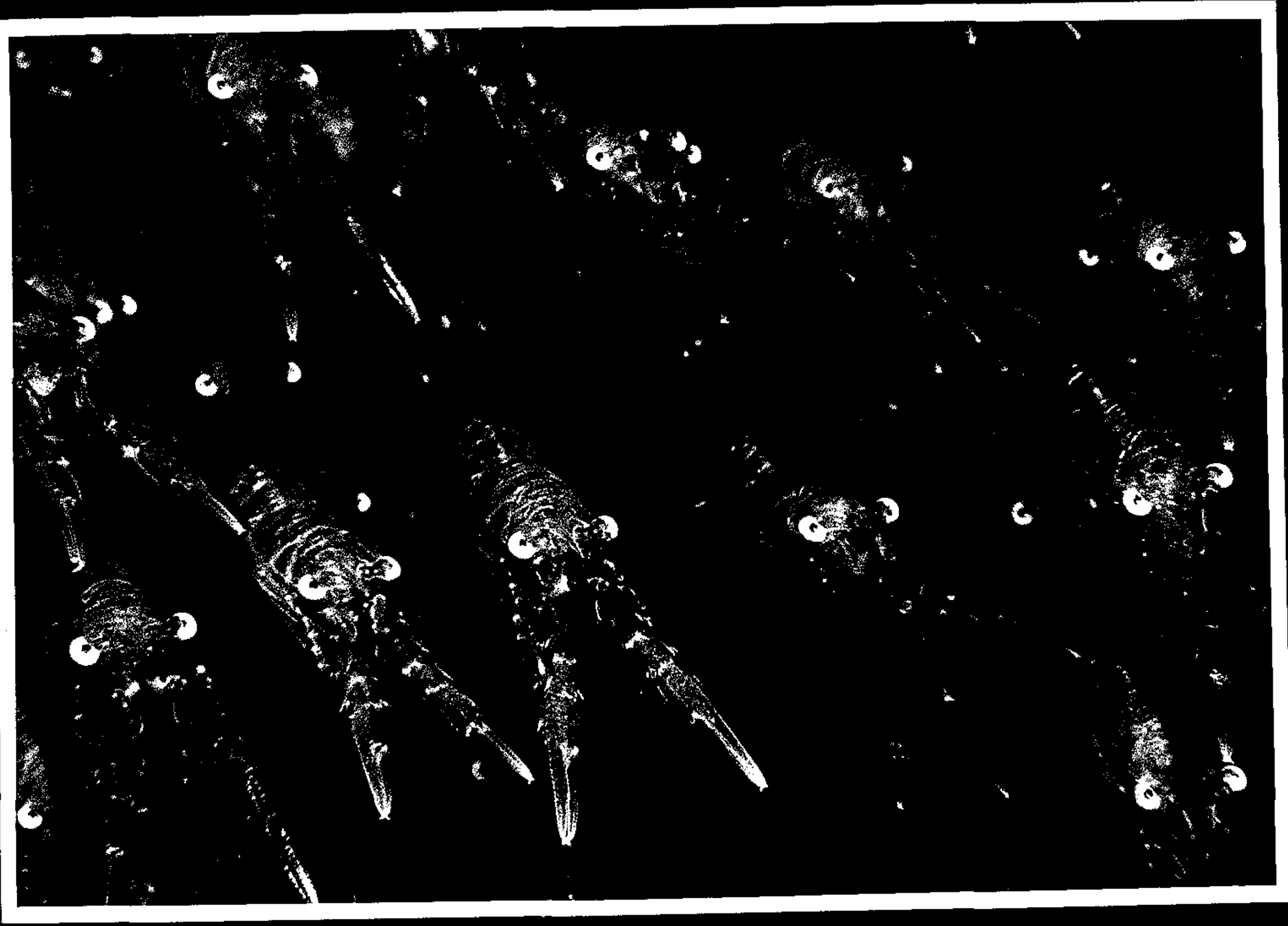
A fishery for *Munida gregaria* in New Zealand: ecological considerations

J. R. Zeldis



New Zealand Fisheries
Technical Report No. 14
ISSN 0113-2180
1989

MAF Fish

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Published by MAFFish
Wellington
1989

ISBN 0-477-08085-5

MAF Fish

MAFFish is the fisheries business group of the New Zealand Ministry of Agriculture and Fisheries. It was established on 1 April 1987 and combines the functions of the old Fisheries Research Division and Fisheries Management Division and the fisheries functions of the old Economics Division.

The *New Zealand Fisheries Technical Report* series in part continues the *Fisheries Research Division Occasional Publication* series. Conference proceedings and bibliographies will now be published in the *New Zealand Fisheries Occasional Publication* series.

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Edited by S. J. Baird

Set in 10 on 11 English Times

Typeset by Comset

Printed by Thames Publications Ltd.

Cover: *Munida gregaria* in Otago Harbour.
(Photograph by Kim Westerskov)

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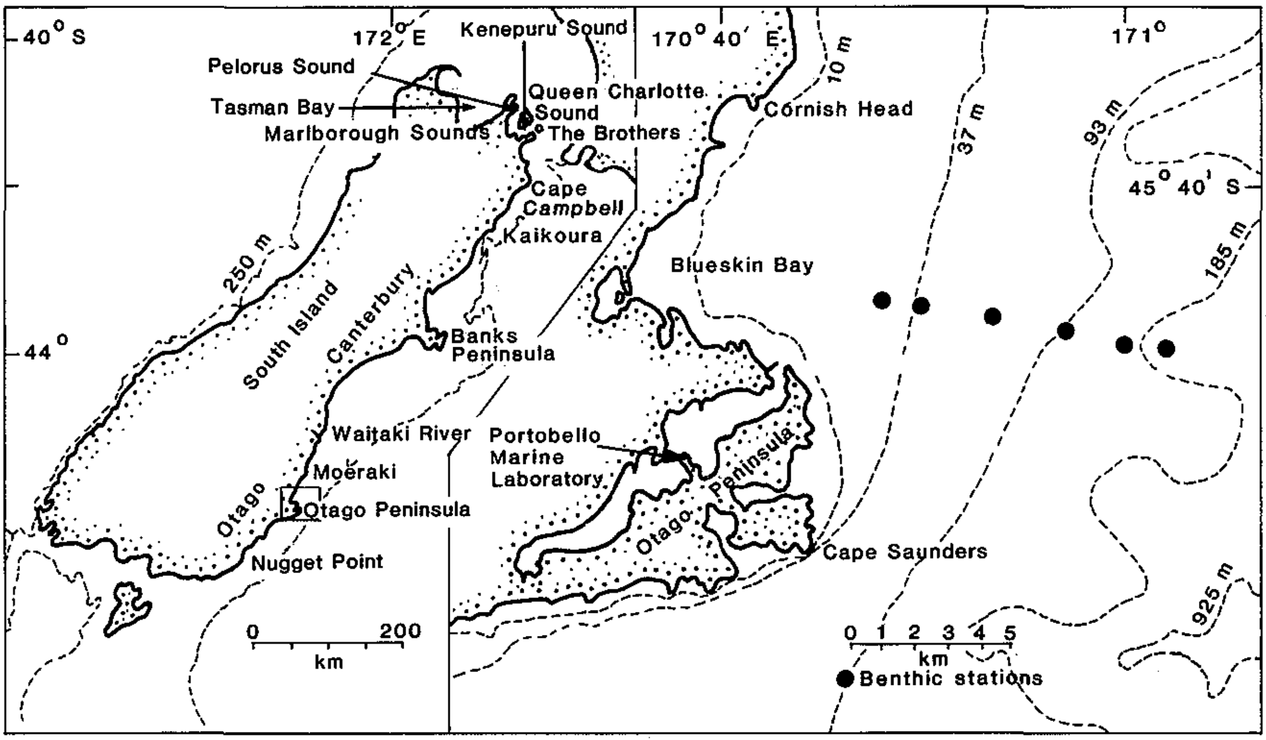

Figure 1: Place names and sampling locations used in this study.

Abstract

Zeldis, J. R. 1989: A fishery for *Munida gregaria* in New Zealand: ecological considerations. *N.Z. Fisheries Technical Report No. 14.* 11 p.

Large shoals of postlarval *Munida gregaria* are present during most summers in coastal waters of the South Island, New Zealand. A fishery for *M. gregaria* is being considered primarily as a source of diet supplement for pen-reared salmon. This paper describes the ecological attributes of *M. gregaria* populations in New Zealand which could affect such a fishery. The fishery should begin after January of each season to maximise both fishing efficiency and recruitment to the *M. gregaria* benthic adult population. Fishing should be conducted over the range of *M. gregaria* to lessen the impact of its removal on the invertebrates, fish, birds, and mammals which prey heavily on it. Because postlarval availability varies widely from year to year, the industry should develop the capacity to store *M. gregaria* products for at least a year.

Introduction

The galatheid crab *Munida gregaria* (Fabricius 1793) or "red krill" is abundant on the continental shelf of the South Island and subantarctic islands of New Zealand. Although *M. gregaria* are typically benthic as adults, they have a pelagic postmetamorphic stage (postlarva or juvenile). Large shoals of these bright red postlarvae are present nearly every summer in surface waters before they settle to the bottom (Williams 1980, Zeldis 1985). So large and brightly coloured are these shoals that they are readily photographed from aircraft at altitudes up to 2000 m (Zeldis and Jillet 1982, Jillet and Zeldis 1985). In this study, shoals are clusters less than a few square metres in area, and aggregations are groups of shoals arranged in formations many metres to a few kilometres in the longest dimension.

Munida gregaria are widely distributed around southern New Zealand (Zeldis 1985). Pelagic shoals have been reported from most of the east and north coasts of the South Island. However, the most consistent shoaling occurs in the region from Cape Saunders on the Otago Peninsula to mid Canterbury, in the bays north and east of Banks Peninsula, and from Kaikoura around Cape Campbell to the Marlborough Sounds and Tasman Bay (Figure 1).

Recently, the New Zealand salmon farming industry has shown interest in *M. gregaria* as a dietary supplement for pen-reared Pacific salmon (*Oncorhynchus tshawytscha*). New Zealand Fishing Industry Board tests have shown that *M. gregaria* contain red astaxanthin pigments useful for colouring the flesh of captive salmon (Hollings 1986). These pigments may also be used in foodstuffs such as soups, pastes, and surimi.

Previous studies have shown that large catches of *M. gregaria* can be made with little fishing effort (Hollings 1985, Zeldis 1985) because the shoals are very dense. The average density has been estimated at 2700 animals per cubic metre (Zeldis 1985). The shoals are formed when the animals come into contact with intense physical discontinuities created at tidal fronts, eddies, river plume fronts, internal wave fields, and Langmuir circulations (Zeldis and Jillett 1982, Jillett and Zeldis 1985). Except for Langmuir circulations, these physical events are associated with coastal features such as promontories, bays, and rivers and changes in bathymetry. Thus, the locations of aggregations are predictable, and, because they are also close to the sea surface and their colour is obvious, they are easy to fish.

This study is based largely on surveys off Otago and South Canterbury from 1978 to 1983. It reviews aspects of the ecology of *M. gregaria* which are relevant to a fishery for the postlarval phase. These include seasonal growth patterns, the development of pigmentation and shoaling behaviour, and the distributions of aggregations along the coastline. Between-year variation in abundance is then considered. Suggestions are made on the fishing season, areas, and quotas with respect to fishing efficiency, the recruitment of pelagic *M. gregaria* to the adult population, and the importance of *M. gregaria* in the coastal pelagic food web.

Growth, pigmentation, and shoaling

Munida gregaria postlarvae are common in the water column from late October to April or May, though young animals have been seen as early as September, and mature, yet still pelagic, animals have been seen as late as August (Zeldis 1985). Carapace lengths of pelagic postlarvae (measured from the posterior mid dorsal edge of the carapace to the tip of the rostrum) for five shoaling seasons are shown in Figure 2. Early in the season (as in October 1977 and 1978) animals are usually about 5 mm long and less than 0.20 g wet weight (estimated from Figure 3). Weights are still relatively low in mid December to early January (0.35 g), when the animals are about 11 mm long. Weight gain is rapid in January, and, by the end of the month, individuals are 0.45–0.60 g at 12–13 mm. Thus, to catch 1 t of *M. gregaria* in late January would require taking only about 40 and 68% of the animals required to achieve a 1 t catch in November and December respectively.

During their spring growth the postlarvae only gradually acquire their red pigmentation. Before late December they are usually nearly transparent or only lightly pigmented. Therefore, salmon feed derived from animals caught early in the season would contain less of the pigment the salmon farmers require.

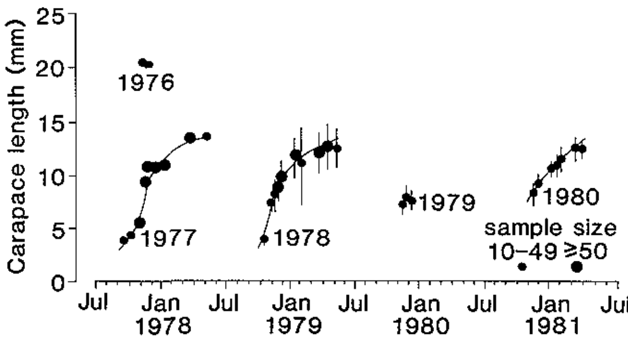

Figure 2: Carapace lengths of pelagic postlarvae for five shoaling seasons. (A few 1976 cohort animals shoaled into the winter of 1977. Only a few samples of 1979 cohort animals were available because of early settlement that year. Vertical lines show 1 standard deviation (variances were not available for 1976 and 1977 cohorts).)

Shoaling behaviour intensifies with growth during the spring and early summer. The postlarvae become concentrated in increasingly dense shoals and increasingly large aggregations of shoals as the season progresses. Therefore, most aerial surveys were conducted from January onwards, after the shoals had become highly visible from the air, and fishing on these aggregations would be more efficient later in the season.

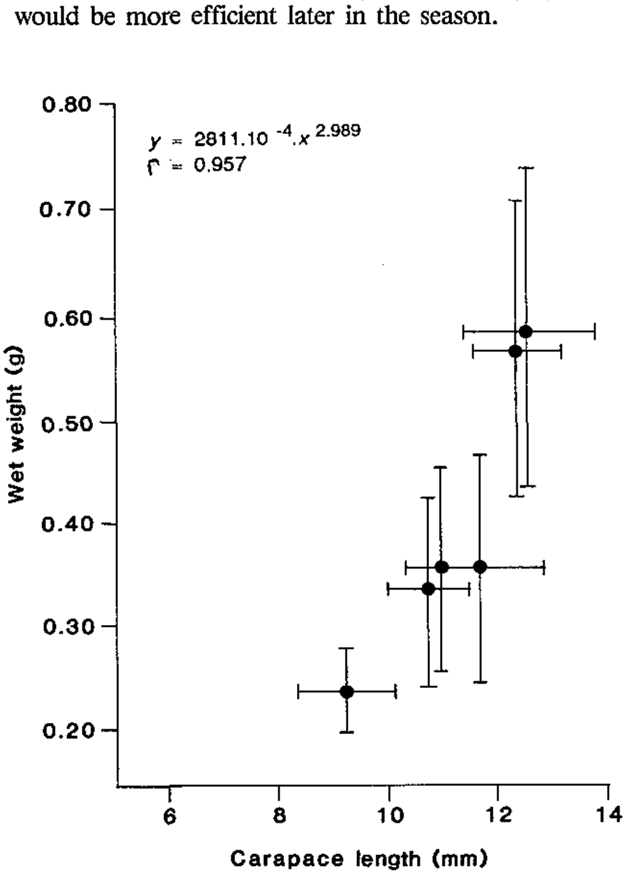

Figure 3: Length-weight relationship in pelagic postlarvae. (Vertical lines show 1 standard deviation, $n = 30$ for each point.)

Distribution

The distribution of *M. gregaria* in the southeastern coastal sea was studied from 10 aircraft flights during December to April between 1978 and 1982. The survey area was from Nugget Point to Banks Peninsula. The area of the shoals was estimated from aerial photographs. Average shoal thickness and density were estimated by surveys at sea. Seasonal length-weight relationships and biomass were calculated from these data. The range of error in these estimates was considered to be minus one-half to plus two times the estimate (Zeldis 1985).

The locations of the aggregations in the 1978–79 season are shown in Figure 4. Non-quantitative flights during late December to mid January of the 1978–79 season showed similar distributions. The surveys suggested that the distributions of postlarvae along the coast were determined by the hydrological features of the area. For example, the large aggregations near the Waitaki River mouth were probably formed at the fronts and internal wave fields created there by the large injections of fresh water into the coastal sea (Zeldis and Jillett 1982, Jillett and Zeldis 1985). Large postlarval aggregations were also common in the Blueskin Bay area between Cape Saunders and Cornish Head. The hydrology and plankton of this area have been investigated over the last decade (Jillett 1976, Robertson 1980, Zeldis 1983, Carter *et al.* 1985, Murdoch 1985, Murdoch *et al.* in press). A general conclusion of these studies is that the area is characterised by a counter current inshore of the northerly set of the Southland Current. This eddy entrains and retains zooplankton and prevents their northward movement. Repeated aerial surveys have shown that *M. gregaria* larvae accumulate there, and the postlarvae are retained for weeks during summer with no apparent replacement from the south. The tendency for *M. gregaria* shoals to be associated with embayments is also apparent in the bays around Banks Peninsula and in the Marlborough Sounds, and this association is probably common throughout the range of the shoals around the South Island.

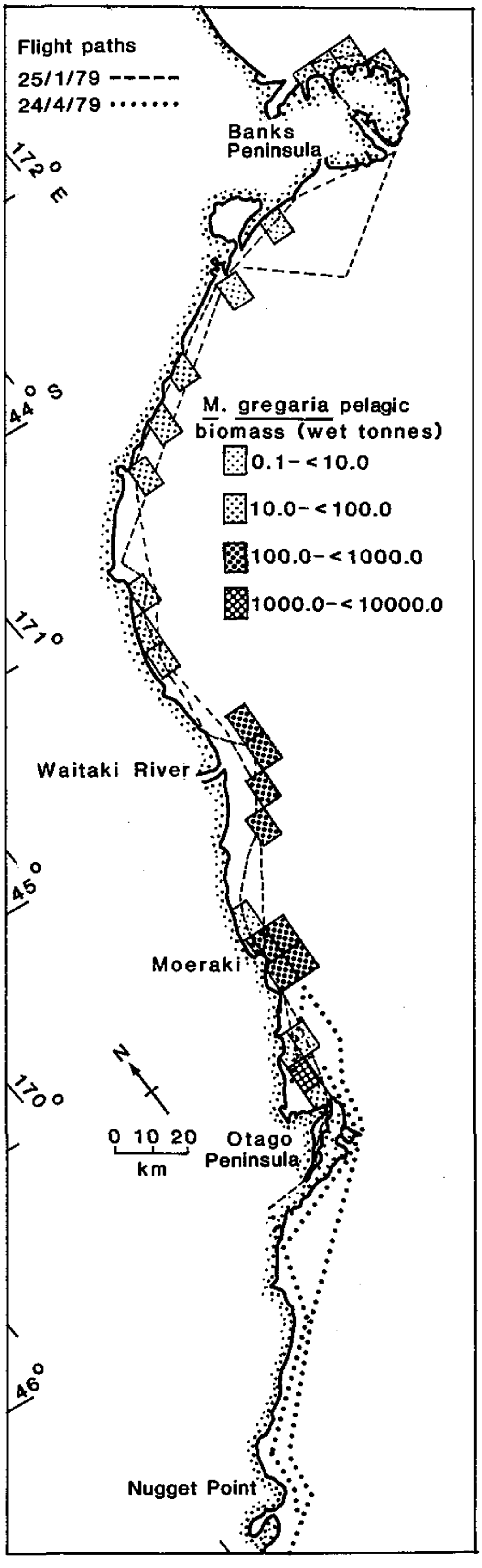

Figure 4: Biomass of pelagic postlarvae for the 1978–79 season along the southeastern coast (from combined aerial surveys).

Abundance

Zeldis (1985) showed that the population abundances of benthic and pelagic stages of *M. gregaria* vary greatly from year to year. In that study, benthic *M. gregaria* abundance was examined by dredging at six stations across the continental shelf and upper slope off Otago at about 6 week intervals from May 1978 to March 1981 (*see* Figure 1). A 5 minute haul was made at each station. Animals were measured and assigned to annual cohorts by length frequency and morphological characteristics. Pelagic *M. gregaria* abundance was studied from aerial surveys. The daily occurrence of pelagic *M. gregaria* shoaling was studied from observations of postlarval occurrence recorded at Portobello Marine Laboratory, from 1953 until 1986 (Figure 5). Lighthouse keepers and fishermen along the south, east, and north coasts of the South Island were asked to record the presence or absence of *M. gregaria* shoals daily in the summers of 1979–80 and 1980–81 (Zeldis 1983), and some of their responses are discussed here.

Data from the benthic and pelagic surveys are summarised in Table 1. The abundance of benthic animals of each cohort fluctuated greatly. From May 1978 to March 1979, adults from the 1976 and 1977 cohorts constituted a dense population on the bottom. Recruitment by the incoming 1978 year class during November 1978 to March 1979 was weak, even though postlarvae were abundant in aerial surveys from December 1978 to April 1979. From March 1979 to November 1979, the total density of benthic animals dropped dramatically, apparently due to mortality (Zeldis 1985). There was a very large recruitment of postlarvae of the subsequent 1979 cohort to this low density habitat, and no postlarvae were seen in the plankton after December 1979. This high benthic density was again reduced after the 1979–80 summer. Recruitment of the 1980 cohort was heavy, and, again, the aerial surveys showed little pelagic biomass after early January 1981 (Zeldis 1985).

Other sampling showed that these patterns in *M. gregaria* population dynamics occurred over wide sections of the South Island continental shelf. Dredge surveys over the shelf from Cape Saunders to Moeraki showed the restoration of the benthic population from low to high levels by the 1979 cohort recruitment over this entire area (Zeldis 1985). The scarcity of pelagic postlarvae in 1979–80 and 1980–81 was recorded from the entire east and north coasts by the fishermen and lighthouse keeper surveys. Furthermore, the early benthic recruitment of these two cohorts was shown by the morphology of newly settled animals dredged from the bottom (Zeldis 1985).

These results showed that the abundance of pelagic animals present after December varied greatly from year to year. The 1953–86 time series of incidence of postlarvae in the plankton showed that in some years shoaling was brief (ending in December) or did not occur. These data do not show whether pelagic animals present after December were abundant or not. However, data from the 1980–81 cohort suggest that in years of heavy benthic recruitment, shoaling after December was probably light. This inverse relationship between benthic and pelagic abundance may be caused by cannibalism and non-lethal agonistic behaviour by benthic adults towards pelagic animals which settle into the adult habitat (Zeldis 1985).

When benthic recruitment was substantial, it peaked by January (*see* Table 1). This suggests that after January the remaining pelagic animals could be removed by a

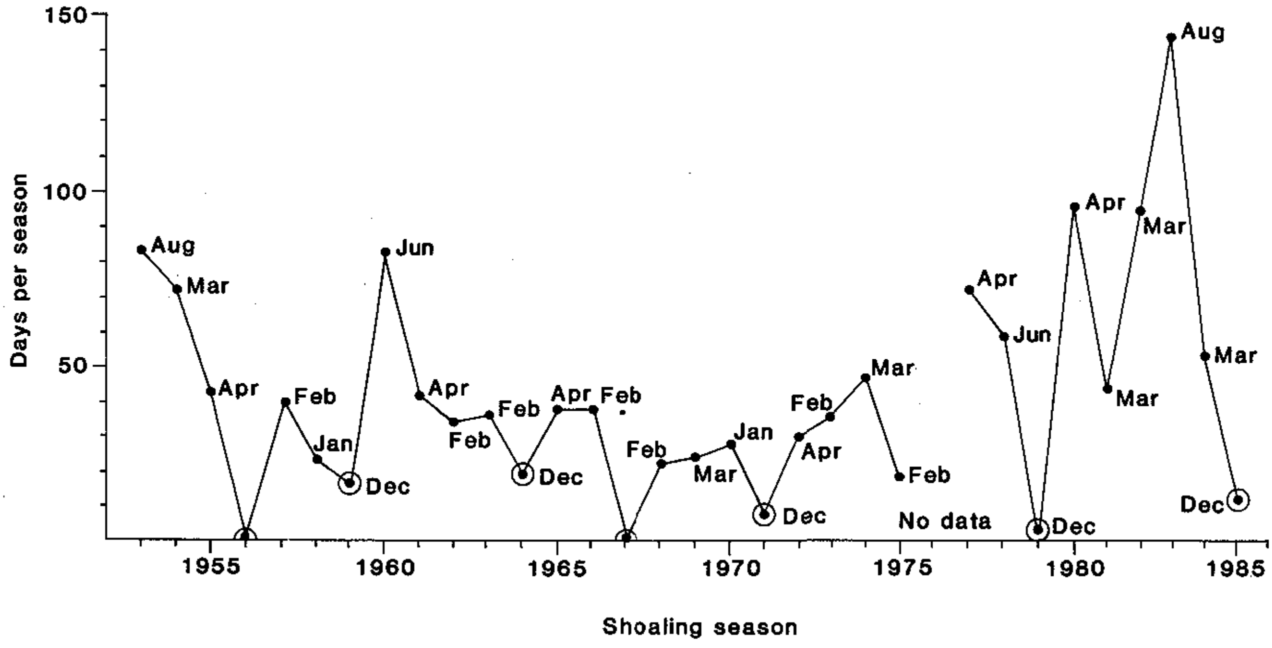

Figure 5: Number of days per shoaling year (September-August) that postlarvae were observed from Portobello Marine Laboratory wharf and vicinity, 1953–85. (The month given for each year is the last month in which postlarvae were seen. Circles show years with a short or nonexistent shoaling season.)

Table 1: Data from benthic and pelagic surveys

Date	No. of individuals per cohort*					No. of individuals†			Pelagic
	1976	1977	1978	1979	1980	0+	≥ 1+	Total	biomas (t) ‡
24 May 1978	5 262	659				659	5 262	5 921	
8 Aug 1978	4 238	377				377	4 283	4 615	
5 Oct 1978	7 132	315				315	7 132	7 447	
20 Nov 1978	2 383	37	107			107	2 420	2 527	
23 Jan 1979	986	35	131			131	1 021	1 152	4 803.2
27 Mar 1979	429	15	296			296	444	740	
23 May 1979	8	21	80			80	29	109	
21 Jul 1979	86	39	106			106	125	231	
5 Sep 1979	25	12	64			64	37	101	
8 Oct 1979	3	14	115			115	17	132	
19 Nov 1979	5	15	72	8		8	92	100	
24 Jan 1980	1	18	35	2 555		2 555	54	2 609	0.0
30 Mar 1980	0	39	236	1 261		1 261	275	1 536	
29 May 1980	0	30	49	1 142		1 142	79	1 221	
7 Jul 1980	0	9	15	406		647	48	430	
9 Dec 1980	0	0	4	170	2 488	2 488	174	2 662	
29 Jan 1981	0	0	5	349	18 429	18 429	354	18 783	381.1
31 Mar 1981	0	0	17	235	3 946	3 946	252	4 198	

* Numbers of individuals from each annual benthic cohort summed from the five shelf stations of the benthic transect.

† Numbers of 0+, ≥ 1+, and total individuals present on each sampling date. Data for 24 May 1978 and 23 May 1979 are less reliable because two stations and one station, respectively, were missed.

‡ Wet tonnage of postlarvae photographed during aerial surveys from January of each season.

fishery without a great reduction of recruitment to the benthic stock. If substantial pelagic biomass were removed before this (e.g., in December to early January), numbers of potential recruits would be reduced, possibly when adult numbers were critically low (e.g., in November 1979). Therefore, *M. gregaria* should not be taken before the end of January.

The data from Portobello Marine Laboratory from 1981–82 to 1984–85, including qualitative observations of abundance (J. Jillett pers. comm.), showed that postlarval shoaling in these seasons was heavier than during the weak seasons of 1979–80 and 1980–81. The 1983–84 and 1984–85 seasons were particularly heavy; at least the magnitude of the 1978–79 season, when 5000 t of postlarvae were seen off the southeast coast. However, the 1985–86 season was the poorest since 1979–80. In Queen Charlotte Sound of the Marlborough Sounds, data gathered from monthly survey sheets from The Brothers islands lighthouse keeper over two summers suggested that the 1979–80 and 1980–81 seasons were unusually poor in shoaling *M. gregaria* (Zeldis 1985). However, in the 1984–85 season shoals were particularly abundant in Kenepuru Sound, Pelorus Sound, and Tasman Bay (B. Hayden pers. comm.).

Abundance is highly variable in Otago and the Marlborough Sounds, though the Otago data suggest that after one or two rather weak shoaling years, three or four stronger years may be expected.

Munida gregaria as prey

Because *M. gregaria* shoals tend to form concentrateu aggregations, they are prime targets for predation by over 50 species, including many fish, birds, and mammals as well as other invertebrates (Zeldis 1983). Many of these are only incidental feeders, but others feed exclusively on *M. gregaria* when shoals are abundant. For commercial fish species, *M. gregaria* predominate in the diet of red cod (*Pseudophycis bachus*) in the Canterbury region during summer and autumn (Habib 1975) and are seasonally important for barracouta (*Thyrsites atun*) in South Canterbury (R. Hurst pers. comm.). Kahawai (*Arripis trutta*), blue warehou (*Seriolella brama*), gemfish (*Rexea solandri*), arrow squid (*Nototodarus sloanii*), and ocean-run Pacific salmon also prey heavily on the shoals over summer and autumn. At sea, *M. gregaria* shoals may be located by the abundant bird life feeding on them. It is also common to see killer whales (*Orca orca*) or fur seals (*Arctocephalus forsteri*) associated with these shoals, though they may or may not be feeding directly on the shoals themselves. Therefore, *Munida gregaria* are important as prey in the coastal pelagic food web in southern New Zealand waters, and this must be considered in the management of a fishery.

Recommendations for a fishery

No large-scale fishery for *M. gregaria* has been initiated in New Zealand. Some control would be needed to regulate the harvest if a fishery were shown to be viable. A quota of 500 wet tonnes, determined from data given by Zeldis (1985), is being considered by MAFFish as an experimental quota to establish a new fishery. Further aerial and sea-based studies are needed to assess the effects of such a fishery on postlarval *M. gregaria* abundance.

If the entire quota were taken from Blueskin Bay, about 25–50% of the available biomass could be removed from this area. The effects of this large removal on predators of *M. gregaria,* which include several local commercial fish species, are unknown. Because *M. gregaria* aggregate densely in specific areas such as bays, their abundance can appear to be immense. However, there are few of these areas and actual abundance is more limited. Furthermore, shoals tend to be resident in these areas because of the hydrographic retention effects discussed above, and, if the shoals were removed by fishing, it is unlikely that they would be replaced.

Therefore, to lessen the impact of removing *M. gregaria* from a single coastal area, the fishing effort must be spread between several areas which could include Otago, South Canterbury, and the Marlborough Sounds. The percentage of the quota taken from each area should incorporate consideration of the total biomass present, as determined from further surveys.

The fishing season should be opened at the end of January each season to target fully grown, pigmented, and maximally aggregated individuals and to avoid the depletion of postlarval numbers before their recruitment to the benthic population from November to January.

Every 3–5 yr *M. gregaria* can be expected to be unavailable to a fishery (because of complete settlement by the postlarvae to the benthos before the end of January) or in very low abundance for 1 or possibly 2 yr. Therefore, industry should develop the capacity to store *M. gregaria* products or supplemented feed for at least 1 yr.

Acknowledgments

This work was supported by a contract from MAFFish and grants from the University of Otago Research Committee. I thank all fishermen and lighthouse keepers who participated in the postal survey and J. H. Annala, D. A. Robertson, R. W. Hickman, and J. L. McKoy for their constructive criticisms of the manuscript.

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