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A Biological Survey of an Artificial Reef at Newcastle Channel, British Columbia

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A BIOLOGICAL SURVEY OF AN ARTIFICIAL REEF AT NEWCASTLE ISLAND, BRITISH COLUMBIA

by

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ABSTRACT

Armstrong, J.W. 1993. A biological survey of an artificial reef at Newcastle Island, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2212 : 21pp.

This survey describes the characteristics of an artificial reef between Shaft and Tyne Points on Newcastle Island, British Columbia, in terms of its dimensions and the distribution of fish, macroinvertebrates, and macroalgae. Growth and abundance on the reef has been monitored since the reef was constructed in 1990 in order to assess growth patterns and species diversity.

RÉSUMÉ

Armstrong, J.W. 1993. A biological survey of an artificial reef at Newcastle Island, British Columbia. Can. Manuscr. Rep. FIsh. Aquat. Sci. 2212 : 21pp.

Ce relevé décrit les caractéristiques d'un récif artificiel situé entre les pointes Shaft et Tyne sur l'Île Newcastle, Columbie-Britannique, en termes de ses dimensions et de la distribution des espèces de poisson, de macro-invertébrés et d'algues microscopiques. On a surveillé la croissance et l'abondance des espèces sur le récif depuis la construction de celui-ci en 1990 afin d'évaluer les profils de croissance et la diversité des espèces.

A BIOLOGICAL SURVEY of an ARTIFICIAL REEF at NEWCASTLE ISLAND, BRITISH COLUMBIA.

1.0 INTRODUCTION

Between January 24 and February 15 1990, the Nanaimo Harbour Commission constructed an artificial subtidal reef between Shaft and Tyne points. The material, mainly broken concrete slabs 0.3 to 1 meter in diameter and 0.2 m thick, was transported to the site by barge and placed in 5 to 15 m of water (at chart datum) using a clamshell dredge. The deposit area had been surveyed by DFO divers as well as by a land survey crew to ensure that the reef was located outside an adjacent navigation channel but still within the photic zone. The reef was made of scrap concrete from demolished buildings on Cameron Island. A few months later, the B.C. Ferry Corporation added to the reef by depositing scrap metal at the north end of the pre-existing reef.

This report describes biological surveys conducted on the reef in 1990, in August 1992 and in June 1993 and assesses the colonization of artificial reefs by fish, invertebrates and algae in southern British Columbia.

2.0 ASSESSMENT METHOD

The reef was surveyed six times over a three year period (Table 1).

Table 1. Newcastle Island Artificial Reef Biological Survey Summary

Dive Number	Date Surveyed	# Transects Surveyed	Assessment method
1	July 12 1990	3	qualitative
2	Sept.10 1990	3	qualitative
3	Nov. 5 1990	23	stationary sampling methodology
4	Aug. 17 1992	4	biological survey
5	Aug. 28 1992	3	biological survey
6	June 24 1993	6	biological survey

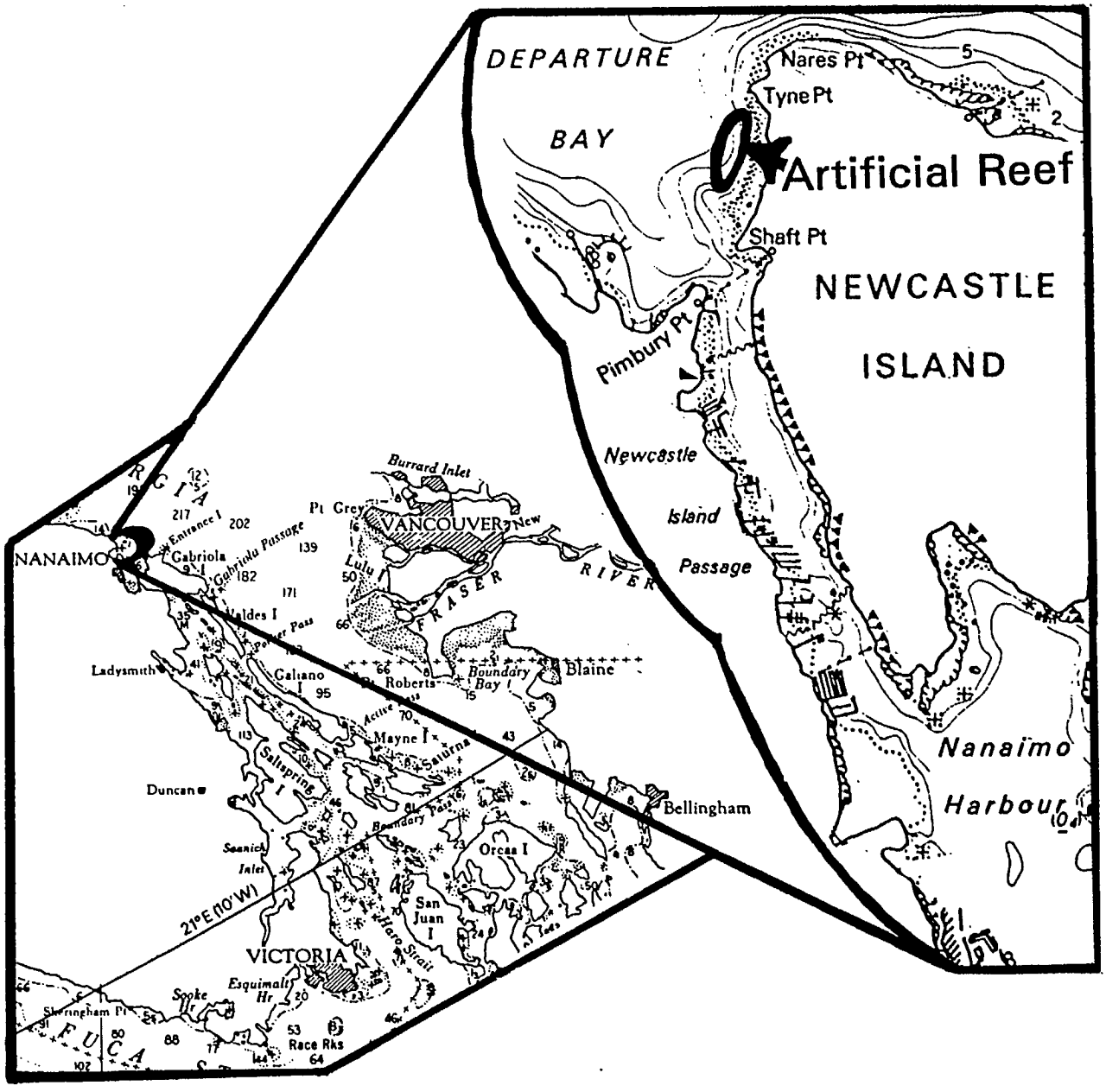
The location of the artificial reef is shown in Figure 1.

Underwater visual observations were carried out using SCUBA on each of the biological surveys. Divers used a plastic slate to record data. Permanent transect lines were established on two separate occasions, however, one of the surveys (dive #3) did not make use of established transect lines. Naito and Russell placed three transect lines across the reef on July 12, 1990. On August 2, 1992 Armstrong and Russell placed a permanent transect line on the eastern side of the reef which runs parallel to the reef long axis. This line, 110 m in length, was weighted lead line marked with flagging tape at 10 m intervals. The 110 m mark denoted the south end of the reef. From this baseline, transects were swum which crossed perpendicular to the reef long axis, and over the top of the reef to the western edge. The dimensions of the reef were calculated from measurements taken along these transects.

Qualitative Survey Method

Three permanent transects were placed on the reef on February 22, 1990 by Naito and Russell. These three transect lines were used on dive #1 and #2 to make qualitative observations of marine life established on the reef. Observations were made for up to two m on either side of the transect lines for fish, macroinvertebrates, and macroalgae.

Figure 1. Location of the Artificial Reef at Newcastle Island, B.C.



Stationary Sampling Methodology

Fish on the reef were counted using three methods. The following method was used on dive #3 (Table 1) and differs from the other dives in both transect placement and fish observation methodology. On this dive fish were surveyed using stationary sampling methodology which is based on censuses taken at randomly selected points. The distance between sampling points is determined by a randomly generated number of swimming kicks between 1 and 10. The direction of the next sampling point is determined by generating random numbers by tens between 0 and 90 representing degrees and randomly selecting a direction as left or right.

Before descending, the SCUBA divers estimated the compass bearing of the main axis of the reef (estimated to be 0 degrees North magnetic). The two SCUBA divers then ascended and started at the south end of the reef. The divers swam in a random direction (left or right of the main reef axis) by a random number of degrees (by tens between 0 and 90) for a random number of swimming kicks (between 1 and 10). The divers performed observations at the end of their short swim and then swam to their next sampling point using another random distance and set of directions.

If the edge of the reef was encountered before the number of swimming kicks was completed the diver switched direction (to the same number of degrees but to the opposite side of the main reef axis) to complete the remaining swimming kicks. The above procedure ensured that the sampling points were always on the reef. If a portion of the sampling area extended beyond the edge of the reef, that portion was estimated with respect to the actual sampling area. If the diver could not observe fish over the reef apex, an estimate of the actual sampling area was provided.

At each sampling point information was collected for all conspicuous fish species observed in ninety seconds within an imaginary cylinder within a predetermined radius from the observer and extending that same distance to the surface. Ninety seconds is the average time required to record all information on the data sheet. The time interval was kept to a minimum to prevent double counting of fish that moved in and out of the sampling area. The dimensions of the imaginary cylinder were determined by the underwater visibility at the time of the survey and the distance at which a fish could be readily identified. For this survey, the dimensions of the imaginary cylinder were set at twenty ft (6.15 m).

Information collected for fish species included estimated number and mean estimated length. Numbers of each fish species at each sampling point were estimated by starting at one point and rotating 360 degrees until the entire sampling area was scanned. Due to the physical complexity of the artificial reef, information was collected only from conspicuous fish appearing over the reef. When large schools of fish were present it was sometimes necessary to count by tens, twenties, or even fifties. Cryptic fish were noted but were not counted. Fish fork lengths were estimated in cm by comparing fish to a rule marked out on the SCUBA diver's clipboard. After all fish data was collected, depth and time were recorded.

The accuracy of the stationary sampling method is highly dependent on the behaviour of fish. Fish, which are counted, could move to other sampling areas (e.g. perch schools which occasionally follow divers and/or lingcod which exhibit diver avoidance). This fish movement could lead to double counting and an overestimate of reef fish density and population. If fish moved entirely off the reef before being counted, an underestimate of density and population could also occur.

To obtain an estimate of total population of fish and fish species on the reef, the mean density of fish per square metre of all sampling areas was calculated. This mean density was multiplied by the total square area of the reef.

Cryptic fish were recorded by observing reef crevices within two m of either side of each transect line. The counts enumerated larger species such as perch, rockfish, lingcod, greenling and large sculpins. Smaller, cryptic fish such as gobies and most sculpins were observed but not counted because representative counts were difficult to obtain.

Qualitative observations of cryptic fish, macroalgae cover and macroinvertebrates were also recorded.

Biological Survey Method

The two surveys conducted by Armstrong and Russell in August, 1992 followed the method used by McElderry et al. on surveys conducted on an artificial reef in Nanaimo harbour. The fish counts were restricted to an area two m on either side of the transect line with the invertebrates and algas enumerated in the same way.

On each of the SCUBA dives, the lead diver clipped the transect line to the baseline and strung the transect line across the width of the reef while observing and recording both swimming fish and fish hidden in crevices. Fish observed included rockfish, perch, gobies, greenling, and lingcod. The lead diver was also responsible for measuring the width of the reef and for determining depths at the edges of the reef.

The second diver swam along the transect line recording invertebrates and macroalgae within two m of each side of the transect. Once at the end of the transect, the first diver returned to the baseline to collect the transect line. The second diver followed and the pair moved along the fixed transect to the next baseline point.

The last survey conducted by Armstrong and Russell in June, 1993, was conducted in a similar fashion to the 1992 surveys except that the perpendicular transects off the lead line transect were swum along a constant compass bearing (180 degrees) without the aid of a fibreglass tape.

3.0 RESULTS

3.1 PHYSICAL HABITAT

The physical dimensions of the Newcastle Island artificial reef recorded during the SCUBA dive surveys are summarized in Table 2.

Table 2 Dimensions of the Newcastle Island Reef

Transect Number	Baseline Distance	Reef Width	Area Surveyed(m^2)	Total Area (m^2)
1	110m	25m	50	250
2	90m	23m	92	460
3	70m	39m	156	780
4	50m	20m	80	400
5	30m	25m	100	500
6	10m	25m	100	500
7	0 m	23m	46	230
Total			624	3120

The base of the artificial reef is located in 5 to 15 m of water (relative to chart datum) on a gently sloping sand/pebble substrate. The mean depth of reef materials is 2.0 m. The reef is approx. 110 m in length and has an average width of 26 m.

The reef consists primarily of broken concrete slabs 0.3 to 1 m in diameter and 0.2 m thick. The complexity factor (number of surfaces of concrete slabs exposed for colonization) of the reef, based on the assumed mean total surface area of a concrete slab 1 m in diameter, is calculated as being 2.2 (the maximum surface area possible would be 2.6 m and the minimum surface area would be 1.8 m). The many crevices among the concrete slabs allow fish and invertebrates to hide while several hollow metal pipes provide additional cover.

On June 18, 1993 additional concrete slabs and columns as well as some scrap metal was placed at the north end of the reef by the Nanaimo Harbour Commission. The new reef material was assessed and measured on June 24, 1993. Dimensions of the new reef (roughly triangular) are: 18 m wide across the shallowest edge, by 30 m out to the edge of the existing reef, by 12 m back to the shallow subtidal.

3.2 BIOLOGICAL CHARACTERISTICS

3.2.1 FISH, MACROINVERTEBRATES, MACROALGAE.

Reef fish population estimates were calculated from the transect surveys using the area density method, where the number of fish on the reef= (the area of the entire reef) x (the number of fish counted along the transects/ the area of the transects).

July 12, 1990 Qualitative Survey

The following is a summary of the marine species diversity assessed in July, 1990. During this dive assessment the transect width for both benthic and neritic fish as well as macroinvertebrates and macroalgas was set at 4 m. The visual search area for the three transects was therefore estimated to be 244 m or 8% of the total reef area. The survey took place between 1100 PST and 1200 PST at which time the tide was falling from a high of 8.2 ft at 0620 PST to a low of 3.0 ft at 1310 PST.

Of the many fish species on the reef, pile perch (Rhacochilus vacca) were the most abundant. Blackeyed gobies (Coryphopterus nichoisi) were estimated to be the second most common species followed by kelp greenling (Hexagrammos decagrammus), quillback rockfish (Sebastes maliger), tubesnout (Aulorynchus flavidus), striped perch (Embiotoca lateralis), kelp perch (Brachyistus frenatus), copper rockfish (Sebastes caurinus), and lingcod (Ophiodon elongatus).

Invertebrates on the reef included numerous juvenile (less than 3 cm length) coonstripe shrimp (Pandalus danae) as well as kelp crabs (Puggettia producta), which were observed on loose pieces of large Laminaria saccharina and Agarum fimbriatum blades. Also present were red rock crabs (Cancer productus), leather stars (Dermasterias imbricata), several small (less than 15 cm diameter) sunflower stars (Pycnopodia helianthoides), and a number of California sea cucumbers (Parastichopus californicus).

The colonization of the reef by algae, while not as rapid as that of fish or invertebrates, is not considered abnormally slow given the short growth period (the reef had been completed only six months previously). The algal colonization compared favourably to other artificial reefs in the Nanaimo area (Naito to file, July 12, 1990). Algas observed on the reef included small tufts of unidentified filamentous red and brown algae (occurring at densities of less than 2 per square metre) and several juvenile Laminaria saacharina (which had attained lengths of approximately 25 cm). Many crabs, as mentioned earlier, were observed clinging to Laminaria saacharina and Agarum fimbriatum, the large broken blades having become wedged in several of the many crevices on the reef.

September 10 1990 Qualitative Survey

The pattern of this survey followed that of the July 12 dive with the transect area and total area surveyed being the same as previously. This survey was conducted by Naito and Russell between 1100 PDT and 1145 PDT (the tide was falling from a high of 12.9 ft at 1054 PDT to a low of 10.4 ft. at 1542 PDT).

Fish observed during the survey included quillback rockfish (Sebastes maliger; both adults and juveniles), shiner perch (Cymatogaster aggregata) in large schools (av 4 cm length), striped perch (Embiotoca lateralis; 20 cm lengths), kelp perch (Brachystius frenatus; 10 cm lengths), pile perch (Rhacochilus vacca; 20 cm lengths), black-eyed gobies (Coryphopterus nichoisi; 5-10 cm lengths) in crevices, lingcod (Ophiodon elongatus; 45 cm length) and, kelp greenlings (Hexagrammos decagrammous; 35 cm length).

Macroinvertebrates seen included numerous acorn barnacles (Balanus glandula), encrusting bryozoans (Schizoporella spp), red rock crabs (Cancer productus), kelp crabs (Pugettia producta), ochre sea stars (Pisaster ochraceus), leather stars (Dermasterias imbricata), short-spined stars (Pisaster brevispinus), sunflower stars (Pycnopodia helianthoides), and California sea cucumbers (Parastichopus californicus).

Macrophytes observed on this survey included Neogardhiella spp. (4 cm length; 50% cover), Laminaria saccharina (20 cm length; 10% cover), Ulva spp. (10 cm length; 10% cover), a small feathery red algae (2 cm length; 5% cover), and brown thin filamentous algae (3 cm length; 40% cover). All of the algas cover only the top horizontal surfaces of the concrete chunks, with the exception of the brown thin filamentous algae which managed to thrive on all surfaces. Patches of sand and gravel covering the concrete blocks appeared to impede algal growth at the time of this survey, although some thin layers of sand had apparently not affected growth.

NOVEMBER 5, 1990 Stationary Sampling methodology

This survey was conducted on the reef on November 5, 1990 between 0900 and 1000 hrs PST. At the time of the survey, the tide (Nanaimo reference) was falling from a high of 15.1 ft at 0745 hr to a low of 11.3 ft at 1251 hr PST.

During the survey, pile perch (Rhacochilus vacca), were estimated to be the most abundant fish species on the reef. Striped perch (Embiotoca lateralis) were the second most common fish species, followed by kelp perch (Brachyistius frenatus), quillback rockfish (Sebastes maliger), kelp greenling (Hexagrammos decagrammus), copper rockfish (Sebastes caurinus), and lingcod (Ophiodon elongatus). Numerous black-eyed gobies (Coryphopterus nichoisi) were observed in crevices during the survey, but were not counted.

A summary of the fish observations is given in Tables 3 and 4 and a summary of macroinvertebrate observations is shown in Tables 5 and 6.

Only qualitative data was collected for the macroinvertebrates observed on the reef. Leather stars (Dermasterias imbricata) were observed in only two of the sampling areas. Pink short-spined stars (Pisaster brevispinus) and red rock crabs (Cancer productus) were observed in only one of the sampling areas. Numerous coonstripe shrimp (Pandalus danae) were observed in reef crevices during the survey. California sea cucumbers (Parastichopus californicus) and sunflower stars (Pycnopodia helianthoides) were also observed. There were no invertebrates recorded from the steel portion of the reef.

The cover by algae included Neogardhiella spp. (60% cover), Ulva spp. (20% cover), unidentified leafy red algas (less than 5% cover), Laminaria saccharina (10% cover), and diatomous brown algas (20% cover). All of these qualitative observations were made on the concrete portion of the reef. No macroalgae were observed on the steel portion of the reef.

Table 3. November 1990 fish survey- raw data

Newcastle Island Passage Artificial Reef — November 5, 1990 Fish Survey Data

FISH RAW DATA — TOTAL REEF AREA = 4500 SQ METRES

Visual Area m^2	Quillback Rockfish	Copper Rockfish	Striped Perch	Pile Perch	Kelp Perch	Green Ling	Ling Cod	
58	0	0	2	9	1	1	0	
58	0	0	0	0	3	0	0	
58	0	0	0	0	1	0	0	
117	0	0	7	0	0	0	0	
117	0	0	0	0	2	0	0	
117	1	0	0	0	0	0	0	
117	0	0	0	0	0	0	0	
117	0	0	5	0	0	0	0	
117	0	0	6	60	0	0	0	
117	0	0	20	100	5	0	0	
117	0	0	20	20	0	0	0	
58	0	0	20	20	0	0	0	
58	0	0	20	2	2	0	0	
58	0	0	4	1	1	0	0	
82	0	0	5	0	0	0	0	
117	1	0	8	0	0	0	0	
117	1	0	20	0	0	2	0	
117	0	0	25	0	0	1	0	
117	0	0	0	3	0	0	0	
117	0	1	0	20	0	0	0	
58	1	0	0	10	0	0	1	
58	0	0	0	10	0	0	0	
58	0	1	0	0	0	0	0	
2125	4	2	162	255	15	4	1	TOTALS
	25 cm	25 cm	15 cm	10 cm	10 cm	30 cm	45 cm	AVERAGE LENGTH

Table 4. November 1990 reef fish estimates.

Newcastle Island Passage Artificial Reef — November 5, 1990 Fish Survey Data

FISH PER 100 SQ M — TOTAL REEF AREA = 4500 SQ METRES

Visual Area m^2	Quillback Rockfish	Copper Rockfish	Striped Perch	Pile Perch	Kelp Perch	Green Ling	Ling Cod
58	0.0000	0.0000	3.4263	15.4182	1.7131	1.7131	0.0000
58	0.0000	0.0000	0.0000	0.0000	5.1394	0.0000	0.0000
58	0.0000	0.0000	0.0000	0.0000	1.7131	0.0000	0.0000
117	0.0000	0.0000	5.9960	0.0000	0.0000	0.0000	0.0000
117	0.0000	0.0000	0.0000	0.0000	1.7131	0.0000	0.0000
117	0.8566	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
117	0.0000	0.0000	4.2828	0.0000	0.0000	0.0000	0.0000
117	0.0000	0.0000	5.1394	51.3939	0.0000	0.0000	0.0000
117	0.0000	0.0000	17.1313	85.6565	4.2828	0.0000	0.0000
117	0.0000	0.0000	17.1313	17.1313	0.0000	0.0000	0.0000
58	0.0000	0.0000	34.2626	34.2626	0.0000	0.0000	0.0000
58	0.0000	0.0000	34.2626	3.4263	3.4263	0.0000	0.0000
58	0.0000	0.0000	6.8525	1.7131	1.7131	0.0000	0.0000
82	0.0000	0.0000	6.1183	0.0000	0.0000	0.0000	0.0000
117	0.8566	0.0000	6.8525	0.0000	0.0000	0.0000	0.0000
117	0.8566	0.0000	17.1313	0.0000	0.0000	1.7131	0.0000
117	0.0000	0.0000	21.4141	0.0000	0.0000	0.8566	0.0000
117	0.0000	0.0000	0.0000	2.5697	0.0000	0.0000	0.0000
117	0.0000	0.8566	0.0000	17.1313	0.0000	0.0000	0.0000
58	1.7131	0.0000	0.0000	17.1313	0.0000	0.0000	1.7131
58	0.0000	0.0000	0.0000	17.1313	0.0000	0.0000	0.0000
58	0.0000	1.7131	0.0000	0.0000	0.0000	0.0000	0.0000
	0.1862	0.1117	7.8261	11.4333	0.8566	0.1862	0.0745	MEAN PER 100 SQ M
	0.1972	0.1537	113.7247	435.3934	2.3345	0.2639	0.1276	VARIANCE
	0.4611	0.4091	10.9751	21.6889	1.2452	0.4093	0.3734	ST DEV
	8.4	5.0	352.2	514.5	38.5	8.4	3.4	ESTIMATED NUMBER ON REEF

Table 5. November 1990 macroinvertebrate raw data.

Newcastle Island Passage Artificial Reef — November 5, 1990 Survey

MACROINVERTEBRATE RAW DATA

Visual Area m^2	Leather Star	Short-Spined Star	Red Rock Crab	
3.1	1	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	1	0	0	
3.1	0	0	0	
3.1	0	0	1	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	1	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
3.1	0	0	0	
72	2	1	1	TOTALS

Table 6. November 1990 reef macroinvertebrate estimates.

Newcastle Island Passage Artificial Reef — November 5, 1990 Survey

MACROINVERTBRATES PER 100 SQ M

Visual Area m^2	Leather Star	Short-Spined Star	Red Rock Crab	
3.1	31.8310	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	31.8310	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	31.8310	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	31.8310	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
3.1	0.0000	0.0000	0.0000	
	2.7679	1.3840	1.3840	MEAN PER 100 SQ M
	84.1006	44.0527	44.0527	VARIANCE
	6.9436	6.9383	6.9383	ST DEV
	124.6	62.3	62.3	ESTIMATED NUMBER ON REEF

While no quantitative data were collected on the reef in the previous surveys, the numbers of quillback and copper rockfish, and kelp greenlings on the reef appear to have declined from previous surveys. This observation is consistent with Moulton et al. (1974), who found that rockfish were nonexistent or very few in number on reefs during the winter. They also suggested that rockfish move off the reefs to deeper water during the winter.

Numbers of macroinvertebrates observed appear to have remained similar to previous surveys. The algal species Neogardhiella and Ulva spp. have increased their percent cover while other species (Laminaria) have maintained similar coverage to that observed in the two earlier surveys.

AUGUST 17 AND 28 1992 Biological Sampling

The four transects completed on August 17 were added to the three transects completed on August 28 and considered as one survey. The visual search for all the transects combined was estimated at 624 m or 20 % of the total reef area.

A summary of fish observations is presented in Table 7. Two large schools of tubesnouts (Aulorynchus flavidus) made this the most abundant species on the reef, followed by shiner perch (Brachyistius frenatus), pile perch (Rhacochilus vacca) and blackeye gobies (Coryphoptera nichoisi). The most common rockfish observed were copper rockfish (Sebastes caurinus) which showed the same abundance as striped sea-perch (Embiotoca lateralis). Present in low numbers were kelp greenling, lingcod, and two unidentified flatfish.

Reef fish populations were comprised of adults and juveniles. Length estimates were taken for most of the fish that were observed. The striped perch had a range in size of 15 to 20 cm, while pile perch ranged from 10 to 20 cm. Copper rockfish adults ranged from 20 to 30 cm and the juveniles were approximately 5 cm in length. The kelp greenling averaged 30 cm and the tubesnouts 10 cm in length.

The number of rockfish counted on this survey (27) was greater than the November 1990 survey (6) indicating consistency with Moulton et al. (1974).

Table 7 Fish observed on the Newcastle Island reef, August 17 and 28, 1992.

Transect #	str.p.	p.p.	b.g.	c.r.	k.g.	s.p.	t.s.	l.c.	f.f.
1	4	11	10	0	0	1a 1j	0	1	0
2	1	20+	20+	5a 5j	0	35+	0	0	0
3	5-10	0	20+	7a 1j	1	30a 20j	0	0	0
4	0	10a 5j	10-20	1	1	0	0	0	1
5	2	10	10-20	3	0	20-30	0	0	0
6	5-10	30	10-20	4	1	6	100+	0	1
7	5	20	2	1	0	0	200+	0	0
Total	27	110	105	27	3	126	300+	1	2
Percent	6.7	27.4	26.2	6.7	0.7	31.4		0.2	0.5
Fish/ 100 m^2	4.3	17.6	16.8	4.3	0.5	20.2	48.1	0.2	0.3
Estimated Total	134	549	524	134	16	630	1500	6	9

str. p=striped perch
p.p.= pile perch
b.g.= blackeye gobie
c.r.= copper rockfish
k.g.= kelp greenling
s.p.= shiner perch
t.s.= tubesnouts
l.c.= lingcod
f.f.= flat fish
a= adult
j= juvenile

Invertebrates observed on this survey included leather stars (Dermasterias imbricata), sunflower stars (Pycnopodia helianthoides), California sea cucumbers (Parastichopus californicus), and several small nudibranchs. There was an average of three red rock crabs (Cancer productus) per transect. The dense growth of algae acted as cover for both the red rock crabs and the kelp crabs (Pugettia producta) that could be seen clinging to the blades of Laminaria spp. On the third transect a few juvenile coonstripe shrimp were observed. Other invertebrates observed included barnacles (Balanus glandula), mussels and the plumose anemone (Metridium senile).

The abundance and distribution of macroalgae did not vary appreciably between the seven transects. Laminaria spp. (30 percent cover), Agarum spp. (20 percent cover), Neogardhiella spp. (10 percent cover), Sargassum spp. (10 percent cover), Macrocystis spp. (10 percent cover), Iridaea spp. (10 percent cover), and Ulva spp. (10 percent cover) made up the algas observed on this survey. The majority of the reef was covered with algal growth.

JUNE 24, 1993 BIOLOGICAL SAMPLING

Six transects were completed between 1100 and 1300 hrs PST while the tide was falling from a high of 11.8 feet at 0849 hrs to a low of 3.7 feet at 1519 hrs. The same survey method and permanent transect line was used as the August 1992 survey. The survey began at the 110 m mark with transect 1, transect 2 was swum at 90m, transect 3 at 70 m, transect 4 at 50 m, transect 5 at 30 m, and transect 6 at 10 m on the permanent transect line.

Table 8 summarizes the fish population on the reef.

The several schools of herring and tubesnouts made these the two most abundant species of fish on the reef in that order. Next in abundance were the blackeyed gobies (Coryphoptera nichoisi), striped perch (Embiotoca lateralis), pile perch (Rhacochillus vacca) and shiner perch(Brachyistius frenatus). The most abundant rockfish on the reef was the copper rockfish (Sebastes caurinus) followed by black rockfish (Sebastes melanops). The latter has not been seen previously in this area by either diver.

TABLE 8 fish observed on the Newcastle Island Reef-June 24, 1993.

Trans. #	str. p	p.p.	b.g.	c.r.	k.g.	s.p.	t.s.	l.c.	b.r.	he
1	16	1	25	2	2	5	170+ yoy	0	0	200+ yoy
2	10	1	75	2	2	4	60+ yoy	0	0	0
3	4	0	100	3	0	9	70 yoy	0	0	100+ yoy
4	2	4	75	1	0	0	300+ yoy	0	0	0
5	7	0	50	5	1	17	160+ yoy	1	2	300+ yoy
6	2	20	50	3	1	0	0	1	0	100+ yoy
Total	41	26	375	16	6	35	760+	2	2	700+
Percent	8.2	5.2	75	3.2	1.2	7.0		0.4	0.4	
Fish/ 100 m^2	7.1	4.5	65	2.8	1	6.1	132	0.3	0.3	121
Estimat. Total	205	130	1876	81	29	176	3800	3	3	3497

b.r.= black rockfish
he= herring

The rest of the abbreviations are the same as Table 7.

In addition to the fish enumerated in Table 8, there was also 1 sculpin and 1 unidentified flatfish. The tubesnouts and the herring were not included in the percent of reef fish which follows the method used by McElderry et al.

Invertebrates observed on this survey included leather stars (Dermasterias imbricata), sun stars (Pycnopodia helianthoides), short-spined stars (Pisaster brevispinus), ochre stars (Pisaster ochraceus), California sea cucumbers (Parastichopus californicus), plumose anemones (Metridium senile), tube anemones (Pachycerianthis fimbriatus), moonsnails (Polinices lewisii), red rock crabs (Cancer productus), kelp crabs (Pugettia producta), coonstripe shrimp (Pandalus danae) as well as a group of small nudibranchs clinging to stalks of Sargassum spp..

The most abundant invertebrate on the reef was the plumose anemone, followed by the short-spined star and the sun star which were present in equal numbers. The sand immediately surrounding the reef supports horse clams and moonsnails as well as the tube anemone (Pachycerianthis fimbriatus).

The algal community on the reef was similar to previous surveys with the exception that Sargassum muticum was abundant (this species appears to be present in greater numbers throughout the east coast of Vancouver Island this summer; personal observation). Agarum spp., Sargassum spp., Irideae spp., an unidentified foliose red algae, Gigartina spp., and Ulva spp. were present in descending order of abundance. Agarum was the most abundant species covering 50 to 80 percent of the reef throughout the survey. Sargassum, not normally present at such densities, was the second most abundant species covering 10 to 30 percent of the reef. The rest of the algal species occurred in much lower densities ranging from ten to less than five percent cover.

4.0 DISCUSSION

At the time of the June, 1993 survey, the Newcastle Island artificial reef was three and a half years old. Marine life had become well established, creating habitat for a diverse group of fish, invertebrates, and algae. The changing community on the reef has been documented from shortly after its construction in early 1990 until the most recent June 1993 survey. The presence of juvenile fish on the reef suggests that it has become a nursery area for some species (Naito, memo to file 1991). The large number of invertebrates and the dense cover by algae are also indicative of a productive marine community. The barren waste concrete that was placed on the site has been transformed into a productive habitat in a relatively short time.

The first two surveys conducted in July and September, 1990, were observational in nature and did not determine percent cover by algas, invertebrates or fish, as insufficient data was collected. These dives were intended as preliminary biological surveys and information collected was intended to summarize the establishment of marine life on the reef.

The percentage differences between perch and rockfish numbers observed on the reef was determined for the August 1992 data and estimated as 65.6 % for Embiotocids (Perch), 8.2 % for Scorpaenids (rockfish, Walton 1979), and 26.2 % blackeyed gobies. The June, 1993, population estimates showed differences from past surveys with Embiotocids accounting for 20 %, Scorpaneids 5.7 % and blackeyed gobies for 75 % of the reef fish population. These estimates of comparative abundance percentage of rockfish are significantly lower than the numerical estimates made on Puget Sound artificial reefs which estimated 65 % for perch and 33 % for rockfish. The latter data were closely matched for a reef in the Nanaimo harbour (close to the Newcastle Island reef) in a study by McElderry (1987). Estimates of the Nanaimo harbour reef showed 66 % perch and 27 % rockfish. The low percentage of rockfish on the Newcastle Island reef may be explained by the findings of Walton (1979) who from observations of eight artificial reefs in Puget Sound states that "the majority of species attracted to an artificial habitat are present within the first growing season and that there is an adjustment period, perhaps of several years, when changes associated with the aging of the reef takes place". The observations by Turner et al., which estimated an adjustment period of approximately 5 years on a near shore reef in southern California, suggests that the reef is still in a state of transition and that a stable climax community has not yet been reached. The percentage of rockfish observed on the reef in the November 1990 survey was 2.7 % while the percentage of perch was 97.3 %. When compared with the 8.2 % and 65.6 % numbers calculated for rockfish and perch respectively on the 1992 survey, the suggestion that the reef is still developing seems to be borne out. The 5.7 % rockfish and 20 % perch on the reef calculated for the June 1993 survey reinforces the evidence that the reef is changing and that a stable population has not yet been achieved.

In a study conducted over a two year period at ten different Strait of Georgia reefs YOY copper rockfish were found to represent 61 and 43 percent of the total fish community for 1984 and 1985 respectively (Richards pers. com.). For the August 1992 survey only 1.5 percent of the fish observed were YOY copper rockfish and for the June 1993 survey this number had dropped to 0.2 percent. This group is often the dominant year class on natural reefs in the area (McElderry 1987), and it may be that the microinvertebrate prey of juvenile rockfish have not yet become well established on the artificial surface of the reef. Another explanation could be that the reef lacks a kelp canopy which may assist in the settlement of young fish from plankton to the reef surface (McElderry, 1987). Since construction, the reef has become well established but may yet be undergoing change and quite likely has not completed the adjustment period suggested by Turner et al.

The substantial increase in the population of blackeye gobies from the August 1992 survey to the June 1993 survey should be noted and may have had an effect on the other fish in the reef community, explaining the decreased numbers of both perch and rockfish. (personal observation).

The colonization of the reef by invertebrates began quickly as crabs, shrimp, seastars, and sea cucumbers were observed on the reef at the time of the first survey on July 12 1990. Since that time, abundance and species diversity of these groups has increased rapidly. The survey of November 1990 showed six different species inhabiting the reef. By the time of the August 1992 survey, this number had increased to 10 and abundance had increased to the point that each transect had an average of three red rock crabs. At the time of June 1993 survey, thirteen different macroinvertebrate species had become established on the reef. Overall, the reef has shown a steady increase in both abundance and diversity of invertebrate species since construction.

Changes in the algal community reflect the increased age of the reef. At the time of the first survey, the algal community consisted of a few species of juvenile plants. Since that time species diversity has increased and the plant community has changed with age. The abundance of algas on the reef did not change drastically from the November 1990 survey to the August 1992 survey, however, the percent coverage by each species has altered significantly. A few species dominate most of the reef surface, while several other species occupy smaller areas. However, there has been a transition over time so that Neogardhiella spp. has become less abundant and Laminaria spp. and Agarum spp. have become the two most dominant species. The June, 1993 survey showed a surprise abundance of Sargassum, but also revealed that Agarum has become more dominant and appears that it will remain so with only minor fluctuations in the accompanying algas. Slight changes in the abundance of algas are likely to continue to occur until the reef is no longer in a transition stage.

Both the qualitative and quantitative surveys carried out over the three and a half year period since the construction of the Newcastle Island artificial reef show that the reef has become a productive and diverse subtidal community of fish, invertebrates and algas. What was once an area of relatively low productivity now supports a rapidly growing and changing reef habitat.

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