RESUMES

Resumés of papers read at the Ecological Society Conference, 1975, are presented (except those presented in full elsewhere in this volume). For the complete programme of papers presented at this conference please refer to the Annual Report appearing on p. 131.

A BROAD CLASSIFICATION OF NEW ZEALAND COASTAL INLETS WITH PARTICULAR EMPHASIS ON THEIR RESIDENCE TIMES

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To date there have been only a few detailed studies of the circulation in New Zealand coastal inlets and most of these have been closely linked with other programmes. There has recently however been a growing need for knowledge of the physical oceanographic aspects of several inlets with the immediate aim of answering questions such as "what is the rate of dispersion of material discharged at a particular site?" Each of these questions has to be answered individually for each inlet or even for each site within an inlet. Rates of dispersion however depend not only on the specific local circumstances but also on the overall residence time of water in the inlet which in turn is governed by the broad scale circulation. The problem of initial dispersion from say an effluent outfall is usually dealt with by the party who are constructing the discharge. However the other pertinent question that of the overall residence time is often not considered. This overall residence time is the particular aspect of interest in the classification.

The inlets considered have been classified into groups in terms of factors such as their tidal compartments, which is the volume of water which enters the inlet on say an incoming tide, the freshwater inflow, bathymetry, etc., or more specifically ratios of these factors.

For each of the inlets the surface area at high tide, area of mudflat at low tide, cross-sectional area and width at the entrance, volume of water at low tide, tidal compartment, perimeter, and catchment area have been compiled. Also estimates of the freshwater inflow to the inlets have been made. The amount of river discharge data that is available for these inlets as a whole is very limited and therefore an indirect method for calculating the freshwater discharge has been used. This consisted of taking the product of the catchment area with the surplus rainfall as presented in broad contours.

It has been shown that in many inlets around New Zealand the entrance cross-sectional area is linearly related to the tidal compartment. If one fits the two parameters, the entrance cross-sectional area and the tidal compartment by least squares one obtains a correlation coefficient of 0.95, whereas the correlation coefficient r for 2 x 16 random numbers where 90% of the estimates are less than r is only 0.29. The overall cross-sectional area at the entrance to these inlets is controlled by the ability of the tidal flow to transport sediment, there being no net erosion or deposition of sediment at the entrances. Further the tidal flow must dominate any other flow in these inlets and they can therefore be classified into one group.

The other inlets can be separated into large groups by considering the probable residence times of the waters in them. The residence time of water in an inlet is the time that the water spends in the inlet from its initial entrance to its final exit.

In many of the inlets considered flushing is dominated by the tides—Moutere, Waimea, Aotea, Whanganui, Avon-Heathcote, Tauranga, Parengarenga, Porirua, Pauatahanui, Kawhia, Nelson, Rangaunu, Raglan, Whangarei, Bluff, Otago, Hokianga, Manukau. The other 14 range from long narrow sounds with probable strong vertical circulation (e.g. Pelorus Sound) to large bays with strong mean horizontal circulations (e.g. Tasman and Hawke Bays). These were divided into groups according to the strength of the tidal exchange.

The 32 inlets then conveniently subdivide into 5 groups. Further subdivision within these groups is then possible by considering the width of the entrance and the length.

To give some idea of the complexity of the flow to be experienced in inlets, the results of measurements made in Pelorus Sound can be given as an example.

Salinity and current measurements over tidal cycles were made in Pelorus Sound in 1973 and 1974. Salinities with depth at four stations in 1974 indicate large amplitude oscillations of the isohalines at tidal periods. Further the speeds observed were about twice as large as those needed to satisfy the continuity requirement of increasing the surface tidal elevations if the flow was uniform from top to bottom. At this time in August 1974 the salinity and density field consisted approximately of a low salinity and density upper layer on a more saline dense lower layer. The flow in the lower layer was not in phase with that in the top layer. All these results suggest the presence of an internal tide, that is a tidal wave existing on the interface between layers. The results of a simple two layered tidal model fit reasonably well to the measurements near the confluence of Kenepuru and Pelorus Sound with the regular barotropic tide reflecting at the sharp change in depth near the confluence of the sounds.

It would appear also that the salinity field and therefore the density and flow field in Pelorus Sound is highly time dependent with the internal tide being probably only a transient feature. Measurements made in June 1975 by Dr L. Carter during a period of high rainfall show a surface layer of low salinity water only about 2 m thick moved quickly down the sound. It would appear then that only during these periods of high runoff is a strong classical estuarine circulation developed. Subsequent mixing then establishes the more regular density field which may have an internal tide associated with it. Further the development of an internal tide then enhances the mixing with one probable interesting mechanism being the breaking of interfacial waves on the density interface when the speed associated with the internal tide becomes larger than the propagation speed of the interfacial waves. Clearly however the process is very complicated.

PAUATAHANUI INLET—PRELIMINARY RESULTS OF A BENTHOS SURVEY

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The Pauatahanui Inlet is one arm of the Porirua Harbour 24 kilometres north of Wellington City on the North Island west coast. It is the only sheltered inlet on this coast south of Kawhia Harbour and is therefore of scientific interest. However there are medium term plans to develop a satellite city in the catchment of the Inlet. In response to these plans a major multi-disciplinary scientific study, the Pauatahanui Environmental Programme, has begun and this benthos survey is a part of that programme.

The inlet is 3.2 kilometres long by 1.6 kilometres wide in the form of a basin about 2 metres deep connected to the sea by a channel up to 9 metres deep which is crossed by bridges carrying State Highway 1 and the North Island Main Trunk railway. The land round the western end of the inlet is urban but most of the catchment is rural. Sediments in the inlet range from shell gravel and coarse sand in the entrance channel to muddy fine sand over the basin. The main freshwater inflow comes from the Pauatahanoi and Horokiwi Streams at the western end of the inlet.

Samples of the sub-tidal benthic fauna were taken at 20 stations disposed on a grid pattern. A diver operated airlift device was used to excavate two 0.25 m^2 quadrats at each station and all the material retained by a 1.0 mm sieve was preserved for study. Only the polychaete worms and bivalve mollusce had been identified and counted when this paper was prepared.

The distributions of individual species fall into one or other of two main groups. First, those species which were found only at the two stations in the entrance channel where current velocities were higher and sediments were coarser. Examples were the polychaetes *Armandia maculata* and *Lepidonotus polychromus* and the bivalves *Gari stangeri* and *Tawera spissa*. Second, those species found more or less all over the basin. Included were the deposit feeding polychaetes *Phylo* sp. and *Sthenolepis laevis* and the bivalves *Nucula hartvigiana, Mactra (Cyclomactra) ovata* and *Macomona liliana.*

Individuals of the deposit feeding *N. hartvigiana* are small but the population density ranged up to 600/m^2. The deeply buried suspension feeder *M. ovata* has a shell length up to 10 cm and a population density of 20/m^2. The surface deposit feeder *M. Liliana* had a population density of 10/m^2. It is also present inter-tidally around the inlet.

Species with apparently special requirements included the cockle *Chione stutchburyi* which is common intertidally but also occurred at the shallower more sandy subtidal stations; and the polychaete *Nicon aestuariensis* which appears to prefer finer sediments and areas subject to lowered salinities.

The limit data allows only tentative conclusions to be drawn. The fauna does not resemble that of deeper sheltered water areas such as Wellington Harbour and the Marlborough Sounds, but there are many similarities to descriptions of Auckland sheltered intertidal areas. The fauna is not dominated by the estuarine organisms and the Pauatahanui Inlet appears to be marine rather than estuarine.

WADERS OF THE MANUKAU HARBOUR AND FIRTH OF THAMES

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Complete censuses of waders (sub-order *Charadrii*) on the Manukau Harbour and Firth of Thames have been made twice yearly since 1960 by members of the Ornithological Society of New Zealand. Before and during the census period severe modifications to the habitat and land surrounding these harbours have occurred. There are little specific data on the influence of these; but many of the changes are presumed to have had an effect on the wader habitat.

Numbers fluctuate greatly from year to year, but show a general increase. No specific reasons can be given for this as breeding success, the availability of food or the birds' other requirements are not known. In one instance the Wrybill population of the Manukau Harbour declined sharply after the construction of sewage ponds on their favourite feeding area.

There are marked differences in average numbers of waders present on each habitat in relation to the area of exposed inter-tidal flats. There is some indication that the Manukau Harbour may be approaching maximum carrying capacity.

A total of 37 species has been recorded on these harbours although only 5 make up 95 per cent of the population. The data are to be published, in full, in the Ornithological Society's Journal 'Notornis'.

CURRENT STUDIES ON THE AVON-HEATHCOTE ESTUARY

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The proliferation of macrophytic algae, particularly *Ulva* and *Enteromorpha* over the tidal flats of the Avon-Heathcote estuary during the last 25-30 years has commanded considerable scientific interest. Much of this has been in response to public pressure. A good deal of attention has also been given to variations in algal abundance and possible relationships with appropriate environmental parameters, particularly the eutrophying characteristics of the effluent from the Christchurch Drainage Board's sewage treatment works situated at Bromley.

Until recently however, the reasons surrounding the emergence of these algal species from obscurity between 1930 and the mid-late 1940's have not been seriously researched. Suggestions to date have invariably intimated a direct relationship with the only immediate reconcilable variable—the corresponding increase in the volume of treated sewage discharged from the Bromley sewage treatment plant.

Investigations currently being carried out by the author have revealed changes of far more dramatic proportions. The inference can be drawn from a consideration of surveyed estuarine surface-sediment levels in 1920, 49, 62 and 75-76 together with noted changes in the distribution and abundance of the marine monocotyledon *Zostera Novaezelandica* that unrecorded, but nevertheless demonstrable, natural forces have extensively modified the basic sediment distribution, contour patterns and consequently the nature and distribution of the biotic component of the Avon-Heathcote estuarine tidal flats. Extensive swards of *Zostera* are now known to have dominated a very large proportion of the estuarine tidal flat prior to and during the early years of this century. Without doubt erosional forces operating over an undetermined period between 1920 and the early 1940's removed a considerable quantity of tidal flat sediment from the ecosystem, resulting in the establishment of a more conducive habitat for algal colonization and subsequently, proliferation.

With *Zostera* currently staging a pronounced comeback in many areas it would appear that a large central section of the estuarine tidal flat is showing signs of a slow reversion to its earlier form.

TRANSPORT AND DEPOSITION OF SUSPENDED SEDIMENT IN PELORUS SOUND, SOUTH ISLAND, NEW ZEALAND

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When viewed on a regional scale, estuaries appear to exert some influence on sedimentation patterns on the adjacent continental shelf. Where estuaries are common, as off Fiordland and North Auckland, the shelf has few modern terrigenous sediments because most rivers, the main suppliers of modern detritus, lead into estuaries which act as sediment traps. At the other end of the spectrum are the Hawkes Bay, Wairarapa, Nelson and Westland coasts which have few estuaries; rivers transport their loads directly onto the shelf which, as a consequence, is blanketed by modern sediment.

This correlation between estuaries and shelf sedimentation is based on generalised regional observations which are unsupported by detailed data particularly that pertaining to sediment transport and deposition within estuaries. To further understand the role played by estuaries, the movement of suspended sediment or seston was studied in Pelorus Sound—a 50 km long, narrow, branching estuary that opens out into Cook Strait.

Field work involved occupation of 9 stations (4 in spring 1974; 5 in winter 1975) sited along the length of Pelorus Sound. Water temperature, salinity and seston concentrations were measured at each station over a period of not less than one tidal cycle. Measurements were made every 2 or 4 hours on samples taken at 5 m or 10 m intervals down the water column. Additional samples, collected in the summer by other workers, were also studied. Consequently it was possible to detect both lateral and vertical variability of the various parameters over a tidal cycle and under varying freshwater inflow as governed by the seasons.

The results reveal that transport of seston in Pelorus Sound is controlled by tides and freshwater inflow. During high freshwater inflow, as measured in the spring, a moderately stratified estuarine circulation is superimposed on the tidal circulation, but the latter is dominant and transports seston seawards and landwards with the ebb and flood phases respectively. With extreme freshwater inflow (measurements made during a winter storm) the estuarine circulation gains impetus and most seston is rapidly transported seaward in the low salinity surface layer.

Irrespective of circulation, a persistent trend in seston concentrations was observed. Highest quantities occur at the sound's head due to (i) the influence of nearby Pelorus and Kaituna Rivers, the main sources of sediment, and (ii) resuspension of bottom sediment by the strong ebb tidal currents in this area. Further towards Cook Strait, seston concentrations wane till near the sound entrance, where quantities increase due to production of biogenic seston (diatoms) and additional seston brought in from Cook Strait with the flood tide. The afore-described trend parallels that of sediment deposition as inferred from variability in the thicknesses of muddy sediments determined with a 3.5 kHz sesmic profiler. Muds are thick at the head where an extensive delta extends from the river mouths; muds gradually thin seaward until near the sound's entrance, where they thicken markedly.

Seston weight and composition profiles and the seismic profiles indicate Pelorus Sound acts as a double-ended sediment trap. The upper reaches receive and retain river-derived seston, whereas the entrance entraps seston derived from Cook Strait.

This paper is being published in full. The reference is: Carter, L. (in press). Suspended sediment transport and deposition in Pelorus Sound, South Island, New Zealand. *N.Z. Jl. mar. Freshwat. Res.*

THE ECOLOGY OF BROWN SKUA IN THE CHATHAM ISLANDS WITH DISCUSSION OF THE EFFECT OF ENVIRONMENT ON BEHAVIOUR

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A population of brown skua (*Catharacta lonnbergi*) was studied over the summer of 1974-75 on Rangatira Island (176° 11 'W, 44° 22 'S) for comparison with McCormicks skua *Catharacta maccormicki.* It was soon obvious that the breeding conditions were so very different that it was not possible to make a direct comparison of their behaviour and feeding and breeding ecologies without taking this into account. An assessment was made therefore of the contributing effects of the environment, especially the effect of climate directly and indirectly on vegetation to the differences noted between the two species so that true species-specific differences might be isolated.

Territorial Behaviour

The territories of skuas in Antarctica are usually closely packed together in sheltered, snow-free basins for protection from wind. On Rangatira the skua territories were strung out along the coast and over the few barren flats and were obviously sited without relation to local weather. They were much bigger than Antarctic territories and less strongly defended, both factors probably related to the low local numbers. Most defence of territories there was by flight and few encounters on the ground were seen. This is in strong contrast to Antarctica where boundaries are marked out by competing pairs displaying and fighting on the ground or by occupying it in spite of attack by other pairs. There is no doubt however, that this major difference in behaviour is because the vegetation on most Rangatira territories prevents ground display. A special feature of brown skua breeding, especially in the New Zealand region, is the occurrence of three adult birds in a high proportion of territories. This is unknown in McCormicks skua and appears to be a species-specific difference.

Feeding Behaviour

Skuas in Antarctica feed at sea on fish or scavenge and prey at penguin colonies. There is a much wider array of food for skuas on Rangatira and their preference there for the adults of small petrel species, especially for broad-billed prions *(Pachyptila vittata)* and white-faced storm petrels *(Pelagodroma marina)* is in keeping with their known habits of exploiting the most readily available food source. It is not therefore to be considered as a specific difference between the two species. It was unusual however, to find them to be nocturnal predators, on Rangatira deserting the territory at night to feed elsewhere.

Breeding

The very early breeding season with laying commencing in late September contrasts with that of Antarctica where it does not begin until mid November. However, a trend line can be produced plotting the breeding season of different skua populations against latitude, which shows that the early breeding on Rangatira is not at all exceptional and is about when expected by comparison with others. McCormicks skua chicks are well known for their sibling rivalry, in which the older chick attacks the younger and forces it from the nest area. Such intense rivalry did not occur in pairs on Rangatira and the two chicks were raised together. This difference may be species-specific, but it has been noted that rivalry is less intense in populations of McCormicks skua at the northern edge of the species range and some environmental influence is certainly also present. The attainment of a very high breeding success of 1.5 chicks raised on average per territory at Rangatira could also be attributed to the environmental effects, to the spacing of territories through vegetation with consequent low risk of predation, and to the more favourable climate.

In summary, most differences found in the behaviour and ecology of the two species can be attributed to their opportunism and to environmental factors, especially to the effects of climate differences. The occurrence of three adults in a territory and the absence of sibling rivalry remain as the only major differences between them once this effect is accounted for.

POPULATION STRUCTURE OF A BREEDING COLONY OF NEW ZEALAND FUR SEALS *(Arctocephalus forsteri)*

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Breeding colonies of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828), change dramtically in numbers and population structure each year, immediately before, during and after the summer breeding season (October-January inclusive). These changes are brought about by various arrivals, departures, births and deaths. In this paper, the main events occurring in the fur seal rookery on Taumaka, Open Bay Islands, South Westland, during the 1974-75 breeding season, are described to illustrate the pattern common to all breeding colonies.

Bulls (adult males) started arriving at the rookery in mid-October 1974, but the early arrivals were predominantly young, inexperienced bulls who proved to be unable to maintain a territory. Bulls continued to arrive throughout late October and early November, and by mid-November territories were well-defined and were occupied largely by experienced bulls. The number of bulls on Study Area 1 on Taumaka fluctuated between 8 and 11, with an average of 10, up to 1 January 1975. Thereafter, there was a rapid decrease in the number of bulls present until none was present on 26 January. After the departure of the large territorial bulls, some young bulls who had arrived early in the season moved into the breeding rocks and held "territories" for a few days.

Cows (adult females) arrived in large numbers after most bulls were established in territories. Between 10 and 15 were present on Study Area 1 from 17-26 November 1974, but this number increased steadily during late November and early December to reach a peak of 45-50 from 7-31 December. During the first week of January 1975, the number of females present declined as they went to sea to feed for successively longer periods. By mid-January the average number of females present was back to 10-15.

Few pups were born during November 1974; only three were seen on Study Area 1 in that month. Births were frequent during December, however, and by the first week of January the average number of pups visible had risen to 48. This average declined to 16 by late January, due partly to mortality, but also to the propensity of pups to wander away into the bush or into the sea as they gained confidence with age.

Females showed definite site preferences on the rookery. Two territories of similar size within Study Area 1 were compared in 1974-75. Territory A was bordered by a rock ledge, had ample shade and easy access to the sea; Territory B was entirely in the open, had little shade and difficult access to the sea. There were no females on Territory B from 17-26 November and 26-30 January. In the intervening period, there were two to six times more females on Territory A than on Territory B. It seems that females will tolerate considerable crowding during the breeding season in order to remain in particular types of locality.

THE NATURAL HISTORY OF THE NEW ZEALAND FUR SEAL, *Arctocephalus forsteri* (Lesson 1828)

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INTRODUCTION

The New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1928), lives and breeds on the rocky shores of southern New Zealand and its subantarctic islands. Although brought close to extinction by commercial sealers during the nineteenth century, the species has recovered well under protection and is increasing steadily in numbers and expanding its range (Csordas and Ingham, 1965; Falla, 1965; Stonehouse, 1965; Stirling, 1968). The fur seal was first given legal protection in 1875, and from then until 1916 seasons were of limited length and permits were required for seal killing. Since 1916 no fur seals have been legally killed (except for research purposes) apart from on Campbell Island in 1924 and 1926, and in parts of southern New Zealand in 1946 (Sorensen, 1969).

By comparison with most other species of otariid seal the biology of *A. forsteri* is poorly known, but there have been rapid advances in knowledge in recent years. In particular, since 1969 there have been intensive studies of distribution, abundance, population structure, breeding biology and behaviour, some results of which have already been published Crawley, 1972 and *in press;* Crawley and Brown, 1971; Crawley and Wilson *in press;* McNab and Crawley, 1975; Miller, 1971, 1974; Stirling, 1970; Wilson, 1974).

In this summary, the aim is to present a brief up-to-date account of the natural history of the New Zealand fur seal, with the emphasis on presenting the most recent information on the topics covered, rather than on reviewing the literature. The account relies a great deal on work by University of Canterbury personnel on distribution, breeding biology and social behaviour. The observational work has been carried out mainly on the Open Bay Islands, Westland, the Snares Island and on Stewart Island.

DISTRIBUTION AND ABUNDANCE

An estimated 35 000 fur seals live on New Zealand shores between latitudes 34°S (Three Kings Island) and 54° 30'S (Macquarie Island). The bulk of the population is on the Fiordland coast, around Stewart Island and on the subantarctic islands, but in winter large (> 500) aggregations of males form at several localities in the north of the South Island (e.g. Kaikoura) and in the vicinity of Wellington (Turakirae Head). Breeding colonies (rookeries) occur south of 44°S, and are normally on protected boulder beaches; non-breeders haul out on terrain varying from terraced rocky ledges to sandy beaches (rare).

ANNUAL CYCLE

Breeding grounds are occupied throughout the year, but the proportions of the various sex and age classes present vary seasonally. Adult males (bulls) arrive ashore in October, establish territories and remain on station until February. Adult females (cows) arrive in November, give birth to their single pup after about five days, mate with the nearest bull about a week later, and thereafter divide their time between suckling and feeding at sea. Bulls depart in February, after remaining ashore continuously for up to three months, but subadults, cows and pups remain. Pups are weaned by August and many leave on feeding trips then. Many subadult males move north to hauling grounds for the winter.

BEHAVIOUR

Agonistic behaviour is ritualised in the fur seal, which has a limited repertoire of postures and calls (Crawley and Wilson, *in press;* Stirling, 1970). Many of the postures and calls are used by territorial bulls during threat displays and serve to indicate territorial status, affirm territorial boundaries, communicate readiness to fight and, in some cases, allow individual recognition. During the breeding season the social scene is dominated by the behaviour of the territorial bulls, which are of equal status. In the non-breeding period, however, a dominance hierarchy based on size appears to operate, irrespective of sex.

Males use threat displays and physical aggression in acquisition and maintenance of territories. Neighbouring territorial bulls seldom fight, but intruders and residents have vigorous battles. Bulls are ineffective in ordering the movements of cows, so true harems are not formed, but as cows remain faithful to their pupping sites they are more likely to mate with the territory owner than with any other bull.

DISPERSION ON THE ROOKERY

Habitat preference and competition for space determine the dispersion of cows. They prefer rock-filled gullies as pupping places and will tolerate considerable crowding rather than move into featureless areas. They fight for favoured resting spots, but normally push and utter threats rather than bite.

Subadults occupy terrain on the fringes of the rookery, often reefs and islets offshore, and generally keep out of the way of both bulls and cows. Pups remain with their mothers for the first ten days and then join other pups to form rather unstable groups (pods) when the cows depart on feeding trips. They are re-united with their mothers every few days until they are finally weaned in August or September.

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BREEDING BIOLOGY OF BENNETT'S OR THE RED NECKED WALLABY IN SOUTH CANTERBURY

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In 1973 I began a study of the breeding biology of Bennett's Wallaby *(Macropus rufogriseus fruticus)* and during the period April to March 1974, 198 bucks, 147 does and 63 pouch young were autopsied. They were shot on routine wallaby control operations in the Hunters Hills. Adults were aged from annual layers in the periosteal zone of the mandible. Age determination was checked against the molar index method and pouch young were aged from foot and tail lengths (Kirkpatrick, 1965). The testes and entire female reproductive tracts were preserved for laboratory and histological examination.

By 19-20 months of age 50% of the males were undergoing spermatogenesis. All were mature by 21-22 months. Rapid testes growth occurred between 17 and 22 months of age. Males would have their first opportunity to breed when 24 months old. From the evidence of corpora lutea, females became mature between 14-17 months of age. Judging from the incidence of lactation, two thirds of the females produced pouch young in their second year, but mortality may have been high. These females had a specific birth rate of 0.581 births per female and females over two years of age averaged 0.947 b/f. Twins may have occurred in 2.8% of the females.

Most births occurred in February and March, but first time breeders gave birth about a month later. Male prostate glands reached peak development in February and March. Joeys emerged from the pouch in November. The sex ratio of pouch young was M:F = 1:0.742 (n = 54) (not significantly different from unity).

Females had a post partum oestrus and fertilization but the blastocysts remained dormant even after the young vacated the pouch. Eighty per cent of adult females carried diapausing blastocysts throughout the year. Non-parous females also exhibited embryonic diapause. It is likely that the next season's pouch young normally develop from blastocysts maintained through lactational and seasonal quiescence.

More males than females were sampled when joeys were large or at foot. This was attributed to the sedentary nature of does at this time. During the snow of August 1973 more females were sampled than expected. This was thought to be due to the need of females to forage more widely to maintain their body condition.

The breeding biology of this wallaby closely resembles that of the tammar *(Macropus eugenii)* which has also been introduced into New Zealand.

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