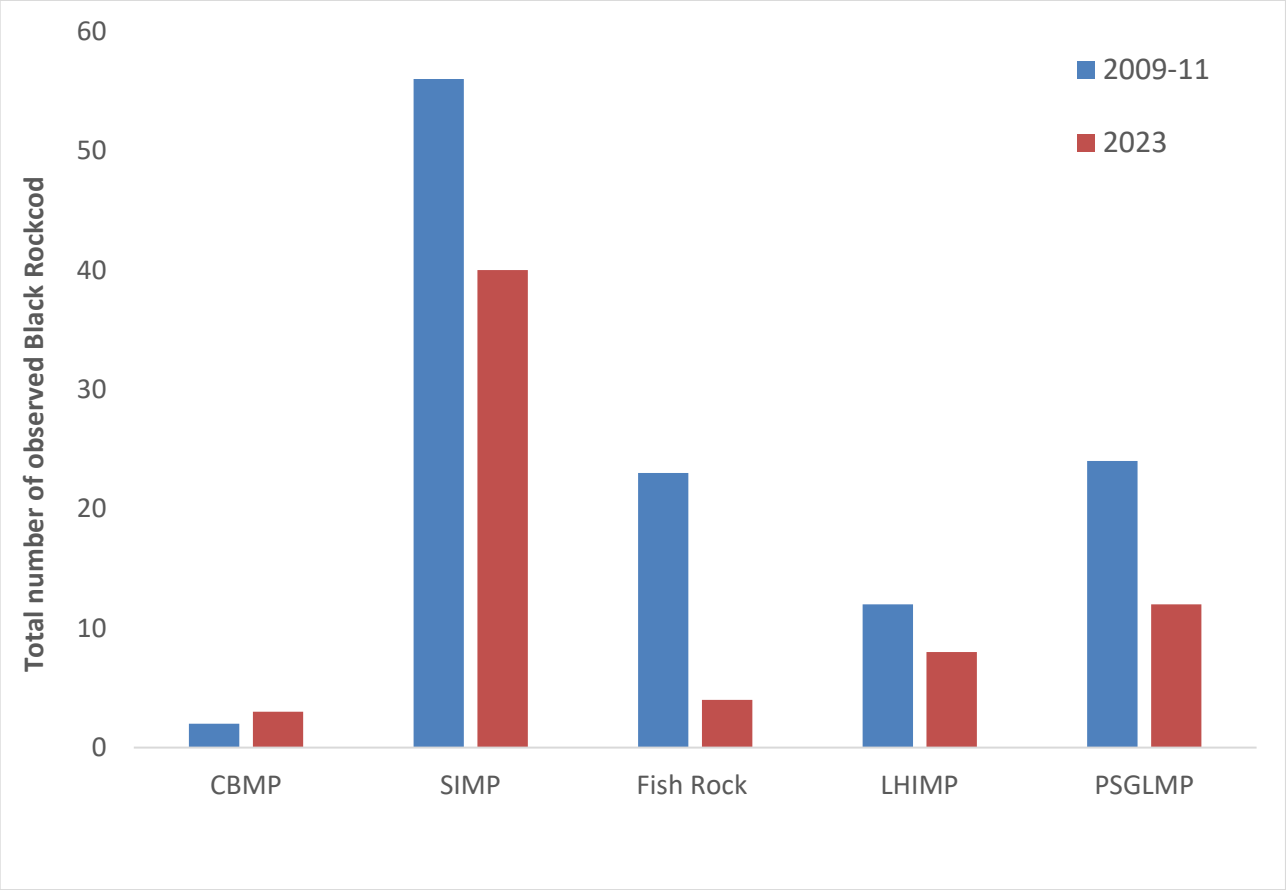

Figure 6 : Total number of observed Black rockcod on broadscale surveys in 2009-2011 and 2023 across NSW Marine Parks and Fish Rock.

An additional eight sites were surveyed in 2023 that were not surveyed in the first broadscale (benchmark) survey in 2009-11. This includes a site in the 4 km^2 Cod Grounds Marine Park (Commonwealth Waters) with 2 Black rockcod observed (not included in the figure above). With this additional site, a total of 69 Black rockcod were recorded in 2023.

Total length of Black rockcod significantly increased from the initial broadscale survey in 2009-11 to the survey conducted in 2023 ($F_{1,184}$ = 12.18 P< 0·01). The mean length of Black rockcod recorded in 2023 was 90.5 ± 2.9 cm S.E compared to 77.9 ± 2.8 S.E in 2009-11. This increase was found across all marine parks surveyed and at Fish Rock (Figure 7). The mean largest fish for both surveys were observed at Pimpernel Rock, Solitary Islands Marine Park (Commonwealth Waters), whilst the mean smallest sized fish were observed at Lord Howe Island for both surveys.

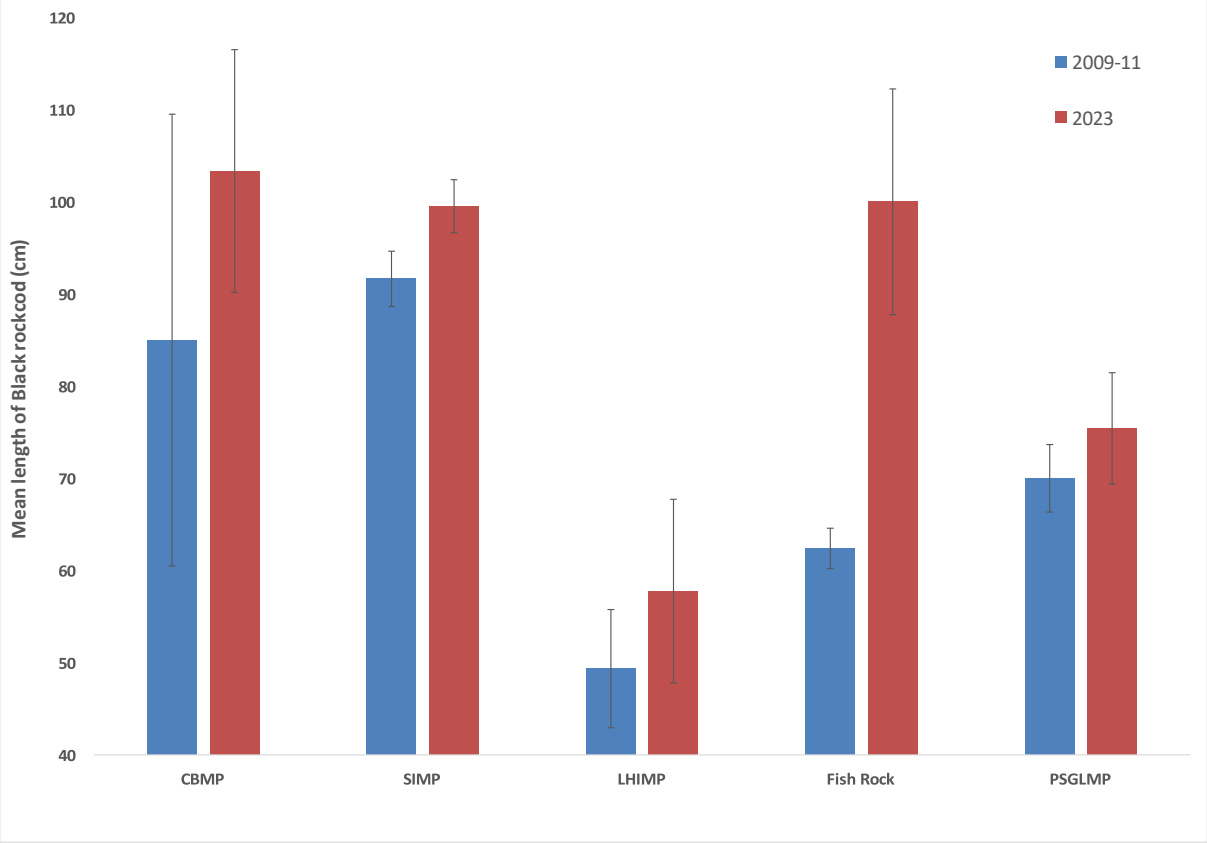

Figure 7: The mean length (cm with S.E) of observed Black rockcod for the broadscale surveys conducted in 2009-2011 and in 2023.

There was an increase in the overall proportion of larger fish from the first (2009-11) to the second (2023) broadscale survey. The length class with the most individuals in 2009-11 was 60 to 70 cm, which are sub-adult. In 2023, the length class with most individuals was 90 to 100 cm, which will be large mature females (Figure 8).

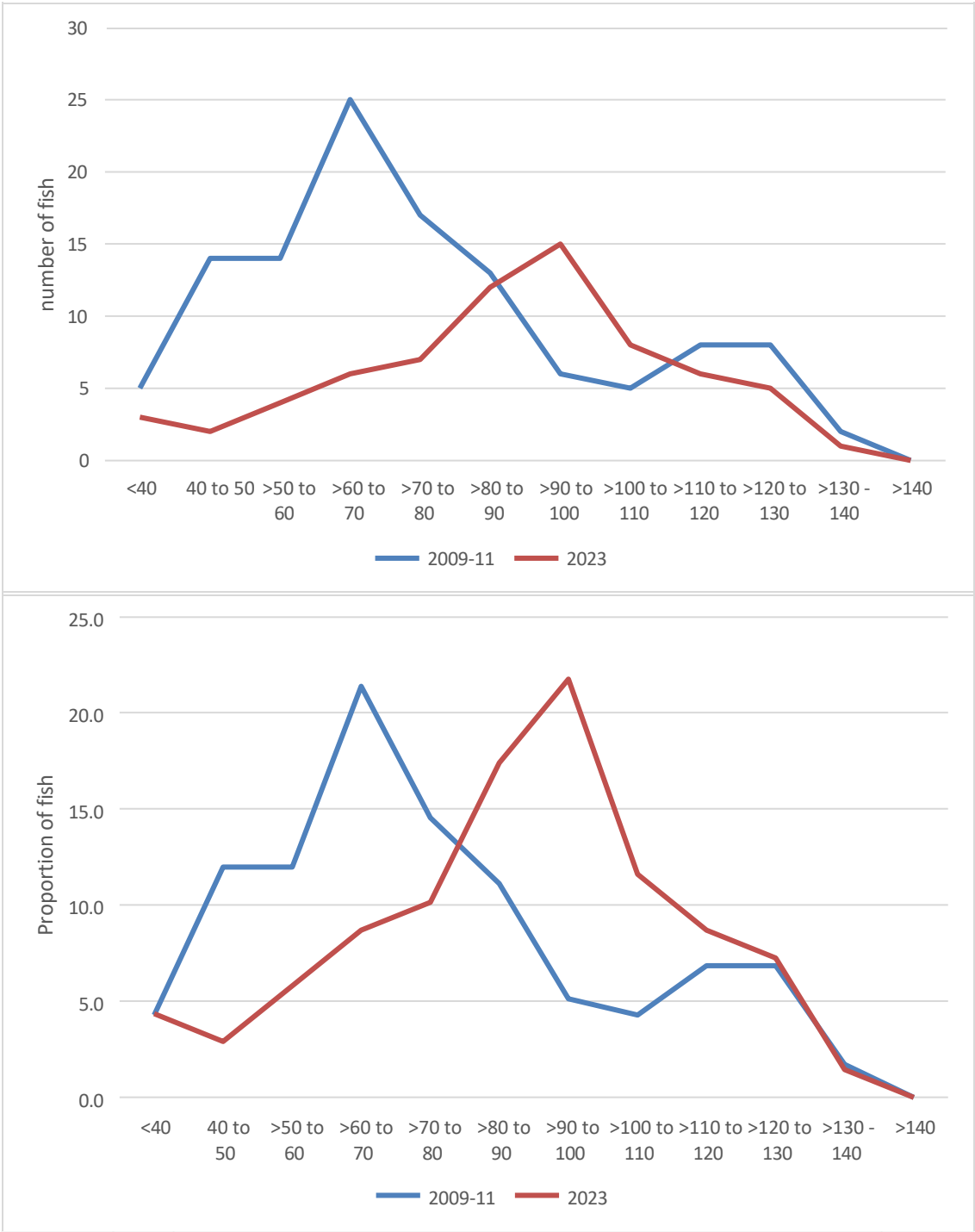

Figure 8: Length frequency by 10cm bins of observed Black rockcod for the broadscale surveys conducted in 2009-2011 and in 2023. Figure 8a = actual number of fish in each length class bin; Figure 8b = proportion of fish in each length class bin.

A Kolmogorov-Smirnov test comparing these two length frequency distributions (2009-11 vs 2023) indicated a significant difference between the two distributions ($p < 0.001$).

PERMANOVA comparison of fished and 'no take' sanctuary zone sites for the two broadscale surveys show a significant difference between Management type ('no take' sanctuary zone versus fished areas) where P(perm) <0.05 and where Period (2009-11 vs 2023) is non-significant: P(perm) = 0.14; and the interaction between Management type and Period is non-significant: (P(perm) = 0.52. The significant difference for management type was due to a higher average abundance in sanctuary zone than in fished areas. Although the average was reduced in 2023 in both Management types relative to the averages in those Management types in 2009-11, the difference between Management types was consistent in each survey period (Figure 9). Of interest is that the difference between 2009-2011 and 2023 is more visually apparent (Standard Error bars fully separated) in fished areas than sanctuary zone, suggesting a potential stronger decline in fished areas over that period, though the interaction was not statistically significant.

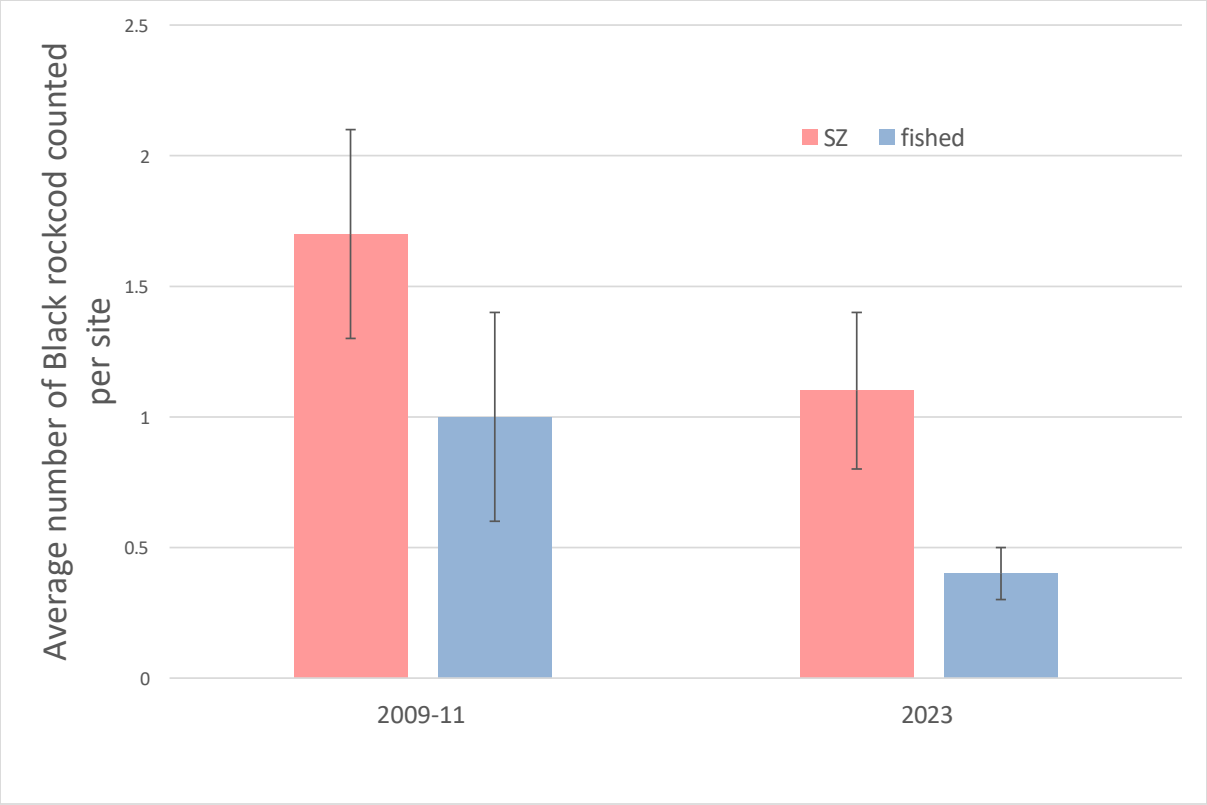

Figure 9: Average number (+/- SE) of Black rockcod counted per site by Management type ('no take' sanctuary zone; fished areas) and by Period (2009-11; 2023).

4. Discussion

Although the Black rockcod has been protected since 1983, the data collected as part of this NESP research project indicates that the species is showing little evidence of consistent recovery over the past 15 years. The repeat of the broadscale surveys (originally undertaken in 2009-2011) in 2023 indicates that the species is declining across its range. From the initial broadscale surveys in 2009-2011, compared with the surveys undertaken in 2023, the relative abundance of Black rockcod has decreased by 43%. These declines are most evident at sites within the Port Stephens-Great Lakes Marine Park, Fish Rock at South West Rocks and Lord Howe Island Marine Park. There was also a reduction in the proportion of broadscale monitoring sites where we observed Black rockcod.

However, relative abundance counts in the 2024 survey of this monitoring program did have some positive indications. The highest total count at Lord Howe Island was recorded in 2024, after the lowest in 2019, indicating that there is hope for recovery occurring in the waters of Lord Howe Island. The numbers of Black rockcod observed at the key sites in 2023 (n= 67) is very similar to that observed in 2024 (n=68). Such similarity in abundance between the two years a is a good indication that the Black rockcod populations at these sites could be considered stable, however, there is yet no indication to show they are recovering.

When compared with observations by spearfishers and captures of Black rockcod from the 1950s and 1960s (Andrewartha & Kemp, 1968), the abundance of Black rockcod observed during the 2023 and 2024 surveys indicate that the species is a long way off from recovering to abundances of over 50 years ago. Oral history records (Johnstone 2022 - PhD Thesis) and historical photographs from Lord Howe Island also suggest Black rockcod were considerably more abundant in the mid twentieth century (see image Appendix C - Lord Howe Island fishing competition catch). One of our highest monitoring counts is at Fish Soup (NW Rock, Solitary Islands) with 18 individual fish recorded. Yet, one oral history record indicates there used to be many more individuals at this site: “..one fisherman caught 40 black cod at Fish Soup back in the sixties” (Johnstone 2022 - PhD Thesis: oral history transcript - Bob Howard).

The Solitary Islands Marine Park (SIMP) is considered a stronghold for the species, with the largest abundances over the past 15 years recorded at sites in the marine park. Sites in the SIMP have shown stable abundances of Black rockcod between 2010 and 2024, with no obvious variation in annual abundance. Black rockcod sites such as the northern end of South Solitary Island, Anemone Bay (North Solitary Island), and Fish Soup (North-West Rock), are located in no-take sanctuary zones which are providing high levels of protection for the species. As these no-take areas prevent all fishing, the incidental capture of Black rockcod is reduced, and subsequent injuries or mortality from hooking injuries, thus increasing the chance of Black rockcod to survive. However, these sanctuary zones mentioned above are all relatively narrow (<200m wide) and there is potential for Black rockcod to move across the zone boundary at times and be on reef that is fished.

One positive finding from the 2023 broadscale surveys is that the mean length of Black rockcod was found to significantly increase from 2009-2011 to 2023. The Black rockcod is considered to change sex from female to male at approximately 1–1.1 m in length (Francis et al., 2015), and in the 2023 surveys, almost half of the fish observed were greater than 1 m in length. As more fish reach maturity, this will hopefully lead to more breeding for the species improving the likelihood of recovery.

The lack of juvenile fish seen during these surveys is not surprising, given it has been shown that juvenile Black rockcod are found in inshore environments, particularly rock pool habitats (Harasti et al., 2014). This project did not assess the inshore habitats where juveniles are known to occur, so an assessment on whether recruitment is occurring within the population is difficult to determine. However, given there were numerous observations in 2023 and 2024 of sub-adult fish at some locations, particularly small fish observed at Lord Howe Island, it is an indicator that recruitment in the species is occurring. Although to provide a better understanding of recruitment, juvenile habitats like rockpools would need to be surveyed.

The incidental capture of Black rockcod by fishers is an ongoing concern. The species is known to suffer from barotraumas when brought to the surface (Francis et al., 2015) and the likelihood of survival of the fish is considered to be low based on observations by the authors and reports by fishers. Research into fishing release methods to improve post-capture survival of Black rockcod is warranted. However, given the threatened species status of the species, and its susceptibility to hook injuries, experiments would not be able to be directly conducted on the Black rockcod, so alternatives would need to be considered.

As suggested by Malcolm *et al.* (2015), further prohibitions on fishing in key locations are likely to be important for the recovery and long-term survival of this species. Given this species is known to display strong site fidelity, the continued protection of sites where Black rockcod occur, through the implementation of no-take zones or other fishing restrictions, will ultimately benefit the species. The comparison of broadscale sites by Management type (i.e. ‘no take’ sanctuary zone versus fished areas) in both broadscale surveys (2009-11 and 2023) found significantly more Black rockcod in sanctuary zones. This is not due to skewed sampling by management type as the number of sites surveyed by Management type by Period were similar. It may be influenced by sanctuary zones in some locations being situated on good Black rockcod habitat, however at Lord Howe Island the best Black rockcod habitat we surveyed (which also had the largest individuals) were in fished areas in the Admiralty Group of islands, so this is not a consistent bias.

This project provides both marine park and threatened species managers with details on current Black rockcod abundance and size structure. Managers can utilise the information to base further management decisions for the protection and long-term conservation of the species. This data will be of great assistance to the NSW Fisheries Scientific Committee to assist them in their biannual review of its threatened species status using the nationally adopted Common Assessment Method based on IUCN threatened species criteria. Data can also be used by marine park managers to assist in meeting conservation objectives for the marine park as well as being used to help inform the development of marine park management plans.

5. Conclusions

Our findings suggest that Black rockcod have not increased in abundance over the 15-year period since the initial surveys for the species were conducted in 2009-2011 at broadscale and key survey sites. If anything, there has been an overall decline over that 15-year period, as indicated by the 43% decline observed between the surveys of the broadscale sites. Surveys of the 12 key sites monitored in all surveys indicated stability until a noticeable decline in 2021, however, abundances in 2023 and 2024 indicate an improvement on what was observed in 2021.

These surveys provide no indication that Black rockcod are becoming more widely spread on rocky reefs in northern NSW and Lord Howe Island, which is a concern given that ideally, we should be seeing signs of recovery given its long-term protection. One positive is that our findings do suggest the size structure of monitored Black rockcod has increased over the 15-year period since 2009-2011 at broadscale and key sites. There are more mature large females (90 to 100 cm length class), which is a positive benefit to the overall population in terms of reproductive potential.

As the species is slow growing, long-lived and late to mature, undoubtably the recovery of this species will take time and they are unlikely to recover to the level of an ‘un-threatened’ population in the near to long (i.e. decadal-scale) future. How long before we see strong positive signs of recovery is unknown, however, the above mixed indications of recovery suggest that more active management may be needed to help assist the ongoing recovery of this threatened species.

6. Recommendations

Management actions: Continued and increased spatial protection from incidental fishing impacts would help recovery of the species, or at least would not be detrimental to the species recovery. There is an on-going review of the Management Plans for Marine Parks in NSW and in this review process, consideration needs to be given to how Marine Park management plans can be used to assist with the recovery of this and other threatened species.

Likewise, an increased targeted education program about the protected status of Black rockcod and measures that can be implemented if accidentally caught would be helpful. Previously, NSW DPI had an education campaign around 2008 for the Black rockcod which included a tackle box sticker that helped provided key identifying features for Black rockcod and how it differed compared to other NSW cod species. A new educational campaign focusing on species identification, and how to release if incidentally caught, would be of use to reduce any unintentional fishing related mortalities.

Future monitoring: Where feasible, annual monitoring of key Black rockcod sites (Appendix A) should be repeated most years to assess changes in abundance and size. As a minimum, if frequent annual on-going monitoring is not possible, some further monitoring is essential to assess ongoing trends. Though overall differences between years was not statistically significant, the noticeable decline in counts in 2021 is concerning. Given the relative abundance at 12 key monitoring sites showed a stable trend from 2010 to 2020, then a big decline in 2021 with an upward trajectory in 2023 and 2024 (Figure 2), further monitoring of these sites in 2028 and 2029 (at a minimum) is recommended. This would be essential to help evaluate this most recent upward trend and inform ongoing management regarding future signs of recovery.

Threatened species status evaluation: Given that a dataset now exists for the Black rockcod populations spanning 15 years, a reassessment of its threatened species status in NSW should be undertaken. The data collected as part of this research can be used by the NSW FSC to evaluate which IUCN Red list threatened species category (Critically endangered, Endangered or Vulnerable) that the Black rockcod should be categorised.

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Appendix A

Table of Broadscale Sites: worksheet 'Appendix A' in Excel spreadsheet: Black cod broadscale surveys 2010-11 and 2023

.

Region	Area	Location	Site	No Take'	Start Latitude	Start Longitude	Dive method	Approx length	Approx length	min depth	max depth	Depth range	Black rockcod count 2009-11	Black rockcod count 2023
Tweed Moreton	CBMP & far north	Cook Is	Cook Is N side	y	-28.19	153.58	SCUBA	400	400	0	18	18	0	0
Tweed Moreton	CBMP & far north	Julian Rock	Julian Rock south side	y	-28.613	153.629	SCUBA	490	350	0	20	20	1	1
Tweed Moreton	CBMP & far north	Julian Rock	Julian Rock north side	y	-28.61	153.63	SCUBA	400	300	0	20	20	1	2
Tweed Moreton	SIMP (Cth)	Pimpernel Rock	Pimpernel Rock	y	-29.69807	153.39742	SCUBA	200	300	12	35	23	5	4
Tweed Moreton	SIMP	NW Rock	NW Rock Fish Soup	y	-29.91275	153.38354	SCUBA	550	400	0	15	15	11	8
Tweed Moreton	SIMP	North Solitary Is.	North Sol Elbow Cave	y	-29.93034	153.39056	SCUBA	575	550	0	18	18	1	3
Tweed Moreton	SIMP	North Solitary Is.	North Sol E side	y	-29.92543	153.390228	SCUBA	550	350	0	20	20	1	0
Tweed Moreton	SIMP	North Solitary Is.	North Sol Anemone Bay	y	-29.9225	153.38918	SCUBA	530	550	0	20	20	8	2
Tweed Moreton	SIMP	North Solitary Is.	North Sol Bubble Cave	y	-29.92699	153.38628	SCUBA	710	500	0	20	20	1	1
Tweed Moreton	SIMP	Baarcoongerie Shoal	Baarcoongerie Shoal	n	-29.91727	153.2811	SCUBA	459	400	3	14	11	0	0
Tweed Moreton	SIMP	Doherties Wash	Doherties Wash	n	-29.94457	153.2805	SCUBA	347	400	8	16	8	4	0
Tweed Moreton	SIMP	Surgeons Reef	Surgeons Reef	n	-30.00762	153.27028	SCUBA	521	400	2	15	13	0	3
Tweed Moreton	SIMP	Chopper Rock	Chopper Rock	n	-30.00804	153.25613	SCUBA		600	8	14	6	ns	0
Tweed Moreton	SIMP	NW Solitary Is.	NW Solitary E side	n	-30.019	153.27	SCUBA	420	400	0	15	15	0	1
Tweed Moreton	SIMP	NW Solitary Is.	NW Sol W side	y	-30.0177	153.2683	SCUBA	700	700	5	18	13	0	0
Tweed Moreton	SIMP	Corindi Reef	Corindi Reef	n	-30.02	153.22102	SCUBA	412	500	4	9	5	1	0
Tweed Moreton	SIMP	Flat top Point	Flat top Point	y	-30.13072	153.21102	SCUBA	473	450	6	12	6	0	0
Tweed Moreton	SIMP	Groper Is.	Groper Is E side	y	-30.15915	153.22929	SCUBA	480	450	0	18	18	3	0

Tweed Moreton	SIMP	Groper Is.	Groper Is N side	y	-30.15952	153.22572	SCUBA	710	700	0	15	15	0	0
Tweed Moreton	SIMP	South Solitary Is.	South Solitary west side	y	-30.20779	153.26631	SCUBA	720	750	0	20	20	4	4
Tweed Moreton	SIMP	South Solitary Is.	South Solitary north end	y	-30.20168	153.26711	SCUBA	575	600	0	20	20	10	10
Tweed Moreton	SIMP	South Solitary Is.	South Sol E Side	n	-30.20331	153.26851	SCUBA	435	600	0	25	25	4	0
Tweed Moreton	SIMP	40 Acres Reef	40 Acres Reef	y	-30.20408	153.21737	SCUBA	645	600	10	19	9	2	2
Tweed Moreton	SIMP	Split Soilitary Is.	Split Sol E side	y	-30.24086	153.18249	SCUBA	400	500	0	15	15	0	1
Tweed Moreton	SIMP	Split Soilitary Is.	Split Sol SW side	n	-30.24234	153.17993	SCUBA		400	0	18	18	ns	0
Tweed Moreton	SIMP	Split Bommie	Split Bommie	n	-30.23968	153.19502	SCUBA	670	400	7	17	10	1	1
Tweed Moreton	SIMP	Little Muttonbird Island	Little Muttonbird Island	n	-30.29515	153.1448	SCUBA	396	300	4	9	5	0	0
Tweed Moreton	Smoky Cape	Fish Rock	Fish Rock SW	n	-30.93912	153.10034	SCUBA	700	700	0	30	30	13	2
Tweed Moreton	Smoky Cape	Fish Rock	Fish Rock NE	n	-30.939	153.10023	SCUBA	805	800	0	30	30	10	2
Tweed Moreton	Smoky Cape	Green Island	Green Island	n	-30.90988	153.09033	SCUBA	442	400	0	15	15	0	0
Tweed Moreton	Smoky Cape	Black Rock	Black Rock	n	-30.94973	153.07568	SCUBA	410	500	0	18	18	0	0
Tweed Moreton	Smoky Cape	Rockpool coastline	Rockpool coastline	n	-30.87722	153.0759	SCUBA	364	350	3	8	5	0	0
Tweed Moreton	Smoky Cape	Gaol breakwater rocks	Gaol breakwater rocks	n	-30.8751	153.06723	snorkel	322	150	0	5	5	0	0
Manning	Cod Grounds	Cod Grounds	Cod Grounds reef	y	-31.68	152.91	SCUBA		300	24	30	6	ns	2
Manning	PSGLMP	Fingal Island - West/north	Fingal Island - West	y	-32.75315	152.190616	SCUBA				9		1	0
Manning	PSGLMP	Fingal Island - South	Fingal Island - East	y	-32.74773	152.197900	SCUBA				12		0	0
Manning	PSGLMP	Cabbage Tree Island	West side	y	-32.68820	152.222716	SCUBA				11		0	0
Manning	PSGLMP	Cabbage Tree Island	East side	y	-32.68863	152.228800	SCUBA				18		0	0
Manning	PSGLMP	Cabbage Tree Island	North-East side	y	-32.68662	152.228783	SCUBA				18		0	0
Manning	PSGLMP	Cabbage Tree Island	North side	y	-32.68613	152.227950	SCUBA				18		0	0
Manning	PSGLMP	Halifax Park	Halifax Park	y	-32.70948	152.161316	SCUBA				18		1	0
Manning	PSGLMP	Fly Point - West	Fly Point - West	y	-32.71432	152.152100	SCUBA				15		0	0
Manning	PSGLMP	Fly Point - East	Fly Point - East	y	-32.71400	152.152316	SCUBA				15		0	0
Manning	PSGLMP	Little Beach	Little Beach	y	-32.71320	152.156883	SCUBA				12		0	0

Manning	PSGLMP	Little Broughton Island	Looking Glass	y	-32.63048	152.334183	SCUBA				22		1	1
Manning	PSGLMP	Little Broughton Island	East Head	y	-32.62353	152.337100	SCUBA				18		0	0
Manning	PSGLMP	Little Broughton Island	Shark Gutters	y	-32.61765	152.334183	SCUBA				14		1	0
Manning	PSGLMP	Big Seal Rock - West	Big Seal Rock - West	y	-32.46188	152.552560	SCUBA				20		0	0
Manning	PSGLMP	Big Seal Rock - East	Big Seal Rock - East	y	-32.46175	152.552983	SCUBA				20		3	0
Manning	PSGLMP	Little Seal Rock	Little Seal Rock	y	-32.47347	152.547100	SCUBA				19		1	4
Manning	PSGLMP	Forster Pinnacle	Forster Pinnacle	y	-32.22850	152.601166	SCUBA				20		6	2
Manning	PSGLMP	Fingal Island - North	Fingal Island - North	n	-32.74090	152.186266	SCUBA				9		0	0
Manning	PSGLMP	Battleship Rock/Boulder Bay	Battleship Rock / Boulder Bay	n	-32.75667	152.178200	SCUBA				10		0	0
Manning	PSGLMP	Boondelbah Island	West	n	-32.70553	152.227000	SCUBA				18		0	0
Manning	PSGLMP	Boondelbah Island	south east	n	-32.70613	152.230850	SCUBA				20		0	1
Manning	PSGLMP	Little Island	Little Island	n	-32.70053	152.244383	SCUBA				15		0	0
Manning	PSGLMP	Red Patch Reef	Red Patch Reef	n	-32.71655	152.133250	SCUBA				10		0	0
Manning	PSGLMP	Dutchies to Pipeline	Dutchies to Pipeline	n	-32.71752	152.138216	SCUBA				8		0	0
Manning	PSGLMP	Nelson Bay Breakwall	Nelson Bay Breakwall	n	-32.71697	152.146633	SCUBA				8		0	0
Manning	PSGLMP	Pipeline	Pipeline	n	-32.71792	152.134583	SCUBA				8		0	0
Manning	PSGLMP	Broughton Island - North	Broughton Island - North	n	-32.61207	152.324030	SCUBA				16		0	0
Manning	PSGLMP	Broughton Bubble Cave	Broughton Bubble Cave	n							10		ns	0
Manning	PSGLMP	North Rock - West	North Rock - West	n	-32.60122	152.319816	SCUBA				9		0	0
Manning	PSGLMP	North Rock - East	North Rock - East	n	-32.60155	152.321600	SCUBA				15		0	0
Manning	PSGLMP	Edith Breaker - Inner	Edith Breaker - Inner	n	-32.48435	152.501250	SCUBA				18		0	1
Manning	PSGLMP	Edith Breaker - Outer	Edith Breaker - Outer	n	-32.49123	152.511116	SCUBA				30		3	3
Manning	PSGLMP	White Top Rock	White Top Rock	n	-32.43048	152.536760	SCUBA				10		0	0
Manning	PSGLMP	Skelton Rock	Skelton Rock - north	n	-32.40543	152.536100	SCUBA				20		0	0
Manning	PSGLMP	Skelton Rock	Skelton Rock - south	n			SCUBA				20		ns	0
Manning	PSGLMP	Latitude Reef	Latitude Reef	n	-32.20868	152.565916	SCUBA				13		7	0
Lord Howe	LHIMP	Admiralty Islands	North Rock	n	-31.48782	159.071630	SCUBA	1100	550	15	30	15	0	2
Lord Howe	LHIMP	Admiralty Islands	10th of June	n	-31.49625	159.071516	SCUBA	1200	450	0	20	20	1	0

Lord Howe	LHIMP	LHI Lagoon	North Bay	y	-31.52128	159.046900	Snorkel	663	450	0	2	2	2	2
Lord Howe	LHIMP	LHI Lagoon	Comets Hole	y	-31.53965	159.066050	SCUBA	566	400	1	8	7	2	0
Lord Howe	LHIMP	Admiralty Islands	Sugarloaf Is.	y	-31.50361	159.066616	SCUBA	1000	650	0	16	16	2	0
Lord Howe	LHIMP	LHI Lagoon	South Passage	n	-31.55765	159.067017	SCUBA	810	550	1	12	11	0	0
Lord Howe	LHIMP	LHI Lagoon	Erscotts Passage	y	-31.55105	159.065433	SCUBA	808	700	0	14	14	1	0
Lord Howe	LHIMP	LHI	Old Gulch	n	-31.51150	159.042860	SCUBA	1100	700	0	16	16	0	1
Lord Howe	LHIMP	Balls Pyramid	WheatSheaf Rocks	n	-31.75588	159.236530	SCUBA	784	480	0	25	25	0	0
Lord Howe	LHIMP	Balls Pyramid	Observatory Rocks	y	-31.75102	159.238160	SCUBA	655	350	0	26	26	0	0
Lord Howe	LHIMP	LHI Lagoon	Ship Rock	n	-31.52607	159.060133	snorkel	1000	750	0	3	3	2	1
Lord Howe	LHIMP	Admiralty Islands	10th of June Deep	n	-31.49540	159.071983	SCUBA	557	350	0	30	30	1	0
Lord Howe	LHIMP	LHI	Malabar	y	-31.51153	159.055200	SCUBA	761	600	5	18	13	1	0
Lord Howe	LHIMP	LHI Lagoon	Sylphs Hole	y	-31.52421	159.05493	Snorkel		350	0	5	5	0	1
Lord Howe	LHIMP	LHI	Yellow Rock	n	-31.52785	159.045800	SCUBA	932	650	4	14	10	0	1
Lord Howe	LHIMP	LHI	Trevally Hole	y	-31.54737	159.054083	SCUBA	1200	500	6	15	9	0	0
Lord Howe	LHIMP	LHI	Neds Beach	y	-31.51838	159.066883	SCUBA	1300	1000	0	14	14	0	0
Lord Howe	LHIMP	Admiralty Islands	Ryans Reef	y	-31.49858	159.063950	SCUBA	679	450	5	20	15	0	0
Lord Howe	LHIMP	LHI Lagoon	NorthPassage south	n	-31.52388	159.049916	Snorkel	697	350	0	3	3	0	0
Lord Howe	LHIMP	LHI Lagoon	Erscotts Hole	y			Snorkel		450	1	6	5	ns	0
Lord Howe	LHIMP	LHI shore	Herring Pools	n			Snorkel		15	0	3	3	ns	0

Appendix B

Table of Key Monitoring Sites

Region	Area	Location	Site	Latitude	Longitude	swim length	min depth	max depth	Depth range	SZ	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Tweed-Moreton	CBMP	Julian Rocks	Julian Rock north side	-28.613000	153.62900	400	0	22	22	y	ns	1	ns	ns	ns	ns	ns	ns	ns	3	0	1	1	ns	2	ns
Tweed-Moreton	CBMP	Julian Rocks	Julian Rock south side	-28.610000	153.63000	490	0	20	20	y	ns	1	ns	ns	ns	ns	ns	ns	ns	0	1	ns	0	ns	1	ns
Tweed-Moreton	SIMP	Pimpernel Rock	Pimpernel Rock	-29.698070	153.39742	200	10	35	25	y	ns	5	ns	ns	ns	ns	10	ns	9	7	5	6	5	ns	4	5
Tweed-Moreton	SIMP	NW Rock	NW Rock Fish Soup	-29.912750	153.38354	550	0	16	16	y	ns	11	13	18	13	13	ns	ns	ns	16	11	14	9	ns	8	7
Tweed-Moreton	SIMP	North Solitary Is.	North Sol Anemone Bay	-29.922500	153.38918	530	0	24	24	y	ns	8	7	5	6	3	ns	ns	ns	9	4	9	2	ns	2	5
Tweed-Moreton	SIMP	South Solitary Is.	South Sol north end	-30.201680	153.26711	575	0	20	20	y	ns	10	6	10	8	12	ns	ns	ns	17	19	15	7	ns	10	12
Tweed-Moreton	SIMP	South Solitary Is.	South Sol W side	-30.207790	153.26631	720	0	25	25	y	ns	4	8	8	9	13	ns	ns	ns	6	1	4	6	ns	4	7
Tweed-Moreton	Smoky Cape	Fish Rock	Fish Rock SW	-30.939120	153.10034	700	0	30	30	n	ns	14	8	9	6	5	ns	ns	ns	8	5	6	2	ns	2	3
Tweed-Moreton	Smoky Cape	Fish Rock	Fish Rock NE	-30.939000	153.10023	805	0	25	25	n	ns	9	7	7	3	3	ns	ns	ns	ns	ns	ns	11	ns	2	4
Manning Bioregion	PSGLMP	Pinnacle - Forster	Pinnacle - Forster	-32.228500	152.60117					y		6	6	4	4	3	3	ns	ns	2	ns	3	2	ns	6	3
Manning Bioregion	PSGLMP	Latitude Reef	Latitude Rock	-32.208680	152.56592					n		7	2	2	4	3	6	ns	ns	0	0	0	0	ns	7	0
Manning Bioregion	PSGLMP	Big Seal Rock (west)	Big Seal Rock	-32.461883	152.55256					y		3	1	0	0	0	0	ns	ns	1	1	1	0	ns	3	0
Manning Bioregion	PSGLMP	Little Seal Rock	Little Seal Rock	-32.473466	152.54710					y		1	2	3	3	5	2	ns	ns	6	6	6	4	ns	1	3
Manning Bioregion	PSGLMP	Edith Breaker - Outer	Edith Breaker - Outer	-32.491233	152.51112					n		3	2	2	2	1	2	ns	ns	3	4	ns	3	ns	3	6
Manning Bioregion	PSGLMP	Fingal Island - North	Fingal Island - North	-32.740900	152.18627					n		1	2	1	2	0	0	ns	ns	1	0	ns	0	ns	1	0
Manning Bioregion	PSGLMP	North Rock	North Rock	-32.601216	152.31982					n		0	1	1	1	1	0	ns	ns	ns	0	0	0	ns	0	0
Manning Bioregion	PSGLMP	Little Broughton SG	Little Broughton SG	-32.617650	152.33418					y		1	0	1	1	1	1	ns	ns	1	0	0	0	ns	2	0
Manning Bioregion	PSGLMP	Looking Glass	Looking Glass	-32.630483	152.33418					y		1	0	0	0	0	0	ns	ns	0	0	0	0	ns	1	0
Manning Bioregion	PSGLMP	Cabbage Tree Island	Cabbage Tree Island	-32.688630	152.22880					n		0	1	1	1	1	0	ns	ns	ns	0	1	0	ns	0	0
Lord Howe	LHIMP	North Rock	Admiralty Islands	-31.487816	159.07163	1100	0	26	26	n	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	2	2
Lord Howe	LHIMP	10th of June	Admiralty Islands	-31.496250	159.07152	1200	0	23	23	n	ns	ns	1	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	2
Lord Howe	LHIMP	North Bay	LHI lagoon	-31.521280	159.04690	663	0	2	2	y	ns	ns	2	ns	ns	ns	ns	ns	ns	ns	1	ns	ns	ns	2	1
Lord Howe	LHIMP	Comets Hole	LHI lagoon	-31.539650	159.06605	566	0	7	7	y	ns	ns	2	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	0
Lord Howe	LHIMP	Sugarloaf Is.	Admiralty Islands	-31.503610	159.06662	1000	0	20	20	y	ns	ns	2	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	0
Lord Howe	LHIMP	South Passage	Outside lagoon	-31.557650	159.06702	810	2	12	10	n	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	1	ns	ns	ns	0	0
Lord Howe	LHIMP	Erscotts Passage	Outside lagoon	-31.551050	159.06543	808	2	18	16	n	ns	ns	1	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	0
Lord Howe	LHIMP	Old Gulch	LHI north end	-31.511500	159.04286	1100	5	17	12	y	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	1	ns	ns	ns	1	2
Lord Howe	LHIMP	WheatSheaf Rocks	Balls Pyramid	-31.755883	159.23653	784	0	27	27	n	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	ns
Lord Howe	LHIMP	Observatory Rocks	Balls Pyramid	-31.751016	159.23816	655	0	25	25	y	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	ns
Lord Howe	LHIMP	Ship Rock	LHI lagoon	-31.526066	159.06013	1000	0	2	2	n	ns	ns	2	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	1	0
Lord Howe	LHIMP	10th of June Deep	Admiralty Islands	-31.495400	159.07198	557	20	33	13	n	ns	ns	1	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	0
Lord Howe	LHIMP	Malabar	LHI north end	-31.511530	159.05520	761	6	17	11	y	ns	ns	1	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	0	0
Lord Howe	LHIMP	Sylphs Hole	LHI lagoon	-31.524210	159.05493	350	1	5	4	y	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	ns	ns	ns	1	1
Lord Howe	LHIMP	Yellow Rock	Outside lagoon	-31.527850	159.04580	500	4	10	6	n	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1	1
Lord Howe	LHIMP	Trevally Hole	Outside lagoon	-31.547366	159.05408	500	6	9	3	y	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	4
Lord Howe	LHIMP	Neds Beach	east side	-31.518380	159.06688	1000	0	13	13	n	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0
Lord Howe	LHIMP	North Passage south	LHI lagoon	-31.523880	159.04990	400	1	3	2	n	ns	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	1
			TOTAL									**86**	**78**	**72**	**63**	**64**	**24**			**80**	**60**	**66**	**52**		**67**	**69**

Appendix C

Addendum Report: Relative abundance and length of threatened Black rockcod (*Epinephelus daemelii*) within the Lord Howe Island Marine Park

Hamish Malcolm, David Harasti

Addendum NESP Report. NSW Department of Primary Industries, June 2024.

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Summary

The subtropical black rockcod (*Epinephelus daemelii*), listed as 'vulnerable' in NSW is a long-lived and slow growing species from the rockcod/grouper family Serranidae. The species became protected in NSW in 1983 due to concerns over a decline in population numbers. It is also classed as 'vulnerable' and protected in all Commonwealth Waters.

Historically, this species was heavily targeted by local fishers from Lord Howe Island (LHI) as it was considered an excellent eating fish and in plentiful supply (refer 2011 report for local knowledge gained from Oral Histories conducted at LHI – Harasti *et al*. 2011). Even though the species has been protected for the past 40 years, anecdotal information provided to NSW Fisheries suggests it is still incidentally caught by line fishing and sometimes taken.

In February 2011, a total of 18 sites were surveyed using diving, with 12 individual black rockcod observed at eight sites (44% of sites). Nearly all of these were subadults (<70 cm) with only 1 (or potentially 2) adults. The largest fish was estimated to be 110 centimetres (therefore a mature male) observed at the site 10th of June deep, and the smallest measured at 26.3 cm (juvenile). The largest female (i.e. a fish <100 cm) was 65 cm, so likely a sub-adult potentially close to reaching sexual maturity.

In March 2019 only 6 individuals were counted (found at 6 sites) although fewer (14) sites were surveyed in total (42% of surveyed sites with black rockcod). Only one of these fish was mature (i.e. >70 cm). This individual was a very large male (135 cm – precisely measured with stereo-video) observed at North Rock.

In March 2023, 20 sites were surveyed including all 18 sites surveyed in 2011. A total of 8 individual black rockcod were counted and these were found at six sites (30% of sites). So, there were more individuals in 2023 than in 2019 but fewer than 2011 and at relatively fewer sites than in the earlier years. The largest individual in 2023 was estimated at 100 cm (so either already changed to male or a mature female at a size it could change into male). This was smaller than the largest in 2019 and 2011. However, on a positive note, at least half the fish (4) observed in 2023 were at a mature size (>70) with most of these mature females, which is considerably more than 1 mature fish in the earlier surveys.

In April 2024, 17 sites were surveyed including all sites where black rockcod had previously been observed. Due to adverse weather conditions during the survey period, the two sites at Balls Pyramid were not able to be surveyed. A total of 14 individual black rockcod were counted and these were found at eight sites (57% of sites). Therefore in 2024, the highest number of individual fish, the highest proportion of sites where black rockcod were observed (= broadest spread) and the largest individual fish overall was recorded. The largest individual in 2024 was 140 cm, with the second largest 130 cm, both at the outer Admiralty Islands. Of the 14 individuals, six were mature and 8 were immature.

In conclusion,40 years on from their protection from being taken in NSW (i.e. 1983 to 2024), black rockcod numbers in the Lord Howe Island Marine Park (LHIMP), at least in the depths covered in our SCUBA diving surveys (0 to 30 metres), have shown minimal evidence of increasing. Although there was considerable suitable black rockcod habitat, relatively low numbers were observed in all surveys. There were

improved signs in 2024, with at least regarding an adult breeding population which requires a spatial mix of mature females and males, as large males were sighted with a large female in the vicinity of one of these. However, overall, there is minimal evidence of recovery during the 13-year period covered by monitoring to date (2011 to 2024).

Most individuals sighted during our surveys were juvenile to sub-adult fish, hence not contributing to reproductive output at that stage. This included a very small (18 cm) individual in 2023, indicating at least some recruitment is occurring in the LHIMP. Every individual recorded within the lagoon from all four surveys were juvenile to sub-adult showing the importance of the lagoon as a nursery for recruitment. In 2024, 57% of individuals overall were juvenile to subadult. However, 43% were at a mature adult length with three of these large males (~ >105cm), and this was the highest proportion of adults out of the four surveys.

From our experience surveying black rockcod throughout NSW, the Admiralty Islands have excellent black rockcod habitat in deeper waters (especially 20+ m depth) with extensive systems of overhangs, caves and swim-throughs. The largest individual(s) observed in 2011, 2019, 2023, and 2024 were found at either the sites North Rock or 10th of June in the Admiralty Islands. Neither of these sites are within sanctuary zone and line fishing is permitted. Although some natural protection from fishing is provided by the caves and swim through systems at these locations, any black rockcod pulled up from these depths are very likely to suffer swim bladder barotrauma (especially if fish are pulled up quickly to avoid shark depredation).

Additionally, baited remote underwater video (BRUVs) surveys have been undertaken in deeper water (ranging 29 to 48 m depth) during the same period as diver surveys using 30-minute baited deployments. This includes waters in both the Lord Howe Island Marine Park (NSW) and the Lord Howe Island Marine Park (Commonwealth). In 2009, ten black rock cod were recorded from 64 BRUV drops in total (from 16 sites). In 2013 and in 2017, only six black cod were recorded in each year from 61 and 64 drops respectively. Three black rockcod were also detected during an additional 20 drops in 2013 and an additional two in 2017. In 2022, there was a considerable decline in the number of black rockcod detected on BRUVs. Only one black rockcod was recorded from 70 drops at the sixteen sites. Black rockcod were not recorded during an additional 29 drops in 2022. Hence from 2009, 2013, 2017, to 2022, the relative number per BRUV drop showed a declining trend of: 0.15; 0.11; 0.11; 0.01 black rockcod observed per deployment.

Key points and findings:

- Historic reports and oral histories indicate that black rockcod, including large reproductively mature individuals, were previously common and regularly caught in the water surrounding LHI.
- Diver surveys of shallow reefs (0-30m) sites were undertaken in 2011, 2019, 2023 and 2024 (14-18 sites per year) to assess the population status of black rockcod in the LHIMP.
- In all years, relatively low numbers of black rockcod were recorded (12, 6, 8 and 14 individuals respectively, representing 44%, 42%, 30% and 57% of surveyed sites).
- In all years, a low proportion of observed black rockcod were reproductively mature individuals (1, 1, 4, and 6 individuals respectively). This improved in 2024 versus earlier years (43% of individuals were at a mature length).
- Highly suitable habitat for black rockcod (reefs with extensive systems of overhangs, caves, and swim throughs) occurs in the LHIMP, indicating that the population is not limited by habitat availability.
- The LHI lagoon is an important nursery for recruitment at LHI, indicated by observation of small juveniles in all diver survey years. Some key sites from observations include Sylphs Hole, North Bay, and Ship Rock.
- In all years, most sexually mature fish (i.e. individuals > 70 cm length) and nearly all males (i.e. mature individuals > 100 cm length) were observed in the Habitat Protection Zone around the Admiralty Islands, including sites at North Rock and 10th of June deep. The only large male observed that wasn't at the Admiralty Islands was at the Trevally Hole site, outside the Lord Howe Lagoon.
- Corresponding data from deeper reef in the LHIMP (30-50 m) using Baited Remote Underwater Video surveys (BRUVs) in 2009, 2013, 2017 and 2022 show a declining trend in black rockcod abundances (10, 6, 6 and 1 individuals respectively, representing 0.15, 0.11, 0.11, and 0.01 individuals per deployment).
- Corresponding catch data from charter fishers in the waters surrounding LHI show a decline in incidental (unintentional) by-catch of black rockcod since 2004.
- Based on this information, the adult breeding population of black rockcod in the LHIMP is small, and there is minimal evidence to suggest recovery of this population.
- If this pattern of minimal recovery is a true trend, then management actions may be required to minimise ongoing threats and protect black rockcod in the LHIMP, in line with the *Review of the Black Rockcod Recovery Plan* (DPI Fisheries - Threatened Species Unit, 2023).

Introduction

The threatened black rockcod *Epinephelus daemelii* is a large (>1.5 m) and long-lived (60+ year) reef-dwelling rockcod/grouper species in the family Serranidae. This species is endemic to the subtropical to warm temperate southwest Pacific: New South Wales (NSW), Lord Howe Island (LHI), Elizabeth-Middleton Reefs, the Kermadec Islands, and northern New Zealand/Aotearoa. They are a protogynous hermaphrodite that change sex from female to male at about 100 cm. Females become sexually mature at about 70 cm. Spawning and fertilisation of eggs is external in the water column, with a pelagic larval transport phase.

Black rockcod were once widespread in NSW (Roughly 1916). However, from the 1950s through to the late 1970s, spearfishers at various locations along the NSW mainland coastline heavily targeted this species (Andrewartha et al, 1968). They were also caught by line-fishing and regarded as an excellent eating fish, including at LHI. Concentrated spearfishing effort combined with line fishing impacts led to a noticeable decline in black cod numbers within NSW. As a result, NSW Fisheries were approached by concerned divers to protect the species in the late 1970s. Even though there was limited information on black rockcod available at the time, it was recognised as being under threat, and the species was afforded total protection in NSW in 1983 under NSW Fisheries legislation in all NSW waters, which includes the LHIMP. It is currently listed as ‘vulnerable’ under the NSW *Fisheries Management Act 1994*.

The recovery and conservation status of this threatened species is also a Commonwealth responsibility in Australian Commonwealth waters, including the Lord Howe Marine Park (Commonwealth). Any decline in abundance and other metrics of recovery within the Commonwealth or adjacent State marine park is a concern to the Commonwealth as it has implications for the overall black rockcod population in Australia and overall. This is a shared issue at LHI between the Commonwealth and NSW.

There are several past reports that mention the status of black rockcod around LHI. Ramsay (1889) noted common fish species he observed in the 1880's. He observed *Serranus daemelii* (= *Epinephelus daemelii*) to be 'common', and of large size, the largest he saw “being 80-90 pounds and the best place to catch these fish were at the western base of Mt Gower, off the Erskine Valley and off the rocky ledges to the east of Neds Beach." Allen *et al*. (1976) considered the black rockcod to be common in the lagoon and outer reef habitats in 2-45 metres whilst Pollard (1985), in his report to the Lord Howe Island Board, indicated “The black rockcod used to be common around LHI but is now reputedly less common than in the past. It is still very common around Middleton & Elizabeth Reef, though it is increasingly being exploited in this area by fishing boats from the mainland".

Some oral histories around black rockcod fishing and observations and photographs from fishing club competitions indicate the importance and regular occurrence of black rockcod as a fished species at LHI prior to 1983 (Harasti *et al*. 2011, Harasti and Malcolm 2013, Francis *et al.* 2016).

A core objective of our research into this threatened species over the past 12 years (2011 to 2023) has been to evaluate the relative abundance and size of black rockcod, both more broadly and at a selection of key sites in subtropical/warm temperate NSW, including the LHIMP. Part of the rationale for this was to indicate if recovery is

occurring, given 40 years since first protected in NSW, and to inform threatened species and spatial management planning around our findings. This unpublished report pertains only to the LHIMP but contributes to our broader study in NSW.

Methods

Sites.

In February 2011, 18 sites were surveyed in the LHIMP (Figure 1). Selected sites were over rocky reefs that had varying habitats of corals and boulders. Most sites were locations where local divers had reported seeing black rockcod. Nine sites were selected within sanctuary zones (SZs) and 9 sites in habitat protection zones (HPZs), to gauge whether SZs were encompassing a proportion of the black cod population in the LHIMP given black rockcod are protected from incidental capture within SZs. Sites were also divided between different aspects to the prevailing ocean conditions in the LHIMP: Eight were associated with the lagoon (four protected inside the lagoon, four outside or in passages); three sites were on the northern and western side, and five sites were at the Admiralty Islands. Two sites were located at Balls Pyramid, which is positioned on a separate volcanic seamount, 23 km to the south of LHI.

In 2019, 14 sites were surveyed, including all sites where black rockcod were recorded in the 2011 survey. One additional site was added at Sylphs Hole in the lagoon.

In early March 2023, the original 18 sites from 2011 and two additional sites were surveyed (Sylphs Hole – as per 2019 - and Erscotts Hole) using the same methods as in 2011 and 2019. Similar areas at those sites (similar tracks, similar habitat, similar depth range) were surveyed to assist comparisons (Table 2, Appendix B).

In early April 2024, 17 sites were surveyed. This included all sites where black rockcod had previously been recorded during the earlier surveys. The two sites at Balls Pyramid were not surveyed due to weather constraints. Similar areas to those previously surveyed at the 17 sites (similar tracks, similar habitat, similar depth range) were surveyed to assist comparisons.

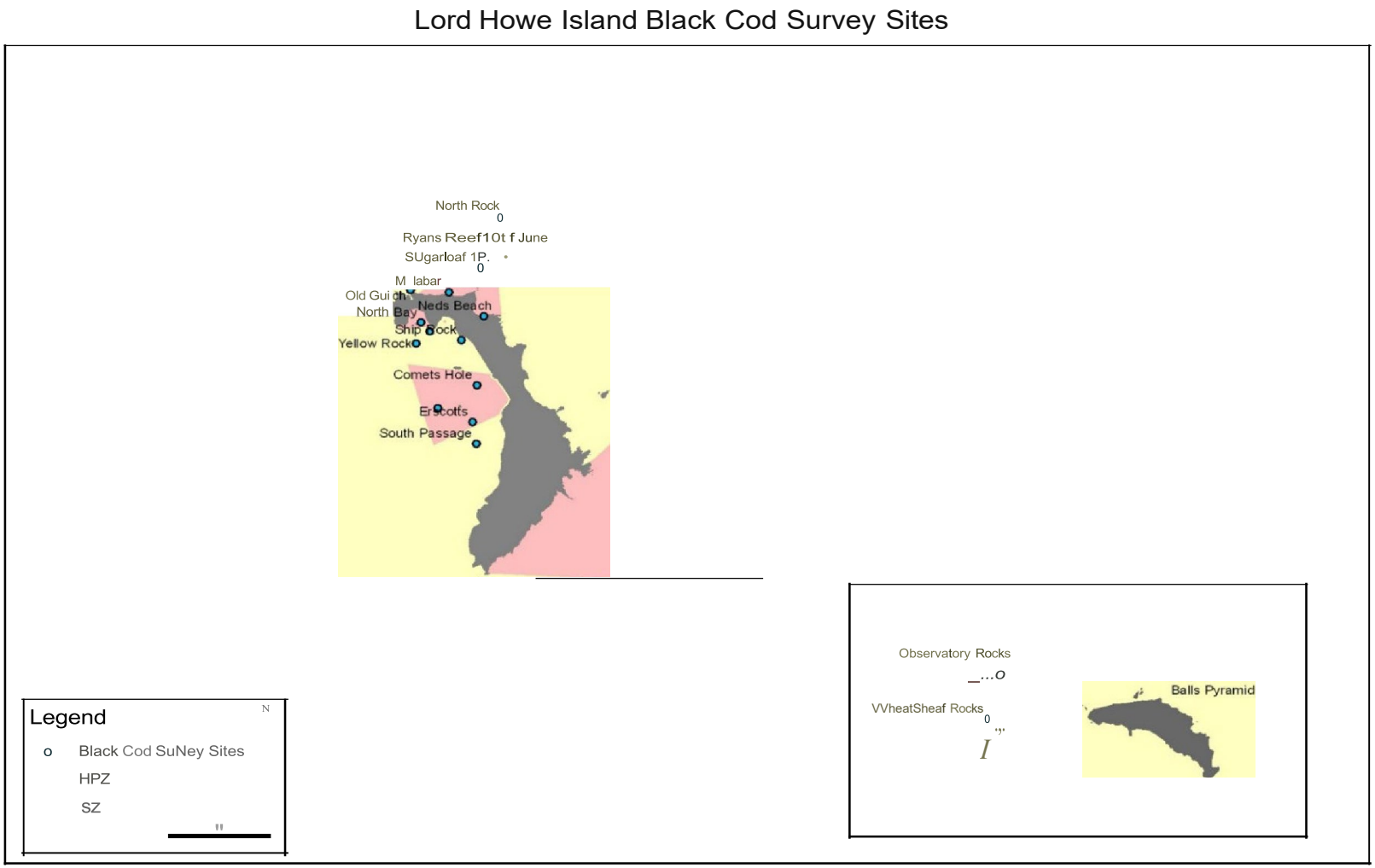

Figure 1: Location of black cod survey sites in Lord Howe Island Marine Park.

Table 1: Sites surveyed for black cod in the Lord Howe Island Marine Park.

Site ID	Site description	Dive method	MP Zone	Date	Start Latitude (S)	Start Longitude (E)	Time start	Time end	Overall swim length (m)	min depth	max depth	Depth range	Sea conditions	CC /8	Vis	Current	Other boats	Other divers	Surveyed 2011	Surveyed 2019	Surveyed 2023	Surveyed 2024
North Rock	deep canyon cave country	SCUBA	HPZ	2/03/2023	31 29.269	159 04.298	10:55	11:40	550	15	30	15	choppy 15 knot northerly	3	25	nil in cod habitat	0	0	y	y	y	y
10th of June	west and northern side	SCUBA	HPZ	2/03/2023	31 29.775	159 04.291	13:05	13:35	450	0	20	20	choppy	3	25	moderate to strong n flow	0	0	y	y	y	y
North Bay	reef, holes, & shipwreck	Snorkel	SZ	2/03/2023	31 31.277	159 02.814	15:40	16:25	450	0	2	2	calm	3	12	nil	0	0	y	y	y	y
Comets Hole	reef edge along hole in lagoon	SCUBA	SZ	1/03/2023	31 32.379	159 03.963	15:15	16:00	400	1	8	7	calm	4	6	nil	0	0	y	y	y	y
Sugarloaf Is.	western side	SCUBA	SZ	27/02/2023	31 30.217	159 03.997	14:00	14:45	650	0	16	16	calm	2	20	nil to moderate N flow	0	0	y	y	y	y
South Passage	South Passage	SCUBA	HPZ	4/03/2023	31 33.459	159 04.021	13:35	14:20	550	1	12	11	surge swell	3	15	light	0	0	y	y	y	y
Erscotts Passage	Erscotts Passage - northern side	SCUBA	SZ	4/03/2023	31 33.063	159 03.926	11:45	12:30	700	0	14	14	surge swell	3	12	light	0	0	y	y	y	y
Old Gulch	Old Gulch and west	SCUBA	HPZ	3/03/2023	31 30.691	159 02.572	13:05	13:50	700	0	16	16	choppy	3	20	moderate W flow	0	0	y	y	y	y
WheatSheaf Rocks	Balls Pyramid	SCUBA	HPZ	28/02/2023	31 45.353	159 14.192	10:35	11:15	480	0	25	25	calm	3	30	light to moderate S flow	0	0	y	y	y	n
Observatory Rocks	Balls Pyramid	SCUBA	SZ	28/02/2023	31 45.061	159 14.290	8:25	9:05	350	0	26	26	calm	3	30	light to moderate S flow	0	0	y	y	y	n
Ship Rock	ship rock complex of reef	snorkel	HPZ	28/02/2023	31 31.564	159 03.608	15:45	16:30	750	0	3	3	calm	3	7	nil	0	0	y	y	y	y
10th of June Deep	deep reef to south of Is.	SCUBA	HPZ	1/03/2023	31 29.724	159 04.319	8:40	9:10	350	0	30	30	calm	3	25	light	0	0	y	y	y	y
Malabar	Malabar	SCUBA	SZ	3/03/2023	31 30.692	159 03.312	11:00	11:45	600	5	18	13	choppy	2	20	light to nil	0	0	y	y	y	y
Sylphs Hole	reef edge of hole and reef flat	Snorkel	SZ	28/02/2023	31.52421	159.05493	15:00	15:45	350	0	5	5	calm	3	8	nil	1	2	n	y	y	y
Yellow Rock	reef to west of lagoon	SCUBA	HPZ	6/03/2023	31 31.671	159 02.748	13:10	13:40	650	4	14	10	choppy	2	15	nil	0	0	y	n	y	y
Trevally Hole	reef to west of lagoon with good holes	SCUBA	SZ	6/03/2023	31 32.842	159 03.245	11:10	11:55	500	6	15	9	choppy	2	15	nil	0	0	y	n	y	y
Neds Beach	reef out from Neds	SCUBA	SZ	6/03/2023	31 31.109	159 04.013	16:30	17:15	1000					3			0	0	y	n	y	y
Ryans Reef	big undercuts along edge of reef N and S	SCUBA	SZ	1/03/2023	31 29.915	159 03.837	10:45	11:20	450				choppy northeaster	3	25	light NW	0	0	y	n	y	n
NorthPassage south	reef edge inside lagoon	Snorkel	HPZ	6/03/2023	31 31.433	159 02.995	14:00	14:30	350	0	3	3	calm	3	10	light	0	0	y	n	y	y
Erscotts Hole	reef edge along hole in lagoon	Snorkel	SZ	7/03/2023			16:00	16:45	450	1	6	5	calm	4	12	nil	1	0	n	n	y	y
Herring Pools	rock pools	Snorkel	HPZ	5/03/2023			12:00	12:30:00	15	0	3	3	calm when swell not entering	3	5	nil	0	0	n	n	y	n
Site ID	**Site description**	**Dive method**	**MP Zone**	**Date**	**Start Lat (S)**	**Start Long (E)**	**Time start**	**Time end**	**Estimated overall swim length (m)**	**min depth**	**max depth**	**Depth range**	**Sea conditions**	**CC /8**	**Vis**	**Current**	**Other boats**	**Other divers**	**Surveyed 2011**	**Surveyed 2019**	**Surveyed 2023**	**Surveyed 2024**
North Rock	deep canyon cave country	SCUBA	HPZ	2/04/2024	31 29.269	159 04.298	10:25	10:55	300	20	32	12	okay	2	25	nil	0	0	y	y	y	y
10th of June	west and northern side	SCUBA	HPZ	2/04/2024	31 29.775	159 04.291	12:00	12:45	500	0	24	24	good	2	25	light N	0	0	y	y	y	y
North Bay	reef, holes, & shipwreck	Snorkel	SZ	8/04/2024	31 31.277	159 02.814	10:30	11:15	450	0.5	2	1.5	sloppy	8	10	moderate	0	0	y	y	y	y
Comets Hole	reef edge along hole in lagoon	SCUBA	SZ	8/04/2024	31 32.379	159 03.963	9:20	10:05	400	1	7	6	okay	8	3	nil	0	0	y	y	y	y
Sugarloaf Is.	western side	SCUBA	SZ	1/04/2024	31 30.217	159 03.997	12:15	13:00	600	0	17	17	good	2	25	light W	0	0	y	y	y	y
South Passage	South Passage	SCUBA	HPZ	3/04/2024	31 33.459	159 04.021	14:00	14:45	500	2	13	12	NW 15 knots, 1m sea, low swell	8	12	nil	0	0	y	y	y	y
Erscotts Passage	Erscotts Passage - northern side	SCUBA	SZ	3/04/2024	31 33.063	159 03.926	13:05	13:50	600	1	15	14	NW 15 knots, 1m sea, low swell	8	10	nil	0	0	y	y	y	y
Old Gulch	Old Gulch and Daves Cave	SCUBA	HPZ	2/04/2024	31 30.691	159 02.572	13:15	14:00	1000	0	14	14	good	2	15	light W	0	0	y	y	y	y
Ship Rock	ship rock complex of reef	snorkel	HPZ	5/04/2024	31 31.564	159 03.608	11:45	12:30	750	0	2	2	20 kn SE offshore	8	8	nil	0	0	y	y	y	y
10th of June Deep	deep reef to south of Is.	SCUBA	HPZ	2/04/2024	31 29.724	159 04.319	11:25	11:55	350	0	32	32	good	2	30	nil	0	0	y	y	y	y
Malabar	Malabar	SCUBA	SZ	1/04/2024	31 30.692	159 03.312	14:00	14:45	600	5	15	10	good	2	20	light E	0	0	y	y	y	y
Sylphs Hole	reef edge of hole and reef flat	Snorkel	SZ	4/04/2024	-31.52421	159.05493	13:00	13:45	350	1	5	4	good	4	3	nil	0	1	n	y	y	y
Yellow Rock	reef to west of lagoon	SCUBA	HPZ	3/04/2024	31 31.671	159 02.748	11:50	12:35	500	4	14	10	NW 15 knots, 1m sea, low swell	8	20	nil	0	0	y	n	y	y
Trevally Hole	reef to west of lagoon with good holes	SCUBA	SZ	3/04/2024	31 32.842	159 03.245	10:10	10:55	500	6	15	9	NW 15 knots, 1m sea, low swell	8	20	nil	0	0	y	n	y	y
Neds Beach	reef out from Neds	SCUBA	SZ	4/04/2024	31 31.109	159 04.013	8:15	9:00	1000	0	13	13	okay	4	15	nil	0	0	y	n	y	y
NorthPassage south	reef edge inside lagoon	Snorkel	HPZ	9/04/2024	31 31.433	159 02.995	11:00	11:30	400	1	3	2	pouring rain and windy	8	10	light seaward	0	0	y	n	y	y
Erscotts Hole	reef edge along hole in lagoon	Snorkel	SZ	9/04/2024			12:00	12:45	500	0	7	7	pouring rain and windy	8	20	light seaward	0	0	n	n	y	y

Diver roving timed counts

Surveys involved divers swimming along each site for up to 45 minutes searching for black rockcod and recording (Table 2, Appendix A) any individuals as well as estimating their length, the habitat it was found in, depth range surveyed and depth that individual black rockcod were found, and if the fish sighting was cryptic (i.e. hidden or camouflaged). For some of the deeper sites (25+ metres), the timed swim was limited to 30 minutes to prevent divers from undertaking decompression dives. The Underwater Visual Census (UVC) technique of diver roving timed counts is a widely adopted method for fish surveys (Kingsford, 1998) and has been more fully described for black rockcod (Harasti and Malcolm 2013). It is a useful method in diving depths where a species is rare and unlikely to be detected using belt transect UVC methods. The habitat where each fish was recorded was described based on topographic structure and this included: cave, overhang, coral, swim- through, wreck. Divers followed the topography of the reef to a maximum depth of 30 m and searched any caves or overhangs that they came across on the dive. Divers carried a dive torch to search in caves and overhangs for any hiding black rockcod. Any other serranid species that were encountered during the timed survey were also identified and recorded.
In 2023, a surface float with a global positioning system (GPS) attached to record the distance travelled and to enable the location of any black rockcod sightings to be determined (see Appendix 2 for tracks). In 2024, the track was estimated based on knowledge of the sites and imagery of the reef area with divers surveying the same areas of reef as the previous surveys.

Stereo length measurements (2011, 2019, 2023) and estimates (2024)

For each black rockcod sighting, the length of the fish was estimated (by both DH and HM where possible) in centimetres. Where possible, the fish was also filmed using a diver stereo system (SeaGIS Pty. Ltd) to obtain an exact length measurement. Measuring individual fish using the diver stereo system was only possible where a side profile was videoed with the fish stretched straight and the full image of the fish appearing simultaneously in both cameras. In many cases, this wasn’t possible due to fish being within constrained habitat and maintaining a head-on profile to the diver or due to the fish taking off when observed before effective video was taken. The diver stereo-video system consisted of two GoPro cameras on a base bar that had been calibrated as per standard operating procedures (Langlois et al 2018, 2020). Comparisons between diver estimates and stereo measurements indicate diver estimates are consistent and accurate for the purposes of discriminating between subadults, sexually mature females and males. Therefore, we utilised only diver size estimates in 2024.

Results

Relative abundance and distribution

During the March 2023 survey, a total of 8 black rockcod were observed (Table 2a). These were located at 6 sites (Table 2a). Three of the black rockcod were found within lagoon sanctuary zones. Half of the fish were able to be accurately measured with stereo camera. Nearly all were found in caves/overhangs or within a wreck structure (North Bay). The smallest individual observed (Sylphs Hole) was amongst coral and small enough to hide within small spaces amongst coral colonies.

North Rock had the highest number of black rockcod (equal with North Bay), and was the only location surveyed with a (likely) male (≥100 cm in length) black rockcod recorded. Three of the sightings (with two of these individuals measured) were likely mature females. This included one of the individuals at North Rock and the individual recorded in Dave's Cave.

In April 2024, a total of 14 black rockcod were observed (Table 2b). These were located at 8 sites (Table 2b). Three black rockcod were found in the lagoon and these included the two smallest individuals observed in 2024.

Table 2a: Observed black rockcod 2023.

Site	Zoning	Size (cm)	Measurement Method	Depth (m)	Latitude	Longitude	Habitat
Sylphs Hole	SZ	18	Diver estimate	2	-31.52054	159.05442	coral
Shiprock	HPZ	35	Diver estimate	1.5	-31.52650	159.05957	overhang
North Bay	SZ	35	Stereo	1.5	-31.52186	159.04572	wreck
North Bay	SZ	48	Stereo	1.5	-31.52186	159.04572	wreck
Old Gulch -Daves Cave	HPZ	71	Stereo	8	-31.51257	159.04558	cave
Yellow Rock	HPZ	70	Diver estimate	8	-31.52833	159.04551	overhang
North Rock	HPZ	85	Stereo	30	-31.48817	159.07273	cave
North Rock	HPZ	100	Diver estimate	30	-31.48817	159.07273	cave

Table 2b: Observed black rockcod 2024.

Site	Zoning	Size (cm)	Measurement Method	Depth (m)	Latitude	Longitude	Habitat
North Rock	HPZ	110	Diver estimate	30	-31.48817	159.07273	cave
North Rock	HPZ	140	Diver estimate	32	-31.48817	159.07273	cave
10th June	HPZ	100	Diver estimate	23	-31.49453	159.06971	open gravel
10th June	HPZ	130	Diver estimate	23	-31.49453	159.06971	open gravel
Old Gulch -Daves Cave	HPZ	50	Diver estimate	12	-31.51257	159.04558	bommie

Old Gulch -Daves Cave	HPZ	80	Diver estimate	12	-31.51257	159.04558	bommie
Trevally Hole	SZ	60	Diver estimate	13	-31.547	159.054	cave
Trevally Hole	SZ	50	Diver estimate	13	-31.547	159.054	cave
Trevally Hole	SZ	40	Diver estimate	10	-31.547	159.054	cave
Trevally Hole	SZ	120	Diver estimate	7	-31.547	159.054	open water
Yellow Rock	HPZ	50	Diver estimate	7	-31.52833	159.04551	underhang
Sylphs Hole	SZ	25	Diver estimate	1	-31.52047	159.05466	reef hole
North Bay	SZ	50	Diver estimate	1.5	-31.52186	159.04572	in wreck
North Passage south	HPZ	25	Diver estimate	3	-31.52047	159.05633	under table Acropora

Size (length)

Only about half the lengths were measured using stereo video in 2023, but where measured, the diver estimates were reasonably similar. This provides confidence for lengths where only estimates were able to be obtained, and for 2024 where all lengths were estimates from divers.

In 2011, the size variation of the 12 observed black rockcod was 26 cm to 110 cm. All except the largest individual were less than 70 cm, indicating they were predominantly juveniles to sub-adults. The largest observed fish was seen at the 10th of June deep site (110 cm length estimated by diver). The smallest fish was seen at North Bay in the lagoon (26 cm length measured using stereo video).

In 2019, the size variation of the 6 observed black rockcod was 35 cm to 135 cm. All except for the large individual were less than 70 cm, indicating they were predominantly juveniles to sub-adults. The largest observed fish was seen at North Rock (135 cm length measured using stereo video). The smallest fish was seen at North Bay, as per 2011 (35 cm length estimated by diver).

In 2023, the size variation of the 8 observed black rockcod was 18 cm to 100 cm (Table 2). Half were less than 70 cm, indicating a mix of juveniles to sub-adults to adults. The largest observed fish was seen at North Rock (100 cm length estimated by diver). The smallest fish was seen at Sylphs Hole in the lagoon (18 cm length estimated by diver).

In 2024, 57% of individuals overall were juvenile to sub-adult. However, 43% were at a mature adult length with three of these large males (~ >105cm) and this was the highest proportion of adults out of the four surveys.

Overall, most individuals sighted during our surveys were juvenile to sub-adult fish (Figure 2), hence not contributing to reproductive output at that stage. This included a very small (18 cm) individual in 2023, indicating at least some recruitment is occurring in the LHIMP. Every individual recorded within the lagoon from all four surveys were juvenile to sub-adult showing the importance of the lagoon as a nursery for recruitment. In comparison, the outer Admiralty Islands provide important habitat for adult mature black rockcod.

Black rockcod can be attached to a territory and occupy a particular cave for many years, though they will move about a location and migrate offshore with ontogenetic change from juvenile to adult (Harasti et al. 2014; Francis et al. 2016). The individual fish in Dave's Cave in 2023 is likely the same individual we recorded in 2019 in this large cave that is positioned underneath LHI itself (underneath the Malabar cliffs). This assumption is based on the extent of Dave's Cave as excellent black rockcod habitat and the change in size from 50 cm in 2019 to 71cm in 2023. In 2024, two individual black rockcod were observed just outside the cave. It is possible that other individual fish have been repeatedly recorded during these surveys, but due to the continuity of habitat at other sites and physiological colour changes precluding individual fish identification unless there are distinctive scar markings, this cannot be determined from the current data. Further work to quantify the chance of detecting and re-surveying residential fish would therefore assist with interpretation of the current results.

Figure 2: Number of individual black rockcod by year within each of four length classes with approximate levels of sexual maturity: juvenile ≤50 cm; sub-adult >50 to 75; mature female >75 to 100; mature male >100

Habitat

Black cod were recorded in four different habitats in 2011 (gutter, overhang, cave and amongst hard coral) with the most common habitat being overhangs followed by coral. In 2023 and 2024, the black rockcod were found in caves, wreck, overhang and amongst coral. The largest individuals observed in 2019, 2023, and 2024 were associated with a complex cave swim-through system at North Rock. This complex system provides multiple linked cave entries and exits; an excellent habitat for large black rockcod. Coral habitat at LHI is suitable for smaller black rockcod, but with fewer openings and interstices at a size and extent suitable for providing protection to large individuals.

Baited Remote Underwater Video (BRUV) survey data provided by NSW DPI Fisheries.

Baited Remote Underwater Video (BRUVs) surveys have also been undertaken in deeper water (ranging 29 to 48 metres depth) between 2009 and 2022 by NSW DPI Fisheries using approximately sixty 30-minute baited deployments at 16 sites, during four dedicated BRUV comparative campaigns:

- In 2009, ten black rockcod were recorded from 64 BRUV drops.
- In 2013, six black rockcod were recorded from 61 BRUV drops.
- in 2017, six black rockcod were recorded from 64 BRUV drops.
- In 2022, one black rockcod was recorded from 70 BRUV drops.

As well as the comparable sites in the above campaigns, other BRUVs have been undertaken at LHI, though these data are not directly comparable through time due to site differences. This includes:

- In 2011, one black rockcod was recorded from 6 BRUV drops.
- In 2013, three black rockcod were recorded from 20 additional BRUV drops (= nine black rockcod from 81 BRUV drops in total).
- In 2017, two additional black rockcod were recorded during longer duration deployments (i.e. detected after more than 30 minutes of deployment).
- In 2022, zero black rockcod were recorded from 29 additional BRUV drops (=one black rockcod from 99 BRUV drops in total).

Therefore overall, there was a considerable decline in the number of black rockcod detected between 2009 and 2022, especially after 2017. From 2009, 2013, 2017, to 2022, the relative number per BRUV drop showed a declining trend of: 0.15; 0.11; 0.11; 0.01 black rockcod observed per deployment.

Catch data provided by LHI charter fishing operators.

Catch data from 2004 to 2018, provided by charter fishing operators from the State and Commonwealth waters surrounding LHI, has been compiled into a report by the University of Sydney (Figueira and Harianto 2022). They found about 10 black rockcod are reported as being caught each year and that this has declined since 2004. The following in regard to black rockcod is copied from their report:

“Black rockcod (Epinephelus daemelii) represent a minor incidental species in the LHI fishery. Black rockcod made up 0.7% (249 kg) of the catch by weight and 0.1% (10 individuals) by number each year (Table 4-5.). The reported catch of black rockcod has declined significantly since 2004. During the first five years 91 black rockcod were caught compared to 32 over the subsequent ten years. Only one black rockcod per year was reported from 2013 to 2014 but between 1 and 7 have been caught per year from 2015-2018. (Table 6-16, Figure 6-31). 90% of the cod were caught in the Lord Howe offshore waters over the time series.”

This decline in catch per year and the small number of individuals that are caught each year (small given they comprised a major part of recreational fishing competition catch prior to 1983), does not contradict the findings from our shallower diving surveys nor deeper Baited Remote Underwater Video surveys. Neither the diving surveys, BRUVs surveys, nor catch information suggest that black rockcod are recovering in the LHIMP.

Catch data provided in 2021 included 13 black rockcod, ranging in estimated size from 80 cm to 160 cm. Many of these were reported as being caught on the shelf or near the shelf edge of LHI although some were also reported as nearshore. This is a higher level than reported in the data analysed from 2014 to 2018. However, only 5 black rockcod were reported to NSW Fisheries in 2022, all big male fish (>130 cm) caught from the LHI shelf.

There may well be under-reporting of black rockcod incidental catch, as suggested by reporting around a compliance operation in 2020 (Figueira and Hariant 2022):

"In January 2020 during a compliance investigation, one charter operator told LHIMP staff that he had caught 6 black rockcod over six weeks during December 2019 and January 2020. Three of these fish were released, and three were kept, filleted and distributed to the local community. The operator suggested that this had always been common practice on the island. None of these interactions were subsequently reported on the catch returns. The operator also informed LHIMP staff that he mostly interacts with black rockcod during the warmer months when the yellowtail kingfish are predominantly found in deeper water and therefore fishing effort is focused in deeper areas. This suggests a level of under reporting associated with this species."

Observations provided by commercial tour operators.

Between October 2017 and April 2019, 46 reports of black rockcod observations were provided by commercial tour operators (diving and snorkelling tours) at habitats outside the lagoon. Sites where observation occurred included North Rock, 10th of June, Malabar, Walshies Wall, Wheatsheaf, Observatory Rock, Relics, South Island, The Arch, Cathedral, Five Star, Roache Island, Soldiers Cap, and others. Some of these may have been multiple sightings of the same individual. There was some ambiguity in the data relating to the site where black rockcod were observed due to multiple locations included in each trip entry. There were also 33 reports of black rockcod in Comets Hole during 2018, which very likely included multiple sightings of the same individual(s).

Anecdotal observations.

Dive shop staff are regularly diving some sites in the LHIMP providing some insight into shorter term temporal patterns, that we can't detect with a single survey one to many years apart. For example, two black rockcod were seen at Sugarloaf Island by Dive Lord Howe divers a few days after our survey at that site in 2023. We hadn't observed any during our survey. One of these was a large black rockcod that was photographed (Figure 3). This was observed in a gutter that we had surveyed.

Qualitative anecdotal observations provide good insight to help evaluate more quantitative data. This natural short-term variability in observations demonstrates the difficulty in obtaining a robust pattern that can be used to indicate a trend in population recovery for a threatened fish that is low in abundance. Confidence in a pattern representing a true trend strengthens with more data, more surveys, increased temporal and spatial scales, and more data sources, data sets and methods.

Figure 3: large black rockcod photographed by Liv Rose (Dive Lord Howe) on 6 March 2023 at Sugarloaf Island

From diver observations, larger individual black rockcod are seen more often as the water temperature cools, there may be a seasonal depth movement pattern. The largest black rockcod we saw were in the 2024 survey which was in April, a later month than previous surveys. However, the water was warm during our survey in 2024 with an active coral bleaching event occurring.

Historical observations

As well as previously documented oral histories and photographs of black rockcod (Figure 4) indicating some good catches at LHI in decades prior to protection (Harasti *et al.* 2011; Harasti and Malcolm 2013; Francis *et al*. 2016) there are some historical written records that also suggest black rockcod were once ‘plentiful’ (Ogilby 1889, Ramsey 1889).

“The" Black Rock Cod" of the islanders. It is plentiful and grows to a large size; one which Mr. Saunders collected weighed seventy-five pounds, and measured forty-two inches, while Captain Langley brought a rather dilapidated skin measuring no less than fifty-four inches, and it is said to attain to even greater dimensions.” Ogilby 1989.

Ramsay (1889) also noted common fish species he observed in the 1880's at LHI. He observed *Serranus daemelii* (= *Epinephelus daemelii*) to be 'common', and of large size.

Figure 4: At least 23 black rockcod, predominantly large individuals, caught during a fishing competition prior to protection as a threatened species - from photographic collection of Lord Howe Island resident and photographer Dick Morris, courtesy of the Lord Howe Island Museum and Historical Society.

Serranid species

A total of 9 different species of serranids were encountered during the time swim surveys in 2023 and 2024 (Table 3a, 3b). In total, 11 grouper / rockcod species have now been recorded during the 2011, 2019, 2023, and 2024 surveys combined (Table 3). In all four surveys the most common serranid observed was *Trachypoma macracanthus* (strawberry cod / toadstool grouper) closely followed by *Acanthistius cinctus* (yellow banded wirrah). All the other serranids observed were much fewer in number (Tables 3, 4).

In 2011, the Comet Hole and 10th of June sites had the most serranid species recorded (5). In 2023, three sites had four species as the highest number: 10th of June, North Rock and Sugarloaf. Most species were rarely recorded. The highest number of individual serranids was recorded at Sugarloaf Island in 2011 but at North Rock in 2023 (Figure 4). In 2023, North Rock had the highest number of black rockcod (equal with North Bay), the only adult black rockcod, the highest number of Serranid species (equal with 10th of June and Sugarloaf) and the highest number of observed Serranid individuals. In 2024, North Rock had the highest number of serranid species, the most serranid individuals, the largest black rockcod This site provides important Serranid habitat in the LHIMP.

Table 3a: Serranid species and number of individuals (2023) encountered during diver surveys. Grey cells reflect the highest number recorded and the location with the most.

	Cephalopholis miniata	*Acanthistius cinctus*	*Trachypoma macracanthus*	*Cephalopholis argus*	*Epinephelus cyanopodus*	*Epinephelus quoyanus*	*Epinephelus polyphekadion*	*Epinephelus daemelli*	*Epinephelus fasciatus*	*Epinephelus rivulatus*	**Number of Serranid species**	**Total Number per site**
North Bay			4					2			**2**	**6**
Comet Hole			6				1				**2**	**7**
Neds Beach		1	1								**2**	**2**
Ryans Reef	1	4							2		**3**	**7**
Sugarloaf Is.	1		2			1			1		**4**	**5**
Erscotts Passage		5	1								**2**	**6**
Trevally Hole		1		1							**2**	**2**
Observatory Rocks	2	4				1					**3**	**7**
Malabar		5	2								**2**	**7**
North Rock	1	8	1	1				2			**4**	**13**
10th of June		1	1	2					1		**4**	**5**
South Passage		5	2								**2**	**7**
Old Gulch / Daves Cave								1			**1**	**1**
Yellow Rock								1			**1**	**1**
Wheat sheaf Rocks			1						1		**2**	**2**
Ship Rock			8					1			**2**	**9**
10th of June Deep		1							1		**2**	**2**
North Passage south			9								**1**	**9**
Sylphs Hole			9					1			**2**	**10**
Erscotts Hole											**0**	**0**
Total Observed	**5**	**35**	**47**	**4**	**0**	**2**	**1**	**8**	**6**	**0**		

Table 3b: Serranid species and number of individuals (2024) encountered during diver surveys. Grey cells reflect the highest number recorded and the location with the most.

	Cephalopholis miniata	*Acanthistius cinctus*	*Trachypoma macracanthus*	*Cephalopholis argus*	*Epinephelus cyanopodus*	*Epinephelus quoyanus*	*Epinephelus polyphekadion*	*Epinephelus daemelli*	*Epinephelus fasciatus*	*Epinephelus rivulatus*	*Epinephelus malabaricus*	**Number of Serranid species**	**Total Number per site**
North Bay			2					1				**2**	**3**
Comet Hole			1									**1**	**1**
Neds Beach		5									1	**2**	**6**
Sugarloaf Is.	1	3	2									**3**	**6**
Erscotts Passage		1	2									**2**	**3**
Trevally Hole		1	1					4				**3**	**6**
Malabar		4	2									**2**	**6**
North Rock		2	2	1				2	1			**5**	**8**
10th of June								2				**1**	**2**
South Passage		1										**1**	**1**
Old Gulch / Daves Cave			2					2				**2**	**4**
Yellow Rock		1	1	2				1				**4**	**5**
Ship Rock			1				1					**2**	**2**
10th of June Deep									1			**1**	**1**
North Passage south		1	1					1				**3**	**3**
Sylphs Hole			2					1				**2**	**3**
Erscotts Hole		1	2									**2**	**3**
Total Observed	**1**	**20**	**21**	**3**	**0**	**0**	**1**	**14**	**2**	**0**	**1**		

Yellow Rock was the only site where serranids were not observed in 2011. In 2023, a black rockcod was sighted there (Figure 4). This reef wasn't surveyed in 2019. There is definitely variability between years as would be expected in a natural system, but the overall pattern does show a decline in most taxa from 2011 to the latter two survey (Table 4). In particular, there was a drop in the number of *Cehpalopholus* species (*C miniata* and *C argus* combined) in 2023. The large wirrah Acanthistius cinctus also showed a slight decline from 2011. This could be driven by natural variation as the non-targeted small and cryptic strawberry cod *Trachypoma macracanthus* also declined slightly from 2011. The survey in 2024 had the lowest numbers of serranids overall, by a considerable margin, even though it had the highest number of black rockcod.

Table 4: Number of individuals (at number of sites) encountered during diver surveys by year.

	2011	**2019**	**2023**	**2024**
Acanthistius cinctus	42 (12)	34 (12)	35 (10)	20 (10)
Trachypoma macracanthus	60 (13)	37 (12)	47 (13)	21 (13)
Epinephelus spp. (excluding *E. daemelii*)	9 (3)	8 (6)	9 (7)	4 (4)
Cephalopholus spp.	17 (6)	15 (6)	4 (3)	4 (3)
Total serranids (inc *E. daemelii*)	128	100	103	63

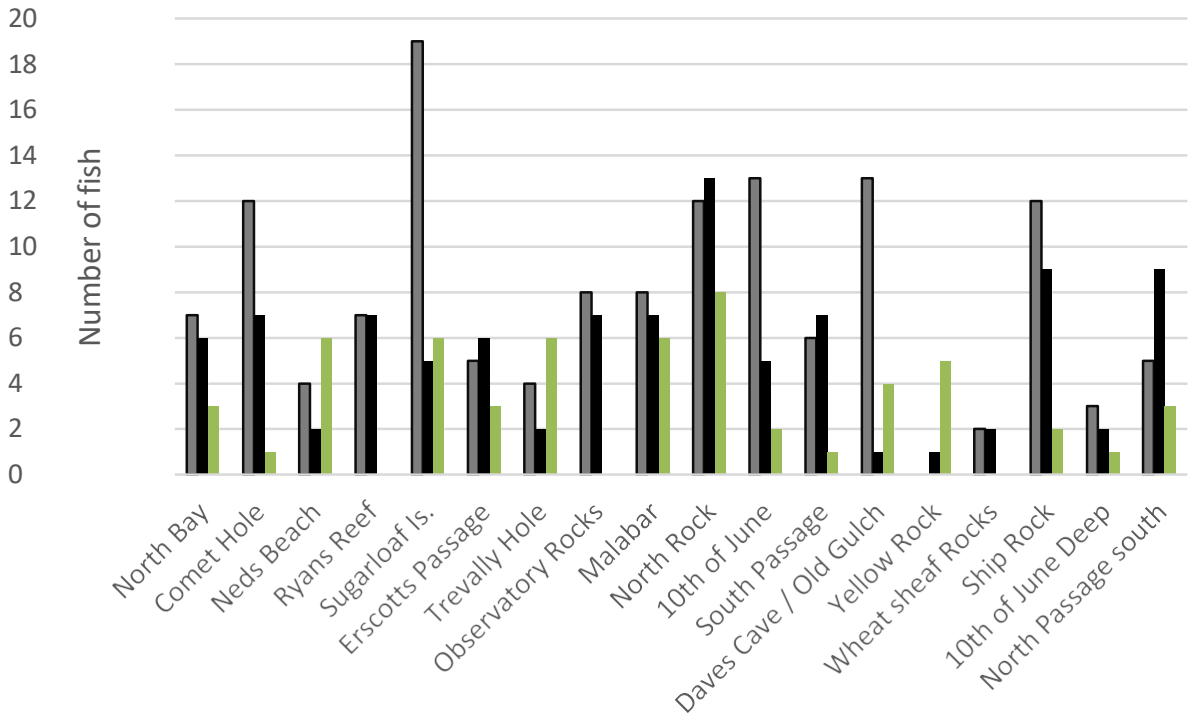

Figure 5: Serranid species encountered during diver surveys in 2011 (grey bars), 2023 (black bars) and 2024 (green bars)

Discussion

These diving surveys, undertaken over a 13-year period (28 to 41 years after black rockcod were first protected across NSW as a threatened species) do not indicate that recovery of this species is strongly occurring in the LHIMP. If a strong recovery was occurring, we would have expected to see an upward trend in abundance from 2011 to 2019 and further increases to 2023 and 2024. In contrast, the opposite occurred between 2011 and 2019, and we found relatively fewer. Since 2019 there has been a positive direction with the most recorded during

surveys to date in 2024. Additionally, there has been a positive trend in length of fish and abundance of mature individuals observed since 2019, with half (4) of the eight individual fish sighted in 2023 of a mature size, although the largest (estimated ~100 cm) was smaller than that seen in 2019 and 2011. At least three large males were observed in 2024, which is a positive sign.

As a protogynous hermaphrodite, which changes from female to male at a length greater than about 100 cm, all male black rockcod are mature. Female black rockcod mature at a length greater than about 70 cm. Only one fish of potentially male size was observed (≥100 cm) in each of the first 3 surveys (2011,2019, 2023). Given both males and mature females are needed for a breeding population, the low observed abundance of both was not a good sign for local recruitment. However, the 2024 result was more positive in this regard. Hopefully over time, if recovery does progress, the breeding population of mature females and males will reach a level that greatly improves self-recruitment to Lord Howe Island.

It is possible that there is a larger breeding population below diving depths of our surveys. Large black rockcod are caught/observed in deeper habitats >30 m at LHI, but large individuals are not exclusive to deeper habitat elsewhere in their distribution and there is no reason they should not occur in shallower water at LHI.

Overall, very few black rockcod individuals were recorded in 2011, 2019 or 2023. We expected the opposite, given there is extensive suitable black rockcod habitat in the depths and locations that our surveys covered, and that other information indicates black rockcod were historically abundant at LHI. This could possibly be influenced by the survey method used, but this is unlikely given our findings using this method elsewhere in NSW (Malcolm and Harasti 2010, Harasti 2011, Harasti and Malcolm 2013, Francis et al 2016). For example, as a comparison numbers of black rockcod appear to have increased in similar depths at the Solitary Islands Marine Park (northern NSW mainland) since black rockcod were protected. We recorded more individual mature black rockcod from a single site at South Solitary Island in 2023, using this same method, than we recorded in total from all 20 sites surveyed in the LHIMP in 2023, likewise in 2024.

There could be multiple potential reasons for this apparent ‘lack of strong consistent recovery’ over the past 13 years and these are not mutually exclusive, but could be acting in combination and cumulative in their impacts. Potential reasons include but may not be limited to:

- Numbers of adult, reproductive black rockcod may have reached a level (prior to 2011, and possibly prior to 1983), where self-recruitment is now very low in the LHIMP. In particular very few mature males (i.e. individuals > 1 m in length) were recorded during our surveys (although 2024 was a more positive result). There needs to be both mature females and males in the same location at suitable times for effective external spawning to occur, and those pelagic larvae then have to reach settlement age/size while still being entrained in the local waters around LHI.
- Recruitment to the LHIMP from other locations where black rockcod are considerably more abundant (i.e. NSW mainland, Elizabeth and Middleton reefs) is likely very sporadic and low in occurrence due to the complexity of the East Australian Current (EAC) eddy field in the Tasman Sea/south-western Pacific. Recruitment from locations further east where black rockcod are abundant (i.e. Kermadec Islands - as the Norfolk population is apparently likewise very low) would be unusual and unlikely due to the EAC oceanic current being predominantly eastwards flowing across the Tasman Sea. Further research is required to understand recruitment and connectivity between black

rockcod populations in the LHIMP and elsewhere (DPI Fisheries - Threatened Species Unit, 2023).

- Post-release mortality from unintentional demersal fishing capture. Swim bladder embolism has been noted in black rockcod pulled from 18 m depth (Duffy pers. Obs.). Black rockcod caught in 20+ m depths and pulled swiftly to the surface are likely to embolise (swim bladder air expansion injury) Those individuals released may not survive unless they are effectively sent back to the seafloor with swim bladder re-compressed and intact.
- Shark depredation during capture and post-release is a possibility.
- Illegal take of black rockcod – fillets taken, even if unintentionally caught in the first place.
- Illegal targeting of black rockcod.
- Climate change influences around larval settlement, post-settlement survivorship, and ongoing mortality rates. This may include changes to EAC patterns and eddies and strength of current impacting larval settlement Further research is required to understand this threat (DPI Fisheries - Threatened Species Unit, 2023).
- Other reasons.

Some of the above possible reasons can be ameliorated by removing fishing mortality (intentional or unintentional). Spatial protection (sanctuary zone) is the most effective management tool to achieve that. It is worth noting that two of the sites where we recorded the large males (North Rock, 10th of June deep) are not in a sanctuary zone, although there is some natural protection through complex systems of caves and swim-throughs at that location. Also, worth noting is that the site where the highest number of black rockcod were observed in 2024, including a large male, was the Trevally Hole, which is positioned within the Lord Howe Lagoon Sanctuary Zone.

Trust in a pattern representing a true trend becomes more robust with an increase in data points, datasets, and data sources, and with consistency in a pattern spatially and over time. Given the suggested pattern over the 13 years of a lack of consistent recovery of black rockcod at LHI (although results in 2024 were positive), there are implications for recovery of this species at this location. Further management action is warranted. If the suggested pattern is false, and black rockcod are effectively recovering at LHI, then further management put in place may be additional to that required to ensure their recovery. However, the implications of this are less dramatic: some people may have to modify their activity, but black rockcod abundance would still likely benefit. A further survey in four and five years (2029 and 2030) would be informative for future management planning and evaluation of black rockcod recovery and recovery planning.

Additional recovery actions outlined DPI Fisheries - Threatened Species Unit (2023) which may benefit recovery of the black rockcod population in the LHIMP include:

- Research into ‘best practice’ release methods and gear types to reduce impacts on accidentally caught black rockcod, particularly from barotrauma. This could be conducted on a similar non-threatened serranid species. Support for proven actions to reduce this impact
- Research projects to investigate the biology and ecology of black rockcod (e.g. life history, habitat requirements, fecundity, reproductive biology, movements, response to climate change and water pollution etc).

- Research projects to examine the impacts of medium and high-risk fishing activities on black rockcod.
- Promote the use of fishing techniques and gear that eliminate or mitigate the impact of high and moderate risk activities on black rockcod. Specifically promote techniques and gear that avoid the capture of black rockcod and minimise impacts on accidentally caught fish.
- Where appropriate, actively encourage community involvement in aspects of black rockcod recovery including for example, research and monitoring programs.
- Consider information on black rockcod distribution, abundance and habitat preferences during development and review of Marine Park Zoning Plans.

Low and potentially unreported catches of black rockcod are of concern. The following additional recommendations from the Lord Howe Island Fisheries Report 2004- 2018 (Figueira and Harianto 2022) are also relevant to increasing knowledge of population trends and improving potential for recovery of black rockcod at Lord Howe Island. These are:

- Participants should be informed of the importance of accurately reporting catch and release.
- Research should investigate the most appropriate release methods to maximise survival of this species caught at depth.
- No take zones offer refuge areas for black rockcod, particularly if they suffer barotrauma when caught from deeper water, with unknown survival rates.
- Deepwater (over 50 m) baited remote underwater video (BRUV) surveys may be used to assess and monitor deep water target species and black rockcod.

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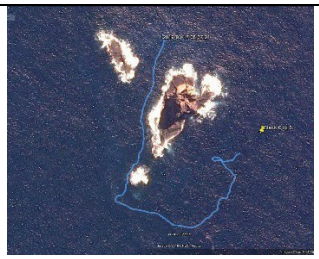
Addendum Appendix 1: Sighting data from all three surveys: 2011, 2019, 2023, 2024

Year	Fish No.	No. at site	Site ID	Time into dive (minutes)	Time	Date	Latitude	Longitude	Length estimates (cm)	Stereo Video	Length measure (cm)	Length used (cm)	Depth	Sighting type	Habitat
2011	1	1	10th of June	40	13:20	21/02/2011			65	yes	66.5	66	18.4	open then went into cave	gutter
2011	2	1	North Bay	34	16:56	21/02/2011			30	yes	26.3	26	1	small overhang	coral
2011	3	2	North Bay	45	17:10	21/02/2011			60	yes	58.9	59	1.5	open, then hid in coral	sand and coral
2011	4	1	Comets Hole	5	8:30	22/02/2011			35	yes	39.8	40	1.8	open then cryptic	Coral
2011	5	2	Comets Hole	5	8:30	22/02/2011			45	no		45	2.6	open then cryptic	Coral
2011	6	1	Sugarloaf Is.	18	11:45	24/02/2011			50	no		50	16.9	cryptic	underhang
2011	7	2	Sugarloaf Is.	30	11:57	24/02/2011			45	no		45	11	not cryptic	underhang
2011	8	1	Erscotts Passage	14	16:58	24/02/2011			40	yes	42.41	42	5.3	cryptic	cave
2011	9	1	Shiprock	30	17:30	26/02/2011			30	yes	34.1	34	1.5	cryptic - underhang	underhang
2011	10	2	Shiprock	40	17:40	26/02/2011			45	no		45	2	cryptic - underhang	underhang
2011	11	1	10th of June deep	26	10:08	27/02/2011			110	no		110	30	open then cryptic	gutter
2011	12	1	Malabar	8	11:37	27/02/2011			25	yes	29.2	29	10.6	cryptic	underhang
2019	1	1	Old Gulch / Daves Cave	38	13:08	16/03/2019			35	yes	50	50	12	Obvious	cave
2019	2	1	North Bay	10	9:50	19/03/2019			35	no		35	2	Cryptic	wreck
2019	3	1	10th June Deep	10	9:40	20/03/2019			60	yes	57.3	57.3	32	Cryptic	underhang
2019	4	1	Erscotts Passage	15	11:35	20/03/2019			50	no		50	10	Obvious	underhang
2019	5	1	South Passage	22	13.26	21/03/2019			50	yes	48.7	48.7	7	Cryptic	cave
2019	6	1	North Rock	10	7:40	22/03/2019	-31.488	159.072	130	yes	135	135	30	Obvious	canyon
2023	1	1	Sylphs Hole	30	15:30	28/02/2023	-31.52054	159.05442	18	no		18	2	cryptic	coral
2023	2	1	Ship Rock	45	16:30	28/02/2023	-31.52650	159.05957	35	no		35	1.5	cryptic	underhang
2023	3	1	North Rock	5	11:00	2/03/2023	-31.48817	159.07273	100	no		100	30	cryptic	cave
2023	4	2	North Rock	5	11:00	2/03/2023	-31.48817	159.07273	82	yes	85	85	30	cryptic	cave
2023	5	1	North Bay	5	15:45	2/03/2023	-31.52186	159.04572	30	yes	35	35	1.5	cryptic	wreck
2023	6	2	North Bay	5	15:45	2/03/2023	-31.52186	159.04572	40	yes	48	48	1.5	cryptic	wreck
2023	7	1	Old Gulch / Daves Cave	25	13:25	3/03/2023	-31.51257	159.04558	70	yes	71	71	8	cryptic	cave
2023	8	1	Yellow Rock	2	13:12	6/03/2023	-31.52833	159.04551	70	no		70	8	cryptic	underhang
2024	1	1	North Rock	10	10:35	2/04/2024	-31.48817	159.07273	110	no		110	30	cryptic	in cave swim-through
2024	2	2	North Rock	15	10:40	2/04/2024	-31.48817	159.07273	140	no		140	32	cryptic	in cave swim-through
2024	3	1	10th June	40	12:40	2/04/2024	-31.49453	159.06971	100	no		100	23	obvious	open gravel
2024	4	2	10th June	40	12:40	2/04/2024	-31.49453	159.06971	130	no		130	23	obvious	open gravel
2024	5	1	Old Gulch - Daves Cave	25	13:40	2/04/2024	-31.51257	159.04558	50	no		50	12	cryptic	bommie
2024	6	2	Old Gulch - Daves Cave	25	13:40	2/04/2024	-31.51257	159.04558	80	no		80	12	cryptic	bommie
2024	7	1	Trevally Hole	15	10:25	3/04/2024	-31.547	159.054	60	no		60	13	cryptic	cave
2024	8	2	Trevally Hole	40	10:50	3/04/2024	-31.547	159.054	50	no		50	13	cryptic	cave
2024	9	3	Trevally Hole	40	10:50	3/04/2024	-31.547	159.054	40	no		40	10	cryptic	cave
2024	10	4	Trevally Hole	45	10:55	3/04/2024	-31.547	159.054	120	no		120	7	obvious	open water
2024	11	1	Yellow Rock	40	12:30	3/04/2024	-31.52833	159.04551	50	no		50	7	cryptic	underhang
2024	12	1	Sylphs Hole	10	13:10	4/04/2024	-31.52047	159.05466	25	no		25	1	cryptic	reef hole
2024	13	1	North Bay	10	10:40	8/04/2024	-31.52186	159.04572	50	no		50	1.5	cryptic	in wreck
2024	14	1	North Passage south	5	11:05	9/04/2024	-31.52047	159.05633	25	no		25	3	cryptic	under table Acropora

Addendum Appendix 2: Maps of black cod survey sites. 2011, 2019, 2023 tracks (GPS tracks not undertaken in 2024, but a very similar path to the previous years was undertaken)

2011	2019	2023
		
North Rock – Max Depth 24m.		



10th June – Max Depth: 22m.



Site: 10th of June Deep – Max Depth: 33m.

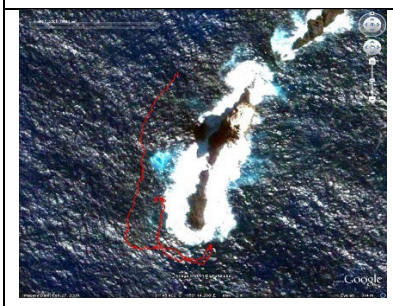


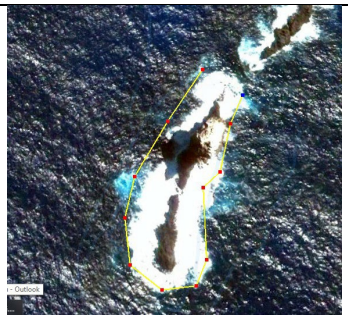
Sugarloaf Island – Max Depth: 20m


Ryans Reef – Max Depth: 24m.

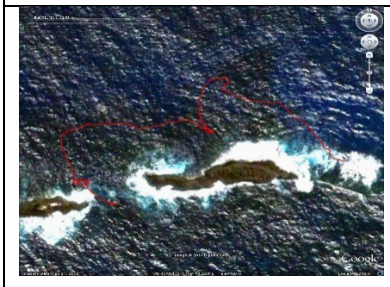
Malabar – Max Depth: 17 m. Black cod (29.2 cm) at 10.6 m.

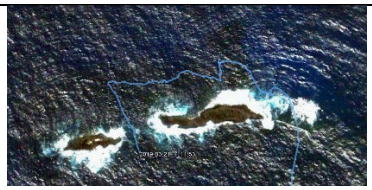
Daves Cave / Old Gulch – Max Depth: 17m.

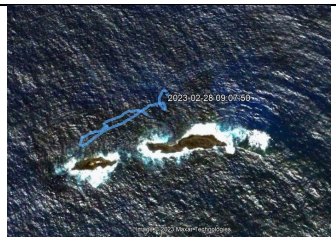




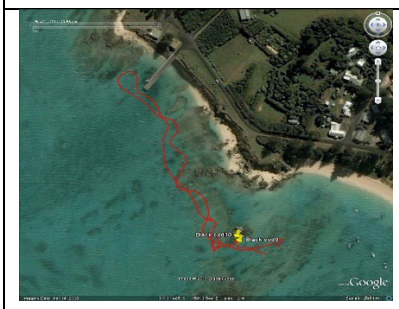
Wheatsheaf Rocks – Max Depth: 27 m.

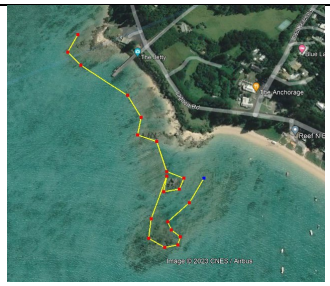






Observatory Rocks – Max Depth: 25 m.





Ship Rock – Max Depth: 2 m



Comet Hole – Max Depth: 7.5m



North Bay – Max Depth: 3m.


Sylphs Hole – Max Depth: 5m

North Passage South – Max Depth: 2.5 m.

Erscotts Hole – Max Depth: 6m.

Erscott's Passage – Max Depth: 22m.

South Passage – Max Depth: 12m.

Yellow Rock – Max Depth: 15m.

Trevally Hole – Max Depth: 15m.

Ned's Beach – Max Depth: 11m.

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