Release of reared turbot in Belgian coastal waters as a tool for stock enhancement

Daan Delbare and Rudy De Clerck

Abstract

The main objective of this project was to investigate the potential of stock enhancement of turbot within a national context. Therefore 3000 juveniles were cultured until they reached a size which was supposed to be suitable for adaptation to the conditions in the wild. After conditioning to natural prey organisms (shrimp and gobies), approximately 1900 juveniles were tagged with a Petersen disk and released in June 1998 in a closed area near the Belgian coast. After one and half year the total capture rate exceeded 15%. During this period specific biological aspects related to migration, survival, and growth were evaluated by means of captured turbot. Spatial distribution showed that most individuals remained in Belgian coastal waters until October of the year of release. During winter, the turbot migrated to deeper waters (Central North Sea). In spring, the migration pattern showed a return to more coastal waters (The Netherlands, France, Belgium, and the United Kingdom). In addition, data from stomach analysis and growth showed that the released turbot adapted very well to the natural conditions, with a similar growth and feeding pattern as the wild population. This experiment demonstrates clearly the potential of restocking as regards turbot.

Keywords: turbot, tagging, restocking, Southern Bight

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Introduction

The ever expanding human population and its hunger to available protein sources, puts a high pressure on agriculture production and fisheries management. Assumptions project a 50% increase on the demand for seafood products by 2025 (New, 1991; Csavas, 1995). However, meeting this requirement is not realistic, since marine fishery resources are of a limited nature. In addition, from the early nineties onwards there is a steadily decrease in annual fishery productions at a rate of 2.5% (Csavas, 1995). This global decline in fisheries biomass and subsequent catches of marine fish stocks must be seen both in terms of overfishing and in terms of recruitment failures. Technical and technological innovations and considerable investments in that area have brought the fisheries capacity beyond sustainable limits. Considering the category of fish for human consumption, the situation is even more dramatic, resulting in crashes of specific fisheries industries, e.g. herring for Northern Europe and sardines for Northern US. Although fisheries management has been applied to many fish stocks, about 90 stocks under research still feature no recovery after 15 years, showing that a recovery is maybe possible, but only in medium-long terms (Hutchings, 2000). On the other hand, a lot of commercial exploited fish stocks are at their limit of their existence due to degradation or loss of spawning and nursery grounds, preventing to replenishing themselves.

Aquaculture has been presented as the most promising sector in the agriculture and still experiences exponential growth. Nowadays, aquaculture production accounts for approximately a quarter of the total fisheries products consumed by humans. But it is already clear that aquaculture will be unable to counterbalance the growing need of protein sources in the future. Furthermore, some activities of aquaculture, more specific intensive culture of shrimps and salmon have a large impact on coastal habitats due to waste disposals, pathogen invasions and the use of coastal ecosystems, further damaging spawning and nursery areas (e.g. large areas of mangroves were exploited for *Peneaus*-culture in Ecuador). Next to that, mariculture still greatly depends on the use of fish meal and fish oil for the production of high quality feeds, depleting other fish stocks (Naylor et al, 2000).

The effects of insufficient natural recruitment may be overcome by stock enhancement, i.e. the release of cultured juveniles to augment natural populations. Introduction of small amounts of juveniles does not cause severe negative impacts on the environment, since the carrying capacity of most habitats are rarely reached (van der Veer et al., 1990; van der Veer et al., 1991; Rijnsdorp et al., 1992; Henderson & Seaby, 1994). So that such a habitat can sustain an extra amount of juveniles. This method has the advantage versus aquaculture that production costs are much lower and the rearing of the juveniles can be done in on-land based fish farms. The disadvantage, however, is that more juveniles must be reared to reach a reasonable production level. This can be overcome with the use of intensive production methods. Restocking has been used for decades and proven to be successful for a wide variety of marine fish and shellfish, mainly in Japan (red sea bream and flounder), USA (mullet and red drum), and Norway (cod and salmon).

The Sea Fisheries Department in Belgium has therefore started to investigate the possibilities of restocking North Sea fish species. Turbot was chosen as the best candidate, as rearing techniques for all life stages are fully understood and under control. The Belgian enhancement programme is being conducted in a step-wise fashion, with the aim to determine the range of conditions most conducive to good survival and growth of the released juveniles. In a first stage, the adaptation of reared turbot is investigated. The second stage will explore the quality and preconditioning prior to release of the juveniles. The last stage will analyse the possibilities of mass releases of reared turbot and perform a cost-benefit analysis.

This paper presents the results of the first stage of the Belgian restocking programme, i.e. the release of reared turbot juveniles in Belgian coastal waters as a tool for stock enhancement.

Materials and methods

Turbot juveniles
Although there is no directed fishery on turbot (landings are solely the result of by-catches in sole and plaice fisheries), it is an economically important quota species. Furthermore, the biological conditions to rear this species are fully understood and controlled, making turbot the most ideal candidate to explore the possibilities of stock enhancement off the Belgian coast. Therefore 3000 juveniles were

obtained from a commercial fish farm: France Turbot – Adrien Group (Noirmoutier, France) and reared for another 6 months in the pilot nursery system of the Department Sea Fisheries – CLO (Ostend, Belgium). The nursery system contains approximately 18 000 l seawater (5 2m³ tanks and 19 small test tanks of 120 l each connected to a filtration system for recirculation: mechanical drumfilter (40 µm mesh size); 10 m³ trickeling filter filled with Bionet 200 PE (specific surface: 260 m² per m³) and UV-sterilisation (2 80 Watts). Aeration is supplied by a blower (5 m³/h). The juveniles were reared on an artificial diet from Provimi: Turbot starter. Before release, however, the juveniles were conditioned for two months to natural live prey organisms, e.g. brown shrimp (*Crangon crangon* L.) and sand gobies (*Pomatoschistus* sp.).

Tagging and release
Approximately 1900 juveniles were tagged with the effective Petersen disk (Petersen, 1893). The disc size was 14 mm in diameter and the fixing was carried out in titanium. At the moment of tagging, length measurements and tag number were taken of each individual. The tagged turbot were than transported onboard the fishing vessel "O.29 – Broodwinner" with provision of pure oxygen and released in a closed area near the Belgian coast (release position: 51°12'000 N and 02°45'600 E). The actual release of the juveniles was carried out just above the sandy bottom in order to minimise losses through predation in the water column.

Analysis
All data, i.e. ID number, date of release (group), length at release, date and location of capture, length and weight at capture, name of vessel, were combined in a spreadsheet. This spreadsheet also contained formulae to calculate the individual migration parameters according to Jones (1965) in Anonymous, 1992: distance travelled (r) and direction of dislocation relative to the North Pole (θ). These were then used to compute the mean direction of displacement (Ψ), mean velocity in this direction (V), mean time in sea (T), average distance (R), and mean square dispersion coefficient (a²) of each group. Next to that, it contained formulae to calculate growth rate and condition factor (= W/L^3*100). The condition factor can indicate if the released turbot are able to find enough food under natural conditions. If not, this should be reflected in a decreasing weight for the same length and consequently in a drop in condition factor (Lucio, 1997). The mean condition factor was determined per month and separately for males and females. Furthermore, stomach analysis (food and parasites) and sexing was carried out on smaller individuals. This was possible up to a length of approximately 30 cm, which is the minimum size for turbot landings. Turbot bigger than 30 cm were all gutted. To estimate fresh weight, the gutted weight was increased with a factor of 1.05. The units used in the calculations were cm, days, and nautical miles. In cases where the exact location was missing, but a name was given, the location was estimated. The results include animals that were captured alive and released again.

To reveal the migration pattern of the released turbot, the captures were grouped corresponding to the date of release (Table 1) and to capture periods of two months.

Results and discussion

Tagging and release
Tagging took place during the night, prior to release, because preliminary tagging experiments showed that the tagging injuries did not cure, but worsen due to friction and the titanium wire inflected injuries to other turbot. The length frequency of the released turbot is shown in Figure 1.

Migration parameters
In total 1962 tagged turbot were released of which 313 were captured in the following six quarters (quarter 2'98 – quarter 3'99), resulting in about 16% returns.

The migration is presented in Figure 2, where the points of capture are plotted out for periods of two months. During the first two months after release, the juveniles staid in Belgian coastal waters with a general direction to the Dutch coast, following the main current. Although reversal water flow through the Dover Straits can occur during prolonged periods of winds with a northern component (Ramster et al., 1976). The direction in the two following months (August-September'98) was clearly north – north-east, with the centre of captures depending on the groups: "Wenduyne Bank" (Group 1), "Oostende Bank" and "Middelkerke Bank" (Groups 6 and 7), "Akkaertbank" (Group 3), "Thornthon Bank" (Groups 2 and 4) and between "Thornton Bank" and "Bligh Bank" (Groep 5). The same

situation is found in October-November'98, although a portion of the animals is migrating into deep water, i.e. the central part of the Southern North Sea. In the months December'98-January'99 some of the turbot was captured in the proximity of the "Thornton Bank", while most migrated into deeper waters. Such an off-shore migration pattern, from shallow water during late spring and summer into deeper water during autumn and winter was also observed by Bagge (1987) for turbot in the Kattegat. In February-March'99 tagged turbot is still captured in deeper waters, but some were found in more coastal waters (the Netherlands and the United Kingdom), but also in south – south-west direction into the Dover Straits, in the proximity of Bologne sûr Mer (France) and Port Rey (United Kingdom). This situation continued in the periods April-May'99, June-July'99 and August-September '99. However, in the latter period, a concentration of turbot was seen again in the area around the "Thornton Bank".

The general migration pattern of the released juvenile turbot followed a north – north-west direction into deeper waters of the North Sea, but with a migration to more coastal waters in late-spring and summer. Only a small portion migrated in south - south-western direction into the English Channel. Migration in northern direction started from October 1998 onwards, while tagged turbot in the English Channel were reported from February 1999 onwards. In tagging experiments with other flatfish species (plaice, dab and sole), it was also observed that a small portion migrated from the North Sea into the English Channel (De Clerck & Cloet, 1975; De Clerck, 1984).

The migration parameters are combined per group (Table 1) and presented in Table 2, 3 and 4 (in which: Ψ is the mean direction of displacement of a group of fish; V is the velocity, with which the centre of a group is moving in direction Ψ; T is the mean number of days in sea of a group; D is the average distance travelled by a group), and Figure 3. Migration in the second quarter '98 was mainly along the Belgian coast, in a east – north-east direction (69° from the North of the release position), except for group 6, which migrated in opposite direction (319°). During quarter 3'98 the main part of the turbot moved in north – north-east direction (15°). The groups spread out with a mean velocity of 0.09 nautical miles per day and with a dispersal rate (a^2) of about 1.74 to 6.77 nautical miles² per day (mean: 3.01 nautical miles² per day). In quarter 4'98 there was an increased dispersion rate, which was continued in quarter 1'99 (Figures 3.A and B), with a mean direction of 18° in quarter 4'98 to 24° in quarter 1'99 to deeper waters in the central part of the Southern North Sea. The dispersal rate was 0.02 to 0.17 nautical miles per day (mean: 0.13 nautical miles per day). Quarter 2'99 was characterised by a general reduction in distance from the release position, dispersal rate and surface area over which the captures were distributed. The reason for this decrease was a change in direction of migration (with a mean direction of 324°) (Figures 3. A, B and C). In quarter 3'99, the dispersal rate and surface area still decreased, with the exception for Group 5. The mean dispersion rate of the turbot was 7.53 nautical miles² per day, which was lower in comparison with plaice (approximately 20 nautical miles² per day), but equal with the results from Aneer & Weston (1990) and Anonymous (1998).

Growth
At the time of release the turbot were 16 months old and had a mean length of 22 cm, which is higher than the length at that age of the natural North Sea population (Mengi, 1963; Jones, 1974, Weber, 1979; Van Leeuwen & Rijnsdorp, 1986) and was caused by the higher water temperatures and *ad libitum* food supply during rearing. Figure 4 shows the growth of the turbot after release. After approximately 150 days in the wild, a differentiation in growth rate can be observed between males and females, since females start growing faster than males.

Sex ratio
The main problem in commercial hatcheries is that the portion of males is higher than the females, since females exhibit a faster growth. The sex ratio of the captured turbot was 66% males, which is equal to the sex ratio of the natural population).

Condition factor
The monthly variation in condition factor shows that the animals well adapted to the natural conditions, with a condition factor between 1.8 and 2.2, which is comparable with the range in wild turbot populations (Ongenae & De Clerck, 1998). Furthermore, no partical trend was noticed in condition factor for both sexes.

Feeding
One of the greatest concerns about the release of reared fish is the question if these animals can find enough food to survive in the wild. Therefore, stomach analyses were carried out on the returned

turbot. Stomach contents of the released turbot by sizes are shown in Figure 5. Turbot of the length class 21-23.9 cm fed exclusively on gobies (*Pomatoschistus* sp.). In this length class 57% of the animals had an empty stomach. In the following length class, there is a change in prey spectrum visible, in which other bottom dwelling fish (e.g. lesser weever, *Trachinus vipera* and dragonet, *Callionymus* sp.) and brown shrimp (*Crangon crangon*) were eaten. More than 90% of the stomachs are filled. In the length class 27-29.9 cm 55% of the stomachs were filled. The most important food items for this length class were still gobies and brown shrimp, but also less obvious preys were found e.g. *Syngnathus rostellatus* and *Ophiura albida*. It was only in the length class 30-32.9 cm that there was a sign of a change in feeding habit, going from eating benthic organisms to hunting for pelagic fish, but gobies and brown shrimp still made out the main food source for this length class. Next to that, bib, *Trisopterus luscus* was found together with not specific food items (other), such as seaweeds and hydrozoid colonies *Obelia* sp. The latter could indicate that the turbot were learning to hunt for pelagic fish and had mistaken these items for potential pelagic prey organisms. Turbot of this length class were found to have an empty stomach for only 25%.

The stomach analysis show that the released turbot were able to adapt to the natural food sources. The percentage of empty stomachs does not need to be a negative symptom, since earlier studies on natural populations show that approximately 50% of the turbot had an empty stomach (Rae & Devlin, 1972; Wetsteijn, 1981). Large turbot (40 to 70 cm) feed from March till May excessive on herring and sprat (Wetsteijn, 1981), to build up enough reserve for the subsequent spawning season. During the other nine months 50 to 70 % of the animals were found to have empty stomachs. This percentage is much higher than for most flatfish species. For example, a complete time of fasting, which is characteristic in the life cycle of lemon sole*, Microstomus kitt* is not observed in turbot, since approximately one third of the population still feeds (Rae & Devlin, 1972).

Parasites
The parasite which was found the most in the alimentary canal, was *Bothriocephalus scorpii* (Müller), a cestode (Pseudophyllidea), which infects mainly turbot and brill (*Scophthalmus rhombus*) (Sinderman, 1970 ; de Groot, 1971). The appearance of this parasite in the turbot is not unusual, since *Pomatoschistus minutus* is the main intermediate host of this parasite and forms the most important food source for juvenile turbot.

General conclusion
All parameters studied (growth, condition factor, and stomach analysis) show that reared turbot is able to adapt itself to natural conditions, indicating a similar growth and feeding pattern as the wild population. The migration pattern, however, shows that restocking of turbot can not be considered as a national activity, since the released turbot manifested a wide spread distribution area (characterised by an off-shore migration during the winter period). Although, this experiment demonstrates clearly the potential of restocking turbot, further research is needed to explore the possibilities of mass releases of reared turbot for stock enhancement as a long term policy in fisheries management, both on national and international level. Special attention should be paid to source of broodstock, parental effect, information on the appropriate location and season for release, size distribution of released animals, quality of the stocked fish, stocking densities, and cost-benefit analysis.

References

Aneer, G. en L. Westin. 1990. Migration of turbot (*Psetta maxima* L.) in the northern Baltic proper. Fisheries research 9: 307-315.

Anonymous. 1998. Evaluation of stock enhancement of marine flatfish. AIR2 CT94-1732. 59 pp.

Bagge, O. 1987. Tagging of turbot and brill in the Kattegat 1965-1970. ICES C.M. 1987/G:10, 27 pp.

De Clerck, 1984. Tagging results of mature dab in the Southern Bight. ICES CM. 1984/G:11.

De Clerck & Cloet, 1975. Tagging experiments on juvenile plaice off the Belgian coast. ICES CM. 1975/F:25.

Hutchings, J.A., 2000. Collapse and recovery of marine fishes. Nature 406: 882-885.

Jones, R., 1965. FAO/UN seminar on sardine tagging, Split, Yugoslavia, 2-14 November 1964, Report and Lecture, FAO Fish EPTA Rep.

Jones, A. 1974. Sexual maturity, fecundity and growth of the turbot, *Scophthalmus maximus* L. Journal of the Marine Biol. Ass. U.K. 54: 109-129.

Lucio, P. 1997. Biological aspects of Spanish (chub) mackerel (*Scomber japonicus*, Houttuyn, 1782) in the Bay of Biscay from the Basque country catches. ICES CM/1997/BB:10. 21 pp.

Mengi, T. 1963. Uber das Wachtum des Steinbutts in der Nordsee. Ber. Dt; Wiss. Komm. Meeresforsch. 17 (2): 119-132.

Naylor, R.L., R.J. Goldburg, J.H. Primavera, N. Kautsky, M.C.M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney and M. Troell, 2000. Effect of aquaculture on world fish supplies. Nature 405: 1017-1024.

Ongenae, E. and R. Declerck, 1998. Collection and modelling of biological data for turbot stock assessment in support of the Common Fisheries Policy. EU-rapport contract N° DG XIV 95/039.

Rae, B.B. and S.D.E. Devlin, 1972. The turbot, its fishery and biology in the Scottish area. Mar. Res. 1: 1-27.

Ramster, J.W., K.J. Medler and S.R. Jones, 1976. Residual drift regimes in the Southern Bight of the North Sea during the Joint North Sea Data Acquisition Project of 1973. ICES CM 1976/C:5.

van Leeuwen, P.J. & Rijnsdorp, A.D. 1986. The analysis of the growth of turbot by backcalculation of otoliths. ICES CM/1986/G:50. 17 pp.

Weber, W. 1979. On the turbot stock in the North Sea. ICES CM/1979/G:12. 21 pp.

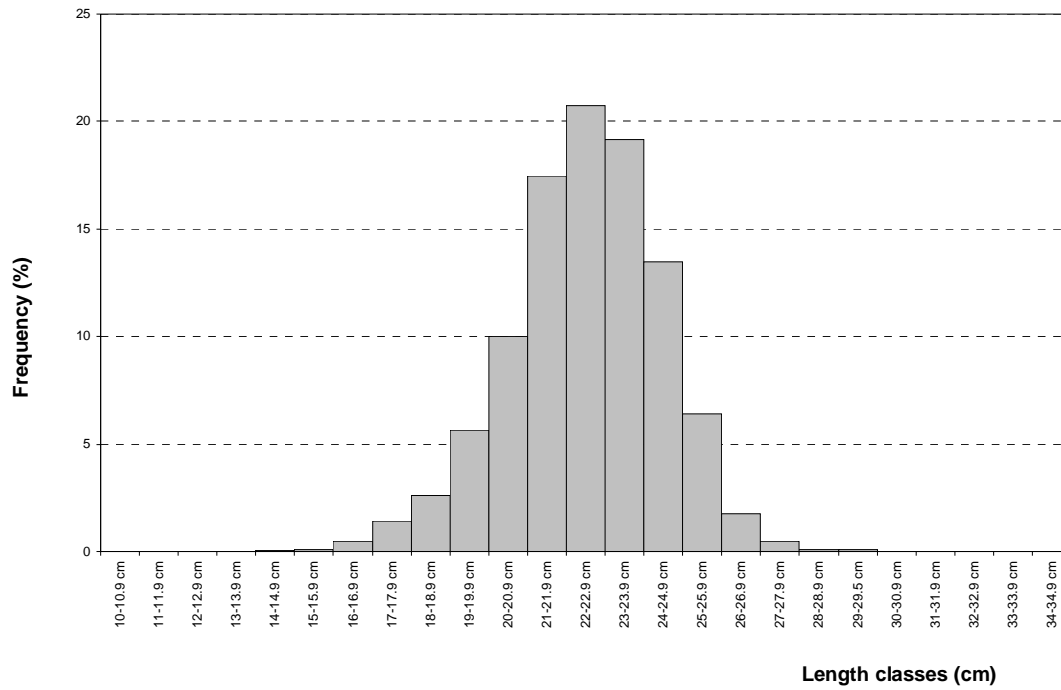Wetsteijn, B., 1976. Feeding of North Sea turbot and brill. ICES paper C.M. 1981/G:74.

Figure 1. Length frequency of the released turbot

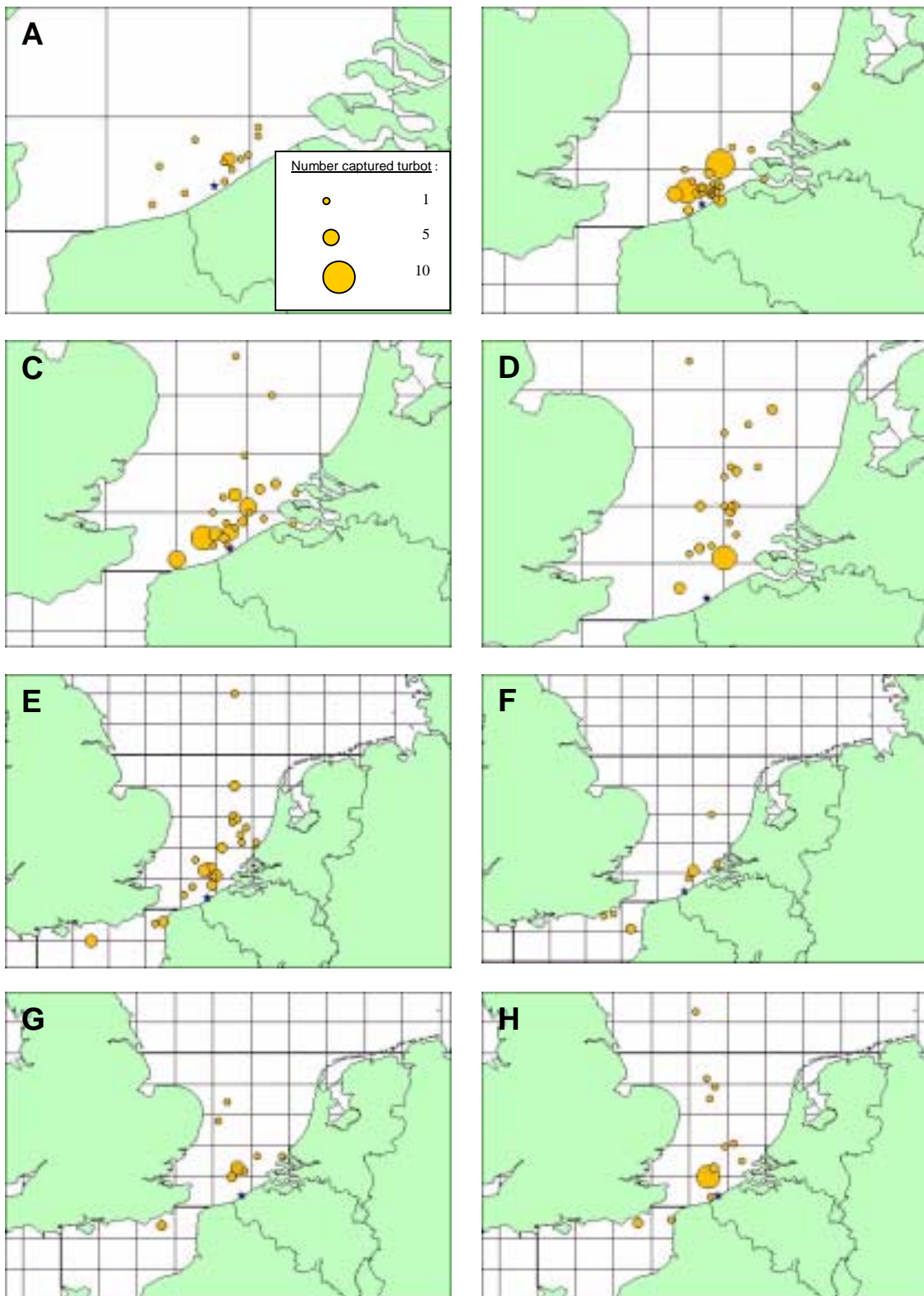| Table 1. groups corresponding the date of release (j)	
Date of release	Group
02/06/98	1
05/06/98	2
11/06/98	3
12/06/98	4
15/06/98	5
16/06/98	6
18/06/98	7

Figure 2. Distribution of the released turbot in time : A. June-July'98 ; B. August-September '98 ;
C. October-November ; D. December '98-January '99; E. February-March '99 ; F. April-May '99 ;
G. June-July '99 ; and H. August-September '99.

Table 2. Mean direction of displacement (Ψ), velocity (V), mean number of days in the sea (T), and average distance (D) travelled by each group per quarter.

		Ψ In degrees	V In nautical miles.day^{-1}	T In days	D In nautical miles
Group 1					
	Quarter 2' 98	71	0.42	22	0.24
	Quarter 3' 98	56	0.10	88	0.25
	Quarter 4' 98	307	0.11	137	0.11
	Quarter 1 '99				
	Quarter 2 '99				
	Quarter 3 '99				
Group 2					
	Quarter 2' 98				
	Quarter 3' 98	19	0.07	96	0.10
	Quarter 4' 98	20	0.13	164	0.19
	Quarter 1 '99	23	0.15	262	0.17
	Quarter 2 '99	8	0.08	367	0.11
	Quarter 3 '99	315	0.04	447	0.04
Group 3					
	Quarter 2' 98	61	0.63	11	0.64
	Quarter 3' 98	18	0.09	82	0.17
	Quarter 4' 98	18	0.09	159	0.16
	Quarter 1 '99	19	0.14	256	0.22
	Quarter 2 '99	72	0.70	334	0.17
	Quarter 3 '99	329	0.10	414	0.11
Group 4					
	Quarter 2' 98				
	Quarter 3' 98	10	0.11	72	0.15
	Quarter 4' 98	29	0.17	154	0.21
	Quarter 1 '99	27	0.17	236	0.19
	Quarter 2 '99				
	Quarter 3 '99				
Group 5					
	Quarter 2' 98	75	0.56	7	0.56
	Quarter 3' 98	8	0.11	84	0.21
	Quarter 4' 98	5	0.11	155	0.15
	Quarter 1 '99	22	0.16	232	0.28
	Quarter 2 '99	37	0.10	339	0.10
	Quarter 3 '99	324	0.15	364	0.15
Group 6					
	Quarter 2' 98	319	0.38	3	0.39
	Quarter 3' 98	2	0.06	66	0.15
	Quarter 4' 98	27	0.02	184	0.12
	Quarter 1 '99	31	0.02	256	0.22
	Quarter 2 '99	276	0.01	346	0.17
	Quarter 3 '99	358	0.04	376	0.06
Group 7					
	Quarter 2' 98				
	Quarter 3' 98	37	0.01	63	0.15
	Quarter 4' 98	280	0.03	140	0.12
	Quarter 1 '99	39	0.08	261	0.08
	Quarter 2 '99	309	0.04	318	0.22
	Quarter 3 '99	319	0.07	459	0.14
Combined					
	Quarter 2' 98	69	0.51	11	0.53
	Quarter 3' 98	15	0.09	84	0.16
	Quarter 4' 98	18	0.10	161	0.16
	Quarter 1 '99	24	0.15	247	0.22
	Quarter 2 '99	324	0.04	328	0.15
	Quarter 3 '99	324	0.09	415	0.11

Table 2. Mean direction of displacement (Ψ), velocity (V), mean number of days in the sea (T), and average distance (D) travelled by all groups (combined) per quarter.

	Ψ In degrees	V In n. miles/day	T In days	R In n. miles	D In n. miles	a^2 In n. miles²/day	$a^2 \cdot T$ In n. miles²
Quarter 2' 98	69	0.51	10.80	5.46	0.53	0.69	7.45
Quarter 3' 98	15	0.09	83.65	7.34	0.16	3.01	251.40
Quarter 4' 98	18	0.10	160.51	15.68	0.16	5.30	850.95
Quarter 1 '99	24	0.15	247.15	36.75	0.22	12.44	3074.58
Quarter 2 '99	324	0.04	327.62	13.21	0.15	9.38	3073.97
Quarter 3 '99	324	0.09	414.95	36.76	0.11	13.06	5418.11

Table 3. Mean direction of displacement (Ψ), velocity (V), mean number of days in the sea (T), and average distance (D) travelled per group.

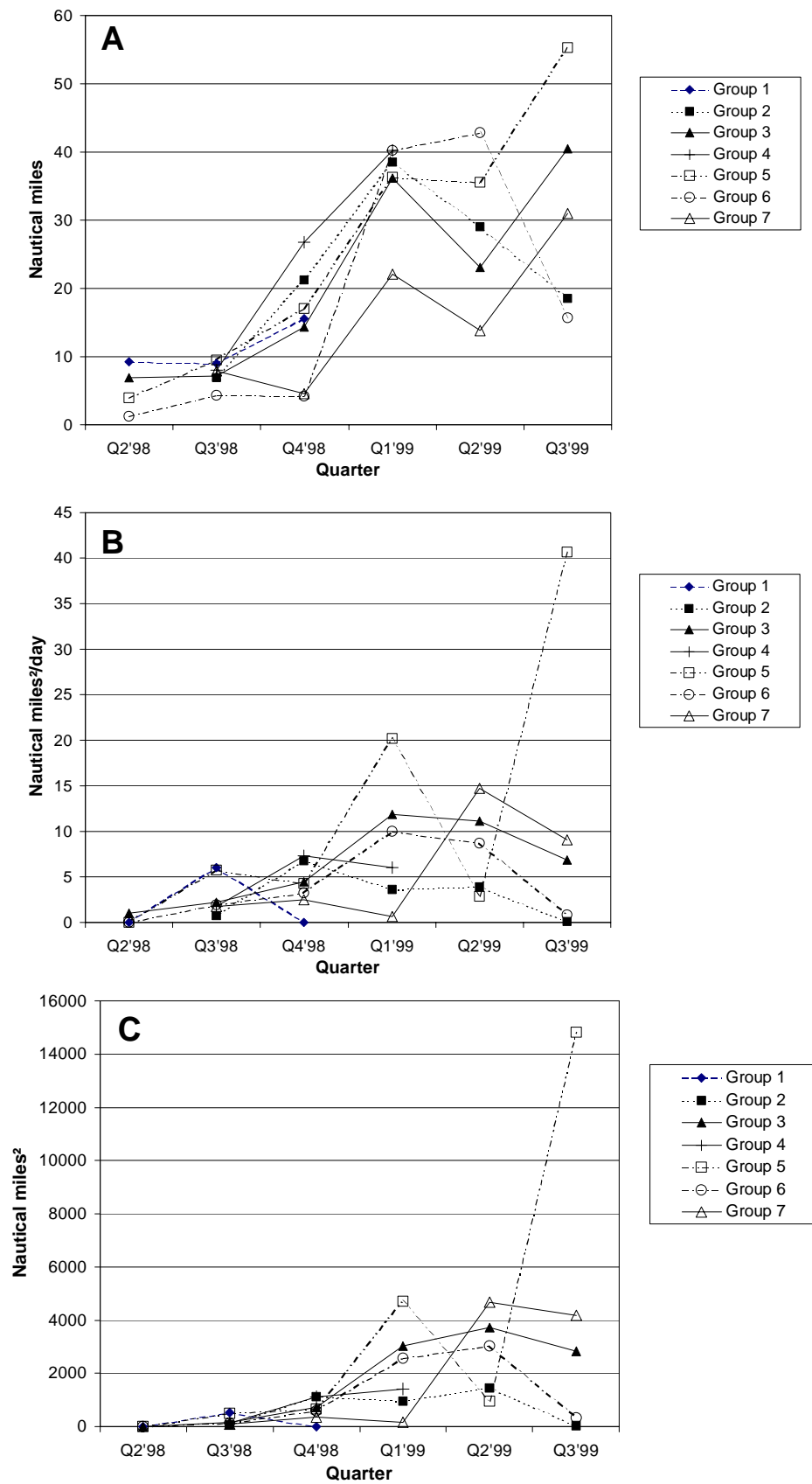|	Ψ In degrees	V In n. miles/day	T In days	R In n. miles	D In n. miles	a^2 In n. miles²/day	$a^2 \cdot T$ In n. miles²
Group 1	39	0.08	84.83	6.98	0.22	5.02	426.27
Group 2	13	0.09	223.43	20.18	0.13	4.31	962.96
Group 3	360	0.08	192.96	16.04	0.16	6.43	1239.90
Group 4	26	0.16	148.55	24.10	0.19	5.36	796.44
Group 5	8	0.12	182.72	22.24	0.20	12.56	2294.61
Group 6	360	0.06	189.21	11.96	0.15	6.00	1135.75
Group 7	358	0.03	217.88	6.91	0.14	5.62	1223.80

Figure 3. Migration parameters in relation with the number of quarters after release. A. distance from position of release (nautical miles) ; B. dispersion rate (nautical miles².day^{-1}) ; C. surface area over which captures are distributed (nautical miles²).
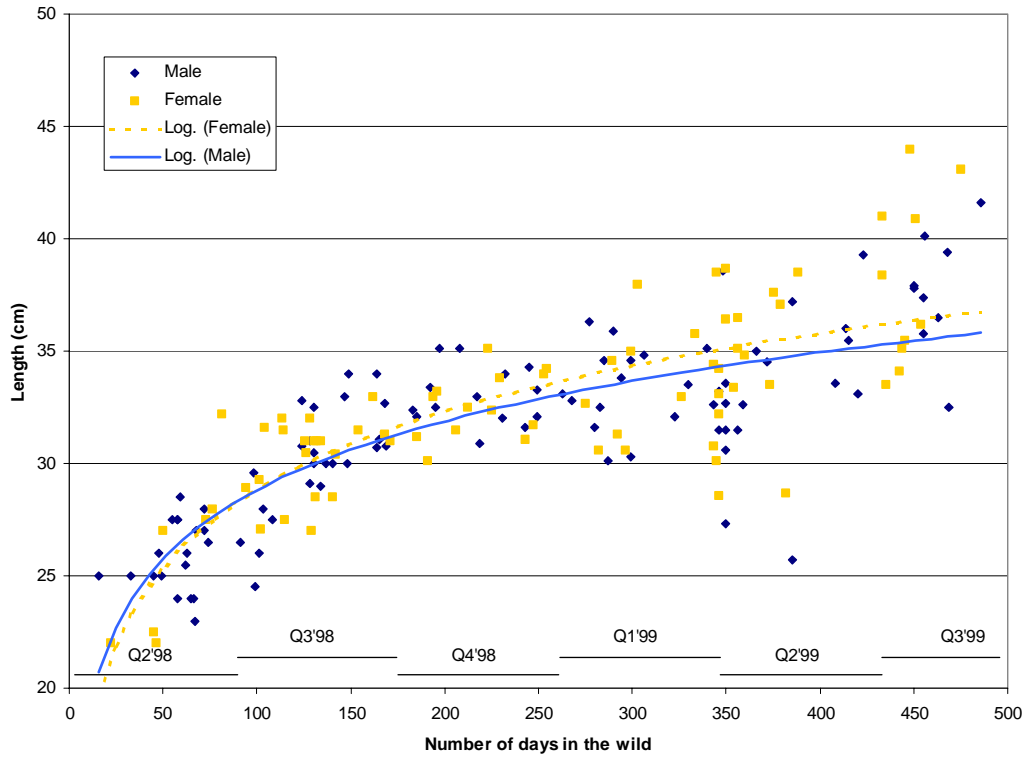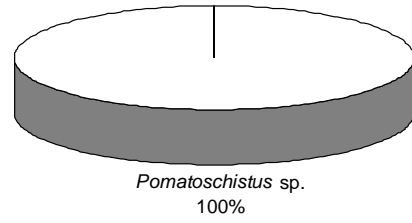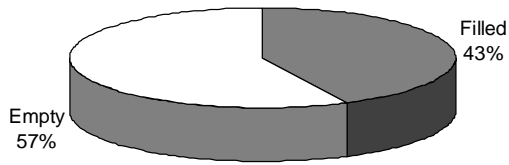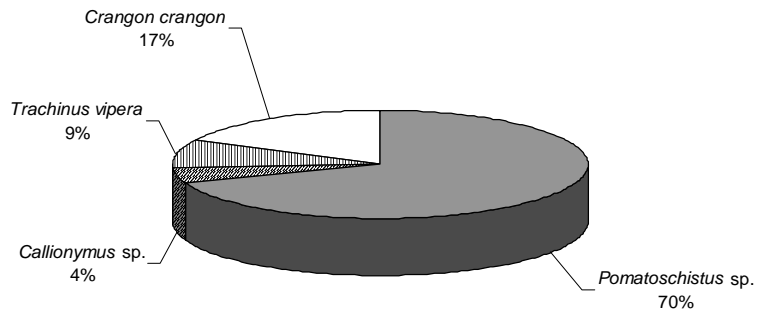
Figure 4. Growth rate for male and female turbot separately.

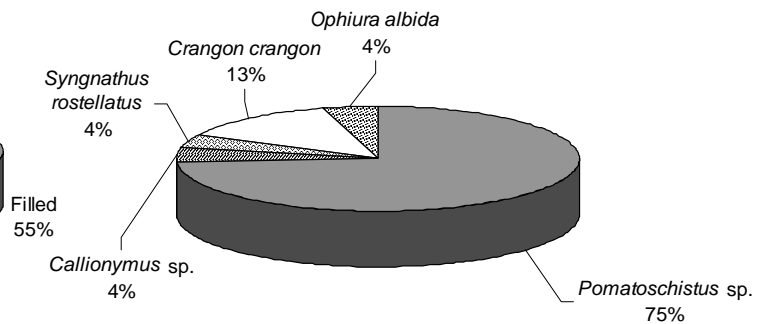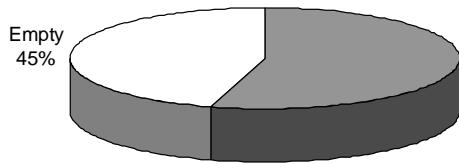**21-23.9 cm**

Filled
43%

Empty
57%

Pomatoschistus sp.
100%

24-26.9 cm

Empty
8%

Filled
92%

Crangon crangon
17%

Trachinus vipera
9%

Callionymus sp.
4%

Pomatoschistus sp.
70%

27-29.9 cm

Empty
45%

Filled
55%

Ophiura albida
4%

Crangon crangon
13%

Syngnathus rostellatus
4%

Callionymus sp.
4%

Pomatoschistus sp.
75%

30-32.9 cm

Empty
25%

Filled
75%

Other
15%

Crangon crangon
23%

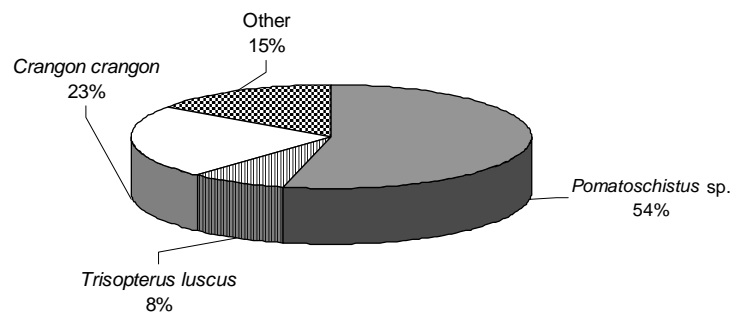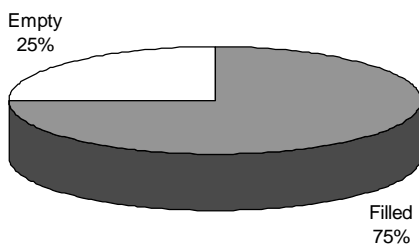*Trisopterus luscus*
8%

Pomatoschistus sp.
54%
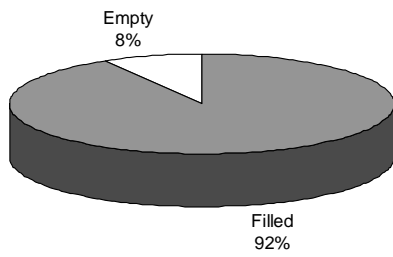
Figure 5. Prey spectrum of turbot according to their length class.