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STOCKING OF SEA TROUT (*Salmo trutta m. trutta*) SMOLTS IN POLAND.

PART I. PRELIMINARY ANALYSIS OF TAGGING EXPERIMENTS

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A b s t r a c t. In 135 experiments 183,203 sea trout smolts were tagged and released into the Vistula River system, to the Pomeranian rivers, and to the Bay of Gdańsk in 1961 through 1986. The average result was 127.3 kg of recaptured fish per 1000 of released smolts and the range was from 0 to 1116 kg. The most successful was stocking the sea (mean 251.8 kg), less tagged fish were recaptured from those released into the Vistula system (120.8 kg), and liberating smolts into the Pomeranian rivers appeared to be the least effective (55.9 kg per 1000 smolts). High correlation between recaptures in successive years following release suggests that a short period after stocking determined the overall effects.

Key words: RECAPTURE RATES, YEARS OF CAPTURE, PLACE OF RELEASE

INTRODUCTION

Pollution and dam construction have considerably limited reproduction of salmonid migratory fishes in the Vistula River system. The Atlantic salmon vanished already in the nineteen fifties (Łysak and Bieniarz 1975) and the access of the sea trout to its subcarpathian spawning grounds became impossible owing to the dam at Włocławek (Wiśniewolski 1987). Sea trout populations still exist in most of Pomeranian rivers (Bartel 1988c), however, their spawning grounds are small and shrinking. Contemporary natural smolt production in all Polish rivers can be estimated at 100 thousand fish (Bartel 1993). Such a state of affairs is not confined to Poland as it seems to be common to the whole Baltic Sea area (Christensen and Johansson 1975).

The primary measure for supporting or, most often, for sustaining the endangered sea trout populations is stocking. However, the capacity of rivers for freshwater stages is limited. On the other hand, the eutrophication of the Baltic Sea and the decreasing cod (a piscivore) population enhances feeding conditions for salmonid fishes in the Baltic (Chrzan 1979). It follows that the stage of smolt is the most suitable one for stocking (Backiel and Bartel 1967, Bartel 1988a) and such stocking has been done for a few decades past. Numbers of sea trout smolts released in Poland during the nineteen seventies and eighties ranged from 189 to 932 thousand per year (Bartel 1989) but their effects has not been assessed.

The basic method of assessing stocking effects is tagging. In the Baltic area numbers of tagged and released smolts of the Atlantic salmon and of the sea trout have oscillated between 150 and 200 thousand annually over the recent years (information from the research institutions of the Baltic states). In Poland this number has ranged from a few to over 10 thousand fish each year. This paper aims at an assessment of recaptures of the released tagged sea trout smolts in Poland over a 25 years period with respect to places of stocking and periods and localities of recapture.

MATERIAL AND METHODS

Data of 135 experiments of tagging and releasing sea trout smolts (total number = 183206 fish) performed by the Laboratory of River Fisheries in Gdańsk-Oliwa were used. The fish 1 to 3 years old had been released into various sites (Fig. 1) at divers periods ranging from the beginning of March to the end June in the years 1961 through 1986. A comprehensive list of the experiments is given in Dębowski and Bartel (this volume......).

In all the experiments celluloid tags were affixed just under the front of the dorsal fin by means of a monel or silver wire using a single needle, making a loop over the back.

Data on particular experiments consisted of: date and place of release, origin and place of rearing smolts, their number and mean length as well as information on recaptured specimens i.e. place and date, length and weight of fish.

The analysis of experiments was preceded by a preliminary evaluation and verification of data as follows.

1. Early recaptures in the rivers or just after the downstream migration in the sea i.e. before the end of July of the year of release or/and fish of length less than 350 mm or weighing less than 300 g were disregarded.
2. In many cases reported data on length, weight and date of recapture were incompatible, i.e. length did not conform with weight or with the period at large. Thus using all available data two relationships (curvilinear regressions) were computed: a) - length versus age (i.e. time at large, Fig. 2); there were 8 such relationships for 8 groups of experiments depending on the origin and place of release; b) weight versus

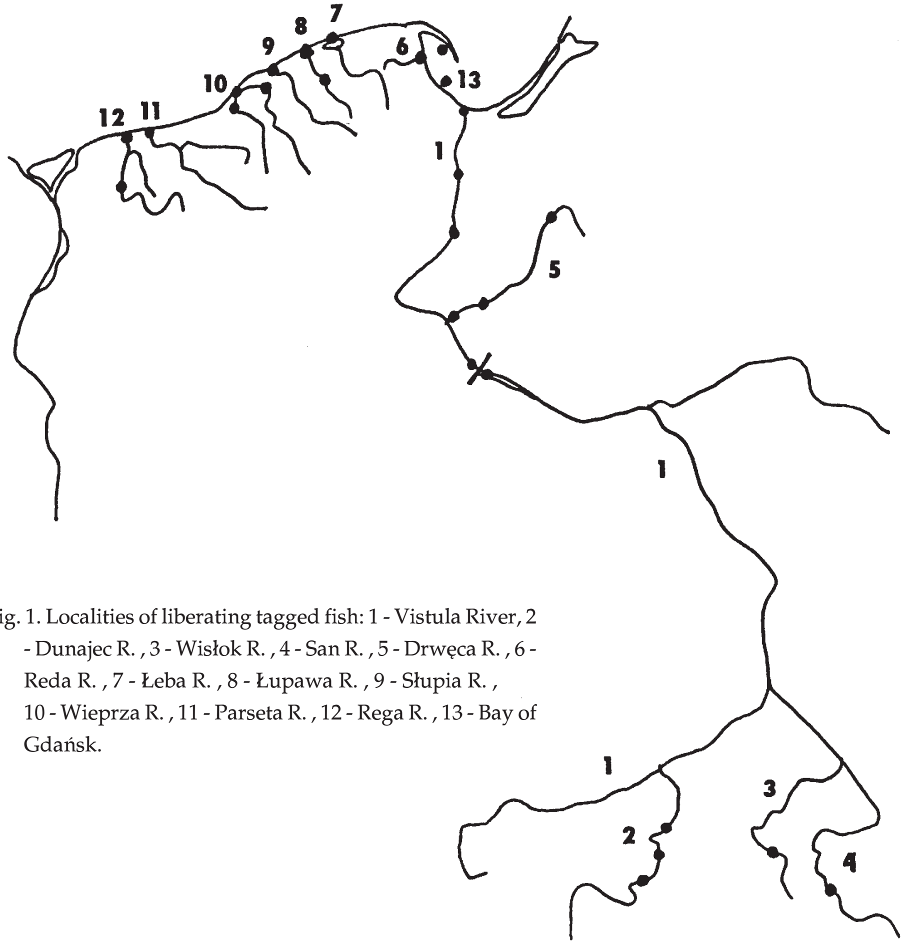

Fig. 1. Localities of liberating tagged fish: 1 - Vistula River, 2 - Dunajec R. , 3 - Wisłok R. , 4 - San R. , 5 - Drwęca R. , 6 - Reda R. , 7 - Łeba R. , 8 - Łupawa R. , 9 - Słupia R. , 10 - Wieprza R. , 11 - Parseta R. , 12 - Rega R. , 13 - Bay of Gdańsk.

length (Fig.3). Data on every fish were checked against these relationships and 95 % prediction limits were used either to supplement missing or to replace outlying measurements. It was further assumed that the most dependable were data on the date of recapture, the least - on individual weight.

Three groups of experiments were distinguished: SEA - releases into the sea, WIS - releases into the Vistula River system, and POM - releases into the Pomeranian rivers. Within the last group four rivers (Łeba, Słupia, Wieprza, Reda) each with more than 6 experiments were treated separately.

Stocking the river mouths were treated as riverine, WIS and POM, respectively. This is a subjective allotment, particularly in case of Pomeranian rivers since such re-

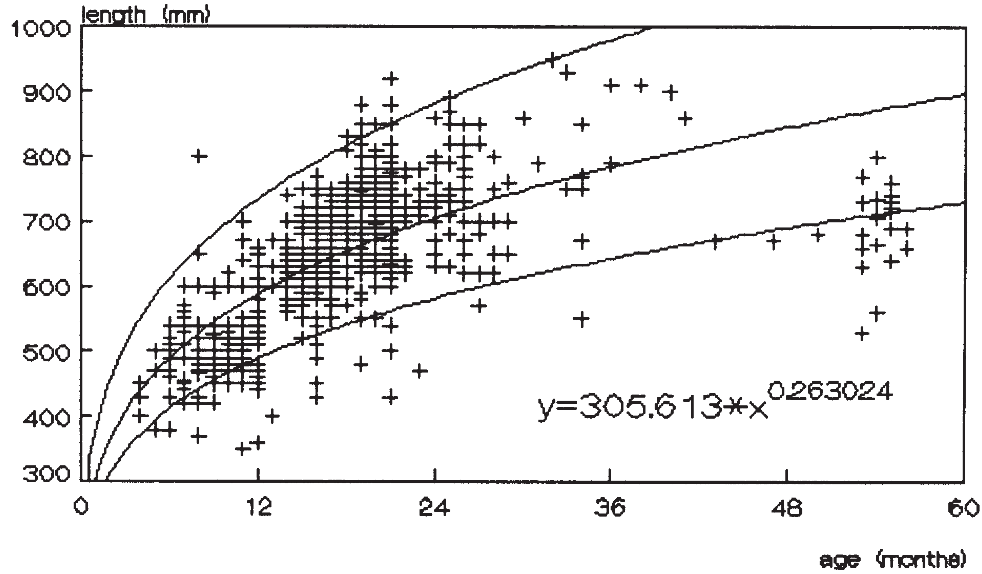

Fig. 2. Relationship between age (time at large) and length of recaptured sea trout released into the lower Vistula River with 95 % confidence limits.

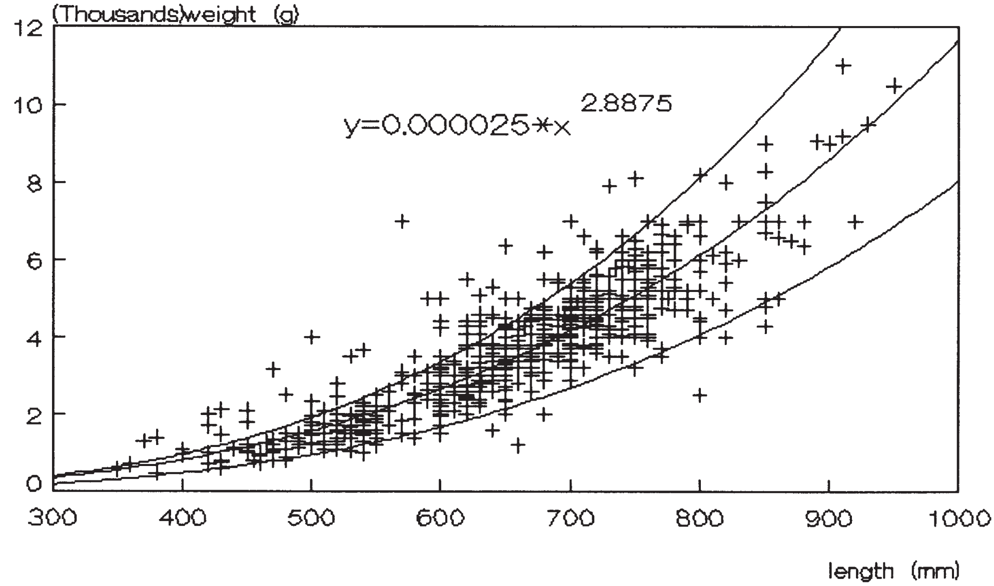

Fig. 3. Weight - length relationship of recaptured tagged sea trout.

TABLE 1

List of tag recovery indices

E0 - total weight of fish (kg) recaptured during the calendar year of release per 1000 of released smolts,
E1 - as above concerning the first year after release,
E2 - as above concerning the second year after release,
E3 - as above concerning the third and later years after release,
ET = E0 + E1 + E2 + E3,
EMT - as above concerning all fish recaptured in the sea,
ERT - as above concerning all fish recaptured in rivers,
WPR - percentage of early recaptures (relative to numbers of released smolts) i.e. of fish recovered until the end of July of the release year and/or fish not longer than 350 mm or not heavier than 300 g,
ZPR - procentage of late recaptures i.e. of all other fish.

leases could be included into the SEA group. Thus, the latter includes places of release which were not immediately affected by river waters.

Results of the experiments were described by means of efficiency indices being weights (kg) of recaptured fish per 1000 released smolts (Table 1). Percent of early (WPR) and late recaptures (ZPR) were also calculated (Table 1). Fish recaptured in river mouths, in lakes and in lagoons (firths) were included among river catches what is a certain simplification as in the case of smolt release places. This concerns Vistula River mouth where drifting nets were used. Similar fishing was carried out in the Vistula water stream flowing in the Bay of Gdańsk for some distance. Fish captured in these areas were counted among river catches.

RESULTS

The mean total efficiency (ET) for all experiments amounted to 127.3 kg/1000 smolt (Table 2). Efficiencies in groups of release areas i.e. Vistula system (WIS), Pomeranian rivers (POM) and the sea (SEA), were significantly different with respect to all efficiency indices (Table 2); the most effective appeared the stocking of the sea (251.8), next was the Vistula system (120 kg), and the least effective was the release into the Pomeranian rivers (55.9 kg). Also different were these indices for particular Pomeranian rivers (Table 2).

Ranges of particular indices appeared very wide, maximum values being several times greater than averages. Even in the Pomeranian group of the lowest efficiency there were experiments showing greater indices than averages for the sea stocking.

TABLE 2

Tag recovery indices.

I	ALL n=135 X (MIN MAX)	H	SEA n=30 X (MIN MAX)	WIS n=58 X (MIN MAX)	POM n=47 X (MIN MAX)	H	ŁEBA n=13 X (MIN MAX)	SŁUPIA n=9 X (MIN MAX)	WIEPRZA n=8 X (MIN MAX)	REDA n=7 X (MIN MAX)
E0	9.2 (0.0 121.0)	-	27.6 (0.0 121.0)	3.4 (0.0 22.6)	4.5 (0.0 50.8)	-	7.9 (0.0 50.8)	1.7 (0.0 5.4)	2.8 (0.0 18.6)	1.7 (0.0 6.1)
E1	52.6 (0.0 418.8)	-	107.1 (0.0 418.8)	41.5 (0.0 321.1)	31.6 (0.0 284.0)	-	67.2 (0.0 284.0)	8.6 (0.0 26.3)	16.4 (0.0 63.9)	22.1 (0.6 61.5)
E2	44.8 (0.0 724.4)	-	87.1 (0.0 524.4)	46.7 (0.0 724.4)	15.5 (0.0 141.6)	-	40.8 (2.8 141.6)	2.7 (0.0 10.1)	4.7 (0.0 20.0)	11.0 (3.2 19.0)
E3	20.8 (0.0 230.3)	-	30.0 (0.0 230.3)	29.3 (0.0 143.5)	4.4 (0.0 29.7)	-	8.6 (0.0 29.7)	0.8 (0.0 4.4)	1.6 (0.0 7.5)	5.0 (0.0 20.3
ET	127.3 (0.0 1116.0)	-	251.8 (0.0 1116.0)	120.8 (0.0 1018.8)	55.9 (0.0 476.5)	-	124.5 (3.3 476.5)	13.8 (0.0 43.1)	25.5 (0.0 105.0)	39.8 (11.6 106.9)
EMT	85.5 (0.0 1005.2)	-	214.0 (0.0 1005.2)	55.3 (0.0 581.8)	40.9 (0.0 409.1)	-	89.4 (1.5 409.1)	10.9 (0.0 38.3)	19.4 (0.0 82.5)	34.1 (11.6 104.5)
ERT	41.8 (0.0 437.0)	-	37.8 (0.0 330.1)	65.5 (0.0 437.0)	15.0 (0.0 100.9)	-	35.1 (0.0 100.9)	2.9 (0.0 8.5)	6.1 (0.0 22.5)	5.6 (0.0 11.3)
WPR	1.2 (0.0 14.0)	-	2.4 (0.0 7.5)	1.3 (0.0 14.0)	0.2 (0.0 1.5)		0.3 (0.0 0.7)	0.1 (0.0 0.4)	0.4 (0.0 1.5)	0.3 (0.0 0.6)
ZPR	4.5 (0.0 33.8	-	9.8 (0.0 33.8)	3.5 (0.0 25.7)	2.3 (0.0 22.1)	-	5.0 (0.1 22.1)	0.6 (0.0 2.0)	1.1 (0.0 4.8)	1.4 (0.4 3.7)

Legend: n - number of experiments, X - average, H - Kruskal-Wallis test for the hypothesis H0 that indices in all three groups are equal: „+" - H0 not rejected, „-" - H0 rejected at α=0.05. For indices see Table 1.

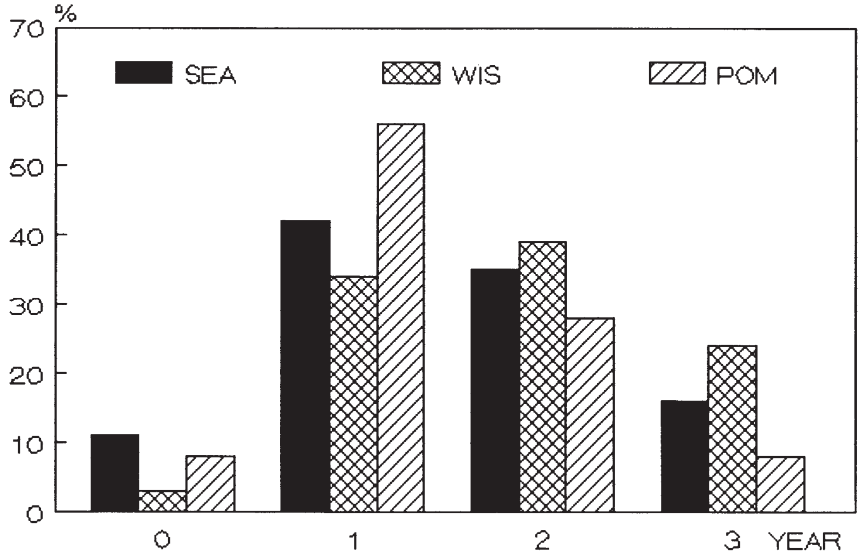

Fig. 4. Total weight of tagged sea trout recaptured during succeeding years after liberation.

Also recapture percentages (WPR and ZPR, Table 2) and the distribution of recaptures at subsequent years after release differed (Fig.4). In the stocking groups SEA and POM the largest catch (in terms of weight) concerned recoveries during the first year after release (E1). In the WIS group this maximum appeared in the second year (E2) although it was not much larger than the catch one year earlier.

The ratio of marine to riverain catches amounted in group SEA to 5.5, in group POM to 2.7, and in WIS to 0.9.

All indices are correlated with each other (Table 3). Correlations between early (WPR) and late recaptures (ZPR) demonstrate that the greatest mortality occurred just after stocking and that the numbers of early recaptures reflect the number of fish surviving this short period. This survival determines also recaptures during all subsequent years.

The ratio of early recoveries (in terms of numbers) to the total recaptures (i.e. WPR/(WPR+ZPR)) denotes the rate of the early recaptures until July of the releasing year. This ratio equalled 0.2, 0.27, and 0.06 in groups SEA, WIS and POM, respectively. It follows that the smolts released to the Vistula system were most exposed to fishing during the few first months at large, slightly less were those released to the sea and the least vulnerable were those stocked to Pomeranian rivers. However, it should

TABLE 3

Spearman's rank correlations between recovery indices.

		E1	E2	E3	WPR		ERT	ET	WPR	ZPR
ALL	E0	++	++	++	++	EMT	++	++	++	++
	E1	X	++	++	++	ERT	X	++	++	++
	E2		X	++	++	ET		X	++	++
	E3			X	++	WPR			X	++
	WPR				X	ZPR				X
SEA	E0		++		++	EMT	++	++	++	++
	E1	X	++	++	++	ERT	X	++		++
	E2		X	++		ET		X	++	++
	E3			X		WPR			X	++
	WPR				X	ZPR				X
POM	E0	++	++	++	++	EMT	++	++	++	++
	E1	X	++	++	++	ERT	X	++	++	++
	E2		X	++	++	ET		X	++	++
	E3			X		WPR			X	++
	WPR				X	ZPR				X
WIS	E0	++	++	++	++	EMT	++	++	++	++
	E1	X	++	++	++	ERT	X	++	++	++
	E2		X	++	++	ET		X	++	++
	E3			X	++	WPR			X	++
	WPR				X	ZPR				X

Legend: For indices see Table 1. „+" - positive correlation at α=0.05, „++" - at α=0.01

be noted that there were conspicuous differences between Pomeranian rivers and the ratio varied from 0.06 for Łeba to 0.27 for Wieprza River.

The highest total efficiency index (ET) and the highest percent of recaptured fish in the SEA group implies that releasing smolts directly into the sea results in their best survival.

DISCUSSION

Published estimates of stocking (strictly of tag recovery) efficiency varied greatly. With respect to the Vistula River they were: 353 kg (Backiel and Bartel 1967), 530 kg (Pałka 1977), from 18.8 to 115.5 kg per 1000 smolts (Bartel et al. 1988). With respect to the Wieprza River they varied from nil to 125.4 kg. Similarly, stocking efficiencies in Finland varied from 1 to 303 kg for the sea trout (Ikonen and Auvinen 1982a) and even to 1367 kg for the salmon (Ikonen and Auvinen 1982b). The range of our estimates was from nil to 1116 kg per 1000 smolts, hence, they encompassed all quoted data.

Estimation of stocking results by means of tagging requires recognition of at least three assumptions:

1. Tagging procedure and the tag itself do not affect behaviour of fish, their mortality, growth rate and vulnerability to fishing.
2. Fish do not loose tags.
3. After recapture of a tagged fish each tag is perceived and delivered to the experimenter together with proper information.

There are some controversial views with respect to the effects of the tag on behaviour, growth and mortality of fish. Young et al. (1972), Roberts et al. (1973b), Earnes nd Hino (1983) did not find any such effect but there is more evidence showing negative effects: on behaviour (Power and Shooner 1966), on growth (Power and Shooner 1966, Fagerstrom et al. 1969), and especially on survival ((Saunders and Allen 1967, Hansen 1988, Berg and Berg 1987, 1990). Fish at the smolt stage are much more susceptible than parr to any handling (Wedemayer 1972). Smoltification results in a strong physiological stress and on top of it, tagging plus ensuing injury brings about another stress (Morgan and Roberts 1976). Loss of scales and the wound caused by tagging make the spot prone to infection (Roberts et al. 1973a, Bouck and Smith 1979, Kostecki et al. 1987). Arnason and Mills (1987) however drew attention to that even in case of high mortality caused by handling it was very difficult to ascertain such incidents.

The presence of a tag can make a fish, particularly a small one like smolt, more vulnerable to net fishing (Sych and Bartel 1976).

Concerning the second assumption the loss of tags is considered by Salminen (1991) as the chief source of errors in the estimation of recapture rates. Percentage of lost tags was assessed at 10 % by Isaksson and Bergman (1983), at 1 to 70 % by Arnason and Mills (1987) at less than 4 % by Earnes and Hino (1983). Backiel (1964) estimated on the basis of double-tagging of *Vimba vimba* in the Vistula R. that after one year from 42.7 to 90.5 % of fish retained tags. Sych at al. (1974) introduced a coefficient 0.782 for tag detachment. In tagging experiments with cyprind fishes kept in ponds Wiśniewolski and Nabiałek (1993) found that tag losses could result in very serious errors in mortality estimates.

As to the third assumption a very serious problem is the incomplete return of tags by fishermen. In tagging experiments with various fishes percentage of returned tags was estimated from 1.8 to 19.5 by Moring (1980), from 30 to 50 by Rawstron (1971) and at 34 by the same author later (1972), at 20 by Hallock et al. (1961). It can be expected that this problem will expand along with implementation of fishing limits and for fear of alterations of catch quotas.

Backiel and Bartel (1967) assumed that the increased mortality, tag loss and incomplete discovery and/or return brought about an underestimation of recaptures by c. 15 %. In view of our analysis of tagging experiments in 1961 through 1986 and of real sea trout catches (Dębowski and Bartel ......) the underestimation of stocking efficiency appeared very much higher than the quoted figures.

The effects of stocking depends on survival during the very first period after release, on growth and survival at later periods, on the behaviour of fish and on their exploitation. Sea trout from Pomeranian rivers grew sightly slower or similar to the Vistula sea trout (Chełkowski 1969). Thus, it can be assumed that the size of the stocked fish of diverse origin did not differentiate stocking efficiency of the distinguished groups, the more so that Sych (1967) showed an eight-fold weaker effect of growth rates of the efficiency than that of numbers of recaptured fish. It can be further assumed that mortalities of various groups were similar because migration routs and feeding grounds of the sea trout originating from various rivers were similar (Jokiel 1955, 1961; Żarnecki and Duszyński 1961, Żarnecki et al. 1962, Chrzan 1963, Backiel and Bartel 1967, Skrochowska 1969, Pałka 1977, Bartel 1988b). Therefore it can be concluded that recaptures depended first of all on the survival during the first period after stocking.

This survival (first year) was affected by the quality of smolt and by the stocking procedure what is analyzed in a separate paper (Dębowski and Bartel .....). But distribution of recaptures in years following release depends on the rates of exploitation and on migration patterns. This distribution was different in the three aforementioned groups, also the ratios of marine to riverain recoveries differed. Fish released to the Vistula system were recaptured later than those stocked into the sea or into the Pomeranian rivers. Also the share of riverain recoveries (ERT, Table 2) were the greatest in that group. Hensen and Jonsson (1994) observed that precision of homing augmented along with the increasing river flow. Hence, the Vistula sea trout went astray less frequently during their spawning migration than the Pomeranian ones. The former had a simpler route and therefore they were less vulnerable to fishing (Dębowski and Bartel 1995).

The fish released to the sea (SEA) were exploited in quite a different manner. More of these fish than of the other groups were caught during the year of release but the share of riverain catch was very small at that time. These facts suggest that they were more vulnerable to marine fishing and that a few only entered rivers (Dębowski and Bartel 1995). Studies on the behaviour of salmon and sea trout released directly to sea waters showed that such fish had difficulties in finding rivers during their spawning migration, they roamed over the inshore zone and were caught mainly in the sea (Bertmar 1982, Einarsson et al. 1987, Gunnerod et al. 1988). The course of exploitation of the sea trout which originated from the experiments described in this paper substantiate the just mentioned observations and, moreover, it suggests that they have difficulties to orientate themselves not only during spawning migrations but also before they reach sexual maturity. This straying increases the chance of their capture during the year of release.

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STRESZCZENIE

ZARYBIANIE SMOLTAMI TROCI WĘDROWNEJ (*Salmo trutta m. trutta* L.) W POLSCE.
CZĘŚĆ I. WSTĘPNA ANALIZA EKSPERYMENTÓW ZNAKOWANIA

W latach 1961-1986 w ramach 135 eksperymentów poznakowano 183206 smoltów troci pochodzących z ośrodków zarybieniowych. Ryby te wypuszczano w dorzeczu Wisły, do rzek Pomorza i do Zatoki Gdańskiej (Rys. 1). Na podstawie zwrotów obliczono wskaźniki efektywności tych zarybień tj. wielkości połowów przypadające na 1000 wypuszczonych smoltów. Wskaźniki takie obliczono zarówno dla połowów całkowitych jak i dla połowów w kolejnych latach po zarybieniu oraz połowów morskich i śródlądowych (Tab. 1).

Efektywność zarybień wahała się między 0 a 1116 kg (średnio dla wszystkich eksperymentów 127,3 kg). Najbardziej efektywne były zarybienia morza (śr. 251,8 kg), mniej - dorzecza Wisły (śr. 120,8 kg) i najmniej rzek pomorskich (śr. 55,9 kg) (Tab. 2).

Rozkład połowów w kolejnych latach po zarybieniu zależał w znacznym stopniu od miejsca zarybienia. W roku zarybienia odławiano 11 % połowów całkowitych ryb z zarybień morza a tylko 3 % ryb z zarybień Wisły (Rys. 4). Większość połowów ryb z zarybień morza i Pomorza przypadała na pierwszy rok po zarybieniu (odpowiednio 42 i 56 %) a z zarybień Wisły na drugi (39 %). Bardzo różnił się także udział połowów śródlądowych w połowach całkowitych: od 15 % w zarybieniach morza do 55 % w zarybieniach rzek dorzecza Wisły.

Stwierdzono bardzo wysoką, dodatnią korelację pomiędzy wskaźnikami efektywności w kolejnych latach po zarybieniu. Sugeruje to, że o rezultatach zarybienia decyduje krótki okres bezpośrednio po zarybieniu.

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