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Upstream and downstream movements of lake chub, *Couesius plumbeus*, and white sucker, *Catostomus commersoni*, at Catamaran Brook, 1990-2004.

by

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ABSTRACT

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From early May to mid-November of every year since 1990, a counting fence has been operated at the mouth of Catamaran Brook, a third-order stream that flows into the Little Southwest Miramichi River in New Brunswick, 40 km away from the nearest accessible lake. Captures for the period of 1990-2004 show two size-classes of lake chub, *Couesius plumbeus*, moving in and out of the stream in June and July, with the larger size-class moving first. The onset of the migrations occurred later on colder years. The median of upstream movement in June-July occurred one week earlier on average than the median of downstream movement. A major lake chub emigration also took place every fall, the first time such a phenomenon has been reported for this species. Lake chub grew by 0.8-1.0 cm per month in summer; allowing for this, the chub emigrating in the fall belonged to the same size classes that had moved earlier in the year. Downstream captures were higher on days with rainfall of 12.5-20.0 mm. White sucker, *Catostomus commersoni*, followed the same seasonal pattern of upstream and downstream migration as lake chub, except that the upstream migration started about one week earlier than for chub. Yearly totals of chub and sucker exiting the stream in the fall were correlated with each other. However, yearly totals of chub or sucker captured in either direction or in summer and autumn separately were not correlated with either water temperature, water level, or precipitation in that year or the year prior.

RÉSUMÉ

Reebs, S., Leblanc, S., Fraser, A., Hardie, P., and Cunjak, R.A. 2008. Upstream and downstream movements of lake chub, *Couesius plumbeus*, and white sucker, *Catostomus commersoni*, at Catamaran Brook, 1990-2004. Can. Tech. Rep. Fish. Aquat. Sci. 2791: iv + 19 p.

À chaque année depuis 1990, de mai à mi-novembre, une barrière de comptage a été en opération à l’embouchure du Ruisseau Catamaran, un cours d’eau de troisième ordre qui se déverse dans la Rivière Southwest Miramichi au Nouveau-Brunswick, à plus de 40 km du lac le plus proche. Les captures de poissons de 1990 à 2004 indiquent que deux classes de grandeur du mené de lac, *Couesius plumbeus*, entrent et sortent du ruisseau en juin, les poissons les plus grands apparaissant en premier. Ces migrations débutent plus tardivement lors d’années plus froides. En moyenne, la médiane de migration de sortie a lieu une semaine après la médiane de migration d’entrée. De grands nombres de menés de lac quittent aussi le ruisseau en automne, un phénomène rapporté ici pour la première fois. Le taux de croissance des menés est de 0,8-1,0 cm par mois, et en tenant compte de ceci il semble que les émigrants automnaux appartiennent à la même classe de grandeur que les poissons capturés plus tôt dans l’été. Plus de menés sortent du ruisseau lors de journées avec 12,5-20,0 mm de précipitation. Le meunier noir, *Catostomus commersoni*, était aussi capturé à la barrière, et ces captures indiquent un patron de migration similaire à celui des menés de lac, à l’exception que les mouvements d’entrée commencent une semaine plus tôt que pour les menés. D’une année à l’autre, les nombres de menés et de meuniers quittant le ruisseau à l’automne sont corrélés positivement entre eux. Cependant, pour chacune des deux espèces, aucune corrélation significative n’a été détectée entre le nombre de poissons d’une part, que ce soit au total ou séparé par direction et par temps de l’année, et diverses variables environnementales d’autre part, à savoir la température, le niveau de l’eau et les précipitations.

INTRODUCTION

Most studies of migration by freshwater fishes have involved species of commercial importance, such as salmonids. Movement patterns by species of lesser economic importance have long been overlooked, even though these species may represent a substantial part of the fish biomass of freshwater ecosystems. Fortunately however, the past decade or so has seen an increasing number of publications dealing with the diel, seasonal, and annual movements of fishes, belonging to many different species, on a variety of spatial scales in streams, rivers and lakes, bringing about a more complete understanding of fish movements in freshwater environments (for a review, see Lucas and Baras 2001).

At the mouth of Catamaran Brook in New Brunswick, Canada, a counting fence has been operated every year since 1990 as part of a long-term study of fish ecology and forestry impacts on the stream environment (Cunjak et al. 1993). The fence intercepts Atlantic salmon, *Salmo salar*, and brook trout, *Salvelinus fontinalis,* that move either upstream or downstream. The chronology and size of movements by these two salmonids in Catamaran Brook have been documented (Cunjak et al. 1993, Cunjak and Therrien 1998, Hardie et al. 1998). But the fence also captures other fish species, two of which are known to undertake spawning migrations: the lake chub, *Couesius plumbeus*, and the white sucker, *Catostomus commersoni* (Brown et al. 1970, Scott and Crossman 1998, Lucas and Baras 2001). In some years, lake chub are the most frequently captured fish species at the fence, while white suckers often include some of the biggest individuals. The present report documents the upstream and downstream migratory patterns of these two species at Catamaran for the 15-year period of 1990-2004. Specific objectives were (1) to provide a description of the seasonal movements of these two fishes, with special emphasis on the lake chub, a species for which such information is generally lacking in non-lacustrine habitats, and whose numbers are high at Catamaran; (2) to measure the influence of water temperature on the seasonal timing of migration onset; (3) to identify environmental factors that promote fish movements on a daily basis; and (4) to seek environmental factors that might explain year-to-year variation in fish numbers.

Lake chub and white sucker are already known to migrate from lakes into streams during the spawning season (Brown et al. 1970, Scott and Crossman 1998, Lucas and Baras 2001). However, there is little information about the timing and direction of movements in river reaches distant from major lakes, especially for lake chubs. Because the nearest accessible lake to Catamaran Brook is 40 km away, the site provided an opportunity to collect such information. The only previous research that provided similar information is the two-year study of Montgomery et al. (1983) who captured lake chub, white sucker and other species with directional hoop nets at the mouth of Rivière à la Truite, a fourth order tributary of the Moisie River a few kilometers upstream from where the Moisie enters the Gulf of St. Lawrence. Montgomery et al. (1983) reported a few lake chub entering the stream in late May and early June, and much larger numbers exiting during the same period. The hoop nets were monitored until November in one year, and no other lake chub movements were observed. Montgomery et al. (1983) also reported white sucker migrating during the same period and in the same direction as lake chub but in much smaller numbers.

MATERIALS AND METHODS

Catamaran Brook (46º 52.7’ N, 66º 06.0’ W) is a third order stream that originates from a small body of water (Catamaran Lake, 0.28 km^2) and runs for 20.5 km through a mature second-growth forest of 65% conifers and 35% hardwoods until it empties into the Little Southwest Miramichi River. The stream has a drainage area of 52 km^2. Falls are present 1 km from Catamaran Lake and block upstream movement into the lake (Cunjak et al. 1990). The middle third of the stream is delimited by complexes of beaver dams that impede, but do not consistently block, fish movements. Fish habitats are shallow riffles, slightly deeper runs, slow-moving flats, and pools (Cunjak et al. 1993). Besides lake chub and white sucker, the most common species in the stream are Atlantic salmon, brook trout, blacknose dace *Rhinichthys atratulus*, and slimy sculpin *Cottus cognatus* (Johnston 1997, Hardie et al. 1998). As opposed to lake chub, to white sucker and to the two salmonids, blacknose dace and sculpin do not normally undertake spawning migrations (Scott and Crossman 1998), and in Catamaran Brook they are infrequently captured at the fence.

Besides Catamaran Lake (and a much smaller pond, 0.03 km^2, also in the headwaters and also blocked by waterfalls), the nearest large bodies of water are Mains Lake, Whitney Pond and Guagus Lake, all more than 40 km from the mouth of the brook in the upstream reaches of the Little Southwest Miramichi River. Downstream from the mouth of Catamaran Brook, the Little Southwest Miramichi River runs approximately 30 km to the Miramichi River and the head of tide without any other accessible lakes.

The fish-counting fence is located 250 m upstream from the mouth of the brook. It is made of rows of conduit pipes spaced 12 mm apart and angled towards a trap that captures upstream-moving fish in one compartment and downstream-moving fish in another (see Mullins et al. 1991). It is set up in early May, after ice-out and snowmelt freshet, and remains in place (except during occasional floods due to storms, 3-12 days a year) until approximately mid-November when freeze-up begins. The trap is checked twice per day (morning and evening) and all fish captured are counted and identified to the species. Fork length (measured to the nearest 0.1 cm) and wet weight (0.1 g) are routinely recorded, but no measurements of reproductive condition are taken for lake chub and white sucker. Fish moving upstream are released about 100 m upstream of the fence, whereas downstream-moving fish are released 50 m downstream. Water level, minimum and maximum water temperatures, and amount of precipitation are also noted daily. Water discharge is also monitored by an automated flow recorder located in mid-basin. The data presented in the present report cover the 15-year period from 1990 through 2004.

A mark-recapture study conducted between 1992 and 1996 with down-migrating salmon smolts indicated a downstream trapping efficiency between 80% and 86% (Cunjak and Therrien 1998). Smolts averaged 12-15 cm in fork length, bigger than most lake chub and many of the white sucker. For smaller fishes such as 1+ salmon parr (approximately 6-9 cm long and thus similar to lake chub and smaller than white sucker), Cunjak and Therrien (1998) assumed a trapping efficiency of 75-80 %. We have no data, however, on the upstream trapping efficiency of the fence. Comparisons from week-to-week or from year-to-year for a given direction of movement should be valid, but comparisons between directions should be interpreted with caution.

Statistical tests were conducted with SPSS 13.0 for Windows. Significance level was set at $P = 0.05$.

RESULTS

Seasonal movements of lake chub

Figure 1 shows the number of weekly captures of lake chub for each year, while the top panel of Figure 2 shows the 15-year average. Lake chub were seldom captured during the first two weeks of May. During the third and fourth weeks of May, a few down-migrating lake chub were intercepted by the fence, typically less than 10 a week. Then, starting in early June, high numbers of lake chub were captured moving both upstream and downstream. There was variation from year to year in the exact timing of the migration peaks, but they usually occurred in June. The downstream migration usually peaked later than the upstream migration (Figures 1 and 2). The mean (± SD, n = 15) Julian day on which 50% of the May-June-July captures was reached was 169 (June 18th) ± 8.8 for the upstream migration and 175 (June 24th) ± 9.3 for the downstream migration. This 1-wk difference is significant on a paired t-test (t = 4.226, P = 0.001, n = 15).

In general, there was relatively little movement of lake chub in August and early September (top panel of Figure 2). Then, from mid-September to mid-November, high numbers of chub moved downstream and exited the brook (Figures 1 and 2). Hereafter, a distinction will be made between the "summer migration" (May-June-July) and the "fall migration" (August-September-October-November).

Figure 3 shows the body size of the lake chub captured for each year, while Figure 4 shows the 15-year average broken down by week. In most years (notable examples on Figure 3 are 1991, 1995, 2000 and 2003; the pattern is also evident on Figure 4), two size classes were present among the lake chub captured in summer. The larger size class, about 8-12 cm in fork length, started moving in late May - early June whereas the smaller size class, 6-8 cm, started moving in late June - early July. The summer growth of the *smaller* size class can be followed from both the upstream and downstream capture data (Figures 3 and 4). In some years the growth of the *larger* size class can also be followed, especially from the downstream capture data (e.g. 1994, 1996, 1999, 2003 on Figure 3; Figure 4). Summer growth is 0.8-1.0 cm per month. Allowing for this summer growth, the fall-moving lake chub appear to belong to the same size classes as the summer-moving ones. There is also some indication that a third size class, 6 cm or less, appears in the upstream movements in September (Figure 4).

Seasonal movements of white sucker

The overall migration pattern of white sucker was similar to that of lake chub, though the downstream movement in the fall did not occur in all years (Figure 5 and bottom panel of Figure 2). One difference regards the timing. Migration onset in the spring took place about one week earlier than for lake chub (mean Julian date ± SD for 10% of all upstream May-June-July captures was 149 (May 29th) ± 11.3 for white sucker and 158 (June 7th) ± 10.9 for lake chub; the difference is significant on a paired t-test: t = 3.672, P = 0.003, n = 15). As opposed to lake chub, there was no difference on average between the timing of the white sucker's upstream and downstream migrations (mean Julian date for 50% of all May-June-July captures was 167 (June 16th) ± 14.3 for upstream and 168 (June 17th) ± 10.4 for downstream; paired t = 0.137, P = 0.893, n = 15)

The summer upstream and downstream migrations involved one size class of white sucker around 35 cm in fork length, and at least one other size class of 20 cm or less (Figures 6 and 7). Some fish also moved in July and August, and at 10 cm or less they were smaller than the size classes that had entered the stream earlier in the summer (see for example the upstream data for 1991, 1993, 1994, and 1997 on Figure 6; and Figure 7). Owing to fewer captures, it is harder to follow summer growth for white sucker than it was for lake chub, but based on those years with the most sizable migrations (for example, downstream for 1995, 1996, 2003 and 2004 on Figure 6), and allowing for some summer growth, it appears that the autumn migrants belonged to the same small size class that had entered the stream in summer.

Effect of temperature on seasonal migration onset

Lake chub undertook their upstream summer migration once the daily minimum (night) and maximum (day) water temperatures in the stream reached 8 ºC and 18 ºC respectively. The migration was delayed on colder years. There was a significant inverse correlation between migration onset (taken as the Julian day on which 10% of the total May-June-July captures was reached) and water temperature (taken as the average daily minimum temperature of May – the correlations are also significant with *maximum* daily temperature taken as an indicator) for both the upstream migration ($r = -0.584$, $P = 0.022$, $n = 15$) and the downstream migration ($r = -0.703$, $P = 0.003$, $n = 15$) (top panels of Figure 8).

In general, white sucker began their upstream migration when water temperature reached a daily minimum (night) and maximum (day) of 6 ºC and 12 ºC respectively. However, migration onset was not as clearly tied to temperature as for lake chub, and on a yearly basis no significant correlation was detected between migration onset and water temperature (bottom panels of Figure 8; upstream migration: $r = -0.295$, $P = 0.285$, $n = 15$; downstream migration: $r = -0.074$, $P = 0.794$, $n = 15$).

Environmental correlates of daily movement

Figure 9 gives examples of the daily synchrony between rainfall amounts, water discharge, and downstream captures. Figure 10 shows that, on average, the largest captures of lake chub and white sucker were on days with 12.5-20.0 mm of rainfall, except for white sucker going downstream in the fall, when maximum captures occurred on days with 17.5-25.0 mm of rainfall, and except for lake chub going upstream in the summer, when large captures could happen on any day with rainfall amounts of 20.0 mm or less. The correlation coefficients between daily captures and daily rainfall amounts (up to a maximum of 20.0 mm), all years combined, are as follows. Chup going up in summer: $r = -0.034$, $P = 0.334$, $n = 796$; chub going down in summer: $r = 0.178$, $P < 0.001$, $n = 796$; chub going down in the fall: $r = 0.228$, $P < 0.001$, $n = 1113$; sucker going up in summer: $r = 0.084$, $P = 0.018$, $n = 796$; sucker going down in summer: $r = 0.122$, $P < 0.001$, $n = 796$; and sucker going down in the fall: $r = 0.190$, $P < 0.001$, $n = 1113$.

Yearly variation in fish numbers

Figure 11 shows the yearly totals of captures. On a yearly basis, no significant correlations were found between the number of lake chub and the number of white sucker *entering* the stream, be it with the numbers taken as totals or in summer and fall separately (Pearson's correlation analyses, all $P > 0.40$, all $n = 15$). In some years (e.g., 2003 and 2004 on Figure 11), upstream numbers were high for both lake chub and white sucker, but in other years (e.g., 1991 and 1992, 1995 and 1996) they were not.

There was, however, a trend towards a significant correlation between the yearly total numbers of lake chub and white sucker *exiting* the stream ($r = 0.492$, $P = 0.062$, $n = 15$), and there was a significant correlation between the yearly numbers of chub and sucker exiting the stream *in the fall* ($r = 0.535$, $P = 0.04$, $n = 15$).

No significant correlations were found between the yearly numbers of lake chub or white sucker moving in or out of the stream (taken either as yearly totals or in the summer and fall separately) and the various mean monthly water temperatures, water discharge, and precipitation levels, either occurring on that year and during the year prior (Pearson's correlation analyses, all $P > 0.05$, all $n = 15$).

In 14 out of 15 years, more lake chub were captured moving downstream than upstream; in only 9 out of 15 years was the same true of white sucker (Figure 11). Over the whole 15-year study period, 16313 lake chub were captured going downstream versus 4532 going upstream; the respective numbers for white sucker are 3031 and 2086.

DISCUSSION

Function of seasonal movements

It seems likely that lake chub and white sucker entered Catamaran Brook in June to spawn, similar to lake-dwelling populations which also move into streams in June for spawning (Scott and Crossman 1998). A spawning function for the summer migration, with lake chub usually moving one week later than white sucker, would be consistent with the observation by Johnston (1997) that young-of-the-year cyprinids, most likely the progeny of lake chub, usually drift downstream in early July in Catamaran Brook, and that young-of-the-year white sucker drift downstream in late June.

The provenance of these spawners cannot be ascertained at this point. The nearest lakes upstream on the Little Southwest Miramichi seem an unlikely source because of the distances involved (> 40 km), though some cyprinids are known to sometimes cover tens of kilometers in their migrations (e.g. Lucas and Batley 1996, Lucas and Baras 2001, Winter and Fredrich 2003). Another possibility is that the spawners spent the previous winter in the Little Southwest Miramichi River.

The lake chub and white sucker exiting the brook in summer may be spent spawners returning to the river, but confirmation of this will require dissection of the captured fish. As to the downstream movement in the fall – which is reported here for the first time for these species, as Montgomery et al. (1983) did not observe it at their site, and studies of lacustrine populations have not mentioned it (Brown et al 1970, Barton 1980, Scott and Crossman 1998) – it may involve spawners returning late to the deeper waters of the main river to seek winter refuge there. Some river-dwelling cyprinids are known to spend the whole summer in the fast-flowing tributaries into which they have moved during the spring for spawning, before exiting in the fall (Lucas and Baras 2001).

The lake chub data on Figures 1-4 are consistent with a scenario of an oldest age class of lake chub moving into the stream in June, probably to spawn, and then exiting for the most part, whereas a youngest age class moves into the stream in July, possibly to grow there, before exiting in the fall. Lake chub could be born in the stream in June, drift out of the stream as young-of-the-year in July, come back into the stream as 1 or 2-year-olds in July, grow there until the autumn when they exit again, then come back the next June to spawn as 2 or 3-year-olds, most of which would exit immediately though some of them might stay until the fall. This hypothetical scenario needs to be confirmed by further studies involving dissection of the fish captured at the fence.

Fish movements were relatively rare in August, yet they sometimes happened in sizable numbers (see for example 1992 and 1996 fo lake chub on Figure 1; 1991, 1993, 1994, 1995, 1999, and 2002 for white sucker on Figure 5). These fish may have been seeking the cooler waters of the stream at a time of warm temperatures in the river (an example of refuge migration). Records indicate that water temperatures usually peaked in late-July and early-August at Catamaran.

Migration onset

The absence of captures in the first few weeks of May gives confidence that the trap was installed early enough every year to record the beginning of all significant movements. Of course, fish movement under the ice or during snowmelt in April – when water levels are too high for the fence to be installed – cannot be entirely ruled out, but it seems unlikely that the fishes would undertake long-distance migrations at the low water temperatures and against the strong currents that prevail at that time, and that they would interrupt their movements in early May.

The inverse correlation between date of migration onset and water temperature, significant in the case of lake chub, is consistent with the notion that the migrations are for spawning, as the timing of spawning migration is commonly dependent on temperature in fish (see Lucas and Baras 2001 for a review). The water temperatures at which the fish initiated migration (daily minimum / maximum of 8 / 18 ºC for lake chub and 6 / 12 ºC for white sucker) are consistent with other observations reported by Scott and Crossman (1998) for these species in Canada. Peak migrations occurring in June are also consistent with the chronologies reported by Scott and Crossman (1998).

Daily movements

Probability of downstream captures increased on rainy days, up to a certain point (number of captures usually decreased during extreme daily precipitations of > 20 mm). Rainy days bring about increases in stream discharge. Higher stream discharge thus appears to be either stimulatory or permissive for lake chub movements, as is the case for many other species (see Lucas and Baras 2001 for a review). High discharge may facilitate passage over riffles. High discharge may also physically displace some fish downstream, though an inability to resist current would be surprising in the case of adults. Finally, high water levels may provide better protection against visual predators during migration, though migrating chub at Catamaran move predominantly at night (Reebs et al. 1995; see also Reichard et al. 2002) and presumably already benefit from the cover of darkness.

Yearly variations

The significant correlation between the numbers of lake chub and white sucker exiting the stream in the fall suggest a common factor underlying the productivity of the stream or the behaviour of the two species. However, none of the abiotic variables we measured was correlated with the yearly number of fish of either species. Future studies might look at winter and early spring conditions for more abiotic factors that could affect fish populations in this riverine system.

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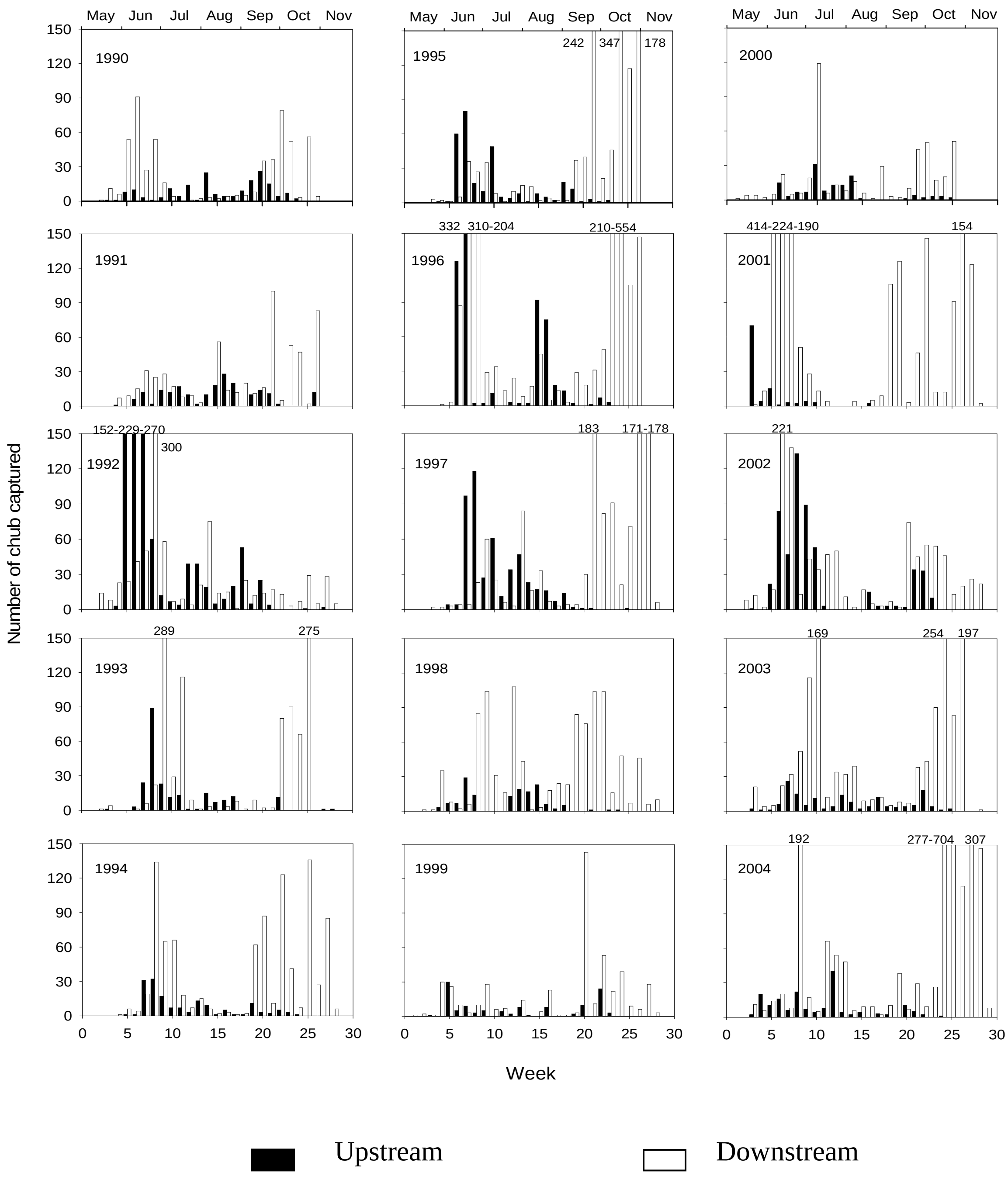

Figure 1. Weekly numbers of lake chub captured while going upstream (black bars) and downstream (open bars) at Catamaran Brook, 1990-2004. The time axis is in weeks at the bottom (Week 1 starts on May 1st) and corresponding months at the top.

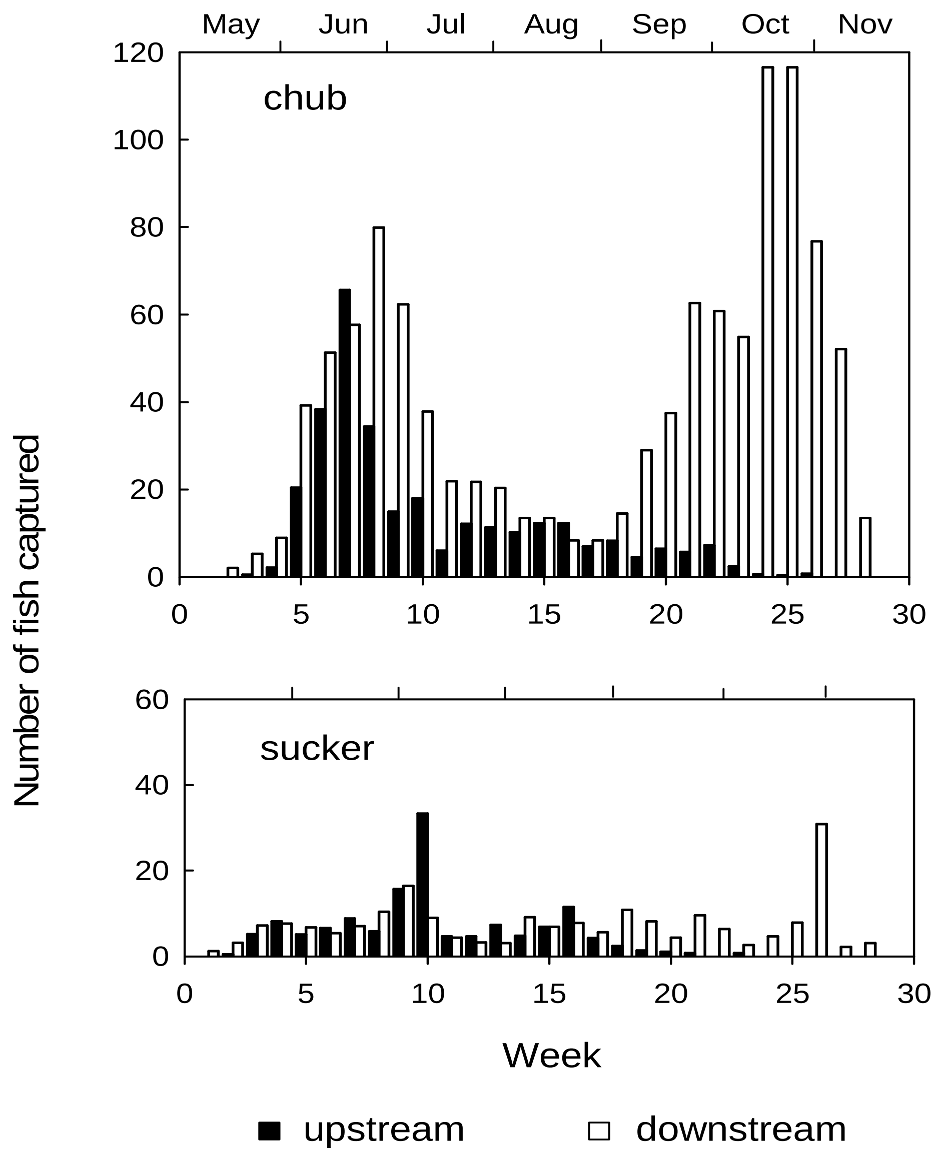

Figure 2. Weekly numbers of lake chub (top panel) and white sucker (bottom panel) captured while going upstream (black bars) or downstream (open bars) at Catamaran Brook, averaged over the years 1990-2004. Standard deviations are omitted for clarity.

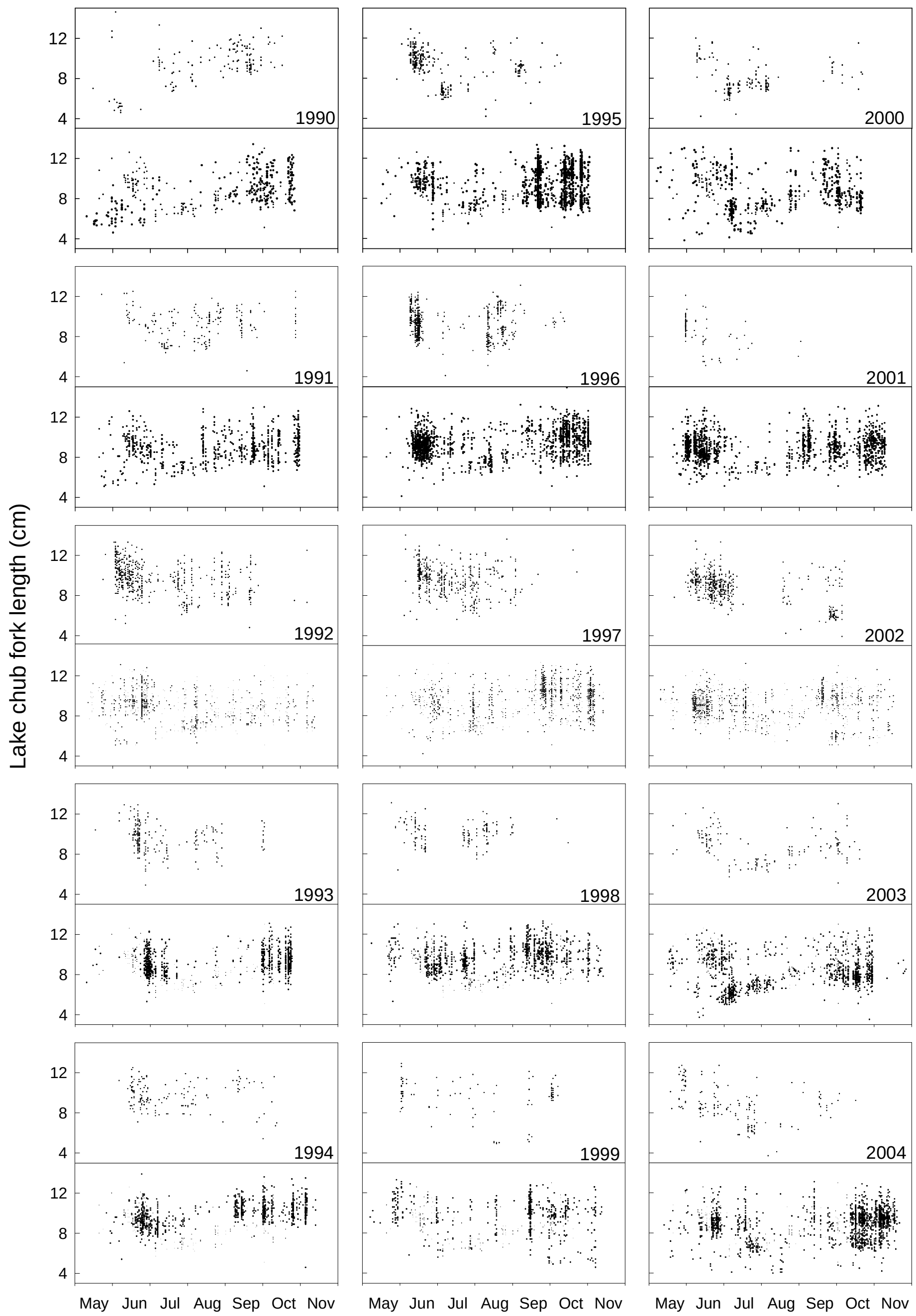

Figure 3. Fork lengths of lake chub intercepted daily by the counting fence at Catamaran Brook from early May to mid-November, 1990-2004. For each year the top panel shows the fish going upstream while the bottom panel shows the fish going downstream. Each data point is a single fish.

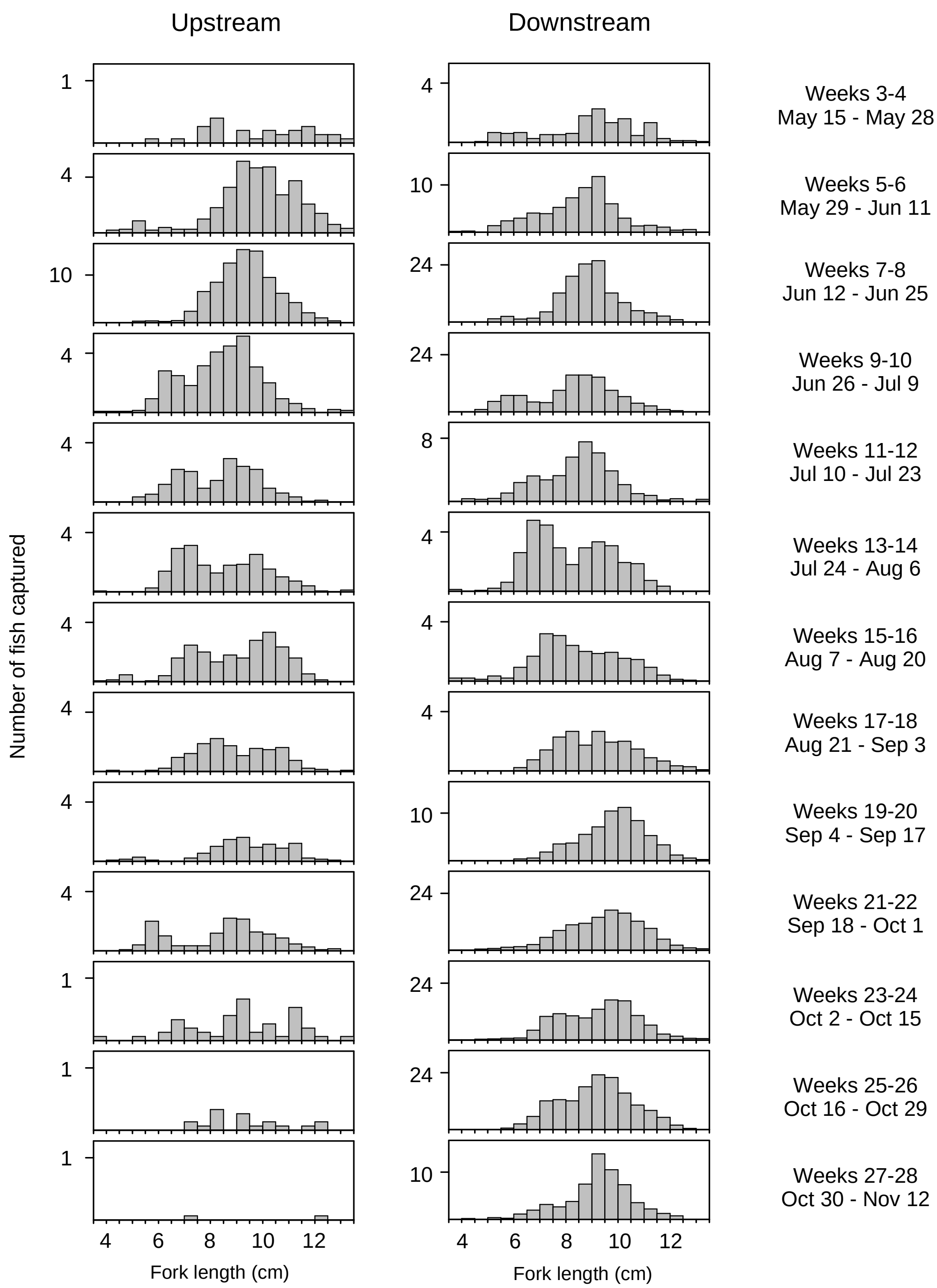

Figure 4. Frequency distributions of lake chub fork length, throughout the sampling season, averaged over 1990-2004. Standard deviations are omitted for clarity. Note that the y-axes are not all to the same scale.

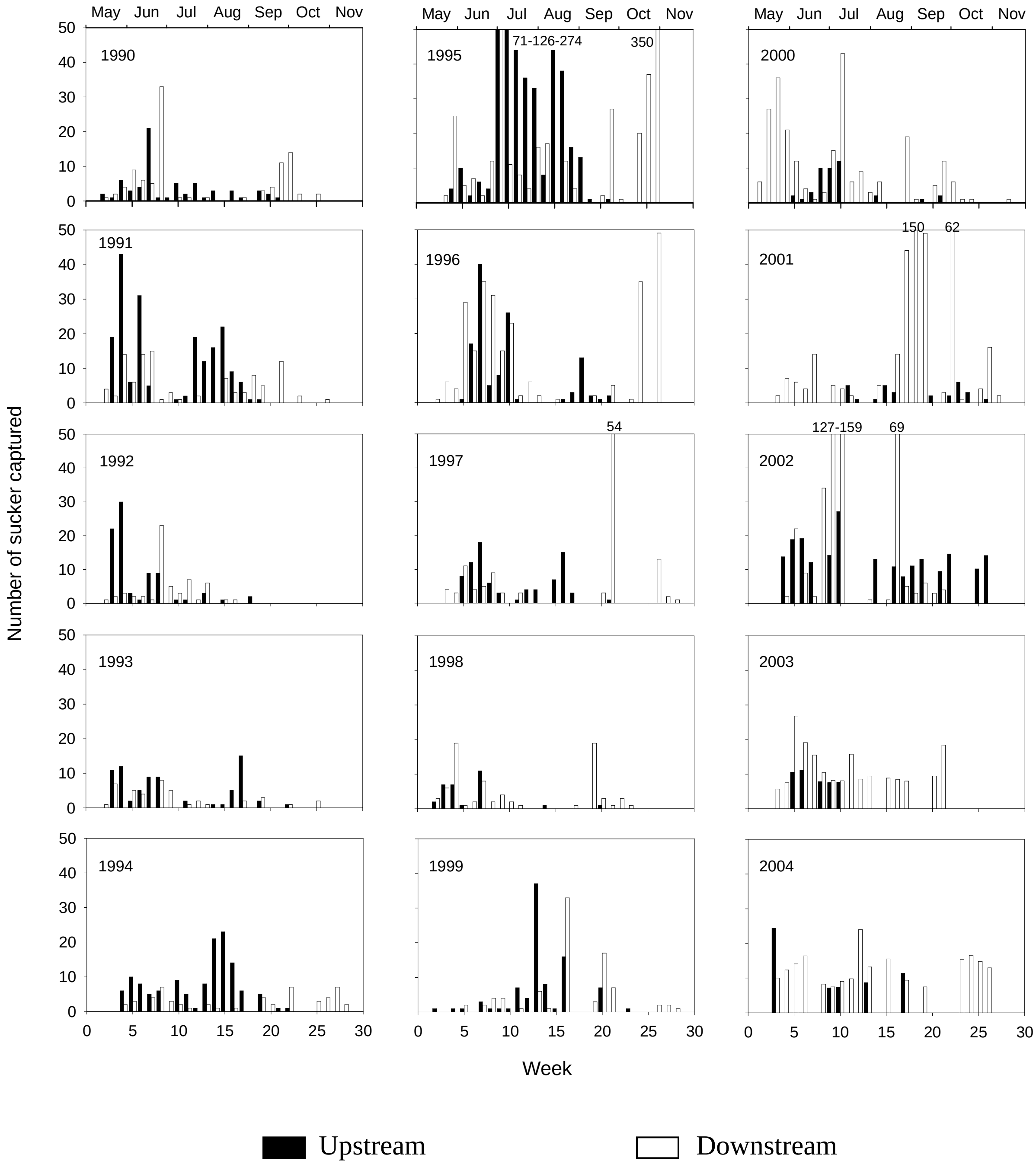

Figure 5. Weekly numbers of white sucker captured while going upstream (black bars) and downstream (open bars) at Catamaran Brook, 1990-2004. The time axis is in weeks at the bottom (Week 1 starts on May 1st) and corresponding months at the top.

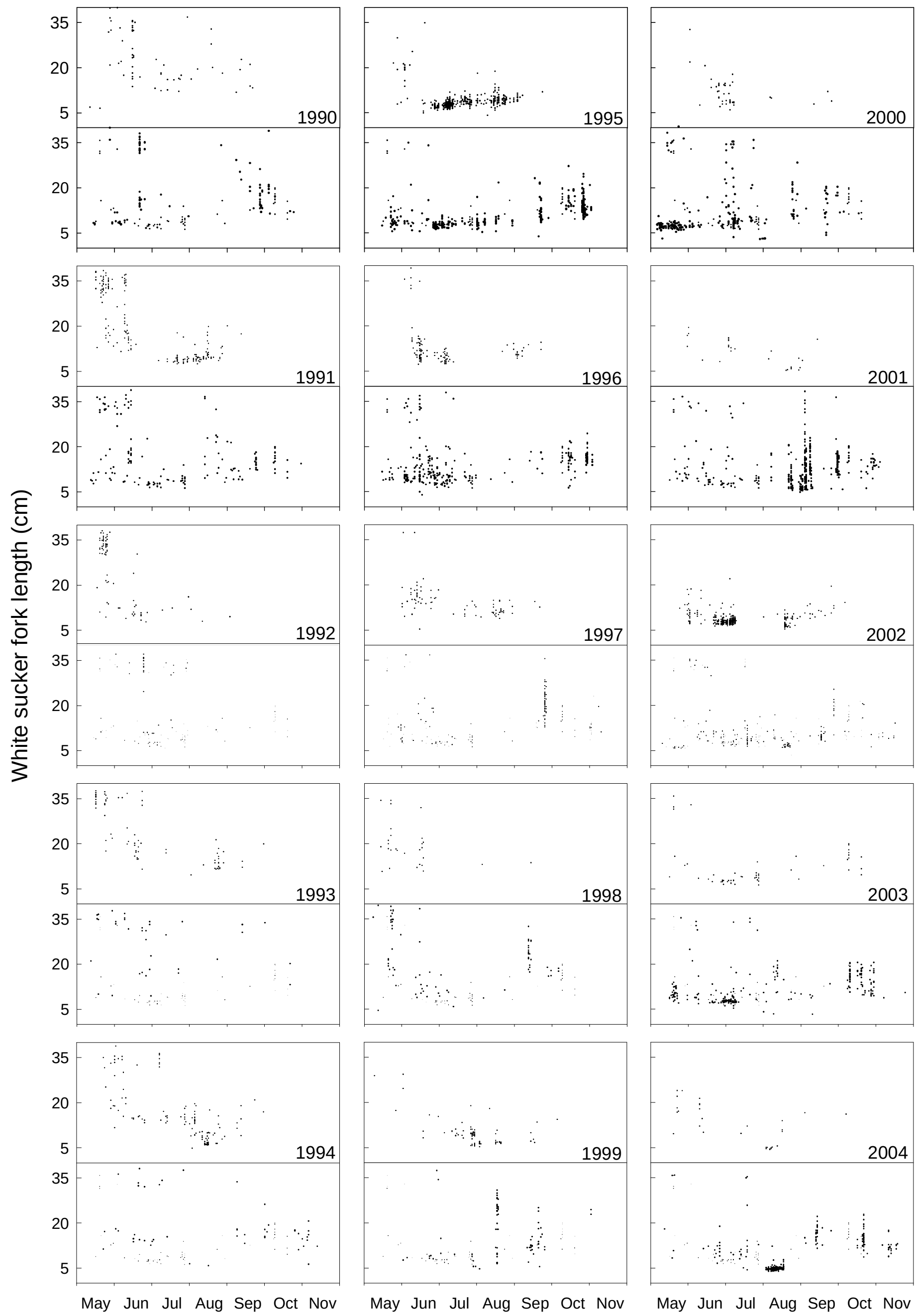

Figure 6. Fork lengths of white sucker intercepted daily by the counting fence at Catamaran Brook from early May to mid-November, 1990-2004. For each year the top panel shows the fish going upstream while the bottom panel shows the fish going downstream. Each data point is a single fish.

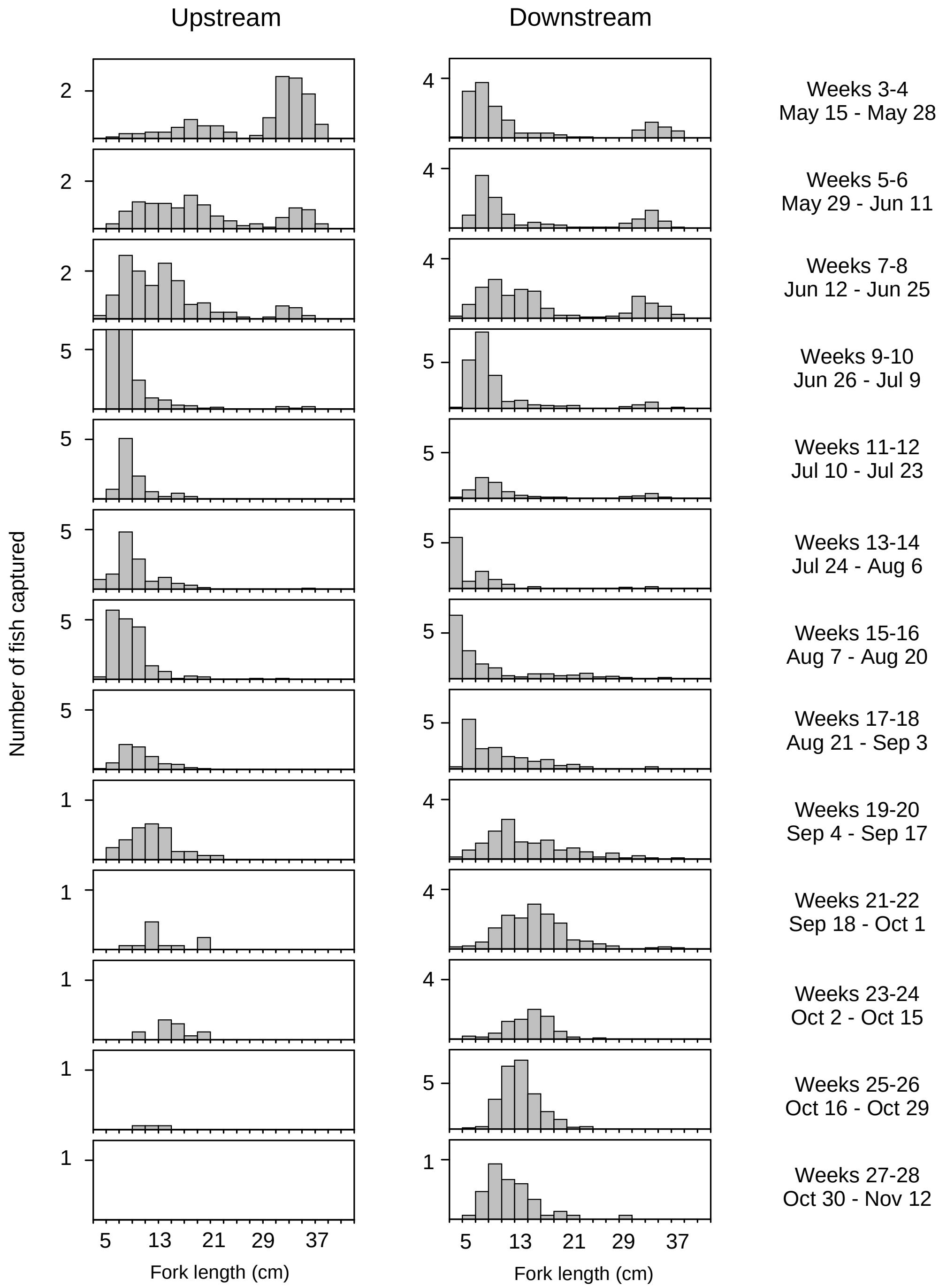

Figure 7. Frequency distributions of white sucker fork length, throughout the sampling season, averaged over 1990-2004. Standard deviations are omitted for clarity. Note that the y-axes are not all to the same scale.

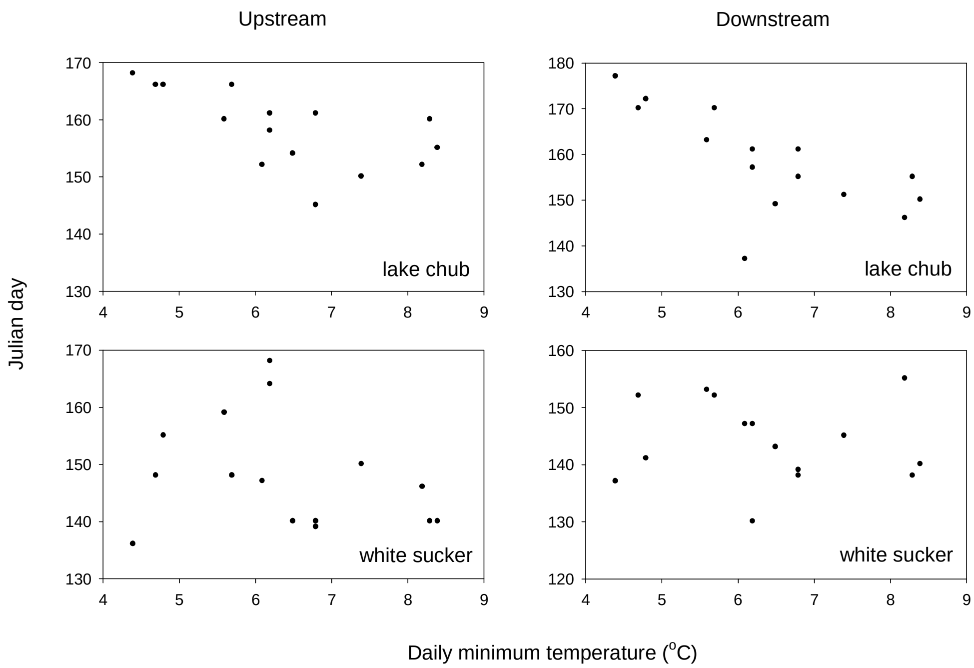

Figure 8. Correlations between yearly migration onset of lake chub and white sucker, taken as the Julian day on which 10% of the total May to July captures was reached for each species, and water temperature, taken as the May average of daily minimums, for 1990-2004.

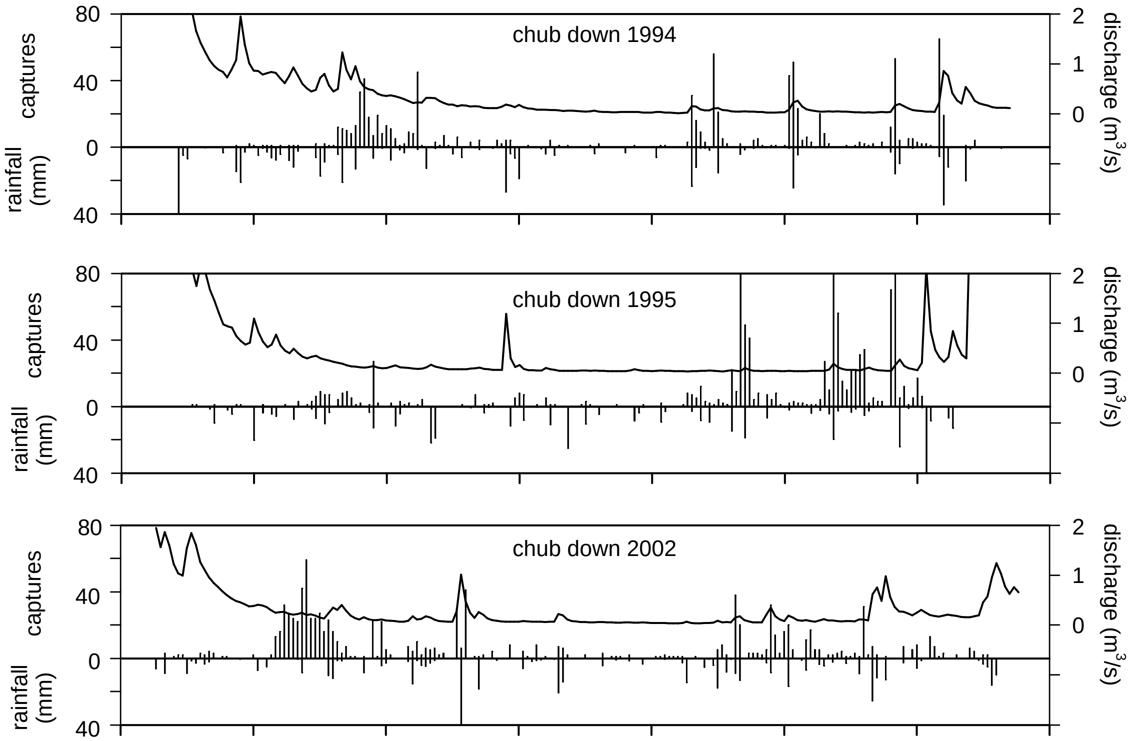

Figure 9. Some examples of the daily synchrony between fish downstream movements (up bars), precipitation (down bars) and water discharge (line) at Catamaran Brook.

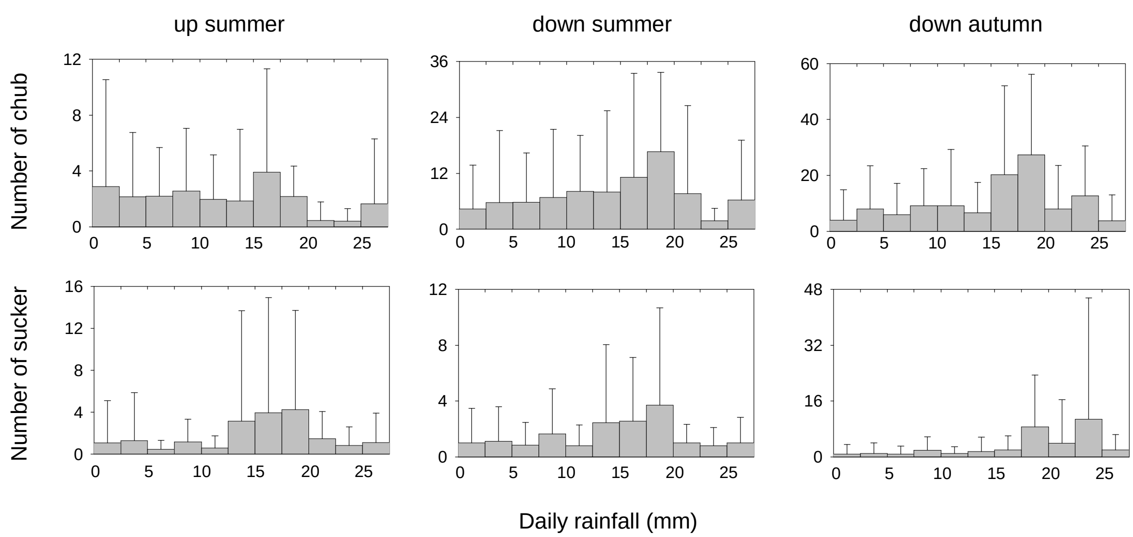

Figure 10. Mean number (± SD) of fish captured at Catamaran Brook, 1990-2004, on days varying by the amount of rainfall. The rightmost bar on each panel is for all rainfalls of more than 25 mm.

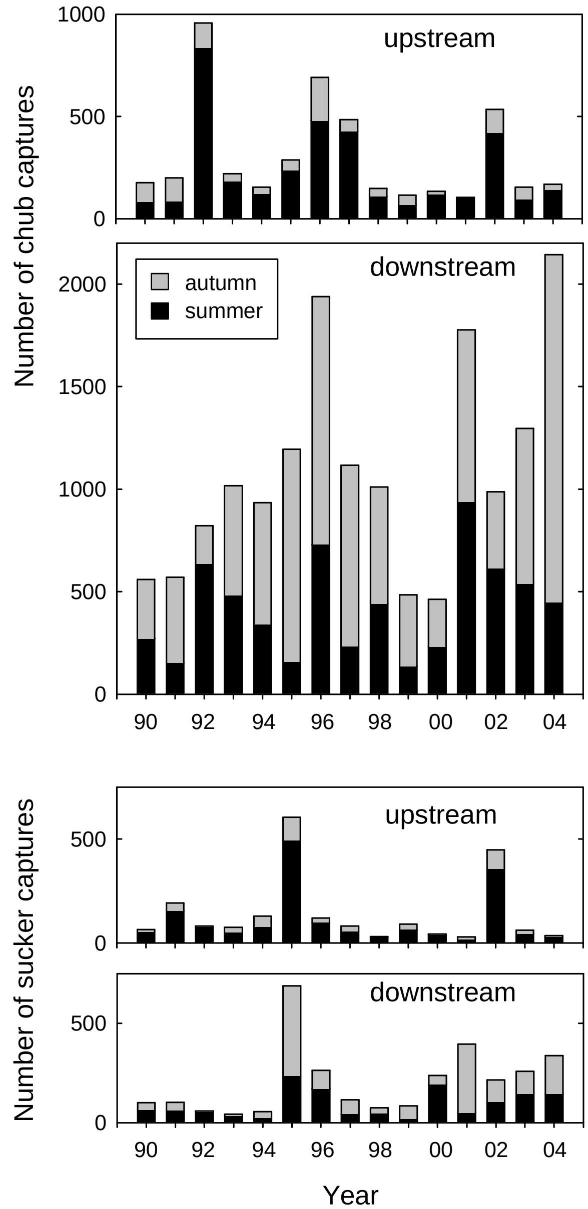

Figure 11. Yearly numbers of lake chub and white sucker captured at Catamaran Brook while moving upstream or downstream in May, June and July (summer) and August, September, October and November (autumn).