Papers in Marine Biology and Oceanography, Suppl. to vol. 3 of Deep-Sea Research, pp. 438-450.

On the breeding areas of the Swordfish (*Xiphias*)*

By Å. Vedel Tåning
Marine Biological Laboratory, Charlottenlund Slot, Denmark

Summary—The Danish oceanographic expeditions with the Research Steamer *Dana* and other ships have obtained about 60 postlarval stages of *Xiphias* (between 5 and 46 mm in length) from all oceans. Most of these, however, were taken in the western North Atlantic.

The distribution of the smallest stages (i.e. smaller than 20 mm in length) indicates that an important breeding area lies north and northeast of the Lesser Antilles in the southern part of the Sargasso Sea. Breeding areas are also indicated by records of small postlarvae west of Sumatra, in the South China Sea, in the Celebes and Banda Seas and off the Marquesas.

Some spawning occurs during all seasons, but maximal spawning seems to take place during February–April in the North Atlantic. Spawning probably takes place at the same season in the western Pacific, but it occurs later in the year in the Mediterranean owing to the special temperature conditions there. The fry are usually found in water of about 24° C. or higher. They are generally captured between the surface and a depth of about 30 metres. The material at hand seems to show a growth rate of about 8 cms during the first year, but sufficient material is not yet available for an accurate determination of the growth rate. The fry preferably feed on fish larvae up to nearly the same size as the small voracious *Xiphias* larva itself (Fig. 1). Figures are given of three developmental stages and outline charts show where fry have been taken. Fishing for swordfish may be possible (by floating lines) in the main spawning area in the western North Atlantic.

Recently the importance of large oceanic fish has increased commercially as well as in sports fishing. It has therefore become not only desirable, but also possible, to broaden our knowledge of the fish fauna on the high seas. Among these large fish, the swordfish (*Xiphias*) is the most appreciated by epicures and sportsmen alike. Although landings of this fish have increased greatly in the last generation, our knowledge of this species still leaves much to be desired. Recently, however, Arata (1954) has made a valuable contribution to its biology, including a description of its earliest development. Therefore, detailed description of the various developmental stages is omitted here, but we have included a few figures of them (Fig. 1).

While many pelagic fish are represented by enormous numbers of fry in the material collected by the *Dana* and other Danish vessels, this is not the case for several of the large species, e.g. the tunny and bill-fish. Thus far, only 500 specimens of the latter have been found in more than 3000 pelagic samples. Some 400 of these belong to the *Istiophoridae*, and only about 60 to the *Xiphiidae*.

The reasons that so few specimens are taken in the youngest stages (about 5–45 mm in length) is undoubtedly chiefly due to the fact that the fry of these large predators of the sea are relatively scarce in comparison with the abundance of the fry of smaller species, and to the fact that they very quickly attain a size which enables them to escape the gear (2 or $1\frac{1}{2}$ metre ring net of stramin or coarse silk) generally used by the *Dana* in catching fish fry. By the time *Xiphias* fry reach a length of about 12–13 mm, they attain sufficient swimming speed to escape the nets (generally towed at a speed of about 1 metre per second). Thus, only about 20% of the fry caught are over

* Papers from the *Dana* Oceanographical Collections No. 45.

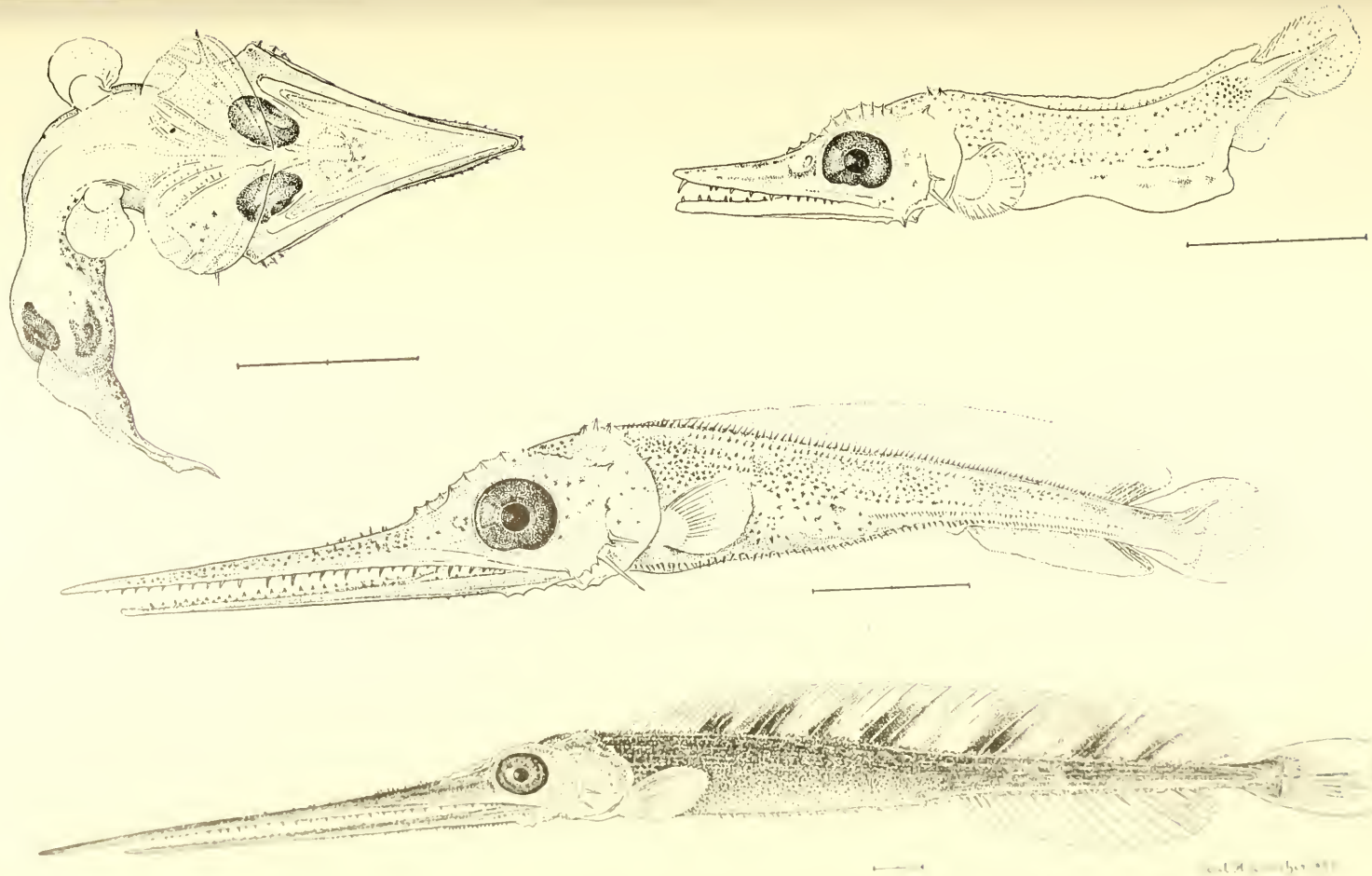

Fig 1. *Xiphias gladius*. Postlarval stages from the North Atlantic. Top, left: 8·2 mm, seen from ventral side; the specimen has swallowed another fish larva (*Dana*, St 1280). Top, right: 7·9 mm (*Dana*, St. 1280). Centre: 15·6 mm (*Dana*, St. 1293). Bottom: 46·3 mm (*Dana*, St 3542). Rule: 2 mm

13 mm in length, and none are over 46 mm. A further reason for the infrequent catches of the fry is that they live near the surface. On the *Dana* expeditions, a ½-metre ring net was usually used in the surface layers rather than a larger one. Even small fry can certainly avoid such a small net. That the fry do indeed frequent the surface layers is also indicated by the fact that the specimens discussed by CHR. LÜTKEN (1880) were collected from a sailing ship at the surface. In addition, most of the 34 *Xiphias* specimens described by ARATA (1954) were small (chiefly 2–3 cm in length), and were taken at the surface in a dipnet during the day. Therefore, in the future some attention should certainly be given to using this or some similar sampling method to delimit the areas frequented by *Xiphias* fry.

As we shall see later, catches of the young stages of *Xiphias* in the *Dana* collection presumably were chiefly taken while the nets were being hauled in, especially when these nets, which had no closing device, were fishing the surface layers just before being hauled in over the ship's side. Furthermore the adult swordfish is a solitary creature and never moves in schools. The scattered catches of the young stages suggests that this habit may be established very early in development.

So few *Xiphias* fry have been reported that they provide only a very limited amount of data for determining the more important spawning areas, the seasonal occurrence, and the vertical and horizontal distribution. Similarly, it is difficult to deduce the relationship between the distribution of the fry and environmental factors. Nevertheless, the material at hand does yield more information than has previously been obtained from earlier, more scattered observations. Therefore, I shall outline the chief points that appear to be indicated by the evidence at hand with the hope that eventually sufficient data will be accumulated to outline the complete life history of this interesting fish.

The map (Fig. 2) with the locations from which Danish vessels have taken specimens of *Xiphias* fry shows that the material comes almost exclusively from the area around the West Indies and the southern part of the Sargasso Sea, and from Indo-Malaya. The former area has yielded by far the greater proportion of these since the Sargasso Sea area has been fished especially intensively and at various times of year. The present paper chiefly aims, therefore, to add to our knowledge of the breeding areas of *Xiphias* in the western part of the North Atlantic.

HORIZONTAL DISTRIBUTION OF FRY

Most of the *Xiphias* specimens from the western part of the North Atlantic were taken on the expeditions of the Motor Schooner *Dana* in April–July 1920, and in February–May 1921, furthermore, on the expeditions of the Research Steamer *Dana* in November–April 1921–1922, and in August 1928. These voyages were undertaken in connection with the investigations of JOHS. SCHMIDT on the breeding areas of the fresh water eel and most of the stations were therefore taken in the Sargasso Sea and adjacent areas.*

We will first consider the distribution of catches of *Xiphias* fry from this area, and the temperature conditions at the localities where they occurred. The captures of

* See list of references for the reports of these expeditions. From these it can be seen how extensive is the network of *Dana* stations in the Atlantic.

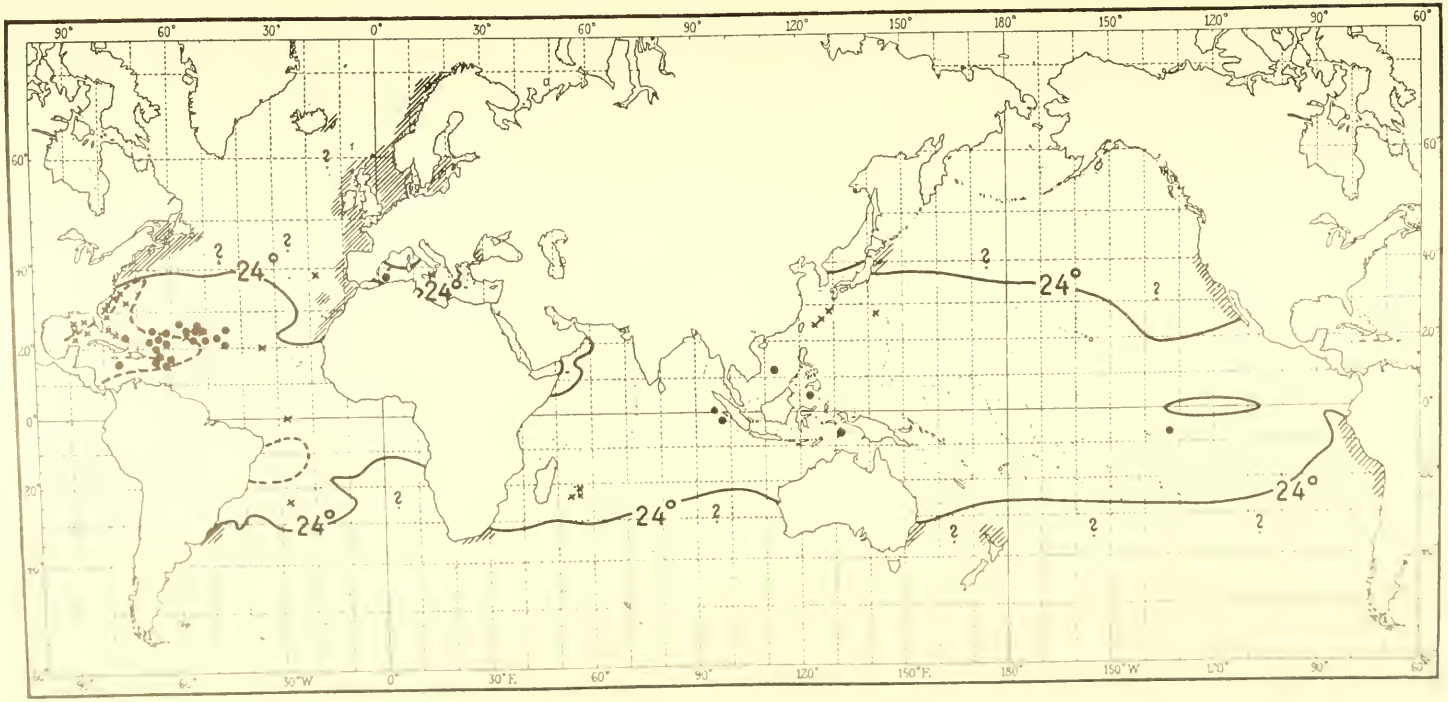

Fig. 2. Records of *Xiphias* postlarvae smaller than 100 mm. ● *Dana* records, × other records. Summer surface isotherm for 24° C is indicated (from SVERDRUP, JOHNSON and FLEMING 1942). (Northern hemisphere: August; southern hemisphere: February) ——— 23° C isotherm in 100 metres depth in the Atlantic (from SCHOTT 1912). //// Dispersion of adult *Xiphias* north and south of the 24° surface isotherm during the northern and southern summer respectively; records from continental waters only available

Xiphias in the Sargasso Sea were not in general from the central part of this area where the most concentrated fishing has been carried out and where the young *Anguilla* larvae have mostly been taken. On the contrary, the specimens were chiefly taken in the southern part of the Sargasso Sea, down toward and among the West Indian islands and thence northeastward. This distribution is clearly illustrated along the track of the Motor Schooner *Dana* in 1921 (Fig. 3). The ship left St. Thomas late in February and surveyed the area between about 20° N and 30° N and 45° W to about 67° W until mid-May. No *Xiphias* fry were taken north of 23° 10′ N, but catches were made at almost all of the southern stations. These extended over the entire section fished between about 45° W and 67° W. At those stations, where the majority of the catches were made, the surface temperatures were about 25° C or more. At two stations, it was 24° C and at only one was it as low as 23·5° C. This locality was not far from an area where the temperatures were 24° C. Fig. 3 shows the positions of the catches in relation to the surface isotherms for 24° C and 25° C. The preceding year (1920), when the Motor Schooner *Dana* left the Mediterranean for this area in late April, *Xiphias* fry were taken as soon as the ship entered water where the surface temperatures were more than 24° C. Then, due to a leak, the schooner was forced to go directly to St. Thomas without making further observations, and could not return to the area before June. At that time, the surface temperatures were 25° C or higher over almost the entire area under consideration, north to about 35° N Lat. (Fig. 4). Despite numerous stations mainly north of 27° N Lat., only a very few *Xiphias* fry were taken in that area, the northernmost being at 26° 19′ N Lat. Therefore, the swordfish's principal spawning season in this area seems to be over by early summer (June).

During the winter of 1921–1922, the Research Steamer *Dana* was in this part of the Atlantic with headquarters at St. Thomas and St. Croix. The ship left the Cape Verde Islands on 3 November heading for French Guiana. It arrived at Barbados on 22 November and proceeded among the Lesser Antilles to a locality east of Barbuda before the first *Xiphias* fry were caught. Since the surface temperatures throughout the area across the Atlantic to Barbuda were between 25° C and 29° C, temperature is not the only factor which limits the distribution of the fry. In December, the vessel worked in the vicinity of St. Croix and then in January on her return from the Pacific (through the Panama Canal), she continued around Cuba to Florida, Haiti and back to St. Croix for further work in that area during March and April. Fishing with pelagic nets was particularly carried out at a locality just west of St. Croix, and here 20 specimens of *Xiphias* fry, chiefly early stages of 5–10 mm, were caught. Some few specimens were caught in other parts of the West Indies area. It may be that the connection with the open Atlantic through the Anegada Passage has something to do with the frequent presence of fry in this particular area. Later in April, the vessel continued into the central portion of the Sargasso Sea, but no *Xiphias* fry were taken there.

In 1928, on the world cruise, the *Dana* went from the Mediterraenean across the Atlantic towards Panama. In the middle of August, the ship passed through the area where most of the *Xiphias* fry had previously been caught. There the *Dana* again caught *Xiphias* fry at every station. Of eight specimens captured, half were 17–46 mm in length and half 6–10 mm. The surface temperatures at this time ranged from 27°–28° C. No more specimens were taken, however, after entering the Caribbean.

In 1911, and for many years thereafter, JOHS. SCHMIDT arranged with various Danish merchant vessels as well as with the Schooner *Margrethe* to fish for eel larvae with pelagic nets, especially in the surface layers of the Atlantic. Later, from 1929 to 1938, the collecting was extended to the Pacific. A few *Xiphias* fry were found in these samples. These individuals were all taken in the area outlined above, i.e. in the especially warm parts of the western Atlantic where there are high temperatures down to a depth of at least 100 metres. When all the Danish records together with the localities for *Xiphias* fry given by ARATA (1954) and by LÜTKEN (1880) in the Atlantic Ocean are plotted (Fig. 2), it is obvious that the portion of the western Atlantic just described, and parts of the Caribbean, must be considered as the most important spawning area for this species in the North Atlantic. Thus, all of ARATA'S and some of LÜTKEN'S specimens came from the western Atlantic and Caribbean. LÜTKEN'S specimens in the Zoological Museum, Copenhagen, range from 10 to 51 mm in length, but only one is smaller than 20 mm in length.

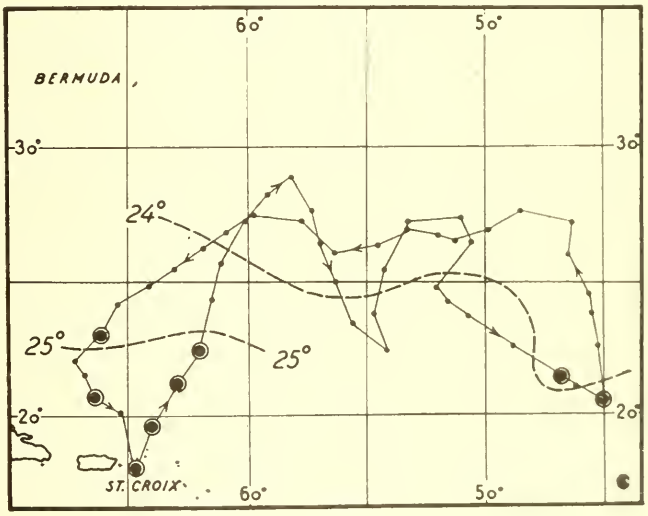

Fig. 3. Records of *Xiphias* postlarvae obtained during the cruise, February–May 1921. ● positive stations, · negative stations. Surface isotherms for 24° C and 25° C indicated.

Despite the extensive collecting by the *Dana* in the Indo-Pacific, especially in the Marquesas–Fiji area, north of New Guinea, Malaya, west of Sumatra and in the Madagascar area, only very few specimens were found (a total of seven specimens, 4·9–17·1 mm in length). These were limited to the area west of Sumatra, the South China, Celebes and Banda Seas and off the Marquesas. LÜTKEN (1880) also mentions a few catches from a merchant ship (commanded by Captain A. F. ANDRÉA) from the Reunion area (Fig. 2), the lengths of three of these specimens (preserved in the Zoological Museum, Copenhagen) are 29·0, 29·5 and 44·5 mm. In addition to these, fry are known in the Pacific, from the North Equatorial Current and from the Kuroshio Current (YABE, 1951; NAKAMURA, 1951). We know of no other records of fry from the Atlantic or Pacific Oceans. Therefore, the boundaries of the breeding areas in these waters cannot be more sharply defined until more specimens are obtained.

SEASONAL DISTRIBUTION OF FRY

Southwestern North Atlantic. To find the breeding areas of a species, the smallest larval stages are the most important, because these are carried by currents alone for comparatively short distances from the spawning area itself. Therefore we will consider only those specimens in postlarval stages smaller than 20 mm in length, in examining the seasonal distribution. As shown below, it is unlikely that any of the postlarval stages were taken in depths greater than 200 metres. Certainly they belong to the warmest, upper water layers, so that we need only consider the nets which fished with 600 metres of wire out or less, because these nets undoubtedly fished only in the upper 200 metres of the sea.

Since various sizes of nets were used, the fishing time was calculated as the number of hours a stramin ring-net 2-metres in diameter was towed.* In the areas where all

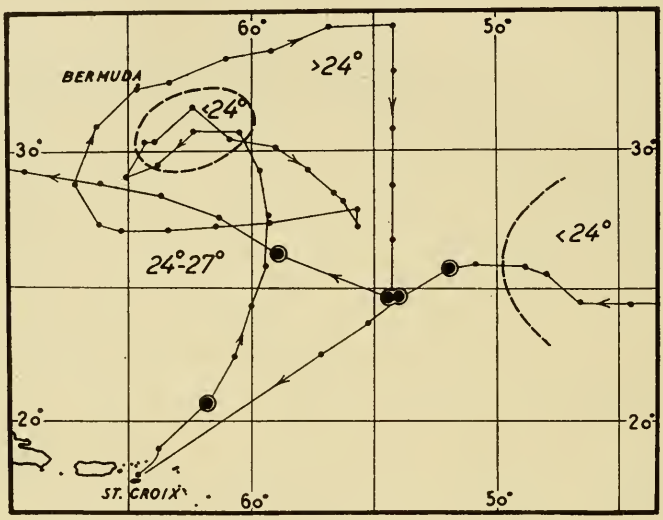

Fig. 4. Records of *Xiphias* postlarvae obtained during the cruise, April–July 1920. ● positive stations, · negative stations. Areas with surface temperatures below 24° C indicated.

the catches were made in the western North Atlantic Ocean, namely in the Caribbean Sea and that part of the Sargasso Sea between 15° N and 30° N and west of 40° W, there have been about 1690 2-metre-stramin-net hours fishing in the upper 200 metres of the sea.

From Table I, it can be seen that the postlarval stages smaller than 20 mm in length, which are mostly less than a month old, occur practically throughout the year. Even the smallest postlarval stages of 5–8 mm in length are found in nearly every month of the year. With so little material, no definite estimate of a peak season can be given. However, omitting the catches for July–September, when little fishing was undertaken in the area, and considering only those months when more than 100 hours or more of fishing actually took place, one notices that the biggest catches occurred in February–March–April. The preceding months show a consistent increase towards

*One hour's fishing with this gear (S200) is calculated as equal to 2 hours with a 1½ m stramin net (S150) or silk net (P150), and to 4 hours with a 1 m stramin net (S100) or silk net (P100).

this maximum, while there is a decline in May through June. Thus, even if *Xiphias* breeds throughout the year in this tropical area, analysis of the data in this way suggests that the maximum is from February to April. ARATA (1954, pp. 234–239), on the other hand, from his own records and those of others which note the appearance of the fry or of mature specimens, concludes that the peak of the spawning season off Florida and Georgia is from April through September. In this connection, it should be noted that our data too indicate the presence of a large number in August (Table I). However, this figure is due to the fact that the *Dana*, on her passage through the southern part of the Sargasso Sea in 1928, chanced on six small specimens in postlarval stages and two a little larger (33·0 and 46·3 mm in length) at the three stations in that area. Consequently, it seems possible that this particular year was an unusually favourable one for the reproduction of this species.

It should be stressed here that the area where the fry discussed in this paper were found *must* be one of the species' chief spawning areas, because equally intensive fishing in adjacent areas to the north and east was carried out from Danish vessels

Table I

The monthly distribution of catches and number of specimens in postlarval stages less than 20 *mm in length per* 100 *hours of fishing*

Month	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Total*
No. hrs. fishing	45	156	274	365	164	214	44	20	4	113	61	216	1690
No. post-larvae <20 mm	1	6	12	14	0	1	2	6	0	1	1	5	49
No. per 100 hrs. fishing	2·3	4·6	4·4	4·0	0	0·5	4·5	30·0	0	0·9	1·5	2·3	3·0

using the same type of gear without taking a single postlarval specimen. Although the area southeast of the main area was fished less intensively, it was sampled rather adequately without finding a single specimen. LÜTKEN (1880) mentions some catches (undated) of specimens in young stages, some as small as 2 cm in length, taken with drag nets at the surface from sailing ships in the centre of the tropical-subtropical Atlantic. Hence, we know that the species *must* also breed there as well. Undoubtedly, spawning is much more scattered there than in the area delimited by the Danish surveys. Thus, when the *Dana* crossed from Capetown to the Canary Islands via St. Helena–Freetown in February–March 1930, no *Xiphias* larvae were taken there despite intensive fishing. In any event, this does not seem to have been the right season to find them in this part of the eastern tropical-subtropical Atlantic.

Mediterranean. In the Mediterranean, where environmental conditions are suitable for the development of a rather sizeable stock of *Xiphias*, only a single *Xiphias* larva has been found to date in the Danish collections. It was taken in the Balearic Sea off Algiers in late September. At Messina (SELLA, 1911; SANZO, 1922; 1930), this species breeds in the summer (June–August) at a time when the surface temperatures

become high enough (> 23°–24° C). Consequently, it is most peculiar that postlarval specimens were not taken during the *Thor* expedition in 1910, since considerable fishing was carried out with pelagic gear in July–August and in early September.

Indo-Pacific. The *Dana* in 1928–29 carried out approximately 1650 hours of pelagic fishing in the surface layers down to roughly 200 metres over wide areas of the Indo-Pacific (Fig. 2). Almost all of the tows were made in areas where the water temperatures were within the limits usual during spawning of this species. Nevertheless, only a few young specimens were taken there. These provide a very incomplete picture of the breeding areas and seasonal distribution. Except for a single specimen near the Marquesas Islands in late September, all of the others are from the Indo-Malaya region during the months of March, April, June, September and November or practically throughout the year.

As mentioned earlier, LÜTKEN's specimens are undated so that they do not help to clarify this point. However, the postlarval specimens of 11–27 mm in length from the western Pacific mentioned by YABE and NAKAMURA were taken from March to May. Consequently, the season seems to correspond to that of the western Atlantic.

VERTICAL DISTRIBUTION OF FRY

It has already been noted that all the evidence points to the fact that the fry are generally found in the uppermost water layers over deep water. The distribution also suggests some connection with island areas (i.e. West Indies, Indo-Malaya, East China Sea, Mediterranean). The reason may be that there is more food in such areas than in the open ocean. Since we only have any significant number of *Xiphias* fry from the western part of the North Atlantic, as previously pointed out, we will delimit the water layers where the fry were taken in that area and consider the size differences at various depths. The material included only two specimens over 2 cm in length: one 33 mm in length, which was taken in a net which was fished at a depth of approximately 30 metres, and one 46·3 mm in length which was taken in a dipnet at night with a light. Therefore our discussion of vertical distribution will include only a consideration of specimens of less than 2 cm in length.

The 53 specimens (< approximately 20 mm) caught in this area of the Atlantic were taken in 43 hauls of the pelagic net. The number per tow was 1 specimen in

Table II

Distribution of Xiphias *fry according to number and size of specimens and the depth of towing*

Metres of wire out	*Approximate depth of capture in metres*	*No. of specimens < 20 mm*	*No. of hrs* fishing*	*No. of specimens per 10 hrs fishing*	*Size range in mm*	*Average size in mm*
Surface–65	0–ca. 20	16	61	2·6	5·9–16·3	8·5
80–100	ca. 30	20	61	3·3	5·8–18·6	9·7
150–200	ca. 50–70	5	35	1·4	6·3–18·2	10·6
300–600	ca. 100–200	8	110	0·7	5·7–20·0	11·2
700–5000	>ca. 230	4	75	0·5	5·6–15·6	10·7

* See p. 444 and footnote on that page for method of calculating fishing hours. The number of fishing hours includes only those stations where specimens were taken.

35 hauls, 2 in 7 hauls,* and 5 in 1 haul, fished at approximately 30 metres. It was exceptional therefore for more than one specimen to be taken in a haul. This indicates that the fry are scattered, and that they often may be captured when the net is being drawn in. From Table II, it appears that the postlarval stages are to be found chiefly in the upper 30 metres. Furthermore, the smallest specimens of 5–6 mm in length were taken in nets which fished for one or more hours at depths down to more than 230 metres. Hence, it is likely that the great majority, perhaps all, of the smaller specimens taken in the nets which were towed rather deep below the surface were actually caught when the nets were being drawn in.

The specimens taken in nets towed in the upper 30 metres were on the average the smallest. This may mean, as it does for the postlarval stages of many other oceanic species, that larger specimens are found deeper than the smaller ones. The latter, we must assume, remain chiefly at the surface where the pelagic eggs presumably float. The small size of our nets and the fact that these were not closing nets makes it impossible, however, to reach any final conclusion on this point. LÜTKEN's and ARATA's findings show, however, that the fry do not avoid strong sunlight in the uppermost layers of the sea. They found postlarval stages of 10 mm and up to 5–8 cm at the surface both during the day and at night. Thus, LÜTKEN has, as already mentioned, records from the Atlantic and Indian Ocean (Fig. 2) taken with a drag-net at the surface. ARATA's series of postlarval specimens and of the adolescent stages of 6·3–80·9 mm from the Gulf of Mexico and Straits of Florida were for the most part taken at the surface in dip-nets. For the time being, it is not possible to determine whether most of the postlarval stages live just below the surface or whether they live somewhat deeper, perhaps within the upper 30 metres.

The few Danish specimens of *Xiphias* from the Indo-Pacific show a vertical distribution similar to that in the Atlantic. Two specimens were taken with 50 metres of wire out, one with 100 metres of wire out, three with 200 metres of wire out and one with 350 metres of wire out. This means that they were from depths of 15–100 metres, unless they were captured when the gear was being hauled in. The size of the specimens ranged from 4·9 to 17·1 mm in length.

ENVIRONMENTAL FACTORS AND THE DISTRIBUTION OF THE FRY

Temperature. The influence of temperature on the distribution of the fry was described above. It is clear that, in the breeding season, *Xiphias* seeks tropical or subtropical areas with high surface temperatures. Although the species migrates far north or south in northern or southern summers respectively, to feed where the water masses have temperatures as low as 12°–13° C or a little lower,† during the breeding season it must migrate to areas where the temperatures are not lower than 23·5° C, more especially in water with temperatures between 25° and about 29° C, as shown by the fact that most fry have been taken at localities where the temperatures were within these limits. Presumably *Xiphias* remains close to the surface during spawning, but there is no definite information on this point. Since the temperature at depths of 75–125 m is less than 23° C at all localities where small

* In one of these hauls from roughly 30 metres depth, one specimen was taken together with the 33 mm-specimen mentioned above. The latter is not included in the table.

† Since *Xiphias* remains in the Mediterranean throughout the year, it must be able to survive in water of 13° C, for the whole water mass falls as low as this in winter.

post-larval stages have been taken, we may assume that the spawning fish do not go any deeper.

In the *southwestern North Atlantic Ocean* surface temperatures between about 23·5° C and 28·1° C have been encountered at all localities where postlarval stages have been taken. Surface temperatures of 24·5°–25·5° C are found during the breeding season from February–April, and this temperature seems accordingly to be the actual lowest spawning temperature. With the approach of summer the temperature rises to 27° to 28° C or a little higher, and then about October it begins to fall again to about 25° C.

In the *Mediterranean Sea*, the surface temperature where the one postlarva was taken was 23·8° C (late September). As already mentioned, spawning apparently takes place in the Mediterranean much later in the year than in the West Indies. The reason for this is apparently that the temperatures favourable for spawning are not high enough until somewhat later (in August it is about 23·3° C–26·5° C).

In *Indo-Malaya*, the surface temperature at the places where postlarval specimens were taken was generally higher than in the Atlantic (namely about 28°–29° C). In the *Pacific* at the Marquesas it was however only about 26° C.

Salinity. Young fry are known to exist at localities where the surface salinities range between about 33·8‰ and 37·4‰; but the adult fish is found at very different salinities, e.g. at 39‰ in the Mediterranean and at 6‰ in the Baltic. The species thus tolerates a wide range of salinities, but it is not possible with the material at hand to determine any correlation between salinity and the breeding habits of *Xiphias*, other than that the salinity must apparently be higher than 34·00‰. Thus, in the general area of the Caribbean, most of the fry have been taken in water with salinities of about 35·9‰–36·7‰ and in Indo-Malaya of about 33·9‰–35·5‰.

Light. Since fry up to 4–5 cm in length have been taken at the surface of tropical seas on clear, sunlit days, and have also been taken there at night with artificial light, this species lives close to the surface under varying light conditions in a manner contrary to many other oceanic species. It is not definitely known how deep they can live and thrive.

GROWTH AND FOOD

Very little is known about the growth of the swordfish. So far as I am aware, no one has made age analyses from the bones or otoliths even in areas such as the Mediterranean where small specimens are regularly caught. SANZO (1922) has reported on the growth under laboratory conditions of newly hatched larvae for a period of ten days.

A review of the postlarval specimens from West Indian waters (ARATA'S and the Danish material combined), although based on fewer than 100 specimens, gives some indication of the growth rate (Table III). Although the method of collection was not the same and the intensity of fishing varied from month to month, it appears that spawning as already mentioned is particularly intense during the early spring. Table III seems to give a rather clear indication of the growth from the early stages (about 8 mm) in March–April to rather larger fry (approximately 23 mm) in July, and to fry of about 70 mm in length by the next spring. To what extent the latter represent the smallest of a larger and far more numerous 1-year group cannot be determined without more material. If specimens of 5–8 cm are representative of the 1-year olds,

a specimen taken in May of 192 mm (ARATA, 1954) should be about 2 years old. This appears however to be far too slow a growth rate for a voracious species such as the swordfish. Unfortunately, NAKAMURA (1951) did not record the measurements of a rather large number of individuals of roughly this size found in the stomach contents of spearfish, measurements which would have provided some useful supplementary data on the growth rate of *Xiphias*. No further information is available on the growth although it is probably very fast, for such a predator, which, in the Pacific, may weigh up to 680 kgs.

Table III

The size of swordfish fry in different months based on the data of ARATA (1954) *and the Danish material*

Size mm	*Month*																	
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*I*	*II*	*III*	*IV*	*V*	*VI*
80–84																	1	
75–79													1			1	1	
70–74																		
65–69																		
60–64																	1	
55–59																		
50–54																1		
45–49								1		1								
40–44																		
35–39					1		1											
30–34					1		3	1										
25–29					1		3											
20–24	1		1				9											
15–19		2		1			1	3				1						
10–14		2	2	3			2	1		1	1	2						
5–9	1	2	9	13	1	3	2	2			1	2						

The stomach contents of young stages indicate that the fry in the postlarval stages very soon progress from a copepod to a pure fish diet. Indeed, they often prey on close relatives (ARATA, 1954). To show how greedy this species is even in very early stages, we need only refer to Fig. 1. It shows a postlarval specimen of about 8 mm which has swallowed another fish larva, almost as large, so that the specimen appears to have eyes at both ends. The prey was swallowed head first. This was also the case in three other *Xiphias* specimens from the same haul with the prey in various stages of digestion. This exceptional catch of 5 postlarval specimens of 7–9 mm in one net, four of which were stuffed with food, suggests that they had become sluggish as a consequence. Thus, this may explain why so many were taken at one time. Normally, the majority would have escaped the net. Thus, it appears that even such small individuals must be very swift swimmers.

From our study, it is apparent how little is known of the breeding places, although it is clear that spawning takes place over all oceans where the surface temperatures are more than 23°–24° C. Little is known of the fry's migration away from the principal breeding areas and of the mature fish's migrations except in certain coastal areas. For example, it is not known whence come the migrants to northwest European waters during the summer and fall months, whether from the stock in the vicinity of the Iberian peninsula and the Mediterranean or from that of the western Atlantic.

With the development of fisheries for large pelagic, predatory species out on the open ocean, it is conceivable that a fishery can be developed in the chief Atlantic spawning area (floating line fishery).

In this and other areas of the open ocean there are also spawning places of other large pelagic fish. The closely related family of the Istiophorids is found in rather large numbers—we have over 400 postlarval specimens from all seas—in the same areas as *Xiphias* as well as over a large part of the Sargasso Sea. In contrast to *Xiphias*, we have however found numerous Istiophorids in the Madagascar area and many west of Sumatra. Otherwise there were relatively few Istiophorids in Indo-Malaya. As for *Xiphias*, the Istiophorids fry were totally absent in an area just north of New Guinea which has been intensively surveyed. The hydrographic conditions there gives no clue as to the reason for this. In the Samoa-Fiji area, there were a number of Istiophorid fry, but none of *Xiphias*.

From the above it becomes clear that, despite the extensive surveys of the Danish Oceanographic Investigations, relatively little has been learned of the life history of these large oceanic fish. Real progress on these problems can only be made with greater co-operation among the research organizations of the world. Thus, much useful information might be obtained with only a few extra hours of work in areas from which we have no records. It should moreover be noted that other fast predatory fish (*Coryphaena*, *Istiophorus*, etc.) are better able to catch fry which swim as swiftly as the *Xiphias* fry than is man. Collection of stomach contents of large predatory fish should accordingly always be carried out when possible.

REFERENCES

ARATA, G. F., JR. (1954), A contribution to the life history of the swordfish, *Xiphias gladius* Linnaeus, from the south coast of the United States and the Gulf of Mexico. *Bull. Mar. Sci., Gulf and Caribbean*, **4** (3), 183–243.

BIGELOW, H. B. and SCHROEDER, W. C. (1953), Fishes of the Gulf of Maine. *Fish. Bull., U.S. Fish and Wildlife Service*, (*Fish. Bull.* 74), **53**, 1–577.

CARLSBERG FOUNDATION (1934), Introduction to the reports from the Carlsberg Foundation's Oceanographical Expedition Round the World, 1928-30. *Dana-Rept.* **1**, 1–78.

GOODE, G. B. (1883), Materials for a history of the swordfish. *Rept. U.S. Comm. Fish and Fish.* for 1880, 289–394.

LA MONTE, F. (1944), Note on breeding grounds of blue marlin and swordfish off Cuba. *Copeia*, 1944, (4), 258.

LÜTKEN, CHR. (1880), Spolia Atlantica. Bidrag til Kundskab om Formforandringer hos Fiske under deres Vœxt og Udvikling, sœrligt hos nogle af Atlanterhavets Højsøfiske. *Vidensk. Selsk. Skr.* (5), **12**, 441–447.

NAKAMURA, H. (1951), Notes on the life history of the swordfish, *Xiphias gladius* Linnaeus. *Japanese J. Ichthyol.* **1** (4), 264–271.

SANZO, L. (1922), Uova e larve di *Xiphias gladius* L. *Mem. R. Com. Talassograf. Ital.*, **79**, 1–17.

SANZO, L. (1930), Giovanissimo stadio larvale di *Xiphias gladius* L. di mm. 6, 4. *Mem. R. Com. Talassograf. Ital.*, **170**, 1–8.

SCHMIDT, JOHS. (1912), Introduction. *Rept. Danish Ocean. Exped.*, 1908–1910, *to the Mediterranean and adj. Seas*, **1**, 1–49.

SCHMIDT, JOHS. (1919), Stations in the Atlantic, etc., 1911–15, with two charts and introductory remarks. *Medd. Komm. Havundersøgelser*, (*Fisk.*), **5** (7), 1–27.

SCHMIDT, JOHS. (1929), Introduction to the oceanographical reports including list of the stations and hydrographical observations. *Danish "Dana"-Exped.*, 1920–22, *in the N. Atlantic and Gulf of Panama, Ocean. Repts.* No. 1, 1–87.

SCHOTT, G. (1912), Geographie des Atlantischen Ozeans. Hamburg, 330 pp.

SELLA, M. (1911), Contributo alla conoscenza della riproduzione e dello sviluppo del Pesca-Spada (*Xiphias gladius* L.). *Mem. R. Com. Talassograf. Ital.*, **2**, 1–16.

SVERDRUP, H. U., JOHNSON, M. W. and FLEMING, R. H. (1942), The Oceans: their physics, chemistry and general biology. Prentice-Hall, Inc., New York, 1087 pp.

TÅNING, Å. V. (1944), List of supplementary pelagic stations in the Pacific Ocean and the Atlantic, with an introduction. *Dana-Rept.* **26**, 1–15.

YABE, H. (1951), Larva of the swordfish, *Xiphias gladius*. *Japanese J. Ichthyol.*, **1** (4), 260–263.