

THE ATLANTIC BLUEFIN TUNA: STUDY OF THE TEMPORAL PATTERN OF SPAWNING IN THE WESTERN MEDITERRANEAN REGION AND REPRODUCTIVE CAPACITY IN CAPTIVITY

Ana Gordo¹

SUMMARY

This study analysed the temporal pattern of Atlantic bluefin tuna (BFT) spawning in the western Mediterranean region and examines the natural reproduction capacity of bluefin tuna after one year of captivity. The spawning was monitored over two groups of tuna kept in transport cages. The first group formed by spawners captured in the reproductive region by Balfegó purse seine fleet at the beginning of 2009 fishing season. The second group was captured during 2008 fishing season and kept in captivity since then. Surface plankton samples were collected every night, the sampling began immediately after the first purse seine catches and finished once the end of spawning was noticeable. The results showed clearly the natural reproductive capacity of tuna after one year of captivity. The results from the group of spawners captured at the beginning of the season showed the beginning of spawning around the 9th of June finishing by the 17th of July. The intensity of spawning was not regular, high densities of eggs were collected between the 11th and 2nd of July with maximum around the 17th and 27th of June. These results showed that the current fishing season takes place mostly during the prespawning period of the Atlantic bluefin tuna in the western Mediterranean. This result call for a regional adjustment of the beginning and the end of the closed season, to protect the prespawning period by allowing purse seine fishing in June and complemented by the permanence of transport cages in the spawning grounds until the peak of spawning is over. This will ensure the spawning of tuna reproducers in the western Mediterranean region.

RÉSUMÉ

Cette étude analyse le schéma temporel de reproduction du thon rouge de l'Atlantique (BFT) dans la région de la Méditerranée occidentale et examine la capacité de reproduction naturelle du thon rouge après une année de captivité. La reproduction a fait l'objet d'un suivi dans deux groupes de thons se trouvant dans des cages de transport. Le premier groupe était composé de reproducteurs capturés dans la région de reproduction par la flottille de senneurs de Balfegó au début de la saison de pêche de 2009. Le second groupe a été capturé pendant la saison de pêche de 2008 et était en captivité depuis lors. Des échantillons de plancton de surface ont été prélevés chaque nuit. L'échantillonnage a commencé immédiatement après les premières captures de senneurs et a été finalisé lorsqu'il apparaissait clairement que la reproduction s'était terminée. Les résultats ont fait clairement apparaître la capacité reproductrice naturelle du thon après une année de captivité. Les résultats pour le groupe de reproducteurs capturés au début de la saison montraient que la reproduction avait débuté le 9 juin approximativement et s'était terminée aux alentours du 17 juillet. L'intensité de la reproduction n'était pas régulière. D'importantes densités d'œufs ont été relevées entre le 11 juin et le 2 juillet, avec un niveau maximal se situant entre le 17 et le 27 juin. Ces résultats mettent en évidence que la saison de pêche actuelle a lieu principalement pendant la période de préreproduction du thon rouge de l'Atlantique en Méditerranée occidentale. Ces résultats montrent aussi qu'un ajustement régional du début et de la fin de la saison de fermeture est nécessaire, afin de protéger la période préreproductive, en autorisant la pêche à la senne en juin, en établissant la permanence des cages de transport dans les zones de reproduction jusqu'à la fin du pic de reproduction. Cela garantira la reproduction des thons reproducteurs dans la région de la Méditerranée occidentale.

¹ Centro de Estudios Avanzados de Blanes (CEAB-CSIC), Acc. Cala St. Francesc 14. 17300 Blanes Girona. España; Email: gordo@ceab.csic.es

RESUMEN

En este estudio se analiza el patrón temporal de la reproducción del atún rojo del Atlántico en la región del Mediterráneo, y se examina la capacidad de reproducción natural del atún rojo tras un año en cautividad. Se hizo un seguimiento de la reproducción en dos grupos de tándidos que se hallaban en jaulas de transporte. El primer grupo estaba formado por reproductores capturados en la región de reproducción por la flota de cerco de Balfegó a comienzos de la temporada de pesca de 2009. El segundo grupo fue capturado durante la temporada de pesca de 2008 y se mantuvo en cautividad desde entonces. Se recogieron muestras de plancton de superficie cada noche, el muestreo comenzó inmediatamente después de las capturas de cerco y finalizó cuando se hizo patente que había finalizado la reproducción. Los resultados mostraban claramente la capacidad reproductiva natural del atún tras un año en cautividad. Los resultados para el grupo de reproductores capturados al comienzo de la temporada mostraban que la reproducción se inició en torno al 9 de junio y finalizó sobre el 17 de julio. La intensidad de la reproducción no era regular, se recogieron elevadas densidades de huevos entre el 11 de junio y el 2 de julio, con un máximo entre el 17 y 27 de junio. Estos resultados ponen en evidencia que la temporada de pesca actual se desarrolla sobre todo durante el periodo pre-reproductivo del atún rojo del Atlántico en el Mediterráneo occidental. Los resultados también muestran que es necesario un ajuste regional del comienzo y del fin de la temporada de cierre, con el fin de proteger el periodo pre-reproductivo, permitiendo a los cerqueros pescar en junio, pero estableciendo la permanencia de las jaulas de transporte en las zonas de reproducción hasta que finalice el momento álgido de la reproducción. Esto garantizará la reproducción de los atunes rojos reproductores en la región del Mediterráneo occidental.

KEY WORDS

Atlantic bluefin tuna, purse seining, western Mediterranean, catch/effort, spawning seasons, spawning grounds, season regulations, ecoefficiency

1. Introduction

The period in which Atlantic bluefin tuna (*Thunnus thynnus*) reproducers are found in the different reproduction areas is an approximate indicator of the spawning period of this species. The moment in which spawning occurs seems to be temperature related. Temperatures in the reproduction areas of the Mediterranean range from 22.5°C to 25.5°C (Karakulak 2004; García *et al.*, 2005; Teo *et al.*, 2007). Spawning in the eastern Mediterranean (Oray and Karakulak, 2005) takes place one month before than in the western Mediterranean (Susca *et al.*, 2001; Corriero *et al.*, 2003), which is probably related to the time lapse until the threshold temperature of 24°C is reached (Rooper *et al.*, 2007) in each region. However, though the approximate spawning period is known, we do not have specific information about the initial date and duration of spawning in each reproduction area. In the western Atlantic population, different swimming behaviour has been observed in specimens during the reproductive period. The duration of this behaviour and the length of time the fish stayed in the reproduction area were reported (Block *et al.*, 2001; Teo *et al.*, 2007). Based on these results, it can be inferred that the individuals in the western Atlantic stay in the reproduction area for around 40 days, but their reproductive behaviour lasts approximately half that time.

The spawning migration towards the Mediterranean is seasonal and progressive, with staggered arrival and exit from reproduction areas. However, we do not know if spawning is also staggered, with a gap in time between the spawning of the reproducers that arrive first and those that arrive last, or whether there is a tendency for spawning to occur at a particular moment in which the environmental conditions are optimum. Differences observed in western Atlantic bluefin tuna stock between the length of time they remain in the reproduction area and the length of time they display reproductive behaviour show that there is a period of time in which the fish stay in the reproduction area without actively reproducing. They may be waiting for specific environmental conditions such as temperature to be optimum for spawning to be triggered.

Moreover, the reproductive capacity and spawning time of recently caged tuna were successfully determined in studies carried out using transport cages (Gordoa *et al.*, 2009). However, the reproductive capacity of specimens kept in captivity for a long period of time was only observed in individuals that had been subjected to hormonal

induction. This result contrasts with the natural reproductive capacity of *Thunnus orientalis* in prolonged captivity and also in individuals born in captivity.

With the aim of learning more about the reproductive behaviour of this species, this study attempted to analyse the temporal spawning pattern of Atlantic bluefin tuna within its reproduction period by monitoring spawning in two groups of independent specimens in the reproduction area of the western Mediterranean. The first group was made up of recently captured spawners and the second consisted of specimens that had been in captivity for one year. The results made it possible to characterize the phases of the reproduction period: pre-spawning, spawning and post-spawning in the western Mediterranean. It was also possible to evaluate the suitability of the current closed season in terms of the impact on the resource, and analyse the reproductive behaviour of individuals in captivity.

2. Materials and methods

Two groups of tuna with different characteristics were monitored in two transport cages. The first group, referred to as the “wild group” (MS), was captured in the first seven purse-seine catches of the Balfegó fleet from 21 to 25 May 2009. The purse-seine catches were transferred to the transport cage for monitoring. The MS group was determined to have 1190 tuna with a total approximate weight of 146 tonnes. The second group, referred to as the “domestic group” (MD), was transferred from the fattening facilities of the Balfegó Group (L’Ametlla de Mar) to the reproduction area and stayed near the MS group in the waters south off Formentera Island. The MD group was determined to have 1000 individuals with a total weight of 55 tonnes. The MD group was transported to the reproduction area for two reasons: to ensure the environmental conditions were optimum for spawning, and to ensure the eggs could be successfully retrieved using the retrieval systems tried out the previous year for sampling in transport cages, but not yet developed for fixed cages.

Sampling of both groups began on 24 May. The MD group was monitored until 28 June, once the individuals’ reproduction capacity was confirmed, whereas monitoring of the MS group was extended until the date on which it was considered that spawning had definitely finished (21 July). Spawning was considered to have concluded when three consecutive days passed without the presence of eggs in the plankton samples.

Plankton samples were collected using bongo nets located behind the transport cage at a depth of three metres. The navigating speed of the transport vessels was constant (around 0.6 knots h⁻¹). The sample protocol consisted of three different phases. The initial collection phase lasted from 3 a.m. to 3:45 a.m., the time interval in which maximum spawning had been observed the previous year (Gordoa *et al.*, 2009). The second phase began the night after it was noted that spawning had begun. In this phase, three night collections were done per day at the following time intervals: 02:00-02:45, 2:45-03:30 y 03:30-04:15. The purpose of the second phase was to determine the time period with the maximum spawning and to adjust the timetable in the third phase based on the results of the second phase. A daily contact was maintained by telephone with the transport vessels in order to adapt and adjust the sampling time based on the results of previous days. Upon retrieval of the gear, plankton samples were immediately preserved in 5% buffered formalin. In several stations samples were not preserved but live eggs were collected and transported to different research laboratories to study larval feasibility and development. The volume of collected eggs was also directly estimated in each of these stations except for one.

A semi-quantitative measurement was made of the amount of eggs collected at each sampling station, and the volume of eggs in millimetres was estimated of the samples collected at each station. The total volume per station was estimated (VT), as well as the volume collected for every 10 minutes of trawling (VR):

$$VR = VT/t \times 10$$

where t = duration of collection in minutes.

3. Results

The results of the volume of eggs in the wild group and the domestic group are summarized in **Tables 1 and 2**. The colours express differences in the volume of eggs in each collection (green: lack of eggs; light yellow: < 50 ml; dark yellow: ≥ 50 ml and ≤ 125 ml; orange: > 125 ml and ≤ 400 ml; red: > 400 ml and ≤ 600 ml; brown: > 600 ml). The colours shown in the tables indicate the total volume of eggs without considering the trawling time

at each station. The station numbers are superimposed and the letter “c” identifies the samples used to collect eggs for larval culture.

The results of the exploratory sample (3 a.m. to 3:45 a.m.) in the MS group showed the first presence of eggs on 9 June. Because weather conditions made collecting samples on the three days prior to this date impossible, we could not determine if spawning activity had begun before 9 June. When spawning was detected, the sampling timetable was expanded until the period of mass spawning was identified. The wild group displayed very regular temporal behaviour and direct observation by the samplers made it possible to detect a very short pulse of mass spawning lasting about ten minutes between 2 a.m. and 2:15 a.m.

The egg samples for culture were collected at the moment of maximum spawning. The duration of these collection periods ranged from about 15 minutes during the maximum reproduction period and lasted from 2 to 3 hours in the final phase of reproductive activity.

The volume of eggs collected for culture during 15-minute sessions was similar to the volume collected in 45-minute sessions. It is worth pointing this out, given that increased trawling time involves a slight increase in the number of eggs collected, but the increase is low and not proportional to time. Therefore, the volume of eggs collected per trawling time gives distorted estimates, as shown below.

The results showed intense spawning from 11 June to 2 July (21 days), with peaks between 15 and 28 June. Starting on 5 July, given the total lack of spawning after 24 consecutive days with the presence of eggs, the trawling time was extended from 60 minutes to 120 minutes and even 180 minutes with the aim of determining with absolute certainty that spawning had concluded.

The wild group (MS) showed massive spawning during a period of approximately 21 days and a period of activity of around 38 days. These results indicate that the spawning period for most of the population was in the same period (15-28 June), with a certain fraction ahead of the group and another fraction behind it. This result may reflect two subgroups with spawning peaks between 17 and 27 June (see **Table 1**), respectively.

From the beginning of sampling until 28 June, the cage remained between 38° and 39° latitudes, with temperatures between 20°C and 21°C, which is much lower than what is considered this species' threshold temperature for spawning (24°C).

Monitoring of the domestic group (MD) was less extensive, given that the objective was not to determine the duration of spawning, but whether or not spawning actually took place. The domestic group, which contained specimens in captivity for one year, also spawned, thus indicating that captivity does not inhibit reproduction in this species.

The temporal behaviour of this group of tunas was different from the wild group in that there was no fixed time of mass spawning. The moment of maximum spawning gradually became later as sampling was carried out. In the beginning (5 June), it was around 3:15 a.m. and by 18 June it had shifted to between 4:30 a.m. and 4:45 a.m.

The maximum volume of eggs in the domestic group was also not as great as the maximum volume observed in the wild group, probably because of the size difference in the individual specimens in each group. The weight of the specimens in the wild group was approximately three times that of the specimens in the domestic group.

Figures 1 and 2 show the maximum daily values observed in the total volume of eggs and in the volume of eggs per ten minutes of trawling. In the wild group (**Figure 1**), as collection progressed, there was a clear increase in the differences between total and standardized volume after 10 minutes of sample collection. These two estimates were only the same or similar when the trawling time for collection was close to ten minutes. This only occurred in three stations (duration time of 15 minutes), when eggs were gathered for culture (circled in **Figure 1**). The fact that maximum spawning occurred in an extremely short period of time (about 10 minutes) led to artificial variations in spawning intensity when the data were standardized in terms of trawling time.

In the wild group, daily spawning without interruption for 21 days was observed; in the domestic group, daily spawning did not appear to occur. However, it is possible that some spawning was not observed, given the variations in this group of tuna when spawning, especially between 14 and 17 June, the period in which there was a drop in the pulse of mass spawning (**Table 2**). The first high concentrations were detected starting on 12 June, one day after they were observed in the wild group.

The trawling duration times at each station shown in **Figures 1** and **2** are broken down in **Figure 3**. As indicated in the Materials and Methods section, the trawling time in the wild group was extended at the end to ensure the ending of the spawning period was clearly detected and to eliminate any uncertainty associated with a potential change in the spawning time.

4. Summary and conclusions

The results obtained in this study reflect the natural reproduction capacity of specimens of Atlantic bluefin tuna after one year in captivity and dismiss the notion that captivity is an inhibiting factor of reproduction. Both monitored groups, the wild group (MS) and the domestic group (MD), presented very short spawning pulses that differed in terms of the time they occurred and the regularity observed.

The clear onset of spawning occurred in both groups of tuna between 12 and 13 June with a surface temperature of around 20°C. As of that date, spawning intensity increased, with peaks observed around 17 and 27 June. A drop was observed starting on 2 July and spawning concluded around 17 July. These results are similar to those observed in studies of gonadal and histological conditions (Sarà, 1964; Sara, 1973; de la Serna and Alot, 1992; Susca *et al.*, 2001; Corriero *et al.*, 2003).

The current date on which the closed season begins (15 June) coincides with the onset of spawning observed in this study. This means that the period in which seine fishing is allowed in the Mediterranean coincides with the period of pre-spawning in the Western Mediterranean. The impact of seine fishing in periods of pre-spawning therefore goes beyond the removal of reproducers and also has a negative effect on the intensity of annual spawning.

Purse seine fishing for tuna fattening could minimize the negative impact of this kind of fishing on spawning if the catch is held until reproductive activity ends or declines. This measure would mean that once the closed season begins (15 June), the transport fleet should remain in the area at least until the date on which reproductive activity begins to decline (around 2 July). In the current framework, a measure of this kind would require the transport fleet to remain in the area for three additional weeks, which would have major economic implications on the fishing industry.

The results and conclusions of this study complement and ratify the results obtained in the analysis of daily CPUE in this region (Gordoa 2010, *in press*) which shown maximum CPUE values between 10 and 30 June when the fishing effort required to reach mean daily performance was from 2 to 5 times less than that required at the beginning or end of the reproduction period.

In summary, considering that the period of maximum daily catches coincides with the reproductive period identified in this study, prudent measurements in terms of sustainability would be as follows: a) allow fishing during the reproduction period, b) maintain cages in the fishing grounds until reproduction activity ends. A sensible proposal to protect the arrival and grouping of reproducers in May and to optimise fishing ecoefficiency purse seine fishing activity should be carried out during June.

The temporal pattern of spawning pattern and of daily catch rates observed in the Western Mediterranean cannot be extrapolated to the entire Mediterranean, which means this proposal cannot be applied to the entire Mediterranean but the terms of sustainability should be common. In summary the current closed season in the Mediterranean is not suitable for the Western Mediterranean. Thus, policy measures should be adapted to the spatial-temporal behaviour of the Atlantic bluefin tuna in the different regions of the Mediterranean.

Acknowledgements

This study was funded by the Balfegó Group as one of the objectives established in the scientific contract (2009-2010) signed with the Centro de Estudios Avanzados de Blanes (CEAB), Consejo Superior de Investigaciones Científicas (CSIC). I wish to thank the crews of transport vessels “Tere Arbó” and “Estela Nova” who helped us in sample collection and the field technicians Gustavo Carreras, Óscar Martínez and Carlos Ribera for their excellent sampling work.

References

- Block, B.A., Dewar, H., Blackwell, S.B., Williams, T.D., Prince, E.D., Farwell, C.J., Boustany, A., *et al.*, 2001, Migratory movements, depth preferences, and thermal biology of Atlantic bluefin tuna. *Science*, 293: 1310-1314.
- Corriero, A., Desantis, S., Deflorio, M., Acone, F., Bridges, C.R., de la Serna, J.M., Megalofonou, P., *et al.*, 2003, Histological investigation on the ovarian cycle of the bluefin tuna in the western and central Mediterranean. *Journal of Fish Biology*, 63: 108-119.
- de la Serna, J.M., and Alot, E. 1992, Análisis del sex-ratio por clase de talla y otros datos sobre la madurez sexual del atún rojo (*Thunnus thynnus* L.) en el Atlántico Este y Mediterráneo. Collective Volume of Scientific Papers, ICCAT, 52: 784-792.
- García, A., Alemany, F., de la Serna, J.M., Oray, I., Karakulak, S., Rollandi, L., Arigò, A., and Mazzola, S. 2005, Preliminary results of the 2004 bluefin tuna larval surveys off different Mediterranean sites (Balearic Archipelago, Levantine Sea and the Sicilian Channel). Collect. Vol. Sci. Pap. ICCAT, 58(4): 1420-1428.
- Gordoa, A., Olivar, M.P., Arevalo, R., Viñas, J., Molí, B., Illas, X. 2009, Determination of Atlantic bluefin tuna (*Thunnus thynnus*) spawning time within a transport cage in the western Mediterranean. *ICES Journal of Marine Science* 66 (in press).
- Gordoa, A. 2010, Temporal pattern of daily CPUE on the bluefin tuna (*Thunnus thynnus*) in the western Mediterranean spawning area. Collect. Vol. Sci. Pap. ICCAT, 65 (inpress).
- Karakulak, S., Oray, I., Corriero, A., Deflorio, M., Santamaria, N., Desantis, S., and De Metrio, G. 2004, Evidence of spawning area for the bluefin tuna (*Thunnus thynnus* L.) in the eastern Mediterranean. *Journal of Applied Ichthyology*, 20: 318-320.
- Oray, I.K., and Karakulak, F.S. 2005, Further evidence of spawning of bluefin tuna (*Thunnus thynnus* L., 1758) and the tuna species (*Auxis rochei* Ris., 1810, *Euthynnus alletteratus* Raf., 1810) in the eastern Mediterranean Sea: preliminary results of TUNALEV larval survey in 2004. *Journal of Applied Ichthyology*, 21: 236-240.
- Rooker, J.R., Alvarado Bremer, J.R., Block, B.A., Dewar, H., De Metrio, G., Corriero, A., Kraus, R.T., *et al.*, 2007, Life history and stock structure of Atlantic bluefin tuna (*Thunnus thynnus*). *Reviews in Fisheries Science*, 15: 265-310.
- Sará, R. 1973, Sulla biologia dei tinni, *Thunnus thynnus* (L.). *Bollettino di Pesca, Piscicoltura e Idrobiologia*, 28: 217-243.
- Susca, V., Corriero, A., Bridges, C.R., and De Metrio, G. 2001, Study of the sexual maturity of female bluefin tuna: purification and partial characterization of vitellogenin and its use in an enzyme-linked immunosorbent assay. *Journal of Fish Biology*, 58: 815-831.

Table 1. Wild group (MS) volume of eggs collected per station. Green: lack of eggs; light yellow: < 50 ml; dark yellow: ≥ 50 ml and ≤ 125 ml; orange: > 125 ml and ≤ 400 ml; red: > 400 ml and ≤ 600 ml; brown: > 600 ml.

Date	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	T°C	Latitude
23/05/2009																
24/05/2009								1								
25/05/2009								2								38°25'
26/05/2009																
27/05/2009								3								20
28/05/2009								4								
29/05/2009																
30/05/2009								5								19.5
31/05/2009																
01/06/2009								6								20
02/06/2009								7								19.5
03/06/2009																
04/06/2009								8								20
05/06/2009								9								20.5
06/06/2009																
07/06/2009																
08/06/2009																
09/06/2009								10								20
10/06/2009								11	12							19
11/06/2009								13	14	15						20
12/06/2009								16	17							20
13/06/2009								18	19	20						20
14/06/2009								c	22	23						20
15/06/2009								c								21
16/06/2009								25								21
17/06/2009								27								21
18/06/2009								28	29							20.5
19/06/2009								c								
20/06/2009								30								21
21/06/2009								31								21
22/06/2009								32								21
23/06/2009								33								20.5 38°48'
24/06/2009								34								
25/06/2009																21
26/06/2009								35								21
27/06/2009								36								21 38°40'
28/06/2009								37								21
29/06/2009																
30/06/2009																
01/07/2009								38								23 40°27'
02/07/2009								39								23
03/07/2009								40								23
04/07/2009								41								23
05/07/2009								42								23
06/07/2009								43	44							24
07/07/2009								c								24
08/07/2009																
09/07/2009																
10/07/2009								45								22
11/07/2009								46								22.5
12/07/2009								48								22
13/07/2009								c								23
14/07/2009								50								22.5
15/07/2009								51								22.5
16/07/2009								52								
17/07/2009								53								
18/07/2009																
19/07/2009								54								
20/07/2009								55								
21/07/2009								56								

Table 2. Domestic group (DM), volume of eggs collected per station. Green: lack of eggs; light yellow: < 50 ml; dark yellow: ≥ 50 ml and ≤125 ml; orange: > 125 ml and ≤ 400 ml; red: > 400 ml and ≤ 600 ml; brown: > 600 ml.

Date	1:00	1:45	2:00	2:30	2:45	3:00	3:15	3:30	3:40	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00	6:15	
24/05/2009								1													
25/05/2009								2													
26/05/2009																					
27/05/2009								3													
28/05/2009								4													
29/05/2009								5													
30/05/2009								6													
31/05/2009																					
01/06/2009								7													
02/06/2009								8													
03/06/2009																					
04/06/2009								9													
05/06/2009								10		11											
06/06/2009																					
07/06/2009																					
08/06/2009																					
09/06/2009																					
10/06/2009						12	13		14												
11/06/2009						15	16		17												
12/06/2009						18	19		20					21							
13/06/2009	22	23	24			25					26				27			28			
14/06/2009						29			30												
15/06/2009						32															
16/06/2009							34														
17/06/2009						35			36												
18/06/2009									37				38								
19/06/2009																					
20/06/2009									39												
21/06/2009									40												
22/06/2009									41												
23/06/2009									42			43									
24/06/2009												44									
25/06/2009																					
26/06/2009												45									
27/06/2009												46									
28/06/2009												47									

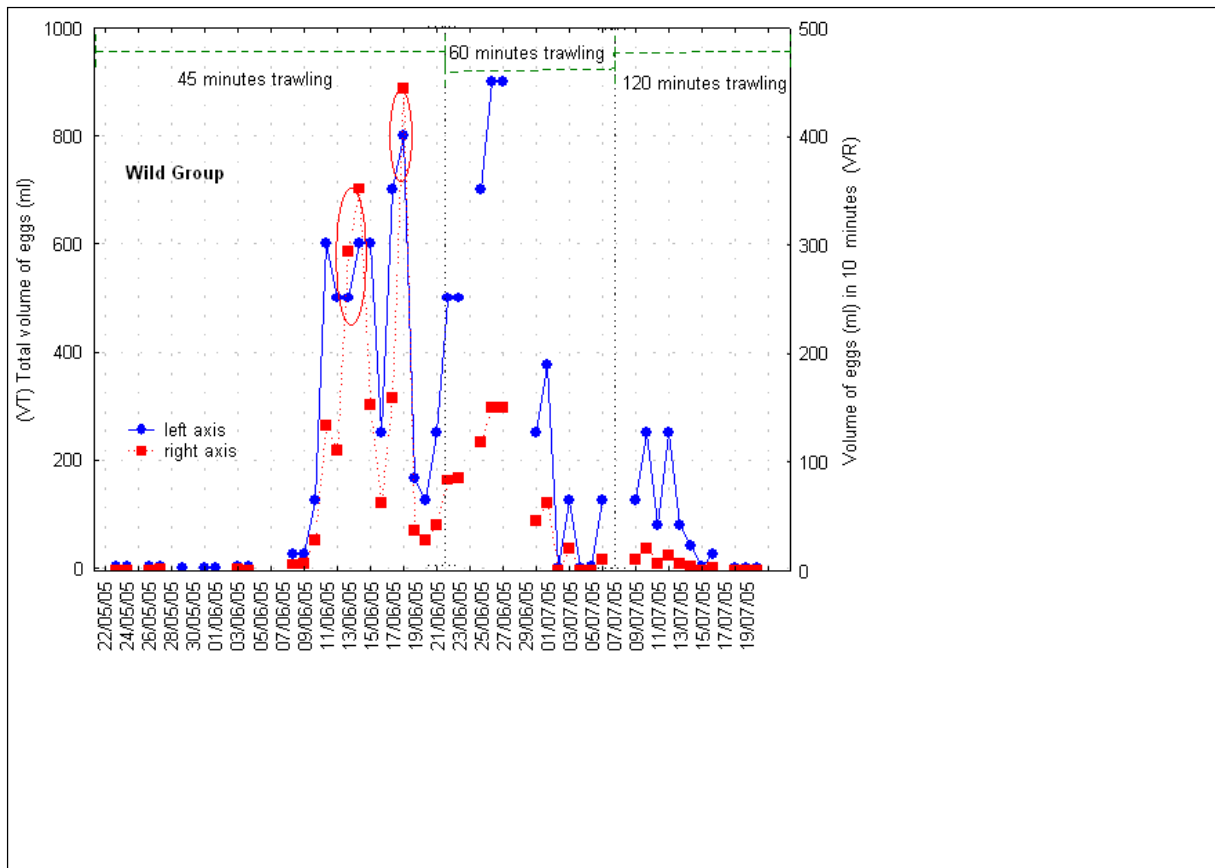


Figure 1. Temporal pattern of Atlantic bluefin tuna eggs collected at each station over the wild group tuna specimens.

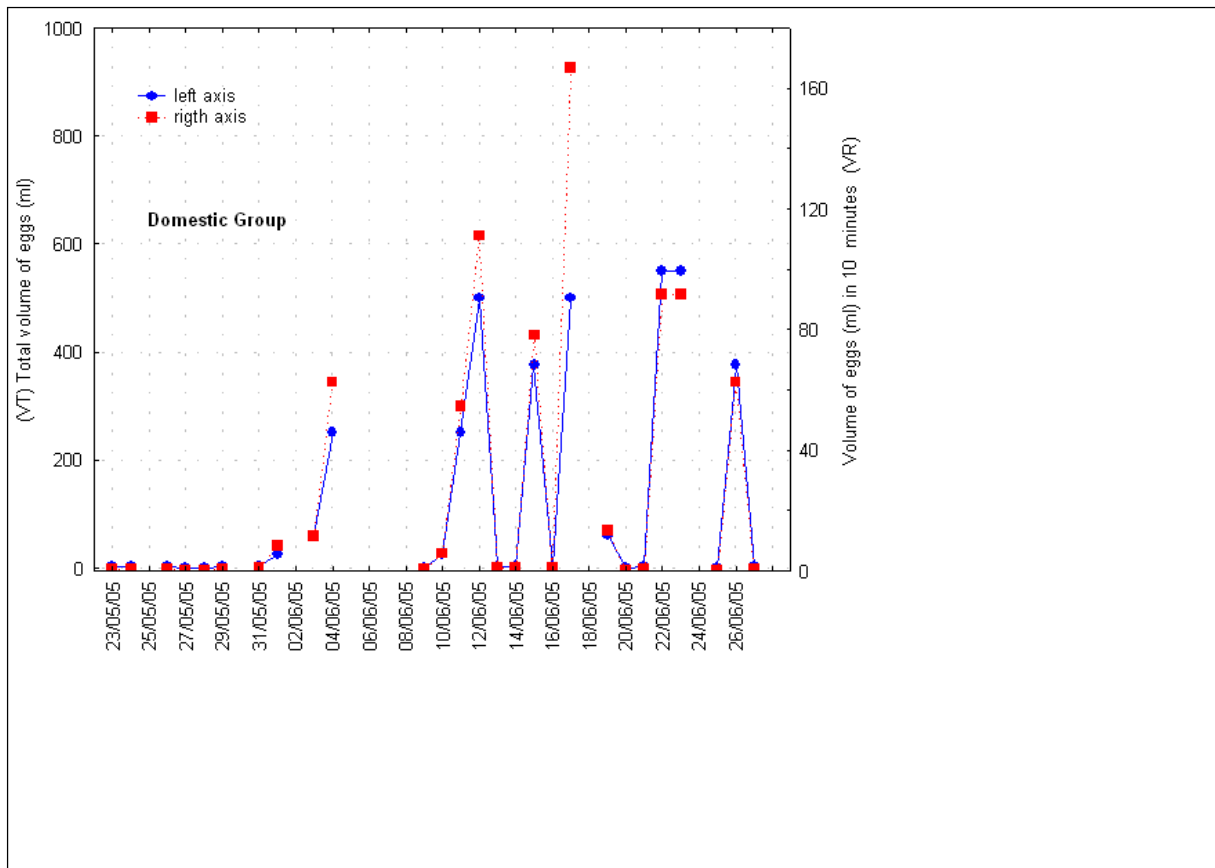


Figure 2. Temporal pattern of Atlantic bluefin tuna eggs collected at each station over the group of specimens kept one year in captivity.

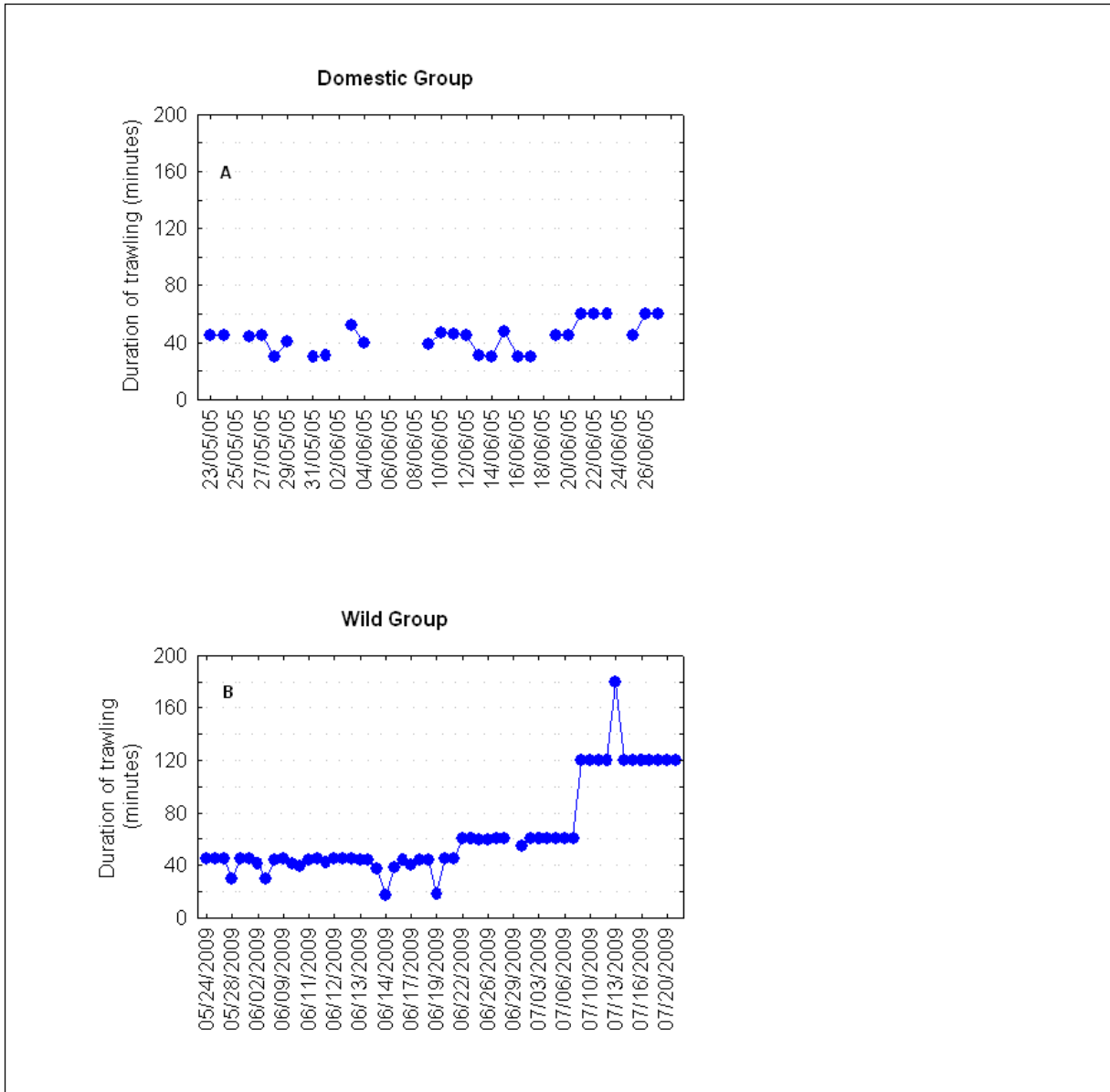


Figure 3. Length of plankton sampling at each station over A) wild group B) domestic group (specimens kept one year in captivity).