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Studies on *Caligus elongatus* infestations on farmed salmonids in Ireland.

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ABSTRACT

Caligus elongatus is a caligid copepod that attaches to the outer surface of a number of marine fish species including salmon cultivated within cages. Its occurrence on cultivated salmon varies greatly, being more frequently found on more exposed farm sites. The species can cause epizootic events which require chemical treatments. Infestation can take place throughout the year. Infestation takes place from copepodids and there is evidence that adult stages can transfer from local fish species, this may be enhanced by storm events.

INTRODUCTION

Two species of caligid copepod are generally found on cultivated salmon in the North Atlantic, *Lepeophtheirus salmonis* and *Caligus elongatus* in Canada (Hogans & Trudeau, 1989a; 1989b), Scotland (Wooten *et al.*, 1982), Ireland (Tully 1989; 1992) and Norway (Bristow and Berland, 1991). In Ireland *L. salmonis* is generally the most frequent species but in Canada *C. elongatus* is more frequent. An explanation for this may be the relative differences of fecundity, the more fecund species in a particular area being the dominant one (Jackson & Minchin, 1992). In Canada *Caligus curtis* was also found associated with farmed salmon and consisted of less than 1% of the number of all samples taken (Hogans & Trudeau, 1989b), this species has not been found associated with salmon in Irish waters although it is present within the Irish fauna (O'Riordan, 1969). *C. elongatus* is known to occur on 37 species of British fishes, including eight gadoid species (Kabata, 1979). The size of the the adult is reported to vary according to sea temperature, with larger adults being produced at lower temperatures in Ireland (Tully, 1989).

Despite its relatively small size, when compared with *L. salmonis, C. elongatus* can strip the mucus covering and feed on the skin, musculature and blood, causing lesions to form (Hogans & Trudeau, 1989). These lesions may result in secondary infections and osmotic stress compromising the health of the fish, which in severe cases can lead to death (Wooten *et al.*, 1982). A detailed account of the histopathology of free-moving stages of *L. salmonis* on salmon is given by Jonsdottir *et al.* (1992), and effects of *C. elongatus* are likely to be similar to this. Once populations of sea-lice expand, chemical treatment of the farmed stock may be necessary (Jackson & Costello, 1992) to relieve the parasite burden. Although common on many native species and on farmed salmonids, epizootics of this species in Irish waters are rare events. Heavy infestation has been recorded attached to herring, *Clupea harengus*, in Scottish waters, where up to several hundred (principally chalimus stages) individuals were recorded on a fish. These numbers caused haemorraging lesions on their host (MacKenzie & Morrison, 1989). In warmer waters it is known to infest pond reared scianids (Landsberg *et al.*, 1991).

The stages of *C. elongatus* consist of two naupliar stages, a copepodite, four chalimus stages a pre-adult and an adult (Hogans & Trudeau, 1989); in *L. salmonis* there are ten stages, this includes two pre-adult stages (Johnson & Albright, 1991). Tully (1989) indicates that over the period July to January there were three generations ranging from 49 to 81 days estimated duration, however Tully (1992) suggests that regeneration may be as short as 23 days during the summer. Hogans & Trudeau (1989a) estimated a generation time of five weeks at 10°C based on laboratory and field studies, with four to eight of these generations within the year.

The following study examines the biology and intensity of infestations on farmed salmonid on the south-western, western and north-western Irish coasts.

METHODS

Each sample comprised 30 salmon individually removed from a selected fish cage at a farm site using a pole net. Fish were placed directly into a bin containing a solution of benzocaine in acetone, used as an anaesthetic, with no more than four fish being anaesthetised at the one time. Each fish in turn was then examined for all free moving stages of sea-lice of both species. These were removed using forceps and placed in 70% ethanol within tubes, one tube per fish. Salmon were returned to their cages following sampling. Once sampling was complete, the numbers of lice remaining within the bin were strained off to provide a gross
mean of the numbers of sea-lice present. Should chalimus stages be present on the one-sea-winter or older salmon, these were noted. On smolts all chalimus stages were removed together with pre-adult and adult stages for both lice species. The bin in which they were anaesthetised was not strained due to the large number of loose scales present.

Pre-adult and adult stages of *C. elongatus* were identified by means of the the presence of the lunules, disc shaped sensory areas at the anterior end of the cephalothorax; these are not present in *L.salmonis*. Pigmentation in both species is different, *C. elongatus* is usually marked with scattered pigment spots, whereas in *L. salmonis* pigmentation tends to be uniform. It was difficult to separate in routine samples pre-adult from adult specimens of *C. elongatus*. Even some of the adults were found to be attached with frontal filaments to their host. For this reason pre-adult and adult stages were grouped together.

Chalimus stages of the two species could be distinguished by means of the longer frontal filament and greater eyespot separation in *C. elongatus*. In addition pigmentation and shape of the cephalothoracic shield and the presence of lunules in the chalimus IV of *C. elongatus* were used.

Native fish examined near to fish cages were captured by means of gill net, seine, and rod and line.

C. elongatus were tested in different salinities ranging from 14‰to 24‰to determine LC50 times following 48 hours. Lice were placed within litre jars and salinities were determined using a refractometer. Cultures were kept at 16.5°C.

In this study more than 25,000 salmon were examined from 22 farm sites (Figure 1).

RESULTS

Chalimus stages of *C. elongatus* are attached by a strong frontal filament to the host, most frequently seen on fins or the ventral surface. These were often difficult to locate as some lacked pigmentation being almost transparent, the shine of surface light on their contours often being the only way they were revealed during examination at sea on dark surfaces of the fish. Most specimens faced towards the anterior end of the fish, specimens were found on all areas of the external body surface, pre-adults and adults were frequent on flanks and many were actively moving. Rarely were a mating pair of *C. elongatus* observed on salmon, however, this was a frequent occurence with *L. salmonis*. Specimens were usually brown in colouration but some had a dark red median line, due to injested blood. The blood was usually evacuated from the gut of detatched specimens within a day. Where many *C. elongatus* were present, salmon had small haemorraging patches, these were most usually along the ventral surface.

C. elongatus was more readily detatched from salmon during examinations, proportionally more are lost of this species than *L.salmonis* (Fig. 1). Detatched adult *C. elongatus* when replaced to sea-water can reattach to their host directly. They would appear to be able to detect their host from a distance of about 30 to 35cm and swim directly and rapidly to it. This appears to be a response to shadow and movement, as this response can be generated using either still or dark moving objects.

Ovigerous females of *C. elongatus* were frequently removed from smolts during the summer, in contrast, *L. salmonis* were seldom found on smolts at this time and none were found on smolts before the end of July (Fig. 2). On older fish all stages of both lice species were found to be present. The variation in the numbers per fish increased with age (Fig 3). Rainbow trout, *Salmo gairdneri*, and unsilvered brown trout, *Salmo trutta*, cultivated in the same way aquired both lice species. The frequency of all lice stages was lower and few ovigerous females present (Table 1) these were principally found ventrally on the caudal peduncle.

Smolts of Atlantic salmon, introduced to the sea in March/April in some cases soon afterwards aquired *C. elongatus*. This species was normally dominant in new farm sites and at sites following periods of fallowing. In sheltered sites within bays few were normally found on salmon. The intensity of infestation in May was normally low (Table 2). *C. elongatus* were generally more frequent in 1992 than in 1991. Levels in 1992 peaked in June (Fig. 4), a similar trend was seen in 1993 when infestation levels were higher and occurred over a wide area on the west coast of Ireland. Areas where these events have been recorded include Clew bay to Ballinakill Harbour and in Bantry Bay.

Several fish species were found associated with salmonid farms.
Some, such as mackerel *Scomber scombrus,* occur seasonally during summer and autumn and feed on food pellets. Captured mackerel were commonly found to have *Caligus pelamydus* present within the gill cavity and some on the body surface and also had a low frequency of *C. elongatus*. The most frequent species present is saithe *Pollachius virens*, present throughout the year and during net changes many can be scooped up within the new net. They feed avidly on the food pellets provided, grow rapidly and become well conditioned to the point of obesity. These fish can aquire *L.salmonis* but on no occasion were there sufficient numbers to result in serious pathology. Saithe also had small numbers of *C. elongatus* (Table 3). Herring, frequent at farm sites during the autumn, were in one sample, found not to have any copepods present.

Of the ten most frequent species associated with farms four were gadoids, and the most common, saithe, were abundant at most sites throughout the year. The presence of *C. elongatus* on saithe in May and July at two sites, on the west and south-west coasts, was one or less per fish (Tables 3 & 4).

C. elongatus was found to have a 48 hour LC50 of 22‰, all of those held at 16‰ or less died and few survived at 18-20‰, whereas *L. salmonis* could tolerate salinties at 14‰ over this period of time (Table 5). The majority of mortalities at salinities of 24-26‰ were due to lice moving above the water surface on the inside of the jar and becoming dessicated, lice in these jars were more active. Temperatures of the period of study ranged from 15-16.5°C.

DISCUSSION

C. elongatus can withstand prolonged periods of cold as evidenced from Hogans & Trudeau's (1989b) work, to conditions in semi-tropical areas (Landsberg *et al.*, 1991). This species has the capability of creating difficulties in the cultivation of marine teleosts over a wide geographical area. It is not clear whether such events that occur from time to time in cultured salmonids are associated with natural epizootics amongst shoaling species or from the low natural background frequencies present on resident wild fish. It can also result in epizootic events in native shoaling fishes, such as herring *Clupea harengus* (MacKenzie & Morrison, 1989). Herring are known to be associated with salmon cages and so may be important in the transmission of *C. elongatus*.

C. elongatus produce egg-strings throughout the year and so presumably is capable of reproducing and infesting fish in any month. The rate of production is likely to be influenced by sea-water temperatures as Tully (1992) has indicated for *L. salmonis*, predicting generation cycles 23 to 125 days. It is likely that the patterns for *C. elongatus* are similar and may even be shorter on account of it's smaller size and fewer moults which could account for their greater intensity during summer months.

In this study *C. elongatus* was more easily detatched from its host than *L.salmonis*. The ability of this species to adhere to a wide range of fishes may compensate for their reduced tenacity when compared with the capabilities of *L.salmonis* which, as far as it is known, is dependent upon salmonids for the completion of its life cycle. Nevertheless specimens of *L. salmonis* in Kenmare Bay have been found attached to saithe adjacent to and up to 0.5km from cages. No chalimus stages of *L. salmonis* were found on these fish, so suggesting that they had become dislodged, possibly during or prior to chemotherapy, and adopted a new host of a different species. Records of high frequencies of saithe associated with salmonid farms are reported from Scotland (Bruno & Stone, 1990) and Norway (Bristow & Berland, 1991; Furevik *et al.*, 1993). Saithe associated with farms have been found with low frequencies of *C. elongatus*. They also had chalimus stages demonstrating that some development took place from copepodite settlement.

Free-living pre-adult and adult *C. elongatus* are known from the plankton in areas where there were no salmon farms (Pearson, 1904; Minchin, diving obs.) and have been seen within and beside salmon cages during summer months. During storms when fish are subject to surge and possibly abraision, greater numbers may become detatched. Minchin (1991) collected specimens following a storm event. The high frequency of *C. elongatus* on farmed salmon following a storm in Kenmare Bay in December 1991 (N. Bass, pers. comm.) may be due to such an event.

Epizoootics of *C. elongatus* occur more suddenly than in *L. salmonis*, evolving over a period of less than a month to cause significant stress to fish. It is readily controlled using standard organophosphate treatments, but these have little effect on attached stages (pers. ob.).

C. elongatus, it would seem, appears in greater numbers earlier than *L. salmonis, and a*t many seaward sites appears following periods of fallowing or at a new site. *Thei*r numbers would appear to fluctuate greatly during the year. *L. salmonis howe*ver build up their numbers slowly and normally in time exceed the numbers *of C. elongatus* present. The epizootics in Bantry Bay and the West coast of Ireland are sourced principally from copepodite settlements, there may, however, be some transfer of pre-adult or adult stages from wild fishes.

The presence of *C. elongatus* on the more seaward farms may reflect its intollerance of brackish water. Experimental studies suggest salinities of <22‰ are unsuitable for this species. Wild salmon and sea-trout probably shed adult stages of *C. elongatus* when entering estuaries.

C. elongatus can develop to adults on salmon smolts, this was not found to be the case for *L.salmonis,* females with egg-strings were not found in June or July. It is not clear whether these detatch, die or whether the host has some influence on their maturation. From September post-smolts can have egg-stringed females present. Levels of lice on one and two-sea-winter fish vary greatly between individuals and the larger numbers present on the oldest fish may reflect their larger surface area. Nevertheless fish from the same cage demonstrate great variability of lice loads.

Small, poorly conditioned salmon normally harboured greater lice loads(pers. ob.). These may be acquired through lethargic swimming or their otherwise stressed condition. The greater numbers upon them may arise from direct settlement and from lice transfers from normally conditioned fish. Bruno & Stone (1990) have demonstrated that transfers between normal salmon do take place for *L. salmonis*. Because lice on poorly conditioned fish are easily detatched there may well be a flow of lice movement from them to normal salmon. Should this be the case *C. elongatus* has implications as a vector of pathogens. It would seem to be a prudent measure to remove all small poorly conditioned and sick fish from cages. Interactions between *C. elongatus* and *L. salmonis* may also take place, the trematode *Udonella caligorum*, present on salmon at many farm sites during the winter and spring (Minchin & Jackson, 1992) may be due to direct transference from *C. elongatus* on the same host.

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Table 1. Mean intensity and prevalence of sea-lice present on rainbow trout and unsilvered brown trout cultivated in the sea.

Date	*L. salmonis* Ovigerous females	Total number	C. elongatus Ovigerous females	Total number
Rainbow trout				
27-5-92 w	0.0	0.63	0.20	0.40
8-7-92 nw	0.50	9.40	1.37	2.34
4-5-93 w	0.0	0.16	0.33	0.40
6-5-93 w	0.07	1.56	0.56	0.66
11-5-93 w	0.03	0.56	1.06	1.30
12-5-93 nw	0.0	6.07	0.0	0.03
Brown trout				
11-5-93 nw	0.0	1.83	0.0	0.10
22-6-93 nw	0.0	4.67	0.17	0.27

Table 2. Frequency each May for total numbers of *C. elongatus* and ovigerous females (brackets). Site class refers to: a, exposed sites; b, semi-exposed sites and c, sheltered areas.

Site	1991		1992		1993		site class	epizootics known
Lough Swilly	0.1	(0)	0.2	(0)	0.3	(0.1)	a	no
Mulroy Bay	0	(0)	+	(0)	0.1	(0)	c	no
McSwynes Bay	0.5	(0.2)	0.3	(0)	0.4	(0)	b	no
Clare Island	2.8	(1.4)	1.9	(1.6)	11.9	(6.5)	a	yes
Killary Harbour	0.1	(0)	-		1.6	(0.6)	b	yes
Ballinakill Bay	0	(0)	+	(0)	+	(0)	c	yes
Ardbear Bay	0.4	(0.1)	-		-		c	no
Bertraghboy Bay	3.1	(2.0)	0.2	(0.2)	-		c	no
Kilkieran Bay	0.4	(0.1)	0.1	(0.1)	0.9	(0.2)	b	no
Deenish Island	0.8	(0.3)	1.3	(1.0)	+	(0)	a	no
Coulagh Bay	1.1	(0.5)	0.3	(0.1)	+	(0)	b	no
Kilmakilloge	0.2	(0)	0.2	(0.1)	+	(0)	c	no
Bere Haven	0.3	(0.1)	2.7	(1.8)	+	(0)	b	yes

Table 3. Copepods removed from saithe taken from inside a salmon cage during harvesting. Saithe were 1+ fish, they became contained during a net change in May 1992 and were examined in July 1992.

	Ovigerous females	Total numbers
L. salmonis	0.05	1.46
L. pollachius	0.07	0.11
C. elongatus	0.08	0.32
Clavella adunca		0.05

Table 4. Mean intensity of pre-adult and adult *C. elongatus* and *L. salmonis* associated with saithe captured beside salmon cages in Kenmare Bay and for cultured salmon in May 1993. Thirty fish sampled in each case.

Saithe	males	females	ovigerous females	Total numbers	Prevalence %
C. elongatus	0.55	0.43	0.23	1.00	67
L. salmonis	0	0	0.07	0.07	7
Salmon					
C. elongatus	0.03	0	0	0.03	3
L. salmonis	1.50	0.86	0.63	2.50	87

Table 5. Results of LC50 studies at 15-16.5°C for *C. elongatus. L. salmonis* survived all of these salinities.

	LIVE			DEAD		
Salinity	Males	Females	Total	Males	Females	Total
14%	0	0	0	18	10	28
16%	0	0	0	11	13	24
18%	4	0	4	13	10	23
20%	4	4	8	11	5	16
22%	7	9	16	8	5	13
24%	9	9	18	7	1	8
26%	11	10	21	8	3	11

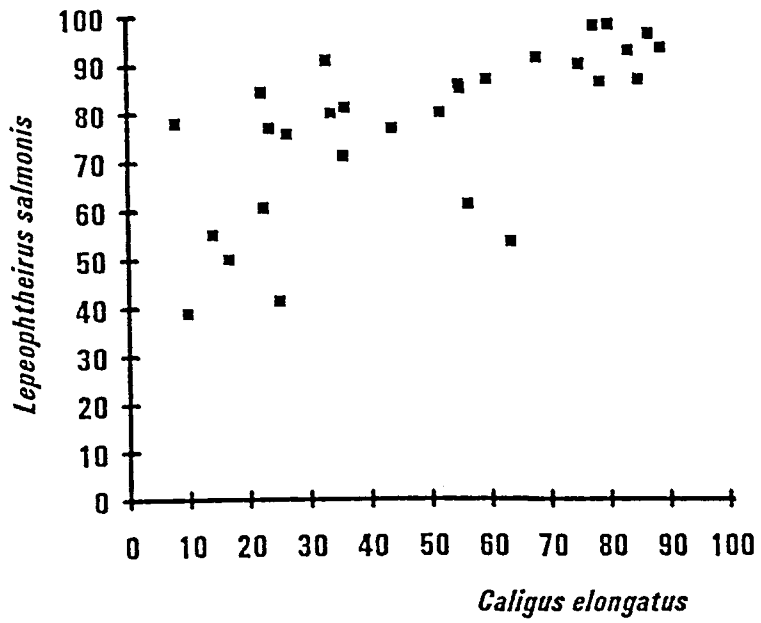

Figure 1. Relative sampling efficiency of lice, in percent, for the two species studied. Efficiency refers to the numbers of lice sampled from fish when compared with the total numbers collected including those that detatched within the bin in which salmon were anaesthetised.

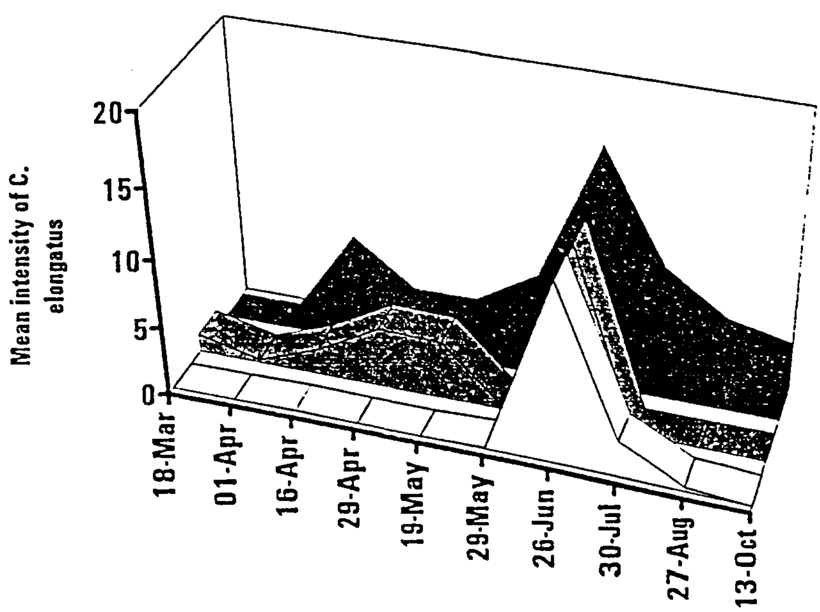

Figure 4. Pattern of an epizootic infestation of *Caligus elongatus* for one region in the west of Ireland fro three farm sites. Dips indicate periods of treatment.

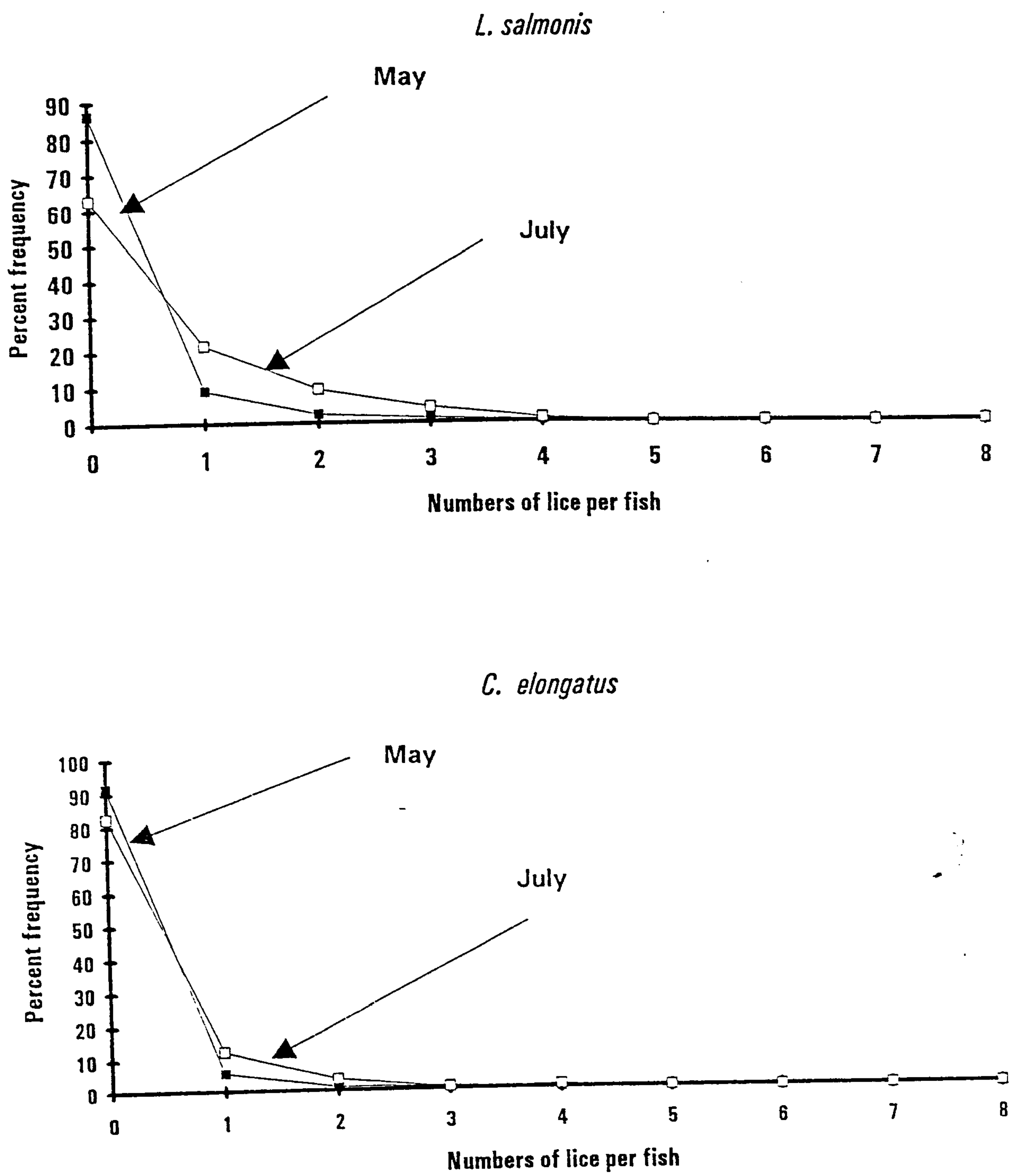

Figure 2. Demonstrates the gradual build up of lice numbers with progression during the summer for the two sea-lice species present. No ovigerous females of *L. salmonis* appeared in samples from May to July. Ovigerous females of *C. elongatus* were found on almost 5% of the fish sampled in July.

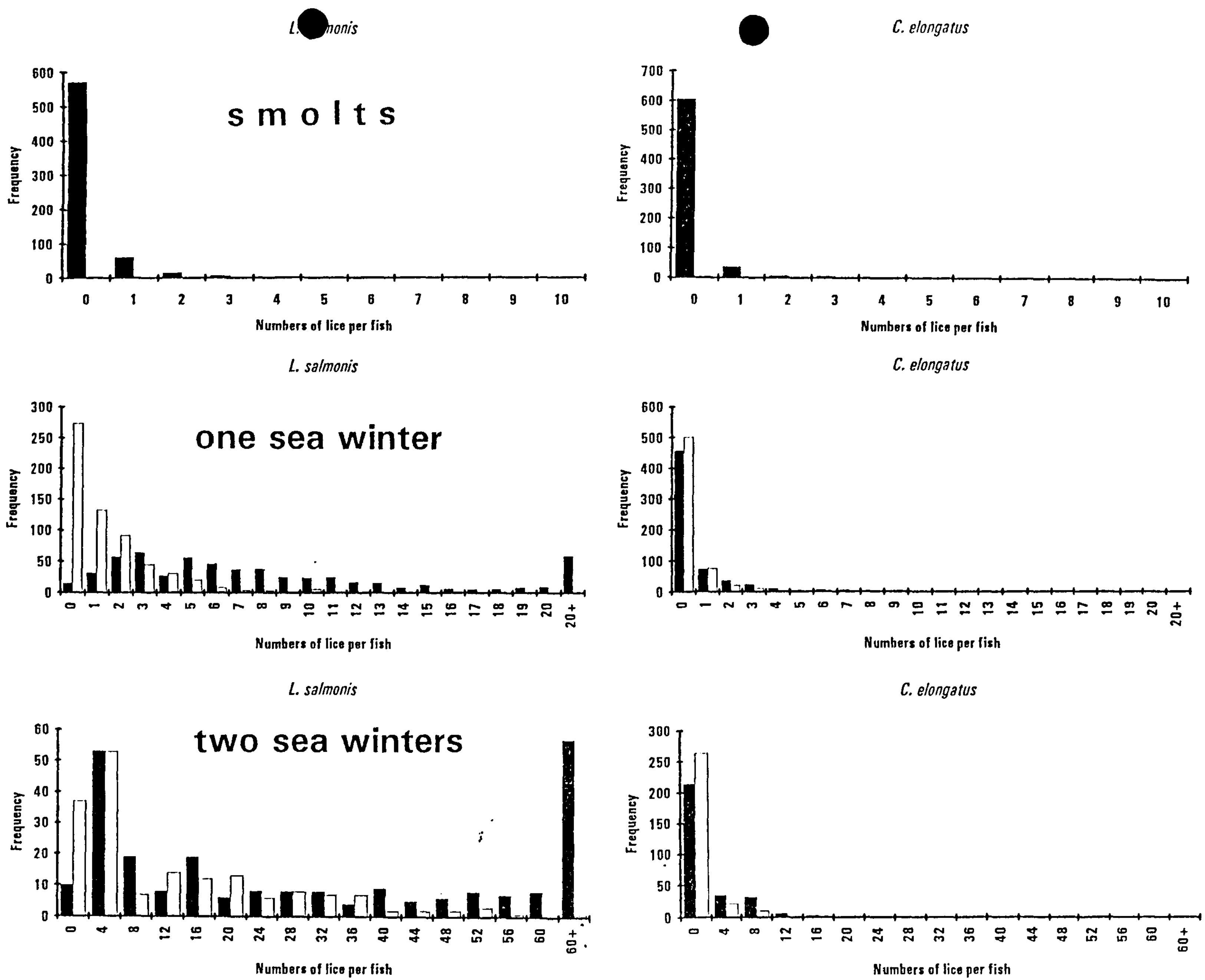

Figure 3. Frequencies of the numbers of lice per fish for smolts and one and two sea winter cultivated salmon for April-May. Dark bars indicate total numbers of free-moving (pre-adult and adult) lice and open bars the numbers of ovigerous females present. No ovigerous females were found on smolts.