Reef fish behaviour towards placebo bait pellets at Lord Howe Island

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Executive summary

We conducted a short field study of the potential vulnerability of nearshore reef fishes to Brodifacoum pellet dispersal as per of the Lord Howe Island Rodent Eradication Program. At seven locations around the Island, we first surveyed the identity, life stage and density of fishes in the nearshore (0-100m from shore) habitats that may be subject to accidental pellet dispersal (i.e., adjacent to steeper terrain). We identified 30 species of fish, the territorial damselfishes by far the most abundant (up to 12 fish per $100m^{-2}$).

For these species we evaluated their potential vulnerability to bait pellets by dropping individual (placebo) pellets and observing fish behaviour (Ignore, Approach, Mouth, Swallow). First, we found no effect of bait colour (white vs green) or bait density (one vs 2-3 pellets in a drop) on fish approaches or mouthing of baits. Several species always ignored baits (e.g, endemics *Chaetodon, tricinctus*, *Amphiprion mccullochi*). At sites where human feeding does not occur, 42% of fish completely ignored baits dropped adjacent to them, 36% approached but swam away, 22% mouthed but rejected pellets, while no fish actually swallowed pellets. By comparison, at 2 "fish feeding special purposes zones" (Ned's Beach, North Bay), both locations are approx. 500 m away from potential aerial broadcast sites, only 33% of fish completely ignored baits dropped adjacent to them, 36% approached but swam away, 29% mouthed but rejected pellets, while 1.5% actually swallowed pellets (and this was only at "feeding" sites). No endemic species were observed to ingest pellets.

Overall, fish rarely swallowed pellets but most showed some interested in them. We expect that actual bait pellets would be treated similarly or be less of interest by the fishes we tested, so actual ingestion of baits would be a rare occurrence based on our findings. It is therefore considered unlikely that the proposed eradication will impact significantly on near shore fish species.

Introduction

Exotic rodent (rat and mouse) invasion to oceanic islands is a major threat to indigenous wildlife (Jones *et al.,* 2016*)*. Eradication of rodents has become a powerful conservation tool to prevent extinctions and restore degraded habitats, but potential impacts to non – target species need to be considered. , Lord Howe Island, off the NSW coast, almost since it's settlement in 1880's has had ongoing problems with invasive rodent species. The high conservation significance of the region was recognised by its inclusion on the UNESCO World Heritage List in 1982 (Environment Australia 2002).

The Lord Howe Island Board is planning a rodent eradication project, and as part of this is identifying and researching potential risks to the marine environment of the baiting program. In particular, a small proportion of pellets dispersed by helicopter on steep hills adjacent to the marine environment may enter the water. Which fishes may be at these sites, and how they may respond to pellet drops, is the subject of this study and report.

The New South Wales Government proclaimed the Lord Howe Island Marine Park (State Waters) (LHIMP) in 1999nto protect marine conservation values within 46,000 ha surrounding Lord Howe Island. An associated multiple-use zoning scheme came into force on 1 December 2004 (Figure 1). Adjoining the NSW marine park immediately offshore, the Australian Government proclaimed the Lord Howe Island Marine Park (Commonwealth Waters) in 2000, thereby providing protection to marine life from ocean long-lining and trawling for an additional 300,000 ha (Edgar et al. 2010) .

The fish fauna of Lord Howe Island has been well documented, with more than 490 species recorded in the region (Allen et al. 1976; Francis 1993) and 433 documented in coastal habitats (Francis and Randall 1993). Of the inshore fish species, the majority are wide-ranging tropical forms, while some 10% are found only at Lord Howe Island, southern Australia and/or New Zealand (Allen et al. 1976). Approximately 4% (15 species) of the shore fishes are endemic to the Lord Howe region (including Norfolk Island) and 32% are restricted to the south-western or southern Pacific Ocean (Allen et al. 1976).

The pellet toxicant selected for the eradication of rats and mice from the Lord Howe Island group is Brodifacoum, a second-generation anticoagulant in the product Pestoff Rodent Bait 20R at 20 parts per million. On tropical Palmyra atoll non-toxic baits were dropped into four marine environments to observe the reactions of the marine species present. In shallow (1m depth) water fish showed no interest in the first pellets entering the water. However, on following occasions 3 species did eat baits. In moderate depth (3m) trials, 2 species took baits falling through the water and in deep (10m) water trials, 1 species was seen to mouth baits but consumption could not be confirmed. In total six of 20 species observed showed interest in the baits (Alifano and Wegmann 2010).

Past studies on pellet interactions (e.g., Swenson, see Appendix 1, *pers. comm.*) in Hawaii suggested that fish families differed in their bait attraction, with about 60% over all approaching bait pellets. This study did not observe any species consuming pellets but also did not record incidence of fish ignoring bait.

As a first step to assessing potential risk to reef fishes of accidental bait drops into nearshore waters, we conducted a short (4 day, June 2017) study *in situ*. Our aims were to:

- document densities, life stages and identities of reef fishes adjacent to Lord Howe Island cliff edges where aerial baiting may occur
- test responses of fishes (by species) to placebo bait pellets
- contrast fish responses among locations, between "fish feeding special purpose zones" and normal areas, and between pellets of different colour and number.

2. Materials and Methods

2.1. Study locations:

LHIB (2016) states "The only habitats potentially affected by the the rodent eradication program (REP) will be near shore habitats (open coast, rock pools and rocky and intertidal reefs within 5-10m of the shore) surrounding rugged or steep areas of the coast line that are aerially baited" (see Appendix 2, Figure 1 of the LHI REP Final Public Environment Report). A small amount of bait may enter the marine environment in these areas. Therefore baits could potentially enter the water in rugged areas of the following zones of the LHI Marine Park.

- Neds Beach and Admiralty Islands Sanctuary Zone (although Neds Beach will be baited by hand broadcast and or bait stations)
- North Bay Sanctuary Zone
- East Coast and Shelf Sanctuary Zone
- The remaining Habitat Protection Zone around LHI (excluding parts of the Lagoon that will be baited by hand or bait station)

The Lagoon Sanctuary Zone will not be impacted due to the 50m zone offset from the shore."

Therefore, we selected sites adjacent to steep hillsides, at sites we could access around Lord Howe Island (Figure 1, see key for sites names). We also sampled adjacent to Blackburn Island since helicopter baiting is being considered for that location. To test the effect of human-feeding on fish bait attraction, we also tested at 2 "permitted" hand feeding sites, in Ned's Bay and in North Bay, within the Special Purpose Zones both likely to be away from sites vulnerable to bait spillage.

2.2 Fish density estimates

Fishes at each site were surveyed via 50m x 2 m belt transects parallel to shore, in 1-3 m of water on rocky/coral reef. A 50m tape was laid and the observer commenced at the tape start after the whole tape was deployed. The observer (DJB) slowly swam above the tape, scanning to 1m either side and recording all fishes seen as species, life stage (recruit,

juvenile, adult), in 5 m segments (i.e., 10, 10m^2 segments in total). After the census was complete, a snorkeler swam the transect to record substrate (on Go Pro camera, vertically down facing) then again Go Pro (forward-facing, angled at approx. 60 degrees from the horizontal), as a record of benthic cover and fishes if required.

2.3 Fish behaviour towards bait pellet

Bait pellets used and in-water characteristics: Howald et al. (2005) showed that when baits were applied aerially to steep cliffs, (application rate of 15kg/ha) a mean of only 72 baits over 500 m stretch of coast (~2ha) ended up in the water. We used Pestoff Rodent Bait 20R non-toxic 10mm Pellets (white or green) to mimic Pestoff Rodent Bait 20R (green only) that would be used during the proposed eradication. Pellets were delivered from several centimetres above the water surface and rapidly sunk to the bottom. Empson and Miskelly (1999) found that the actual breakdown time will depend on wave action, current etc. but have shown that break down in sea was about 15 minutes.

Bait delivery treatments: We tested the following:

1. White pellet (one only)
2. White pellet (2-3 together) vs white pellets (one)
3. Green pellet (one) plus white Pellet (one). NB: We had limited green pellets so most of the study was conducted using white pellets. Green pellets will be used in actual baiting.

Bait delivery methods and video analyses: Where pellets were delivered, the observer threw one or more pellets (depending on treatment) ahead approximately 1-2 m to the water surface. Pellets dropped rapidly to the bottom. Go Pro video was taken before the pellets struck the water surface and this footage continued until pellets had disappeared from site or for 1-3 min, with an angle of view covering approx. 2 m in radius of the benthos. Each video was analysed as follows: all species present (with their number and life history class) were enumerated. For each fish, its behaviour towards the bait pellet(s) was recorded as: Ignore (fish showed no reaction to bait), Approach (fish made directed movement towards bait), Mouth (fish contacted bait briefly then rejects), Swallow (bait taken into fish's buccal cavity and did not appear to exit.

Figure 1: Lord Howe Island indication study locations (1= Ned's Beach North (-31.515673, 159.063612); 2= Ned's Beach SPZ (-31.517734, 159.066819); 3= Boat Harbour **(**-31.565438, 159.098065**)**; 4=Little Island **(**-31.567863, 159.074930); 5=Blackburn Island **(**-31.535311, 159.059539); 6=North Bay **(**-31.519579, 159.045527); 7= Sylphs **(**-31.522107, 159.049764). North is to top of page.

Results

AIM 1: To document densities and identities of reef fishes adjacent to Lord Howe Island hillsides

We recorded 30 species of fish along transects, a total of 461 individuals (Table 1, Figure 2). Territorial damselfish dominated, including bookfish *Parma polylepis* (mean density = 38 individuals per 1200m^2), *Neoglyphidodon polyacanthus* (mean density = 150 individuals per 1200m^2), *Stegastes fasciolatus* (mean density = 88 individuals per 1200m^2) and *Stegastes gascoynei* (mean density = 38 individuals per 1200m^2). Overall, 69% of the fish surveyed were territorial damselfish, 9% labrid wrasses, 4% chaetodontids (mostly the endemic *Chaetodon tricinctus*). More mobile species of mugilid and kyphosid plus the girellid *Girella cyanea* (bluefish) were surveyed, mainly at Blackburn Island. At some sites, wrasses (*Thalassoma lutescens*) were common, while the wrasse *Pseudolabrus luculentus* was present at most sites. Endemic species made up only 4% of total fish abundance censused.

Table1: Summary of fish encountered (# per 100 m^2) along transects at study sites (see Figure 1).

Family	Species	Size Class	BLACKBURN South	Blackburn NORTH	Boat Harbour West	Boat Harbour East	North Bay Transect #	North Bay #2	Neds North #1	Neds North #2	Neds Feeding area tr	Sylphs #1	Sylphs Transect #2	Little Bay	SUM
		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae	*Parma polylepis*	Juvenile	4	8	0	1	0	0	0	0	1	2	0	0	16
		Adult	0	1	1	1	0	0	7	0	8	0	4	1	23
		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae	*Neopomacentrus polyacant*	Juvenile	0	0	1	0	3	1	0	0	2	3	0	0	10
		Adult	1	3	3	0	33	49	5	0	2	24	1	19	140
		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae	*Stegastes fasciolatus*	Juvenile	0	2	5	2	0	0	0	0	0	0	0	0	9
		Adult	1	2	29	25	0	0	9	0	5	0	4	4	79
		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae	*Stegastes gascoynei*	Juvenile	0	3	0	2	0	0	0	0	0	0	0	0	5
		Adult	0	0	3	2	12	4	6	0	2	3	10	0	42
Girellidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Girella cyanea	Juvenile	2	0	0	0	0	0	0	0	0	0	0	0	2
		Adult	2	1	0	0	0	0	0	0	0	0	0	0	3
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pseudolabrus luculentus	Juvenile	0	4	1	0	0	0	0	0	0	0	0	0	5
		Adult	1	6	2	2	0	0	4	0	3	2	0	0	20
Acanthuridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Acanthurus dussimeri	Juvenile	0	0	0	0	1	0	0	0	0	0	0	0	1
		Adult	0	3	0	0	0	0	0	0	0	0	0	0	3
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Thalassoma lunarae	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	1	0	0	1	0	0	0	0	0	0	1	3
Mugilidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Myxus elongatus	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	10	0	0	0	0	0	0	0	0	0	0	10
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Thalassoma janseni	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	1	0	0	0	0	0	0	0	0	0	0	1
Kyphosidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Kyphosus sydneyanus	Juvenile	0	0	0	0	0	0	0	0	0	1	0	0	1
		Adult	0	24	1	3	0	0	0	0	0	0	0	0	28
Tetraodontidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Diodon hystrix	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	1	0	0	0	0	0	0	0	0	0	0	1
Acanthuridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Acanthurus triostegus	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	7	0	0	0	0	0	0	0	0	0	0	7
Chaetodontidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chaetodon tricinctus	Juvenile	0	0	1	0	0	0	0	0	0	1	0	0	2
		Adult	0	2	0	0	0	0	3	0	0	7	3	0	15
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Thalassoma lutescens	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	1	0	0	0	0	0	0	2	2	0	0	5
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gomphosus varius	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	1	0	0	0	0	0	0	0	0	0	1
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Thalassoma hardwicki	Juvenile	0	0	1	0	0	0	0	0	0	0	0	0	1
		Adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae		Recruit	0	0	1	0	0	0	0	0	0	0	0	0	1
	Amphiprion mcculochi	Juvenile	0	0	1	0	0	0	0	0	0	1	0	0	2
		Adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Apogonidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ostorhinchus doederleini	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	1	1	0	0	4	0	0	0	7	0	13
Cheliodactylidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cheilodactylus ephippium	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	1	0	0	0	0	0	0	0	0	0	1
Pomacentridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dascyllus aruanus	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	0	0	1	1	0	0	0	0	0	0	2
Girellidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chaetodon citronellus	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	0	0	1	0	0	0	0	0	0	0	1
Scaridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scarid unidentified	Juvenile	0	0	0	0	0	0	0	0	0	2	0	0	2
		Adult	0	0	0	0	0	5	0	0	0	0	0	0	5
Tetraodondicae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Canthigaster valentini	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	0	0	0	1	0	0	0	0	0	0	1
Chaetodontidae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chaetodon melannotus	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	0	0	0	1	0	0	0	0	0	0	1
Pomacentridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Abudefduf sexfasciatus	Juvenile	0	0	0	0	0	0	0	0	0	1	0	0	1
		Adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Thalassoma janseni	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	0	0	0	0	0	0	0	0	0	1	0	0	1
Pomacentridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chromis notialis	Juvenile	0	0	0	0	0	0	1	0	0	0	0	0	1
		Adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Labridae		Recruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Unid small wrasses	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
		Adult	1	0	0	1	1	3	0	0	0	0	0	0	6

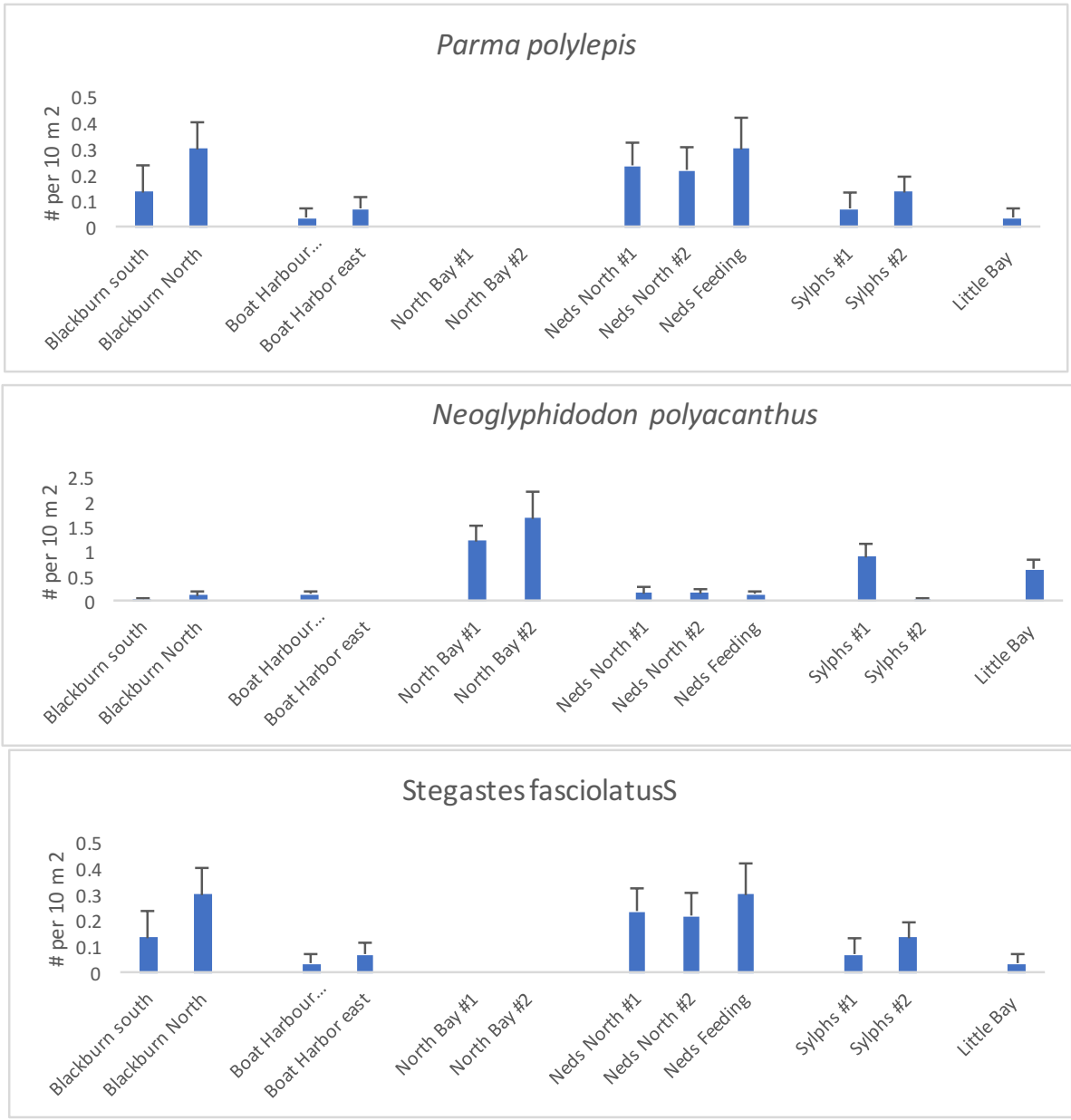

Figure 2: Densities of 3 common reef fish species across locations, n= 10, SE shown

AIM 2: Fish behaviour towards baits

General observations: Most pellet drops solicited interest among fishes present. In many cases, multiple species were present at a "drop" and often an individual would dominate by mouthing a pellet and swimming to shelter, followed by several of the same or other species. For example, the surge wrasse *Thalassoma purpureum* at Ned's Beach public feeding site, while rare at the site (not detected on transect surveys above) was readily attracted by diver presence, and was often the first fish to reach a dropped bait. In many cases, several *Pseudolabrus luculentus* approached a pellet, one mouthed it and swam rapidly to shelter with the others in pursuit (Figure 3). In no case except for *Pseudolabrus luculentus* did we observe juveniles of any species approach baits.

Fish response to bait (single white pellet): Overall, 140 individual fish were observed, 37% of fish ignored the pellet, 36% approached but deflected, 25% mouthed the bait then rejected, and only 2% were observed to apparently swallow the bait (Table 2). The latter (2 fish) were at a hand-feeding area. For three individual species (and all species combined), a higher proportion of fish showed interest in bait pellets (Chi squared tests, see Table 2)

Fish response to white vs green baits: Of 22 trials where both pellets were dropped together, in 14 cases the white pellet was approached first, in 8 cases green was approached first, indicating no significant preference for bait colour (Binomial test p=0.143 ns).

Fish response to single vs to multiple white pellets: Proportion ignored: we compared the ratios of Ignore:Approach:Mouth:Swallow between trials with one white pellet (n=140 fish) vs trials with 2-3 white pellets (n=91 fish). A higher proportion of fish approached baits when a single pellet was dropped Chi squared test df=3 18.3, p<.01, but similar proportions mouthed and swallowed pellets.

Fish responses in human feeding vs non-feeding locations: For all fish combined, and for three common territorial damselfish separately, fish within the feeding areas responded more actively to pellets (Chi squared tests, Table 2).

(a) (b)

(c) (d)

Figure 3: Images of reef fish interactions with bait pellets. (a) *Thalassoma purpureum* mouthing a bait pellet, (b)*Pseudolabrus luculentus* mouting a bait pellet, (c) *Parma microlepis* on a transect, (d) Mullet approaching a pair of baits, the green pellet (RHS) mouthed first.

Table 2 Summary of pellet presentation trials at Feeding sites (Ned's Beach SPZ Fish Feeding area, North Bay SPZ feeding area) and non-feeding sites (Ned's Beach north, Boat Harbour, Little Island, Blackburn Island, North Bay, Sylphs).

	Feeding				NON Feeding				TOTAL FISH				
SPECIES	IGNORE	APPROACH	MOUTH	SWALLOW	IGNORE	APPROACH	MOUTH	SWALLOW	IGNORE	APPROACH	MOUTH	SWALLOW	Chi-Squared
Abudefduf sexfasciatus	1								1				
Amphiprion mccullochi	1				3				4				
Chaetodon citrinellus	1								1				
Chaetodon flavirostris	1								1				
Chaetodon tricinctus	29				4				33				
Coris bulbifroms	2								2				
Coris bulbifrons		1								1			
emperor	4	1	1	1					4	1	1	1	
Girella cyanea					1	8	8		1	8	8		
lizardfish	1								1				
Mugil sp					20	14	6		20	14	6		
Neopomacentrus polyacant	16	22	28		14	9	3		30	31	31		**53.9****
Parma polylepis	12	10	1		7	4	1		19	14	2		**2.19 ns**
Pseudolabrus luculentus	9	25	11	1	1	8	9		10	33	20	1	**22.4****
rainbow runner	2	2							2	2			
Stegastes fasciolatus	3	1			3	2			6	3			
Stegstes gascoynei		1								1			
Stegtastes fasciolatus	1								1				
Thalassoma hardwicki	1								1				
Thalassoma lutesens	4	24	17		1	1	1		5	25	18		
Thalassoma purpureum	1	10	19	2					1	10	19	2	
Thalassopma janseni					1				1				
Grand Total	**89**	**97**	**77**	**4**	**55**	**46**	**28**	**0**	**144**	**143**	**105**	**4**	**5.49***

Discussion

A subset of fish species found on reefs in Lord Howe Island Marine Park is found on the nearshore rocky/coral reef habitat adjacent to steep hillsides. We found that territorial pomacentrids accounted for 69% (4 of 30 species) of fish across all locations, with endemics (*A. mccullochi*, *C. tricinctus*) being rare at all sites, making up only 4% of the fish abundance. Conditions at these sites often include high waver action/surge with limited visibility.

A majority of fish showed some interest in placebo bait pellets, with little difference among single vs multiple pellets and with white vs green colour. However, apparent pellet swallowing was extremely rare across the study, under 1% of all observations. While uncommon at our sites, 2 endemic species (butterflyfish *Chaetodon tricinctus*, anemonefish *Amphiprion mccullochi*) showed no interest in the baits we dropped.

We showed that fishes overall behaved differently towards placebo bait pellets in human feeding vs non-feeding areas, with a lower proportion of mouthing or swallowing pellets (zero) away from hand feeding areas. It should also be noted that pellets are quite large (1cm long) and any fish that mouthed pellets had trouble holding them.

A limitation of the study was the use of placebo baits, for ethical reasons. However, we feel the results are applicable to the proposed eradication bait pellets given no difference was observed between the white and green placebo pellets trialled and that the green placebos pellets were identical in all other respects to the bait pellets apart from the exclusion of tasteless and odourless Brodifacoum in the placebo pellets. What we can conclude is that few fish took baits except in feeding areas which supports the suggestion that limited ingestion of bait pellets due to aerial application would occur from the rodent eradication on Lord Howe Island and supports the use of hand broadcast at feeding sites such as the feeding site at Ned's Beach.

In addition to limited uptake of pellets, Brodifacoum is practically insoluble, particularly in cold seawater (Primus et al. 2005) such as will be found off Lord Howe Island in winter (sea temperature at our sites during the study were 19-20C, unpub data). Therefore extremely little Brodifacoum dissolved out from the baits into the water column as pellets fall (pers. obs.) We noted that while most pellet interaction happened in the water column while

pellets dropped, some fish investigated pellets on reef substrate. While we did not continue to observe such pellets, they dissolve in about 15 minutes (pers.obs.).

Further investigation of bait impacts on nearshore reef fishes if required, could include lab testing of bait toxicity to determine whether any particular species was more vulnerable to bait pellets, via mortality or changes in behaviour if pellets are ingested. It is possible for marine organisms to absorb Brodifacoum through their gills or skin although this is considered unlikely to happen in the sea given wave action and dilution (Empson and Miskelly 1999), and Brodifacoum is considered to be toxic to aquatic organisms, but our study concluded that bait consumption may be a rare occurrence.

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References

Alifano A, Wegmann A. (2010). The ecotoxicology and palatability of two rodenticide products: Field-based assessment at Palmyra Atoll. Island Conservation report prepared for the Palmyra Atoll Rainforest Restoration Project. 51 p.

Allen, Gerald R., Douglass F. Hoese, John R. Paxton, J. E. Randall, C. Russell, W. A. Starck, F. H. Talbot, and G. P. Whitley, 1976. Annotated checklist of the shes of Lord Howe Island. *Records of the Australian Museum* 30: 365–454. [21

Edgar G, Valentine J, Cooper T, Stuart-Smith R, Gudge S, Kerr I (2010) Ecological monitoring of reef communities at Lord Howe Island Marine Park, New South wales, 2006-2010. NSW MPA 2010. 70pp

Empson, R.A. and Miskelly, C.A. (1999). The risks, costs and benefits of using Brodifacoum to eradicate rats from Kapiti Island, New Zealand. New Zealand Journal of Ecology 23(2), 241–254.

Environment Australia (2002). Lord Howe Island Marine Park (Commonwealth Waters) Management Plan. 2002, Environment Australia, Canberra

Francis MP (1993) Checklist of the coastal fishes of Lord howe, Norfolk, and Kermadec Islands, southwest Pacific Ocean. Pacific Science 47, 136-170

Francis MP, JE Randall (1993) Further additions to the fish faunas of Lord Howe Island and Norfolk Island, Southwest Pacific Ocean. Pacific Science 47:118-135

Howald, G.R., Faulkner, K.R., Tershy, B., Keitt, B., Gellerman, H., Creel, E.M., Grinnell, M.,Ortega, S.T. and Croll, D.A. (2005). Eradication of Black Rats from Anacapa Island: biological and social considerations. In Proceedings of the Sixth California Islands

Jones H. P., Holmes N. D., Butchart S. H., Tershy B. R., Kappes P. J., Corkery I., Aguirre-Monoz A., Armstrong D. P., Bonnaud E., Burbidge A. A., Campbell K., Courchamp F., Cowan P. E., Cuthbert R. J., Ebbert S., Genovesi P., Howald G. R., Keitt B. S., Kress S. W., Miskelly C. M., Oppel S., Poncet S., Rauzon M. J., Rocamora G., Russell J. C., Samaniego-Herrera A., Seddon P. J., Spatz D. R., Towns D. R. and Croll D. A. (2016) Invasive mammal eradication on islands results in substantial conservation gains. *PNAS* **113**, 4033-8

Lord Howe Island Board, (LHIB) (2016). Lord Howe Island Rodent Eradication Project – Public Environment Report, Lord Howe Island Board, Lord Howe Island. December 2016

Primus, T., Wright, G. and Fisher, P. (2005). Accidental discharge of Brodifacoum baits in a tidal marine environment: a case study. *Bulletin of Environmental Contamination and Toxicology* **74**, 913–919.

APPENDIX 1

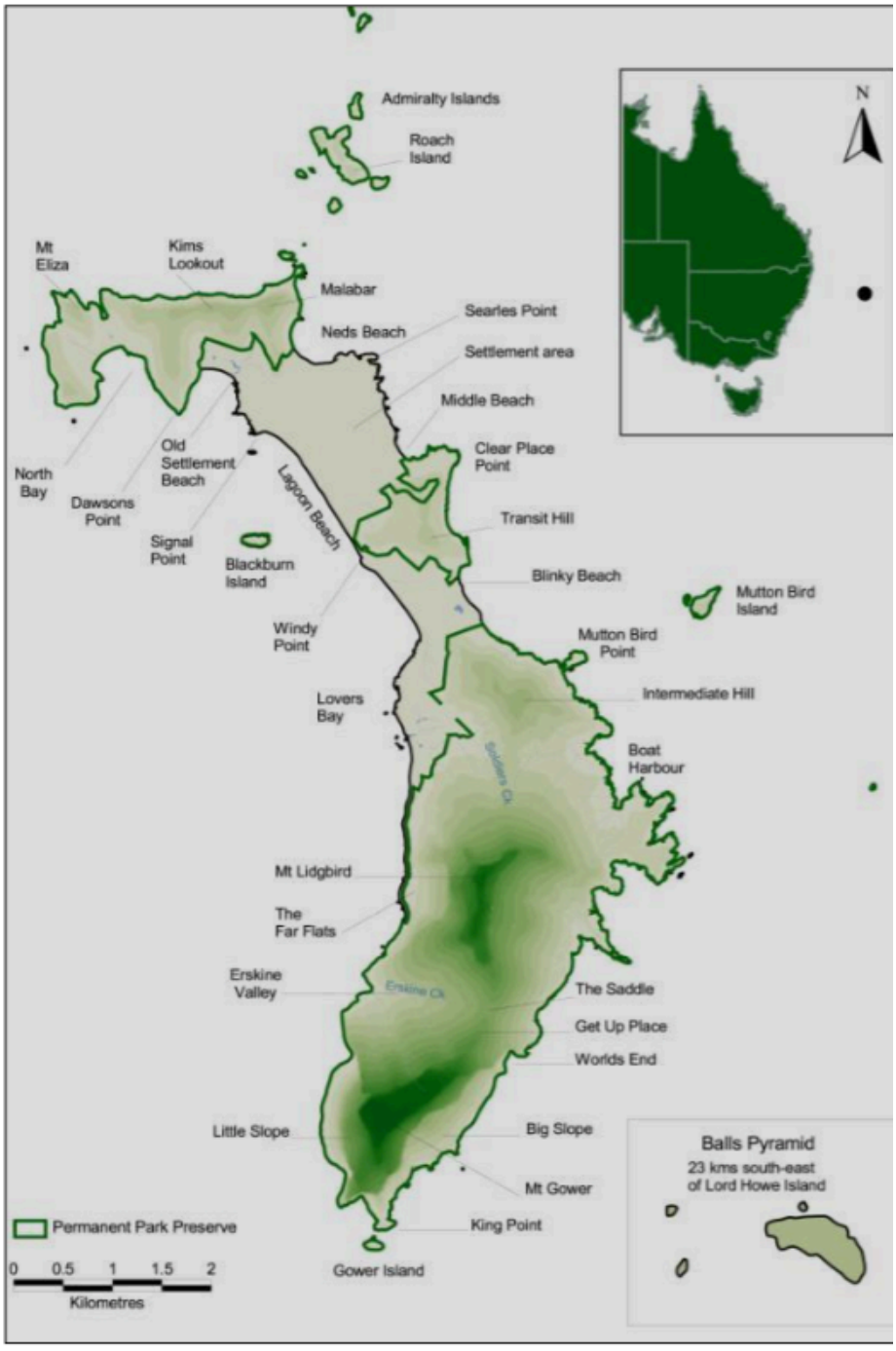
Attraction of marine fishes to placebo Ramik Green rat bait pellets (2 - 3 gram size)
Lehua Island, Hawaii, September 18-19, 2004 – Chris Swenson

Common name	Species name	Total # of fish	Number of bait interactions observed (some individuals interacted multiple times)			Number of bait interactions per species
			Inspected bait	Touched bait	Consumed bait	
Orangespine unicornfish	*Naso literatus*	13	10	8	0	18
Convict tang	*Acanthurus triostegus*	8	0	0	0	0
Whitebar surgeonfish	*Acanthurus leucopareius*	85	19	0	0	19
Orangeband surgeonfish	*Acanthurus olivaceous*	7	3	5	0	8
Achilles tang	*Acanthurus achilles*	2	0	0	0	0
Ringtail surgeonfish	*Acanthurus blochii*	1	0	0	0	0
Eyestripe surgeonfish	Acanthurus dussumieri	1	0	0	0	0
Lagoon triggerfish	*Rhinecanthus aculeatus*	1	1	0	0	1
Black durgon	*Melichthys niger*	6	21	13	0	34
Pinktail durgon	*Melichthys vidua*	5	13	9	0	22
Moorish idol	*Zanclus cornutus*	1	0	0	0	0
Ornate butterflyfish	*Chaetodon ornatissimus*	1	0	0	0	0
Longnose butterflyfish	*Forcipiger longirostris*	1	0	0	0	0

Cornetfish	*Fistularia commersonii*	1	0	0	0	0
Bigeye emperor	*Monotaxis grandoculis*	1	0	0	0	0
Yellowstriped coris	*Coris flavovittata*	1	0	0	0	0
Blacktail wrasse	*Hinalea lauhine*	1	0	0	0	0
Christmas wrasse	*Thalassoma lauhine*	1	0	0	0	0
Saddle wrasse	*Thalassoma duperrey*	1	1	1	0	2
Blackspot seargant	*Abudefduf sordidus*	1	0	0	0	0
Trevally sp. (juveniles)	*Caranx sp.*	3	0	0	0	0
Butterflyfish sp.	*Chaetodon sp.*	1	0	0	0	0
Manybar goatfish	*Parupeneus multifasciatus*	5	0	0	0	0
Yellowtail goatfish	*Mulloidichthys vanicolensis*	4	0	0	0	0
Unidentified school of fish	----------	15	0	0	0	0
Totals (24 species observed)		136 fish counted	18 bait inspections observed	29 bait touches observed	0 bait consumptions observed	47 total bait interactions observed

Notes on Study methodology: Observations were made at two locations on the south side of Lehua Island on July 8 and 9, 2004, in 5-6 meters of water. A snorkeler waited about 10 m offshore while a second person on shore threw placebo Ramik Green bait pellets (approximately 8 grams each) into the water to locations with fish, as indicated by the snorkeler. Fifty pellets were thrown into each study site (100 pellets total) and the fish's reactions were observed and noted on waterproof paper by the snorkeler. Because the same groups of fish were exposed to pellets multiple times, some individual fish had multiple pellet interactions.

APPENDIX 2


Admiralty Islands
Roach Island
Mt Eliza
Kims Lookout
Malabar
Searles Point
Neds Beach
Settlement area
Middle Beach
Clear Place Point
North Bay
Old Settlement Beach
Dawsons Point
Lagoon Beach
Transit Hill
Signal Point
Blackburn Island
Blinky Beach
Mutton Bird Island
Windy Point
Mutton Bird Point
Intermediate Hill
Lovers Bay
Boat Harbour
Mt Lidgbird
The Far Flats
Erskine Valley
The Saddle
Get Up Place
Worlds End
Little Slope
Big Slope
Mt Gower
King Point
Gower Island
Permanent Park Preserve
0 0.5 1 1.5 2
Kilometres
N
Balls Pyramid
23 kms south-east of Lord Howe Island