Ecological Studies on the Jelly-fish, Aurelia aurita (L.), in Urazoko Bay, Fukui Prefecture-V.: Vertical Distribution of the Medusa

能登臨海実験所年報，第 10 巻
Ann. Rep. Noto Mar. Lab.,
Vol. 10, Dec. 1970, pp. 15—22.

Ecological Studies on the Jelly-fish, *Aurelia aurita* (L.), in Urazoko Bay, Fukui Prefecture - V. Vertical Distribution of the Medusa*

Tôru YASUDA

Fukui Prefectural Fisheries Experimental Station, Matsushima, Tsuruga, Fukui Prefecture

In spite of the common and world-wide occurrence of the jelly-fish, *Aurelia aurita*, studies on its vertical distribution have been reported by rather a small number of authors including AGASSIZ (1862), MAYER (1900), BROWN (1901) and VERWAY (1942) who all qualitatively investigated it by eye-observation. Recently, ÔSHIMA *et al.* (1967) and KUWABARA (1969) made quantitative studies on the vertical distribution of the medusa in Lake Hamana-ko, and KUWABARA *et al.* (1969) reported two cases observed in the northeastern part of Tokyo Bay. But, these are all concerned with the observations made in limited seasons. The present author formerly reported on the patterns of local occurrence of medusa and ephyra of *Aurelia aurita,* and its growth and breeding season in Urazoko Bay along the coast of the Sea of Japan (YASUDA, 1968, 1969, 1971). The present report, as a part of the series of ecological studies of the medusa, deals with the vertical distribution which was observed nearly throughout all the seasons in the same bay.

The author wishes to express his sincere gratitude to Professor Kikuya MASHIKO, Director of the Noto Marine Laboratory, University of Kanazawa, and Dr. Saburo NISHIMURA of the Seto Marine Biological Laboratory, University of Kyoto, for their helpful suggestions and critical reading of the manuscript. Thanks are also due to Professor Emer. Tadashi TAMURA and Professor Hikoei OHMI of the Hokkaido University and Mr. Masakazu NIWA, Director of the Fukui Prefectural Fisheries Experimental Station, for their valuable suggestions and encouragement shown to the author during the course of his investigation.

Materials and Methods

Urazoko Bay is a small inlet in Wakasa Bay situated along the coast of the south-eastern part of the Sea of Japan (Fig.1). The detailed topographical and oceanographical conditions of the bay were described in the previous reports (YASUDA,

* The present work was supported in part by a grant from the Nihon Electric Power Company Inc.

1968, 1969). The medusae were collected by means of vertical hauls of a conical plankton-net (60 cm in mouth aperture, 2 mm in mesh size, 200 cm in length) from different depths at each fixed station and at the sites where the medusae were densely distributed during the period from January of 1967 to March of 1968. The hydrographic and meteorological observations were also simultanously made. The number of medusae in each layer was calculated from the difference between the catches by the deeper and shallower hauls successively made as was done by KUWABARA (1969).

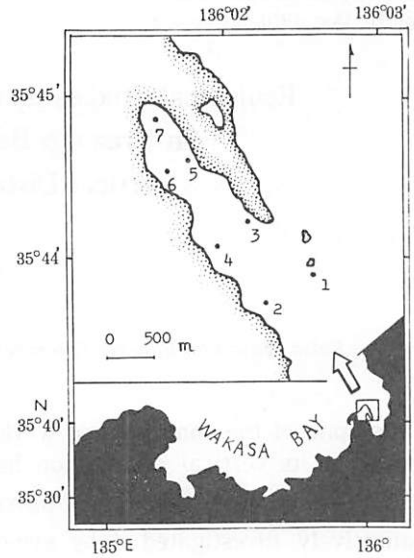


Fig. 1. Map of Urazoko Bay showing the stations where the researches were carried out.

Results and Discussion

The vertical distribution of the medusae, the water temperature and the water density *in situ* are shown in Fig. 2. As seen in this figure, the vertical distribution of the medusa is variable according to the station, season and meteorological condition. In regard to the patterns of occurrence of the highest density, however, the following four types are remarked: A, most abundant in the layer of 0-5 m; B, most abundant in the layer of 5-10 m; A-B, abundant in both 0-5 and 5-10 m layer; C, most abundant in the layer deeper than 10 m. The relation of the occurrence of each type to weather condition and season is shown in Table 1.

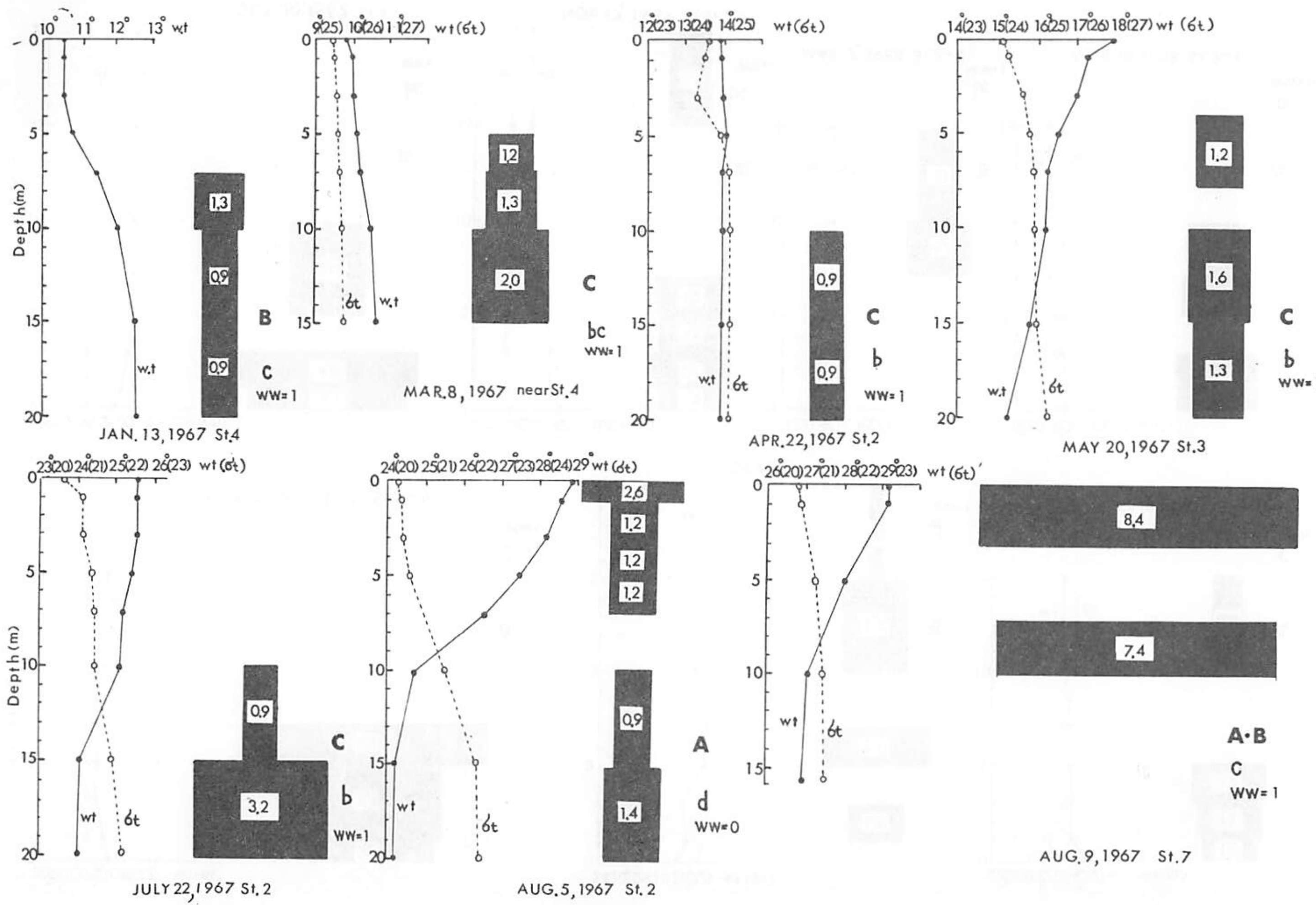
In regard to the sea surface condition, only two cases of Type A were observed in the smooth condition, while all of the other surveys were carried out in the ruffled condition where all the types, A, B, A-B and C, were detected. Though some remarkable thermocline was often found, no definite realation was recognized between the water temperature and the vertical distribution of medusa. The density *in situ* of the sea water had no notable relation with the vertical distribution of medusa as well.

According to the studies of ÔSHIMA *et al*. (1967) and KUWABARA (1969) in Lake Hamana-ko, the maximum occurrence of *A. aurita* was found in the middle layer, and they are of the opinion that this phenomenon may be attributed to the balance with

Fig. 2. Representative cases of the vertical distribution of the medusae of *Aurelia aurita* in Urazoko Bay under various conditions during the period from January 1967 to March 1968.

Figures in shaded areas indicate cubic roots of the individual number per m^3. Large letters A, A-B, B, C mean types of the vertical distribution.

Small letters indicatate the weather condition. b, blue sky; bc, blue sky with a little clouds; c, cloudy; o, overcast sky; d, drizzling rain, and w. w. means the condition of wind wave.



Depth(m)
JAN. 13, 1967 St.4
B
C
WW=1
MAR.8, 1967 near St.4
C
bc
WW=1
APR.22,1967 St.2
C
b
WW=1
MAY 20, 1967 St.3
C
b
WW=1
JULY 22, 1967 St.2
C
b
WW=1
AUG.5, 1967 St.2
A
d
WW=0
AUG.9, 1967 St.7
A·B
C
WW=1

Fig. 2

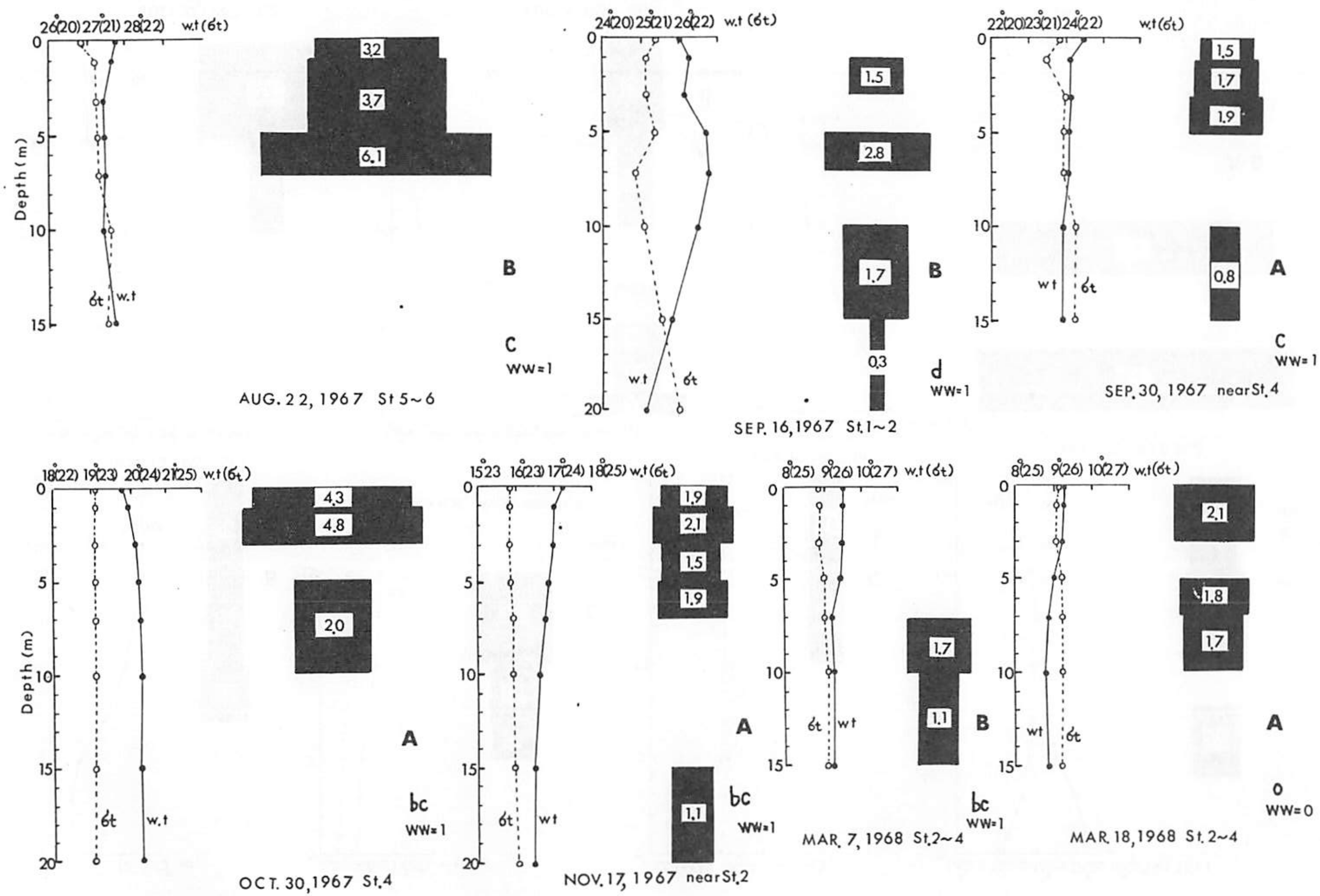


Fig. 2 (continued)

Table 1

Weather \ Type \ Season		Spring (Mar.-May)	Summer (June-Aug.)	Autumn (Sept.-Nov.)	Winter (Dec.-Feb.)	Total
Bright	A	—	—	—	—	—
	A—B	—	—	—	—	—
	B	—	—	—	—	—
	C	2	1	—	—	3
Fair	A	—	—	2	—	2
	A—B	—	—	—	—	—
	B	1	—	—	—	1
Cloudy or Drizzling rain	A	1	1	1	—	3
	A—B	—	1	—	—	1
	B	—	1	1	1	3
	C	—	—	—	—	—
	Total	5	4	4	1	14

the water density *in situ*. From the results obtained in Tokyo Bay, on the other hand, KUWABARA *et al.* (1969) suggest that the vertical distribution of the medusa may have close relation to the movement of water resulted from the difference of density of water rather than to the water density itself. In Urazoko Bay, however, there seems to be no definite correlation, as mentioned above, between the vertical distribution of medusa and the density *in situ* as well as the water temperature.

In the present study, it was noticed that during the spring (March to May) and summer (June to August) the medusae were distributed most abundantly in the lower layer deeper than 10 meters on bright and fair days while they were mostly found in the upper 5 meter layer on cloudy or drizzling days, and that during the autumn (September to November) the medusae were observed most abundantly in the upper layer from surface to 5 meters even on fair days in contrast with the spring-summer condition. This tendency described above agrees very well with the observation of AGASSIZ (1862) along the coast of Florida and that of MAYER (1900) at Havana Harvor and also with the experience of observation by many fishermen of the Urazoko Bay region. It seems to be a noteworthy fact that during the autumnal season the medusae were abundant in the upper layer even on fair days. This may indicate that the medusae swim more actively when the underwater illumination becomes weaker day by day as compared with condition in the spring-summer season when the illumination becomes increasingly stronger. In this connection, the result shown by IRISAWA *et al.* (1956) that the bell pulsation of *A. aurita* increases with the decrease of light intensity may deserve a particular attention. The similar response in the shadow reaction was proved for Schyphomedusa *Dactylometra pacifica* GÖTTE (TAMASHIGE, 1969) and the Hydromedusae *Spirocodon saltatrix* TILESIUS (KIKUCHI, 1947; HIṢADA, 1956) and *Polyorchis* *karafutoensis* KISHINOUYE (TAMASHIGE and YAMAGUCHI, 1967). In view of these facts, it may be safely concluded that under ordinary conditions, the main factor affecting the vertical distribution of *A. aurita* is the underwater illumination. The same view was also suggested by RUSSELL (1928), VERWEY (1942) and UCHIDA (1961), though they showed no concrete data. The influence of the sea surface condition on the vertival distribution of the medusa also seems often to be important as seen in Fig. 2, and this agrees with the observations of AGASSIZ (1862) of the Florida coast and VERWEY (1942) in the North Sea. CHAS and HARGITT (1910) noticed for the Schyphomedusa *Cyanea arctica* PÉRON nearly the same correlation with the wind wave conditions. For further discussion on this problem, however, more detailed researches may be required.

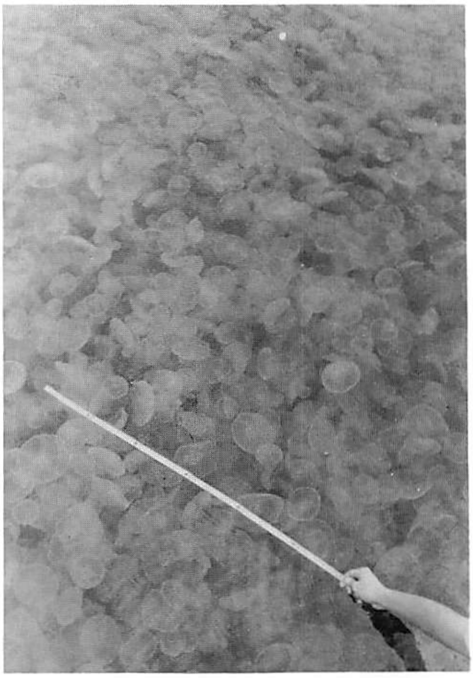


Fig. 3. *Aurelia* medusae in a large belt-like patch observed at the inner part (St. 7) of Urazoko Bay on 9th August, 1967.

As the maximum occurrence of medusae, 596.4 individuals per m^3 in the upper layer from surface to 3 meters and 410.7 in the middle layer from 7 to 10 meters were recorded at the inner part of the bay on Aug. 9, 1967 (Figs. 2 and 3). As the patches observed at that time were mainly composed of medusae of 6 to 7 cm in bell diameter, the body weight can be calculated to be 13.1 to 21.5 g by the following empirical relationship (YASUDA, 1969):

$$W = 0.1673L^{2.498}$$

where W is the body weight, L is the bell diameter. Hence, the biomass of medusae in each layer attains the values from 7.8 to 12.8 kg per m^3 and 5.4 to 8.8 kg per m^3 in the surface layer and the middle layer, respectively. These values are near the highest biomass given by KUWABARA *et al.* (1969) which were obtained in the north-eastern part of Tokyo Bay at the period of the highest population density. It may be added that the above mentioned patch of the surface layer took forms, about 2 meters in width and 30 meters in length in one belt and about 4 meters in width and 60 meters in length in the other, and both the patches drifted away towords the mouth of the bay. If it can be assumed that the medusae were distributed evenly down to 3 meters in these patches, their biomasses may be calculated approximately to be 1.4 to 2.3 tons in the smaller patch, and 5.6 to 9.2 tons in the larger one, in the volume of sea water of about 180 and 720 m^3, respectively.

As the atomic power-plant which is now being built on the coast of the inner part of Urazoko Bay takes in 20 m^3 of sea water per second for the purpose of cooling the condenser, *Aurelia* patches of about 1.4 to 9.2 tons may, at the time of the peak of occurrence, attack the water intake of this plant in a few minutes (YASUDA, 1969). Although the thermal powerplants and other littoral factories in Japan now use preventive nets or bar screens with rotary rakes as countermeasures for the accidents or damages caused by the medusae (MATSUEDA, 1969), it is nessary to examine carefully whether or not these apparata have the ability sufficient to prevent the damage caused by the above-mentioned biomasses at the peak of their occurrence.

Summary

As a part of ecological studies on the jelly-fish, *Aurelia aurata* in Urazoko Bay, Fukui Prefecture, the vertical distribution of medusa was investigated by means of successive vertical hauls of a net at different layers during the period from January of 1967 to March of 1968. No definite correlation was recognized between the vertical distribution of the medusae and the water temperature as well as the density *in situ*. On the whole, the medusae mostly occurred in the lower layer (below 10 m) on bright days, and in the upper layer (0-5 m) on cloudy or drizzling days. In autumnal season, however, the medusae tended to occur most abundantly in the upper layer even on fair days. This may indicate that the main factor affecting the vertical distribution of *A. aurita* is the condition of illumination in the sea. The biomass of the patches of the medusae at the peak of its occurrence is calculated to range 1.4 to 9.2 tons approximately.

References

AGASSIZ, L., 1862, Contribution to the natural history of the United States of America, 4, pp. 12—86, Boston.

BROWNE, E, T., 1901, Variation in *Aurelia aurita*. Biometrika, 1 : 90—108.

CHAS, W., and HARGITT, G. T., 1910, Stdies in the development of Scyphomedusa. J. Morph., 21 (2) : 217—263.

HISADA, M., 1956, A study on the photoreceptor of a medusa, *Spirocodon saltatrix*. Jour. Fac. Hokkaido Univ., Ser. 6, Zool, 12 : 529—533.

IRISAWA, H., IRISAWA, T., and NISHIDA, Y., 1956, Responses on the receptor of a medusa, *Aurelia aurita*, light stimuli. Kagaku, 26 : 312—313 (in Japanese).

KIKUCHI, K., 1947, Shadow reaction and vertical distribution of a medusa, *Spirocodon saltatrix*. Zool. Mag., 57 144—146 (in Japanese).

KUWABARA, R., 1969, Ecological studies of the medusa *Aurelia aurita* LAMARCK—II. Distribution and biomass of *Aurelia* in Lake Hamana in summer 1965. Bull. Mar. Biol. Stat. Asamushi, Tôhoku Univ., 13 (3) : 193—200.

KUWABARA, R., SATO, S., and NOGUCHI, N., 1969, Ecological studies of the medusa *Aurelia aurita* LAMARCK—I. Distribution of *Aurelia* paches in the north-east region of Tokyo Bay in summer 1966 and 1967. Jap. Soc. Sci. Fish, 35 (2) : 156—162 (in Japanese with English summary).

MATSUEDA, N., 1969, Presentation of *Aurelia aurita* at thermal power station. Bull. Mar. Biol. Stat. Asamushi, Tôhoku Univ., 13 (3) : 187–191.

MAYER, A. G., 1900, Some medusae from Tortugas Florida. Bull. Mus. Com. Zool. Harvard College., 37 (2) : 13—82.

ÔSHIMA, Y., KASAHARA, S., FUTAMURA G., and KUWABARA, R., 1967, Kurage haijyo ni kansuru chosa kenkyu. Toden Gijitsu Kenkyusho. pp. 1—23 (in Japanese).

RUSSELL, F. S., 1928, The vertical distribution of marine macroplanktons-VI. Further observations on diurnal changes. Jour. Mar. Biol. Assoc. U. K. 15 : 81—106.

TAMASHIGE, M., and YAMAGUCHI, T., 1967, Equilibrium orientation controlled be ocelli in an Anthomedusa, *Polyorchis karafutoensis*. Zool. Mag., 76 : 35—36 (in Japanese with English summary).

TAMASHIGE, M., 1969, The marginal sense of medusa. Bull. Mar. Biol. Stat. Asamushi, Tôhoku Univ., 13 (3) : 211—214.

UCHIDA, T., 1961, Dôbutsu keito bunrui gaku 2 : 55—204, Nakayama Shoten, Tokyo (in Japanese).

VERWEY, J., 1942, Die Periodizität in Auftreten und die aktiven und passiven Bewegungen der Quallen. Arch. Neerland. Zool., 6 (4) : 303—468.

YASUDA, T., 1969, Ecological studies on the jelly-fish, *Aurelia aurita*, in Urazoko Bay, Fukui Pref.-I. Occurrence pattern of the medusa. Jap. Soc. Sci. Fish., 35 (1) : 1—6 (in Japanese with English summary).

YASUDA, T., 1968, Ecological studies on the jelly-fish, *Aurelia aurita*, in Urazoko Bay, Fukui Pref.-II. Occurrence pattern of the ephyra. *ibid.*, 34 (11) : 983—987 (in Japanese with English summary).

YASUDA, T., 1969, Ecological studies on the jelly-fish, *Aurelia aurita*, in Urazoko Bay, Fukui Pref.-III. Growth. The Aquicultrue, 17 (3) : 145—154 (in Japanese).

YASUDA, T., 1971, Ecological studies on the jelly-fish, *Aurelia aurita*, in Urazoko Bay, Fukui Pref.-IV. Monthly change in the bell-length composition and breeding season. Jap. Soc. Sci. Fish., 37 (5) : 364—370 (in Japanese with English summary).