Capture and Husbandry of Juvenile (0-year) Atlantic Mackerel (*Scomber scombrus*)

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ABSTRACT

D'Amours, D. & J. Landry. 1989. Capture and husbandry of juvenile (0-year) Atlantic mackerel (Scomber scombrus). Can. Tech. Rep. Fish. Aquat. Sci. 1679:vi + 11 p.

Juvenile (0-year) Atlantic mackerel were captured in August 1988 in the Gulf of St-Lawrence. Early in the month, more fish were captured with a beach seine inside a semi-enclosed tidal pond than from a beach on the open ocean. Juvenile mackerel were also captured in open water with gill-nets later in the month. Some fish were kept alive in a holding tank for at least a month, and fed chopped fish at a rate of ca. 24% wet body weight/day; the gross efficiency (mass gained/mass consumed) was 31.6%. The captive fish grew from means of 95 mm and 8 g on August 14, to 144 mm and 29 g on September 4 (fork length and wet body weight, respectively). Quinaldine sulfate was an effective sedative at a concentration of 3 p.p.m. Fish preserved in anhydrous alcohol shrank by 3.9% and lost 19% of their wet weight. The condition factor was higher for the detained than for the wild fish, but lengths were similar at corresponding dates. A one-cycle Gompertz curve was fitted to the length data of the captive fish and the parameters were: L_∞=186 mm, K=0.053, and t_o(julian day)= 220 (August 7). From extrapolation on the growth curve of the captive fish, date at hatching length was July 11. Given the water temperature prevailing near this date, spawning had occured 9 days earlier on July 2. Juvenile Atlantic mackerel grow rapidly, are easily caught with simple fishing gears, and support detention well at least up to a length of 145 mm: they are an ideal species for testing various growth related hypotheses.

RÉSUMÉ

D'Amours, D. & J. Landry. 1989. Capture and husbandry of juvenile (0-year) Atlantic mackerel (Scomber scombrus). Can. Tech. Rep. Fish. Aquat. Sci. 1679:vi + 11 p.

Des juvéniles de maquereau bleu ont été capturés en août 1988 dans le Golfe du Saint-Laurent. Au début du mois et avec une seine de plage, plus de poissons ont été capturés à l'intérieur d'un chenal semi-fermé qu'à partir d'une plage de sable directement ouverte sur la mer. Des juvéniles ont également été capturés à l'aide de filets maillants en pleine eau à la fin du mois. Plusieurs juvéniles ont été maintenus vivants pendant au moins un mois; les poissons captifs ont été nourris de poissons émincés au rythme de ca. 24% de leur poids corporel humide par jour; le taux de conversion (masse consommée/masse gagnée) a été de 31.6%. Les poissons captifs ont grandi de 95 mm et 8 g au 14 août, à 144 mm et 29 g au 4 septembre (longueur standard moyenne et poids moyen humide, respectivement). Le sulfate de quinaldine a été utilisé comme sédatif à la concentration de 3 p.p.m. Les poissons préservés dans l'alcool anhydre ont perdu 3.9% de leur longueur et 19% de leur poids corporel. Le facteur de condition était plus élevé chez les poissons captifs que chez les poissons du milieu naturel; par contre, à date correspondante, les longueurs n'étaient pas significativement différentes. Une courbe de Gompertz à un cycle a été ajustée sur les données de taille des poissons captifs avec les paramètres L_∞= 186 mm, K= 0.053, et t_o (jour julien)= 220 (7 août). Selon cette courbe, la taille à l'éclosion aurait été atteinte le 11 juillet; considérant la température de l'eau à ce moment, la ponte aurait eu lieu neuf jours plus tôt, soit le 2 juillet. Les juvéniles de maquereau bleu croissent rapidement, peuvent être capturés avec de l'équipement simple, et supportent bien la captivité au moins jusqu'à la taille de 145 mm: ils sont une espèce idéale pour tester certaines hypothèses concernant le rythme de croissance chez les jeunes poissons.

INTRODUCTION

The success of recruitment of fish is considered to be determined over all their life stages (Rothschild 1986). However, the juveniles are often little studied compared to the larvae or the adults (Sissenwine 1984). This prevalence of the extremities of the life cycle as the focus of investigation is marked in the case of Atlantic mackerel (Scomber scombrus). While various detailed studies exist on the larval (e.g. Grave 1981; Peterson & Ausubel 1984) and adult (e.g. Ware 1977; Morse 1980) stages, the available information on the juveniles is somewhat sketchy (e.g. Sette 1950; Ware & Lambert 1985). This lack of basic information on the juvenile stage of Atlantic mackerel is partly due to difficulties in capturing the fish (MacKay 1979). In this report, we present the results of a field study on the distribution of juvenile (0-year) Atlantic mackerel in a coastal environment. The purposes of the study were to document the use of near-shore habitat by 0-year fish, and to establish appropriate collection, sedation, and nursing techniques. Lastly, the growth of wild and captive fish are compared.

METHODS AND STUDY SITE

The study was carried out in the Gulf of St-Lawrence during August 1988. Juvenile mackerel were captured with a beach seine at stations O, S, and B (Fig. 1). The wings of the beach seine were each 22 m long, with depth increasing from 1.2 m at the tip to 3.6 near the bunt, and 1.9 cm mesh; the centered bunt was 6 m long, 3.6 m deep, with 1.2 cm mesh. The seine was set with a motorized boat and retreived with 25 m lines at station O, and set by foot at stations S & B. Juvenile mackerel were also captured with gill-nets at station F (Fig. 1). A set consisted of three nets, each 20 m long and 2 m deep, with 2.5 cm multi-filament mesh. The nets were tied end to end, and set near the surface. Stations S & B were located inside Shippegan channel, at the edge of a broad Zostera sp. meadow. Station S was inside a tidal pond, with ca. 2 m of water at high tide, while station B was near a bridge inside the 4 m deep basin of an abandoned marine lift. Station O was located on a sand spit in the surf zone, while station F was located 0.6 km offshore. Some of the fish captured with the beach seine were transferred by hand from the bunt to pails filled with surrounding water, and from there to a larger carrying tank also filled with surrounding water. The live fish were transported to the Aquarium and Marine Center in Shippegan (Fig. 1) and finally transferred to a 2000 l circular holding tank, with a continuous water flow (10 l/min). The tank was covered with a fine net to prevent the initially very active fish from leaping out. Water from the transport tank was gradually replaced with some from the holding tank until their difference in temperature was less than 1°C. Transportation of the fish from the fishing stations and acclimation to water of the holding tank, took ca. 1 hour. The captive mackerel were fed finely chopped juvenile Atlantic herring (Clupea harengus harengus); their daily ration of ca. 24% wet body weight/day was dispensed in three equal portions at 0800, 1600, and 2200 hours. From August 9 to 11, a total of 115 of the fish captured at stations S and B, were stocked in the holding tank.

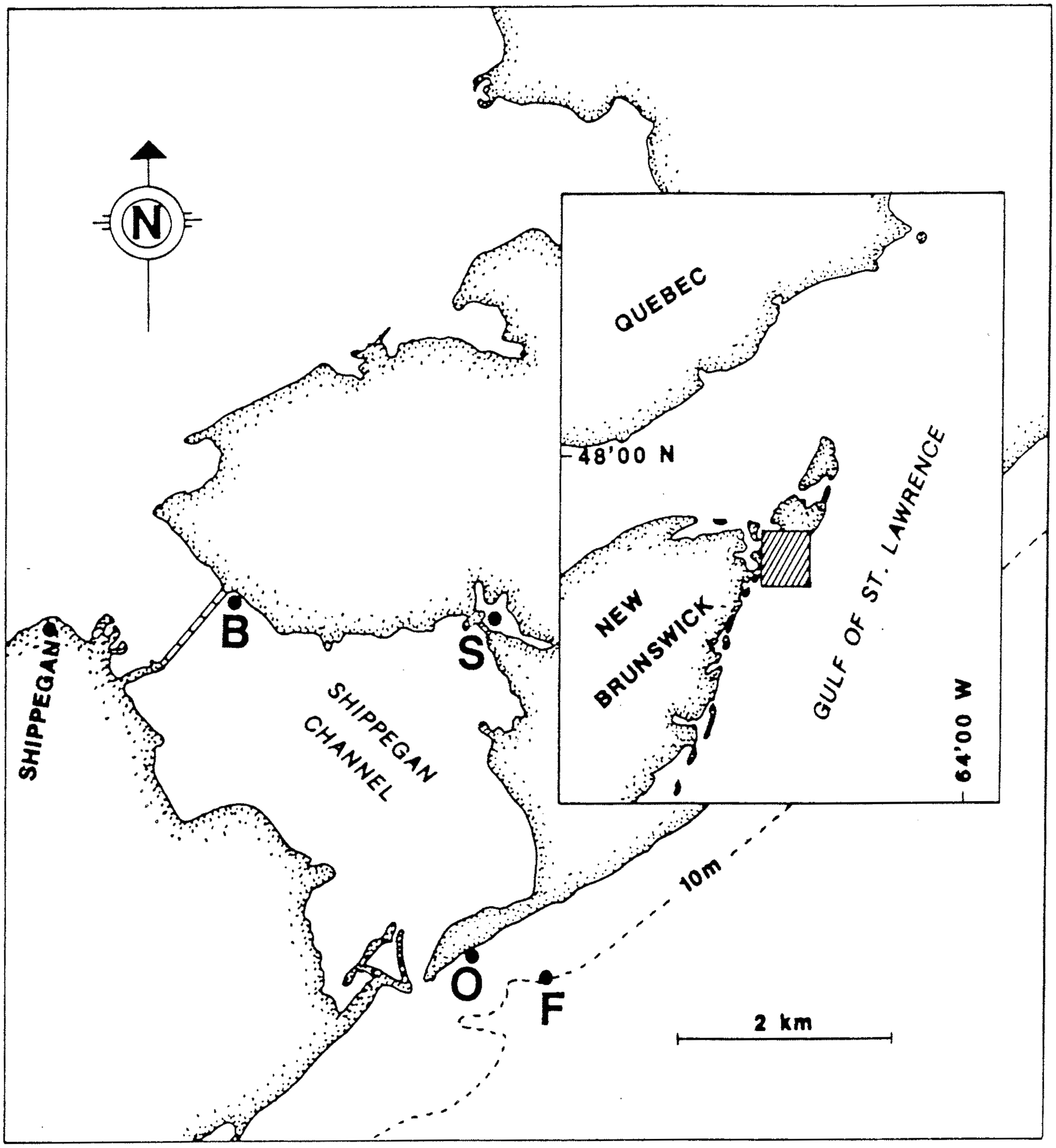

Figure 1. Location of fishing stations on study site. Dashed line indicates 10 m isobath.

The water temperature in the tank ranged from 20 °C on August 8 to 16 °C on September 4, with a constant salinity of 27 ‰. During the detention period, 69 fish were removed over eight sampling dates for other studies; weight and length data of captive fish were measured on those fish. A one-cycle Gompertz curve was fitted on the length data of the captive fish with secant method (Rolston & Jennrich 1978) on SAS PC™. The total gain in fish biomass in the tank was computed as:

$$G=(B_e-B_b) + \Sigma N_iW_i,$$

where G=gain in biomass, B= total biomass in tank (at end (e) and beginning (b) of experimental period), N=number of fish removed from tank (death or experimental) on day i, and W=mean individual weight of fish on day i (actual measurement or linear interpolation between consecutive measurements).

The effect on the fish of the sedative quinaldine sulfate (2-methylquinoline sulfate) (Blasiola 1977) was determined. A stock solution of the sedative was prepared by simple dilution in tap water at a concentration of 1 % w/w. Anhydrous ethanol was used to preserve the fish. On September 6, six fresh fish were measured and weighed (length: 142.3 ± 6.7 mm; weight: 26.32 ± 4.26 g) and preserved in alcohol. Seven days after preservation, the mean weight had stabilized at 21.32 ± 3.74 g, and the mean length, at 136.7 ± 6.9 mm. Correction factors of 23% and 4% were used to transform preserved weight and length data respectively.

Length measurements represent fork lengths, and variables are expressed as means ± 2 S.E. A condition factor was computed as weight(g) / length(cm)^3 X 1000. Variable means were compared with two-tailed t-tests with α=0.05, except when stated otherwise.

RESULTS

Capture and Size of Wild Juvenile Mackerel

Juvenile mackerel were caught at the various fishing stations from August 7 to 31 (Table 1). In early August, most of the captures were made inside Shippegan Channel at stations S and B. At noon on August 7, ca. 200 juvenile mackerel were observed at the mouth of a culvert pipe connecting a boggy tidal pond to Shippegan channel (Station S, Fig. 1) Until August 16, the water temperature at this station ranged from 22 to 26 °C, with a constant salinity of 22 ‰. Three beach seine sets on the pond side of the culvert yielded 10, 7, and 115 juvenile mackerel respectively (length: 80 ± 2.4 cm; weight: 3.7 ± 0.33 g). Due to the strong tidal current and the rocky bottom, it was difficult to set the seine in a standard manner; this difficulty is likely to be responsible for the great variability in catches. On August 8, at 2100 hours, a beach seine set at station B yielded an estimated 20,000 juvenile herring. As much as 75% of the fish had been released when it was realized that juvenile mackerel were also present in the catch; 32 juvenile mackerel (length:86 ± 3.3 mm; weight: 5.1 ± 0.61 g) were identified in the remainder of the haul.

Table 1. Number of juvenile mackerel (N) caught and number of beach seine sets (Set) at the fishing stations during summer 1988; mean length (L) (mm) and weight (W) (g) of fish; n (number of specimens measured)=N, except when stated otherwise. Measurements on preserved specimens;size data transformed for effect of preservative.

Date	Station	Set	N	L(±2S.E.)	W(±2S.E.)	n
August						
6	O	12	1			
7	S	3	132	80(2.4)	3.7(0.33)	30
8	O	3	0			
8	B	1	32	86(3.3)	5.1(0.61)	
9	B	5	2			
9	S	3	36	(to tank)		
10	S	3	65	(to tank)		
11	B	2	14	(to tank)		
11	S	3	0			
15	S	3	1			
15	B	1	0			
16	B	6	7	105(6.9)	7.5(1.70)	
16	S	2	0			
18	B	2	0			
18	O	3	0			
19	B	2	0			
22	O	5	0			
23	O	5	4	96(5.8)	5.3(1.78)	
24	F	n.a.	1			
24	O	4	2			
24	B	2	0			
25	F	n.a.	0			
27	F	-	20	130(2.5)	15.4(1.26)	17
28	F	-	13	133(2.3)	15.1(0.66)	
29	F	-	1			
30	F	-	45	135(2.6)	17.3(1.08)	30
31	F	-	15	141(4.3)	20.1(1.80)	10
Sept.						
1,5,8	F	-	0,0,0			

Occasionally at station S, fishing was unsuccessful although several fish were observed, as on August 11. The fish were observed on the pond side of the culvert pipes, fighting the current at ebb tide; no fish were observed at other tide stages. The juvenile mackerel swam against the current and attacked drifting swarms of unidentified fish larvae; this predatory behaviour was observed repeatedly at station S.

Juvenile mackerel were regularly captured at stations S and B until August 16. After this date, not a single fish was sighted at station S, and only a few were caught at station B. At station O, on the open ocean, juvenile mackerel were captured throughout August, but in small amounts. The fish captured at station O on August 23 were smaller than those captured seven days earlier at station B (96 ± 5.8 mm versus 105 ± 6.9 mm). In late August, most of the captures were from station F in open water. The gill nets yielded a total of 95 juvenile mackerel between August 24 and 31 (length=141.3 ± 4.3 mm, weight= 20.1 ± 1.80 g, on August 31). Subsequent fishing at station F in early September was unsuccessful. The condition factor of the wild fish ranged from 7.6 ± 0.2 on August 8, to 7.0 ± 1.8 on August 30 (Table 2).

Feeding and Growth of Captive Juvenile Mackerel

Over the detention period, the juvenile mackerel consumed a total of 5888 g of finely chopped herring in daily rations of ca. 280 g. Pieces of food that reached the bottom of the tank were wasted; their dispensing rate had to be adjusted accordingly to ensure that dispensed food was consumed. With the growth of the fish and the gradual removal of individuals (experimental and death), this daily ration amounted to 24 ± 2.5% of the total wet biomass of fish in the tank. The total gain in fish biomass in the tank and the total amount of food dispensed from August 14 to September 4 were 1828 g and 5287 g respectively, for a gross efficiency of 31.6 % (1670 g/5287g). The fish were voracious, but only if the food was presented in small pieces (each piece not exceeding 3 to 5% of a fish body weight).

The captive fish grew from length and weight of 95 ± 4.7 mm and 8.1 ± 1.6 g on August 14, to 144 ± 12.9 mm and 29.3 ± 7.8 g on September 4 (Table 3). The parameters of a one-cycle Gompertz growth curve were: L_∞= 186 ± 85 mm, K=0.053 ± 0.060, and t_o (inflection point)= 220 ± 5 julian days. The condition factor of the captive fish ranged from 9.2 ± 0.6 on August 14, to a high of 10.4 ± 0.8 on September 1 (Table 2). Eleven fish died between August 10 and 13, likely because of injuries caused during a manipulation required for a parallel experiment; 7 fish died in early September, probably because of the removal technique (see below).

Sedation of Juvenile Mackerel

On August 16, eight juvenile mackerel (mean length: 104 mm) were captured at station B and maintained alive in a separate holding tank. The following day, the fish were exposed to various concentrations of quinaldine sulfate, at a water

Table 2. Mean condition factor (C.F.) (weight (g)/length(cm)^3 X 1000) of wild and captive juvenile mackerel during August 1988.

Date	C.F.(±2S.E.) Wild	C.F.(±2S.E.) Captive
August		
8	7.6(0.2)	
14		9.2(0.6)
22,23,24	6.3(0.5)	
23		9.8(0.9)
29		10.0(0.4)
30	7.0(1.8)	
Sept.		
1		10.4(0.8)
4		9.1(0.5)

Table 3. Number of juvenile mackerel (N) in holding tank at end of each day during detention period; number of death (D), number of live fish removed from tank (R), and amount of food (F) given, per day, during detention period; mean length (L) (mm) and weight (W) (g) of fish (n=R). Size data from fresh specimens.

Date	N	D	R	F (g)	L(±2S.E.)	W(±2S.E.)
August						
10	110	5		78		
11	110			70		
12	106	4		243		
13	104	2		210		
14	98		6	215	95(4.7)	8.1(1.6)
15	98			220		
16	98			220		
17	92		6	220	104(9.6)	10.9(3.4)
18	92			227		
19	91	1		240		
20	83		8	270	112(5.3)	13.4(2.5)
21	83			270		
22	83			283		
23	75		8	291	117(11.7)	16.6(2.7)
24	75			281		
25	75			272		
26	65		10	281	126(6.3)	19.7(3.0)
27	65			279		
28	65			279		
29	55		10	283	142(7.8)	28.9(4.0)
30	54	1		282		
31	54			288		
Sept.						
1	42	1	11	281	145(9.1)	34.0(7.8)
2	41	1		115		
3	39	2		140		
4	26	3	10	50	144(12.9)	29.3(7.8)

temperature of 19 °C. At a concentration of 1 p.p.m., a dip-net was easily avoided, and the fish remained in a school. At a concentration of 2 p.p.m., the dip-net was still avoided, but the fish could be captured with a sweep. At a concentration of 3 p.p.m., the fish occasionally brushed the side of the tank and the school would dissociate at times; their cruising speed increased, and the fish would swim directly in an interposed dip-net. At 4 p.p.m., the school dissociated, some fish would swim on their side, and many would collide head first with the side of the tank; many fish swam frantically up or down, and then sank passively to the bottom, from where they could be captured by hand. After transfer to untreated water, the fish regained their normal swimming behavior and their ability to avoid the dip-net within minutes. On September 6, the sedation was repeated on 25 fish with a mean length of 138 mm; again, 3 p.p.m. was determined as the ideal concentration of quinaldine sulfate for sedating the fish.

DISCUSSION

In early August, more fish were caught with a beach seine inside Shippegan channel than from a sand spit on the open ocean. This could be caused by the greater difficulty of seining the fish from an open beach in the surf zone compared to seining them in a nearly enclosed small body of water. Although the capture data cannot be interpreted as indicative of a preference of the fish for the inner water, they nonetheless indicate that sheltered and reticulated bodies of water such as Shippegan channel, with rich Zostera sp. meadows, could be an integral part of the habitat of the fish. Also, the presence of juvenile mackerel in sheltered nearshore water makes the fish readily available for experimental purposes with simple and inexpensive equipment.

In late August, fishing inside Shippegan channel was unsuccessful; at the same time, several fish were caught at offshore station F. Since fishing was only started at station F in late August, the presence of fish there can not be interpreted as a displacement of the fish from inside the channel. However, the abrupt drop in capture at station F in early September, and the earlier drop in capture and sightings inside the channel, suggest that the juvenile fish had initiated their offshore migration sometime between mid-August and early September.

The mean length of the wild and captive fish proved to be similar at corresponding dates, with the exception of the fish from station O. On August 16, the length of the wild fish from station B was not significantly different from that of the captive fish on August 17. On August 23, the length of the wild fish from station O was significantly smaller than that of the captive fish on the same day, but on August 31, the mean length of the wild fish (from station F) was again not significantly different from that of the captive fish on the next day. At station B, the water body was closed by the beach seine, and no fish could have had an easier escape based on its size; at station F, entangling multifilament gill-nets were used, that were assumed to be non size-selective. At station 0, a sand spit on the open ocean, the seine may have been escaped with more ease by the larger fish, which could explain the drop in size observed in the third week of August. Then, the drop in mean size of the wild fish would not preclude using the Gompertz curve, computed with length data from captive fish, to determine the hatching date of the wild fish. The Gompertz curve indicates that the fish were 3 mm long (hatching length) on July 11. With a mean (top 10 m) water temperature of 10 °C around Miscou Island at that time (M. Castonguay, Department of Fisheries and Oceans, personal communication), the development time of the eggs would have been nine days (Worley 1938), which puts the spawning on July 2. With the same type of growth curve computed with length data from wild juvenile mackerel, Ware & Lambert (1985) calculated June 26 as the mean spawning date of the fish in southern Gulf of St-Lawrence, from 1973 to 1976. The computation of hatching date from growth curves could be useful for management purposes, specially if it were to involve the relatively simple follow up of the growth of a representative sample of the juvenile population each year. Before practical use, this method would need to be fully assessed with studies on the size distribution of juvenile mackerel and their vulnerability to various fishing gears, to determine if a "representative sample" of the juvenile population is easily obtainable. Sette's (1950) comment that little was known on the size distribution of juvenile mackerel is still valid today. It must also be noted that the 95% confidence intervals of the parameters of the Gompertz curve are broad (see results, above). This is likely because the length data were obtained only for the nearly linear growth segment. Further attempts at deriving a hatching date from a growth curve should involve specimens at both curving ends of the growth curve.

As for the growth in weight, it was somewhat higher for the detained than for the wild fish, judging on the condition factors. Significant differences were observed in the condition factor of the fish between the wild on August 8 and the captive on August 14; between the wild on August 22,23,24, and the captive on August 23; and (marginal difference, $0.1<p<0.05$) between the wild on August 30 and the captive on August 29. This indicates that the energy budgets of the wild and captive fish differed, likely because the ration of the captive fish (ca. 24% wet body weight/day) was higher than that of the wild.

It was difficult to remove fish from the holding tank in a non-selective manner. Initially, the fish were scooped out of the holding tank with a plastic pail, towards which the fish were attracted with food pieces. However, it became obvious that this technique favored the capture of the bigger fish, perhaps because of their higher voracity. To try to avoid this size-selection, removal of fish was attempted with a small hook. Many food pieces were dropped in the tank, one of which contained a tethered hook. This technique attracted fish of all size, but was rejected for causing apparently deadly injuries to those fish who would bite the hook and still manage to escape: the days following removal with hooks, several fish were found dead (as in early September, Table 3). Finally, the protective net covering the holding tank was used to remove the fish. The net was immersed during feeding, and used as a seine to trap the fish.

A concentration of quinaldine sulfate of 3 p.p.m. was ideal for capturing and handling the detained fish, as it induced a Stage I Plane 2 anaesthesia (after McFarland 1959, reported by Ross & Ross 1984). For sedation of adult Atlantic mackerel, Lambert (1982) used pure quinaldine dissolved in acetone. Because quinaldine sulfate is soluble in water, the problems of evaporation of acetone and condensation of quinaldine noted by Lambert (1982) were eliminated. There remains to be verified if quinaldine sulfate could be used routinely to remove fish from a holding tank in a non-selective manner without harming the fish.

Because of their growth rate, ease of capture, and sturdiness at least until a length of 145 mm, Atlantic mackerel are an ideal species for testing various growth related hypotheses at the juvenile stage. As discussed above on the growth, ration, and hatching date, much can be learned on the wild fish by studying captive fish. However, there remains to be determined if juvenile mackerel can support captivity above a length of 145 mm, or for more than a month. It is hoped that the techniques of capture and husbandry described in this report foster more work in that direction.

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REFERENCES

Blasiola, G.C. Jr. 1977. Quinaldine sulphate, a new anaesthetic formulation for tropical marine fishes. J. Fish Biol. 10:113-119.

Grave, H. 1981. Food and feeding of mackerel larvae and early juveniles in the North Sea. Rapp. P.-v. Réun. Cons. int. Explor. Mer 178:454-459.

Lambert, T.C. 1982. Techniques for the capture and handling of Atlantic mackerel with special reference to the use of quinaldine. Prog. Fish-Cult. 44:145-147.

Mac Kay, K.T. 1979. Synopsis of biological data of the northern population Atlantic mackerel (Scomber scombrus). Fish. Mar. Serv. Tech. Rep. No.885.

Morse, W.W. 1980. Spawning and fecundity of Atlantic mackerel, Scomber scombrus, in the middle Atlantic bight. Fish. Bull. 78:103- 108.

Peterson W.T. & S.J. Ausubel. 1984. Diets and selective feeding by larvae of Atlantic mackerel Scomber scombrus on zooplankton. Mar. Ecol. Prog. Ser. 17:65-75.

Rolston, M.L. & R.I. Jennrich. 1978. DUD, A derivative-free algorithm for non-linear least squares. Technometrics 1:7-14.

Ross, L.G. & B. Ross. 1984. Anaesthetic and sedative techniques for fish. Institute of Aquaculture, University of Stirling, Scotland.

Rothschild, B.J. 1986. Dynamics of fish populations. Harvard University Press, Cambridge.

Sette, O.E. 1950. Biology of Atlantic mackerel (Scomber scombrus)of North America. Part II. Migrations and habits. U.S. Fish Wildl. Serv., Fish. Bull. 51:249-358.

Sissenwine, M.P. 1984. Why do fish population vary? Pages 245-262 in R.M. May, editor. Exploitation of marine communities, Dahlem Konferenzen 1984. Springer Verlag, Berlin.

Ware, D.M. 1977. Spawning time and egg size of Atlantic mackerel, Scomber scombrus, in relation to the plankton. J. Fish. Res. Board Can. 34:2308-2315.

Ware, D.M. & T.C. Lambert. 1985. Early life history of Atlantic mackerel (Scomber scombrus) in the Southern Gulf of St-Lawrence. Can. J. Fish. Aquat. Sci. 42:577-592.

Worley, L.G. 1938. Development of the egg of the mackerel at constant temperatures. J. Gen. Physiol. 16:841- 857.