Effects of salmon farming in the Marlborough Sounds on the prey of king shag, *Leucocarbo carunculatus*

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EXECUTIVE SUMMARY

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The aim of the work documented here was to determine the possible effect on the prey species of the endemic king shag, *Leucocarbo carunculatus*, of moving six existing salmon farms currently at low flow sites and re-establishing them at nominated high flow relocation sites. Previous publications on the feeding of this species included two documented feeding studies, of which one in particular provided a reliable investigative methodology and recorded the presence of the flatfish species *Arnoglossus scapha*, commonly known as witch, with a relative frequency of about 90% in two sampling episodes 6 months apart (November 1991, May 1992).

Based on this information it was clear that witch had only been recorded in the most recent study. Previous information came from documents published from 20 to 50 years previously which did not include witch. Witch is a species without any commercial value. As an attempt to determine whether there had been any major increase in commercial fishing pressure that could account for a switch in prey target by king shag, the catch history of flatfish for the fishing management area that includes the Marlborough Sounds was examined. It showed an increasing catch through the period of interest, although it is not clear what amount of this increased pressure is relevant to the outer Sounds.

An alternative explanation for this apparent switch in preferred prey species by king shag could be misidentification of witch during feeding studies. It is unlikely that this could account for a 90% relative frequency in the most recent study. Considering that a combination of some misidentification in the early records and a possible increase in fishing pressure on the commercially viable flatfish species could account for the apparent switch to a predominance of witch, it was concluded that the recent study did not represent an anomalous event and that the prey of king shag is mainly witch with other bottom dwelling species (particularly opalfish, *Hemerocoetes monopterygius*, common sole, *Peltorhamphus novaezeelandiae*, and lemon sole, *Pelotretis flavilatus*) taken when available.

As a means of determining the effect of farms on king shag prey species, the biology of the prey's forage was investigated. A feeding study on seven flatfish species, including witch, common sole and lemon sole, had been carried out in Wellington Harbour in 1976–78. From the gut contents and a knowledge of feeding morphology, this study concluded witch and lemon sole as visual feeders, while common sole and the remaining species were adapted for non-visual feeding. Witch showed a diet largely limited to crustaceans and small pelagic fish; the diet of lemon sole was a little more extensive; and the non-visual feeders had the most extensive diets.

A recent benthic study at the relocation sites showed a range of epifaunal and infaunal species able to provide forage for the king shag prey species. These would be affected by the proposed relocations to varying degrees, depending on the feed regime that was utilised. A study on benthic macrofauna carried out in 1983 included samples from 97 stations distributed throughout the Sounds which showed taxonomic groups that would provide forage for the king shag prey species to be widespread.

It was concluded that the nett effect of relocations would not be significant for the following reasons.

- Similar epifauna and infauna to that of the relocation sites is widespread within the Sounds; the total area represented by the relocation is small compared to the total area of the Sounds.
- The dominant prey species, representing some 90% of the king shag diet, is a visual feeder; its own diet includes a range of epifaunal species as well as small pelagic finfish, which is an alternative to benthic foraging and is largely beyond the influence of the salmon farm.

Any reduction in the availability of prey resulting from the relocations would be offset by recovery of the vacated sites, but effective recovery would probably require several years.

CONTENTS

1. SCOPE

This report was written for the NZ King Salmon proposal to relocate farms at six of its existing low flow sites in the Marlborough Sounds to areas of high flow. In it I have summarised existing background information on the prey species of the king shag and applied this information to the relocation sites. The aim here was to determine what the likely effect would be of the relocations on the prey of the king shag as an input to separate work being carried out to determine the overall effect of the relocations on king shag.

2. INVESTIGATING POSSIBLE EFFECTS ON PREY SPECIES AT PROPOSED SITES

2.1 Which species are the prey of king shags

2.1.1 Background

According to a study by Lalas and Brown (1998), the diet of king shag (*Leucocarbo carunculatus*) is limited to witch (*Arnoglossus scapha*), lemon sole (*Pelotretis flavilatus*), and one species of opalfish (*Hemerocoetes monopterygius*), with witch accounting for 90% of prey items and 95% of wet mass. These authors also state that, despite this dominance of witch in the samples, this species had not been recorded previously as prey of king shag, and that “This anomaly indicates that our study restricted to Pelorus Sound cannot be taken as representative of King Shags elsewhere in Marlborough Sounds”.

One conclusion of Lalas and Brown (1998) was that their results were consistent with previous conclusions by Nelson (1971), Marchant and Higgins (1990), and Schuckard (1994) that that king shag preys primarily on bottom dwelling fish species. However, they do point out the low level of overlap between the prey species they recorded and those recorded “in published reports based on incidental observations: blue cod (*Parapercis colias*), red scorpionfish (*Scorpaena papillosus*) , red rock lobster *Jasus edwardsii*) and crabs by Falla (1932, 1933); pilchard[1] (*Sardinops neopilchardus*), red cod (*Pseudophycis bachus*) and lobster krill (*Munida gregaria*) by Oliver (1955); and common sole (*Peltorhamphus novaezeelandiae*) and sandfish (*Gonorynchus gonorynchus*) by Nelson (1971)”.

Overall, this list suggests king shag as a generalist forager, feeding on a range of bottom dwelling prey species, but the predominance of witch in the study of Lalas & Brown (1998) raises the questions of why was witch the predominant prey species and Is this anomalous within this area? Certainly the other listed authors do not mention this species, and while the modern obscurity of the publications by Falla (1932, 1933) and Oliver (1955) prevents easy access to determine exactly where any field observations were made, Nelson (1971) “made visits to all five known colonies”: White Rocks, Sentinel Rock, Duffer's Reef, North Trio Island, and Te Kuru Kuru Island and supposedly made similar observations to the following at each of these: “when birds disturbed at their nests in 1964 [they] regurgitated soles *(Peltorhamphus novaezelandiae)* and sand-eels *(Gonorhynchus gonorhynchus)*”.

One point immediately obvious is that the other publications are much earlier than Lalas & Brown (1998), whose field sampling was carried out in 1991–1992. Nelson’s (1971) field observations were made in 1964, about 27 years previously; observations for the remaining publications must have been recorded some 10 to 30 years before that. One explanation for the difference is that prey availability has changed over time, perhaps due to increased fishing pressure on commercially viable species. Another is that there has been some level of prey species misidentification.

[1] Pilchard is usually described as a pelagic species, but this may be consistent with Baker’s (1972) assertion that pilchard display a demersal phase during the winter months.

2.1.2 Fishing pressure

Fishing records may provide a clue to change. Because witch is not commercially valuable it is not targeted by fishers, whereas the other flatfish species listed are targeted. For recording purposes within the quota management system (QMS), New Zealand waters are divided into a number of fisheries management areas (FMAs); the Marlborough Sounds are included in the FMA with the code FLA 7 (Figure 1) (within fisheries statistical area 017), which is a large area. Recorded commercial catches in FLA 7 began in fishing year 1931-32 (Figure 2) and were variable but comparatively low (up to about 250 t) up until about 1957 when they began to rise; the 1964 total is about 400 t. The variability is evident throughout the time series with catches in some groups of years between 1975 and the early 1990s (e.g., 1976-1979) being around 1000-1250 t and one single year (1983-84) almost 1500 t.

This suggests an increasing fishing pressure through the period of interest from 1964 to 1991–1992. However it is not clear what amount of this increased pressure is relevant to the outer Sounds. The area FLA 7 includes Golden-Tasman Bays and the West Coast down to a little south of Jackson Bay. Clarification requires an analysis of catch data at a finer spatial resolution than is not possible here.

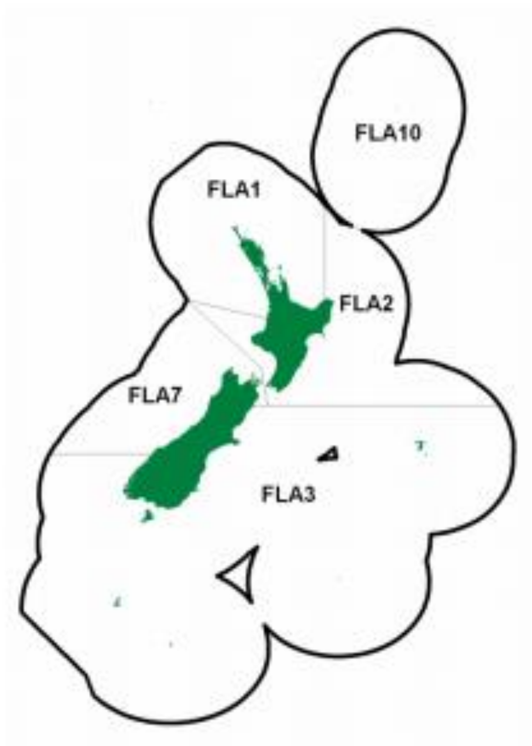

Figure 1: Flatfish quota management areas and their boundaries. Source: MPI 2015 Plenary report for flatfish species (species code FLA).

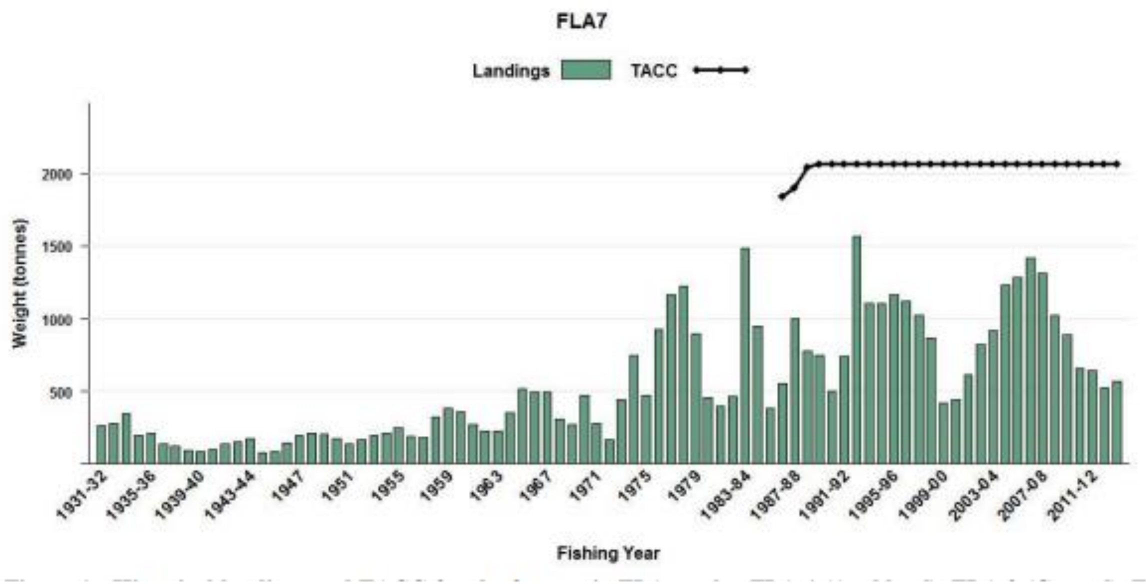

Figure 2: Historic commercial catches of flatfish species in Area FLA 7. Source: Minstry for Primary Industries (2015) — Plenary report for flatfish.

2.1.3 Conclusions

If we assume that the apparent increase in fishing pressure evident in FLA 7 has impacted the flatfish population in the outer Sounds area, then it is possible that the predominance of witch in the diet of king shag is not anomalous, either spatially or temporally, and the results of Lalas & Brown (1998) are generally applicable. Under this assumption we might suggest that the prey of king shag is mainly witch with other available bottom dwelling species (particularly opalfish, common sole and lemon sole) taken when available. The next question requiring an answer is: is the distribution of the prey of king shag, particularly witch, within the area of the potential relocation sites?

2.2 Distribution of king shag prey

2.2.1 Feeding and relevant biological features of king shag prey species

One way to get a handle on the distribution of king shag prey is to investigate the distribution of the prey of witch and the distribution of sediment types within the Sounds. One study on flatfish in Wellington Harbour by Livingstone (1987) investigated the diets of seven flatfish species, including the three species recorded by Nelson (1971) and Lalas & Brown (1998) — common sole, lemon sole, and witch. Results of this study showed that "both *P. novaezelandiae* [common sole] and *P. Flavilatus* [lemon sole] fed on polychaete worms, however, worms in the gut contents of *P. novaezeelandiae* were infauna[2], while those identified in *P. flavilatus* were epifauna[3]. *A. Scapha* [witch] had a diet consisting almost equally of small fish and shrimps". The analysis indicated that "the same food types comprised the most constant, most frequently taken, and greatest biomass in the diet of each flatfish species".

Livingston (1987) refers to the seven flatfish species in her study as co-occurring and cites several northern hemisphere authors whose studies have shown that co-occurring species are typically from different feeding groups defined as fish-feeders, crustacea-feeders, polychaete/mollusc-feeders by de

[2] Organisms that are largely sedentary living in permanent or temporary burrows within the bottom sediment.

[3] Organisms living in or on the sediment surface that leave their burrows from time to time.

Groot (1971), the conclusion being that such minimises competition for food (Lande 1973; Stickney et al. 1974; Kravitz et al. 1977; Pearcy & Hancock 1978; Steinarsson 1979). Livingston (1987) cites de Groot (1971) further, suggesting that the feeding groups defined in that work are characterised by their morphological and behavioural adaptations to feeding.

Livingstone's (1987) results showed that the predominant major taxonomic groups within their diets differed for the seven flatfish species included in the study. For the species of interest here, both common and lemon sole fed on polychaete worms, although worms from the gut samples of common sole were infauna, while those identified in lemon sole were epifauna. In the case of witch, the diet comprised almost equal proportions of shrimp (Palmonidae) and small fish (i.e., mainly anchovy, *Engraulis australis*). The predominance of these two components varied seasonally, such that there was a high representation of shrimp in Autumn which switched to anchovy in Spring.

Livingstone (1987) compared her results with those from studies carried out in Otago coastal waters by Graham (1956) and the Avon-Heathcote Estuary by Webb (1973). In the Otago study, lemon sole and witch were shown to be feeding on what are described as active prey - small fish and crustaceans as well as polychaetes and ophiuroids. In the Avon-Heathcote study, the diet of common sole was mainly crustaceans. From these results as well as some variations in the three other species in her study, Livingstone (1987) concluded that the flexibility in morphology and behaviour of the flatfish species being studied allows food selection to be of a greater range of categories than just those consumed in Wellington Harbour.

Livingstone (1987) also discussed variations among these species in the level of specialisation of their feeding morphology, citing work by Livingstone (1981) on this subject, and the observation that common sole was a nocturnal feeder and exhibited "external taste buds" as well as a superficial neuromast system and other specialisations indicating that this species was a non-visual feeder. By contrast, witch and lemon sole did not show these specialisations, indicating that their diurnal feeding pattern was visually based. Also discussed was the possible effect of water turbidity on the visual feeders, by possibly limiting the range of available prey species. This may be an important factor in explaining the narrow range of prey items taken in Wellington Harbour compared with the highly adapted non-visual species, which were shown to feed on a much wider range of prey species.

In summary then, the seven flatfish species whose feeding behaviour is described by Livingstone (1987) are not restricted to any particular food item or trophic role in a global sense, but are selective according to their particular level of morphological and behavioural specialisation with regards feeding. With a higher level of specialisation they are able to be more non-visual feeders. By contrast, the absence of specialisations like external taste buds ensures that a particular species is more of a visual feeder. Therefore, to some degree local conditions dictate which prey species are available to each, in that visual feeders may become restricted to a narrow range of prey items where, for example, turbid conditions dominate.

One interesting outcome of the work by Livingstone (1987) in the present context is the vertical distribution of the prey of witch. As Livingstone (1987) observed, the small fish prey are pelagic species and, while there appears to be no observation in the study of witch actually feeding in the pelagic zone, it is clear that such a strategy would avoid high levels of turbidity near the bottom in Wellington Harbour. Other useful information from this study includes the observations that witch is found in deeper water than the other species (attributed to Graham 1956) and on more coarse-grained sediments, although the author states that little is known about preference of sediment types in these flatfish species.

Opalfish was listed as a prey item of kings shag by Lalas & Brown (1998) with a relative frequency of 4 and 7% in two sampling episodes 6 months apart, which was higher than flatfish other than witch. Unfortunately, little information is available on the biology of this species. According to Ayling & Cox (1982), there are six species of opalfish found on sand or mud bottom around the coast of New Zealand which are all very similar. Their maximum length is usually less than 25 cm. The forage of the opalfish species most commonly described in the literature, *Hemerocoetes monopterygius*, is listed by Roberts et al (2015) as small crustaceans (specifically as crabs and shrimps by Ayling & Cox 1982) and small fishes.

2.2.2 Distribution of king shag prey within the area of the potential relocation sites

Based on the discussion in the previous section and the results of the Benthic Report (Brown et al 2016a) and Tio Point Report (Clark & Taylor 2016) which between them characterise the nine relocation sites, many potential forage items of king shag prey are available at the relocation sites. Epifaunal species recorded included crustaceans at all relocation sites, although sites in Tory Channel did not show the range of species observed in Pelorus Sound; hermit crabs were a dominant species recorded at three of the four Tory Channelites. Crustaceans dominated epifaunal catches at sites 34, 122, and 125, and ran a close second to echinoderms and bivalves at sites 106 and 124 respectively. Generally, crustaceans represented about 25-30% of the epifaunal catch at the Pelorus Sound sites. Infaunal samples included a range of polychaete taxa which represented from 23 to 35% of the catch in most cases, although proportions were lower at the two Tory Channel sites 42 and 82, at 13 and 15 % respectively.

However, assemblages comprising these and other potential forage taxa are not restricted to the areas within the Sounds close to the relocation sites. McKnight & Grange (1991) sampled macrobenthos from 97 stations throughout in the Sounds and summarised the stations into four groups based on a community score system of the dominant species recorded at each station. Overall, almost 60% of species were infaunal, the dominant species being deposit feeders (43%) and scavengers/carnivores (31%), with suspension feeders representing only 23% of the total. Included in these groups were taxonomic Families (e.g., Maldanidae[4]) recorded by Livingstone (1987) as providing flatfish prey in her Wellington Harbour study.

One issue here is that these infaunal forage items are not accessible to witch. Benthic foraging of infauna requires the specialisations of the non-visual feeding flatfish species as discussed by Livingstone (1987). However, witch can forage on epifaunal benthic species such as the crustacean groups mentioned above. Its foraging behaviour also allows it to take advantage of the presence of small pelagic fish species.

A range of small pelagic finfish species is known from the Marlborough Sounds, including pilchard (*Sardinops neopilchardus*), sprat[5] (*Sprattus muelleri*), yellow-eyed mullet (*Aldrichetta forsteri*), garfish (*Hyporhamphus ihi*) and anchovy (*Engraulis australis*), as well as medium-sized species, including jack mackerel (*Trachurus* spp.), trevally (*Pseudocaranx dentex*), john dory (*Zeus faber*), and kahawai (*Arripis trutta*), and larger pelagic predatory finfish such as yellowtail kingfish (*Seriola lalandi*) (Morrisey et al. 2005, Whitehead et al 1985, Webb 1972, Slack 1969, Tunbridge 1969, see review by Taylor & Dempster 2016). The five larger species potentially provide additional small schooling forage in their juvenile phases. The behaviour of pilchard during winter months reported by Baker (1972), when it adopts a demersal habit may well make this species more available to witch at that time.

Note that opalfish were themselves recorded as epifaunal species at sites 34, 106, 124, and 47.

2.2.3 Distribution of king shag prey within the area of the vacated sites

a. Recovery of benthos

[4] Maldanidae provided forage for all 7 of the flatfish species in Livingstone's (1987) study and were recorded in the Sounds as important subdominant species in 3 of the 4 groups reported by McKnight & Grange (1991); the 4th group comprised only 1 of the 97 stations sampled.

[5] Two species occur in New Zealand but only *S. muelleri* is distributed in the Sounds (Whitehead et al. 1985).

It seems reasonable to consider that any loss in habitat caused by transferring farms to the relocation sites will be offset by a gain in habitat at the vacated sites. However, this assumption must be qualified by an associated consideration of the time to recovery. In the present context, a measure of recovery might be the degree to which the benthic community within the shadow of the relocated farm comprises a species assemblage with the density capable of contributing to the forage of the main king shag prey species at a level of productivity similar to locations with similar characteristics (i.e., depth, flow/currents, sediment type etc) that have not been the site of an marine farm. Given the non-quantitative nature of available information on which a baseline can be developed (e.g., McKnight & Grange 1991), such a measure cannot be obtained without undertaking some study in the field. It can be assumed however, that if full recovery was achieved, then the benthic community structure would resemble something similar to one of the four groups reported by McKnight & Grange (1991), but only in a qualitative sense.

Based on the location of the possible vacated sites, the most likely benthic community that would become re-established at these sites would be the one categorised as Group 1 by McKnight & Grange (1991). This group is "dominated by infaunal mud dwelling echinoderms; the ophiuroids *Amphiura collecta* and *Ophiocentrus novaezelandiae*, and the heart urchin *Echinocardium cordatum*. The subdominant species are infaunal bivalves, polychaetes, the priapulid *Priapulis australis* and the holothurian *Pentadactyla longidentis*". The taxa listed for this group also shows a range of epifaunal species, including cirolanid species (isopods), brachyurans (crabs), and polychaetes.

b. Recovery time

Published results on recovery of benthic sediments and communities indicate that the time frame to what proved to be only partial recovery in each case occurred over periods of 4 to 23 months. Mazzola et al (2000) used meiofauna[6] to monitor the initial short and medium-term recovery of benthic assemblages in sandy-muddy sediments following removal of a fish farm (European seabass, *Dicentrarchus labrax*). They reported that after two months, meiofaunal densities showed about 30% recovery compared with the control, and that community structure recovered only partially to what was typical of the study area. They noted an increased importance of nematodes (about 70% of total density) and a reduced copepod contribution, with a lower number of taxa remaining after four months. Their conclusion was that after four months "meiofaunal recovery after fish farm disturbance is rapid, but far from complete".

Pereira et al (2004) monitored geochemical parameters (redox potential, organic carbon, oxygen flux) as well as macrofauna for 15 months at three locations following the end of production at the beginning of a fallowing period at a salmon farm site. Sediments at the monitoring stations were silty with median grain diameter of 0.05 and a silt-clay content of 55%. Although there were signs of recovery with time in the macrobenthic community at the two stations furthest from the fish cage (at 3m and 33m from the cage edge), by the end of the study the measures of indicator species, number of species and abundance were still moderately to slightly disturbed. There was also evidence of recovery in the macrobenthic community at the station nearest to the former site (0m from the cage edge), but the benthos at this station remained highly impacted with opportunistic species dominant 15 months after fish production ceased. At this time samples from subsurface sediments at the stations on the periphery of the former fish cage site showed that highly reduced conditions were still persistent there, and bulk sediment organic carbon was not found to be a significant indicator of recovery.

Karakassis et al (1999) monitored a different set of geochemical parameters (redox potential, total organic carbon and nitrogen, total phosphorus), as well as algal pigments and macrofauna for 23 months at three sampling stations: one under the previous location of the cages, a second at 10 m distance from the edge of the cages, and a control site more than l km distance from the site. Sediments (silty with about 70% clay and medium grain size diameter = 0.026–0.075 mm) at both stations near the farming

[6] Small benthic invertebrates defined by their size as intermediate between microfauna and macrofauna.

site were initially anoxic and overlain by a highly organic black layer. At the station under the cage location there were large fluctuations in most variables over the 23 months, indicating that full recovery did not occur before observations were completed.

Results from this study showed a similar outcome for the macrofaunal analysis, such that after 23 months a high proportion of benthic fauna at the under-cage station still comprised opportunistic species. Marked changes in the direction of a recovering succession were evident from the species abundance and composition, which was related to a secondary disturbance from a benthic algal bloom resulting from the seasonal release of nutrients from the farm sediment.

c. Factors affecting severity of benthic degradation

With the aim of assessing "the spatial distribution and severity of the benthic effects in different geographic areas, depth and sediment types", Kalantzi & Karakassis (2006) reviewed the results from 41 studies reporting on the benthic effects of fish farming, extracting values for the studied variables for use in a meta-analysis of effects. To avoid bias towards a particular set of conditions, the studies covered a wide range of farmed species, geographic regions, management practices and specific site characteristics, including depth, exposure, and sediment type. More than 120 biological and geochemical variables had been monitored, which on occasion had used different sampling and analytical protocols for the same variables. The rank correlation analysis between all possible pairs of variables in the dataset showed many significant correlations, both positive and negative, which reflects a response in these variables to organic enrichment of the sediments. Results from the stepwise regression showed that a combination of distance from the farm with bottom depth and/or latitude were important in determining most biological and geochemical variables.

The stepwise regression was repeated separately for each type of sediment. Results showed a similar general pattern for different types of sediments, but there were changes over distance caused by the settling of particulate organic material for different types of sediment. Overall, it was concluded that difficulties in determining environmental quality standards for benthic effects of fish farming are caused by the complex interactions between variables and a paucity of data for variables such as current speed; these should account for differences between geographic regions, depth zones and sediment types.

d. Conclusions

Any reduction in the availability of prey from loss of available habitat resulting from the relocations would eventually be offset by recovery of the vacated sites to a level of production similar to areas with similar characteristics but where no farms had been located. It is clear from available information on recovery times following farm production that this would likely require several years before a level approaching full recovery could be achieved. The probable speed of recovery in the vacated sites of the Marlborough Sounds relative to the published examples discussed above is most likely a function of the characteristics of the usage (e.g., production levels and feeding regime), possibly the species being farmed, and characteristics of the site, particularly sediment type, but also other factors such as bottom depth and temperature range, the latter probably being related to geographic region. The time to full recovery is unknown.

The benthic community at the vacated sites that is most likely to follow relocation can potentially provide forage for most of the listed prey species of the king shag. For non-visual feeders such as the common sole, the infaunal species of Group 1 (McKnight & Grange 1991) offer prey, whereas components of the epifauna could provide prey for the visual feeders, opalfish (crabs and other small crustaceans) or lemon sole (e.g., polychaetes). While the Group 1 list makes no mention of the shrimp species that were recorded as an important prey item for witch in the Wellington Harbour study of Livingstone (1987), the generalist feeding characteristic of this species that can be assumed following the results of Graham (1956) and Webb (1973) discussed above in Section 2.2.1 indicates that many of the epifaunal species listed for Group 1 could also provide forage for witch.

3. SUMMARY AND CONCLUSIONS

The prey list for king shag summarised in Section 2.1.1 suggests a range of possible species dominated by the flatfish species *Arnoglossus scapha* (or witch) to such an extent that it seems reasonable to suggest that the prey of king shag is mainly witch with other available bottom dwelling species (such as opalfish) taken when available. In contrast with other flatfish species, observations by Livingstone (1987) indicate that specialisations for non-visual feeding in witch appear to be largely absent. This species seems to rely on visual feeding strategies, which are diurnal and, in the Wellington Harbour study at least, limit the species to two main prey groups, crustaceans and small pelagic fish, which is similar to the prey of opalfish referred to above, although details of its feeding behaviour appear to be unknown. This, plus additional information from Graham (1956) and Webb (1973) suggest a generalist feeding strategy for witch.

Five of the six other flatfish species included in Livingstone's (1987) study exhibit a highly adapted feeding morphology and associated feeding behaviours for non-visual predation. The infaunal prey available to these species within the Sounds is widespread and varied, although, of these, only the common sole has been listed as a king shag forage item. The sixth species, lemon sole shows the feeding characteristics of a visual feeder and is therefore similar to the witch.

While it is clear that a move to the relocation sites would undoubtedly affect the infauna and epifauna within the deposition zone of the farms to a greater or lesser extent, depending on the salmon feed regime utilised (Brown et al 2016b), it is concluded that the nett effect on the prey of king shag would not be significant for the following two main reasons.

1. Similar epifauna and infauna to that of the relocation sites is widespread within the Sounds, and the total area represented by the relocation sites is small compared to the total area of the Sounds.
2. The dominant prey species, which represents some 90% of the king shag diet, is a visual feeder whose own diet includes a range of epifaunal species as well as small pelagic finfish; the latter provides an alternative to benthic foraging and is largely beyond the influence of the salmon farm.

Any reduction in the availability of prey from loss of available habitat resulting from the relocations would eventually be offset by recovery of the vacated sites. However, this would probably require several years before a level approaching full recovery to original habitat quality and re-establishment of benthic community was reached.

4. FUTURE WORK

The main challenge in producing this report was the scarcity of published information available. While the information that was available provided particularly germane insights in this case, there remain a number of areas that would benefit strongly from well organised research. These include, additional feeding studies on the king shag itself, as well as a feeding study on witch in the relevant area of the Sounds. An exploratory investigation of flatfish commercial catches at a fine spatial resolution within fisheries statistical area 017 would also be useful.

5. ACKNOWLEDGEMENTS

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