Growth rates of captive dolphin, *Coryphaena hippurus*, in Hawaii

Daniel D. Benetti
Rosenstiel School of Marine and Atmospheric Science
Division of Marine Biology and Fisheries, University of Miami
4600 Rickenbacker Causeway, Miami, Florida 33149

The Oceanic Institute, Makapuu Point
P.O. Box 25280, Honolulu, Hawaii 96825

Edwin S. Iversen
Rosenstiel School of Marine and Atmospheric Science
Division of Marine Biology and Fisheries, University of Miami
4600 Rickenbacker Causeway, Miami, Florida 33149

Anthony C. Ostrowski
The Oceanic Institute, Makapuu Point
P.O. Box 25280, Honolulu, Hawaii 96825

Dolphin, *Coryphaena hippurus*, also known as mahimahi or dolphin fish, are pelagic, predatory fish distributed in tropical and subtropical regions throughout the world (Johnson, 1978; Palko et al., 1982). They are an important resource, supporting commercial and sport fisheries throughout their range (Oxenford and Hunte, 1986) as well as having considerable potential for aquaculture (Hagood et al., 1981; Szyper et al., 1984; Kraul, 1989, 1991).

Gibbs and Collette (1959) and Palko et al. (1982) reviewed the distribution and biology of dolphin, including age and growth data on wild and captive fish. Age and growth of wild (Oxenford and Hunte, 1983) and captive (Uchiyama et al., 1986) fish have been estimated from daily increments on otoliths and scale annuli (Beardsley, 1967; Rose and Hassler, 1968), from modal progression in length-frequency distribution (Wang, 1979), and from fish of known age reared in captivity (Hassler and Hogarth, 1977; Hagood et al., 1981; Szyper et al., 1984; Ostrowski et al., 1989, 1992; Iwai et al., 1992). There is considerable variability in the data, reflecting environmental and nutritional differences associated with experimental designs for captive fish, as well as differences in size, age, and origin of wild fish. In this paper, growth rates of dolphin reared in Hawaii are presented and compared with those of captive and wild dolphin from different populations, as well as other teleost species. The data presented suggest that there are differences in growth rates and morphology between captive and wild dolphin.

Materials and methods

Fish were reared in captivity at The Oceanic Institute, Hawaii, from eggs obtained from wild Hawaiian broodstock fish (F_1; first generation) maintained at Anuenue Fisheries, State of Hawaii. Up to 3 months-of-age juveniles were fed a semi-moist (27.86% moisture) manufactured diet (pellet) twice daily (4% of their body weight per day). The diet contained 53.75% crude protein, 21% crude fat, and a caloric content of 5.13 $cal \cdot mg^{-1}$ (dry matter basis). Between 3 and 9.5 months, fish were fed to satiation once a day on a mixed diet of extruded salmon pellet (Moore-Clarke), frozen squid, and fish. The feed conversion ratio (FCR) is expressed as a ratio between the dry weight of the total amount of food given and the weight gain of live fish.

Up to 3 months-of-age juvenile fish were reared in an outdoor circular tank of 18,800 L (4 m diameter × 1.5 m water column height). After 3 months, fish were transferred to a 28,000-L tank (6 m diameter × 1 m water column height) used for broodstock maintenance. Both tanks had running ambient seawater (25–27°C and 33–35 ppt salinity) at high flow rates (water turnover rate was at 10 tank volumes per day) and under constant aeration.

The initial population was 48 fish, stocked at approximately 3 fish per m^3. Growth data presented correspond to pooled male and female fish periodically sampled during the period studied (1–9.5 months). Data are of individually sampled fish and are not averages. Small fish (1–3 months) were sampled daily. Sampling frequency of intermediate (3–6 months) and large (6–9.5 months) fish was weekly and bimonthly, respectively, owing to difficulties in handling larger dolphin and because there were fewer individuals available for sampling. Since dolphin metamorphosis occurs during the third week after hatching and one month-old fish are fully developed juveniles (Benetti, 1992; Kim et al., 1993), all data corresponding to fish from 1 to 9.5 months-old were combined.

Manuscript accepted 31 May 1994.
Fishery Bulletin 93:152–157 (1995).

Results are expressed as:

Absolute growth	$AG = W_2 - W_1$
Absolute growth rate	$AGR = (W_2 - W_1) / (t_2 - t_1)$
Relative growth	$RG = (W_2 - W_1) / W_1$
Relative growth rate	$RGR = (W_2 - W_1) / W_1 (t_2 - t_1)$
Instantaneous growth rate	$IGR = (\ln W_2 - \ln W_1) / (t_2 - t_1)$
Specific growth rate	$SGR = (\ln W_2 - \ln W_1) / (t_2 - t_1) \times 100$
Length-weight relationship	$W = a L^b$
VGBM (length)	$L_t = L_\infty (1 - e^{-K(t-t_0)})$
VGBM (weight)	$W_t = W_\infty (1 - e^{-K(t-t_0)})^b$,

where W_1 = initial wet weight of fish; W_2 = final wet weight of fish; t_1 = time at the beginning of an interval; t_2 = time at the end of an interval; L = fork length in cm; a and b are constants; L_t = fork length (cm) at time t; W_t = total weight (kg) at time t; L_∞ and W_∞ = theoretical asymptotic length and weight, respectively; K = constant indicating the rate of change in length and weight (the Brody growth coefficient); t= time; t_0 = time of hatching; and VBGM is the von Bertalanffy growth model (Ricker, 1975, 1979; von Bertalanffy, 1962; Fabens, 1965):

Table 1

Growth rates of captive dolphin, *Coryphaena hippurus*, in Hawaii, fed a mixture of semi-moist manufactured diet[1] (1–3 months) and Moore-Clarke extruded salmon pellets, squid and fish (3–9.5 months).

Parameter	Value
Absolute growth (g)	4,929
Absolute growth rate (g/day)	19.18
Relative growth	70,413
Relative growth rate	273.98
Instantaneous Growth Rate (g)	0.043
Specific Growth Rate (%/day)	4.33
VGBM[2] Asymptotic length (L_∞) (cm)	169.6
VGBM[2] Asymptotic weight (W_∞) (g)	58,417
t_0 (yr)	0.068
K (annual)	0.72
b (constant; Brody coefficient)	3.07

[1] Manufactured diet contained 27.86% moisture, 53.75% crude protein, 21% crude fat and caloric content of 5.13 cal·mg^{-1} (dry–matter basis).

[2] Von Bertalanffy growth model.

Results

Fish grew to 4.93 kg and 75.8 cm from hatching in 9.5 months. Absolute growth rates (AGR's) in weight and length were 19.18 g·d^{-1} and 0.227 cm·d^{-1}, respectively (Table 1). Specific growth rate (SGR) of 1–3 month juveniles was 10% of their body weight per day, decreasing to 4.3% throughout the adult stage.

Most of the data correspond to fish younger than 6 months. The calculation of separate growth curves for males and females was not legitimate because sexual dimorphism could not be detected before that age. Therefore, the growth curves and the von Bertalanffy growth parameters were calculated from combined data for all male and female fish. Growth in length of dolphin was best expressed by a linear relationship (r^2=0.98), though an asymptotic curve also fit the data well (r^2=0.90). From Figure 1 it appears that a linear fit is better because of a weighting of the regression by the smaller fish. Growth in weight was best expressed as a quadratic equation (r^2 =0.98, Fig. 2). The length-weight relationship is expressed by the equation

$$W = 0.00836\, L^{3.07}\ (r^2 = 0.98;\ \text{Fig. 3}).$$

The von Bertalanffy growth models (VBGM) were used to estimate dolphin growth beyond the scope of data measured and, therefore, should be interpreted

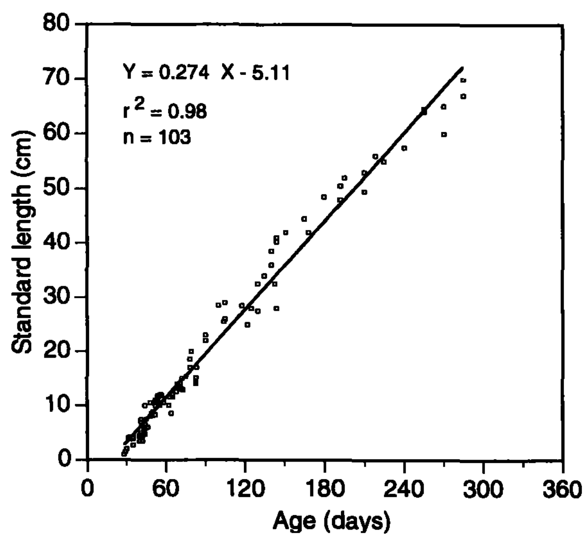

Figure 1

Growth in length of captive dolphin, *Coryphaena hippurus*, in Hawaii.

with caution. The VBGM applied to length-at-age data for captive dolphin in Hawaii is

$$L_t = 169.6 \text{ cm } [1-e^{-0.72\,(t-0.068)}] \text{ (Fig. 4).}$$

The calculated VBGM for weight is

$$W_t = 58.41 \text{ kg } [1-e^{-0.72\,(t-0.068)}]^{3.07}.$$

The feed conversion ratio (FCR) of juveniles up to three months of age was 1.1 (dry feed/live fish), and averaged 1.6 for the entire period studied.

Discussion

There have been several reports of growth rates of wild and captive dolphin, as well as of wild caught fish kept in captivity for various periods of time. Beardsley (1971) reported that a wild caught juvenile kept in captivity grew from one to 35 lb in one year. Schekter (1983) recorded a growth rate of 4.3 kg (from 0.7 to about 5 kg) in 30 days. In Barbados, dolphin may reach lengths of over 80 cm in 5.5 months and over one meter in less than one year (Oxenford and Hunte, 1986). In Hawaii, they also attain a length of over one meter at the end of the first year (Uchiyama et al., 1986). By applying the length-weight regression of Rose and Hassler (1968) to these data, it would correspond to a mass of about 8 kg in one year.

The growth rates presented in this study (4.93 kg and 75.8 cm in 9.5 months) are lower than many of those reported for wild and cultured dolphin in the literature. This may be due to the diet fed to the experimental fish. For instance, Kraul (1989) reported growth rates of 2 kg in 6 months and 9 kg in one year for dolphin that were fed fish and squid in tanks in Hawaii, and of 5.4 kg in 8.7 months for fish reared under identical circumstances but fed commercially available pellets (Kraul and Ako, 1993).

The data suggest that captive dolphin grow slower than their wild counterparts. Yet, even when they are fed artificial diets, growth rates of captive dolphin are among the fastest recorded for teleosts. The specific growth rate (SGR) of dolphin reported in this work (4.3%–10 body weight·d^{-1}), by Ostrowski et al. (1992) (10.7–13.3% bw·d^{-1}), and by Iwai et al. (1992) (9.3–13.0% bw·d^{-1}) are much higher than those of other marine and brackish water fish raised in captivity. For instance, SGR of the common snook, *Centropomus undecimalis*; barramundi, *Lates calcarifer;* hybrid sea bass, *Morone* spp.; Nassau grouper, *Epinephelus striatus;* spotted seatrout, *Cynoscion nebulosus;* red drum, *Sciaenops ocellatus* (Tucker, 1989); three species of mullets, *Liza ramada* (El-Sayed, 1991), *Mugil liza*, and *M. curema* (Benetti and Fagundes Netto, 1991); and the common grouper, *E. guaza* (Fagundes Netto and Benetti, 1984) range from 0.55 to 3.46% of their body weight per day.

The absolute growth rate (AGR) in length of wild and captive dolphin vary between 0.1–0.58 cm·d^{-1}

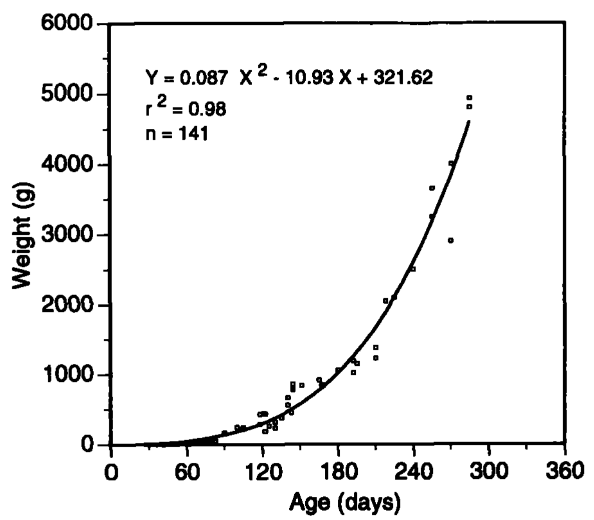

Figure 2

Growth in weight of captive dolphin, *Coryphaena hippurus*, in Hawaii.

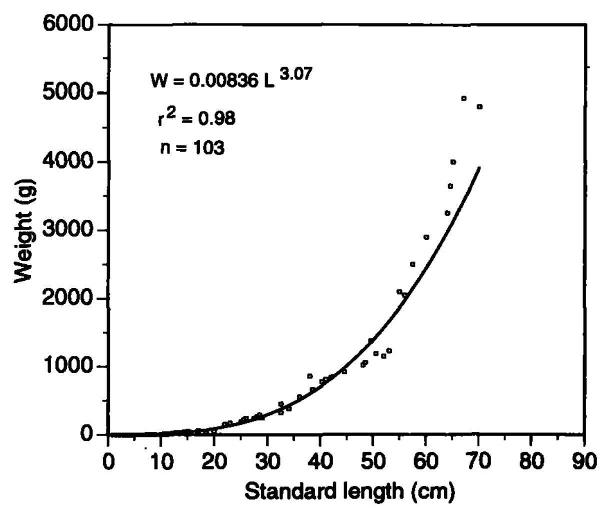

Figure 3

Length-weight relationship of dolphin, *Coryphaena hippurus*, reared in captivity in Hawaii.

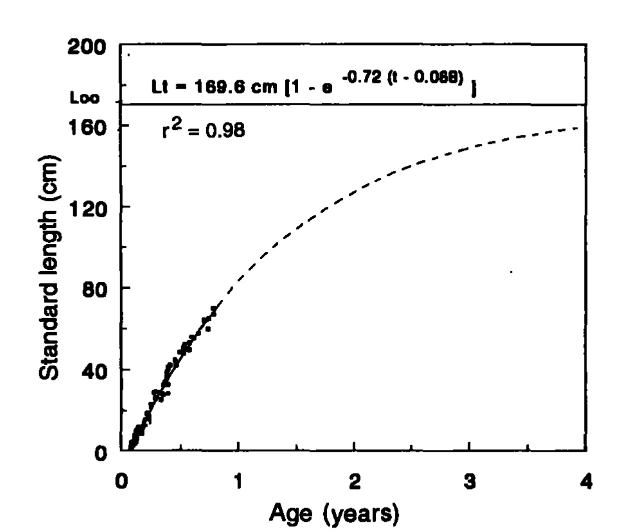

Figure 4

The von Bertalanffy growth model applied to length-at-age data for 1–9.5 month-old captive dolphin, *Coryphaena hippurus*, in Hawaii.

for the first year of life (Oxenford and Hunte, 1983). The AGR value reported in this study (0.227 cm·d^{-1}) is well within this range and the 0.1–0.6 cm·d^{-1} range reported by Brothers et al. (1983) for the Atlantic bluefin tuna, *Thunnus thynnus*, another pelagic teleost. Only a few other pelagic teleosts exhibit growth rates comparable to or higher than dolphin. These include the Atlantic blue marlin, *Makaira nigricans*, and the Atlantic sailfish, *Istiophorus platypterus*, two of the largest North Atlantic pelagic teleosts. Prince et al. (1991) estimated the AGR of young Atlantic blue marlin from otolith microstructure as 1.66 cm·d^{-1}, a value nearly three times higher than that reported for dolphin. From length frequencies of Atlantic sailfish, de Sylva (1957) estimated a maximum absolute growth rate of 1.10 cm·d^{-1}, twice as fast as that reported for dolphin. Although the scope of these comparisons is limited owing to the different age classes of fish, both the blue marlin and Atlantic sailfish exhibit AGR's several times higher than those measured in this work.

In this study, the feed conversion ratio (FCR) was 1.6 (dry feed/live fish). Similarly, Kraul and Ako (1993) obtained a FCR of 1.6 with dolphin fed on a commercially available pellet. FCR's of about 1.0 have been reported for dolphin by Ostrowski et al. (1992), Kraul (1989), and Kraul and Ako (1993), indicating that they are efficient in converting the energy intake from feeds into growth. Relative to other species, dolphin do not appear to require extraordinary food intake to sustain their high growth rates, similar to blue marlin (Prince et al., 1991). In this study, cultured dolphin were fed 4% (dry feed) of their body weight per day. This feeding rate is commonly used for other fish species in captivity, which invariably exhibit slower growth rates and higher FCR. Dolphin appear to exhibit higher energetic efficiency than most other teleosts because they use a proportionally larger portion of the total gross energy ingested for growth and metabolism than for excretion (Benetti, 1992).

Although no spawning was observed, the slight trend of decelerated growth after 180 days (Fig. 1) could be due to the onset of maturation, which in captive dolphin generally occurs in 6 months at 50–55 cm and 2.0–2.5 kg (Kraul, 1991; Ostrowski et al., 1992), but has been observed to occur as early as 3–4.5 months (Uchiyama et al., 1986). Somatic growth rates in teleosts usually decrease after the onset of maturation (Jones, 1976). For dolphin, however, the linear equation fitted the data for the period studied with the highest coefficient of correlation (r^2=0.98). A reason for this may have been the larger sample size during the juvenile stage, when young fish grow very fast. For instance, Hassler and Rainville (1975)[1] found that the length-age relationship of larvae and early juvenile dolphin (13–83 days) was exponential.

The VBGM's were used to model growth beyond the scope of the data and therefore must be considered speculative. Although the data fitted both VBGM's (length and weight) with a high coefficient of determination (r^2>0.98), the asymptotic sizes predicted by the models can not be tested because it has not been possible to keep dolphin alive in captivity for longer than 18 months. In this respect, the age structure of the population should be considered. It is possible that the potential longevity of the Hawaiian dolphin stock may not exceed this maximum age in captivity (about 18 months). For instance, the longevity of dolphin from Florida was estimated to be 4 years, but only 2% of the population was found to be older than 2 years (Beardsley, 1967), and only 4% in North Carolina (Rose and Hassler, 1968). The maximum life span of the Southern Caribbean dolphin stock does not appear to exceed 18 months, and few individuals of the North Caribbean stock live longer than 2 years (Oxenford and Hunte, 1986).

The asymptotic length estimated by the VBGM (L_∞=1.69 m) compares well with existing data for wild fish in the literature (L_∞=1.89 and 1.53 m for males and females, respectively) (Beardsley, 1967). The estimated asymptotic weight (W_∞=58.4 kg), however, is much higher than the maximum weight of 46 kg reported for this species (Florida Sportsman, 1979).

[1] Hassler, N. W., and R. P. Rainville. 1975. Techniques for hatching and rearing dolphin, *Coryphaena hippurus*, through larvae and juvenile stages. Sea Grant Publ. UNC-SG-75-31, 17 p.

This may be explained by the higher value of the exponent (b) of the length-weight relationship calculated for captive dolphin in this study (3.07) compared with wild fish from North Carolina and Florida, $2.58 < b < 2.75$ (Rose and Hassler, 1968). Oxenford and Hunte (1986) reported b values of 2.94 for male and 2.84 for female dolphin from Barbados. These differences indicate that dolphin tend to have shorter, deeper bodies in captivity than in the wild. Blaxter (1988) found that fish reared in captivity tend to be shorter and fatter and have a higher condition factor than fish from the wild, possibly because fish are likely to swim less when confined, diminishing the effect of exercise on growth (Jobling 1990; Christiansen and Jobling, 1990; Benetti, 1992; Christiansen et al., 1992; Boisclair and Tang, 1993). This is consistent with the predictions of the VBGM's in this study, which indicate that it would take longer for dolphin to reach asymptotic length and weight in captivity (6 years) than in their natural environment (4 years or less).

Results presented in this study suggest that captive dolphin grow slower and are less streamlined than in the wild. However, morphological and growth disparities of wild dolphin have been attributed to genetic (Oxenford and Hunte, 1986) and environmental (Rose and Hassler, 1968) differences in unit stocks. The larval development of dolphin from the Gulf of Mexico and from the western Pacific Ocean is similar, but both differ from that off Japan (Ditty et al., 1994). Although Benetti (1992) reported no significant differences between growth rates and development of dolphin larvae in Hawaii from F_1 and F_7 generations inbred in captivity, nothing is known about differences in growth during the juvenile and adult stages among offspring from brood fish from other stocks.

Acknowledgments

We thank Peter Lutz (Florida Atlantic University), Larry Brand (RSMAS, University of Miami), Eirik O. Duerr (The Oceanic Institute), Eric Prince and Victor Restrepo (Southeast Fisheries Science Center, NMFS, Miami Laboratory), and Syd Kraul (Waikiki Aquarium) for reviewing an early manuscript. The authors also thank two anonymous reviewers and the Scientific Editor, Ronald Hardy, for comments which greatly improved the original manuscript. We also thank Arietta Venizelos for editorial help, and Thomas Capo for use of laboratory facilities (Experimental Hatchery, University of Miami). This work was part of the senior author's Ph.D. dissertation, funded by the Brazilian Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). Partial funding was also provided by U.S. Dept. of Agriculture, ARS, grant 59-91H2-9-218 to the Oceanic Institute in Hawaii.

Literature cited

Beardsley, B. L.

1967. Age, growth and reproduction of the dolphin, *Coryphaena hippurus*, in the straits of Florida. Copeia 2:441–451

1971. Dolphin spectacular. Sea Front. 17:194–201

Benetti, D. D.

1992. Bioenergetics and growth of dolphin, *Coryphaena hippurus*. Ph.D. diss., Univ. Miami, 196 p.

Benetti, D. D., and E. B. Fagundes Netto.

1991. Preliminary results on growth of mullets (*Mugil liza* and *M. curema*) fed artificial diets. World Aquaculture 22 (4):55–57.

Bertalanffy, L., von.

1962. Modern theories of development: an introduction to theoretical biology. Transl. and adapted by J. H. Woodger Jr., Harper and Row, New York, 204 p.

Blaxter, J. H. S.

1988. Pattern and variety in development. *In* W. S. Hoar and D. J. Randall (eds.), Fish physiology, Vol. 11a, p. 1–58. Acad. Press, NY.

Boisclair, D., and M. Tang.

1993. Empirical analysis of the influence of swimming pattern on the net energetic cost of swimming in fishes. J. Fish Biol. 42:169–183.

Brothers, E. B., E. D. Prince, and D. W. Lee.

1983. Age and growth of young-of-the-year bluefin tuna, *Thunnus thynnus*, from otolith microstructure. *In* E. D. Prince and L. M. Pulos (eds.) Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfish, and sharks, p. 49–59. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8.

Christiansen, J. S., and M. Jobling.

1990. The behavior and relationship between food intake and growth of juvenile Arctic charr, *Salvelinus alpinus* L., subjected to sustained exercise. Can. J. Zool. 68: 2185–2191

Christiansen, J. S., Y. S. Svendsen, and M. Jobling.

1992. The combined effects of stocking density and sustained exercise on the behavior, food intake, and growth of juvenile charr (*Salvelinus alpinus* L.). Can. J. Zool. 70:115–122.

De Sylva, D. P.

1957. Studies on the age and growth of the Atlantic sailfish, *Istiophorus americanus* (Cuvier), using length-frequency curves. Bull. Mar. Sci. Gulf Carib. 7:345–362.

Ditty, J. G., R. F. Shawn, C. B. Grimes, and J. S. Cope.

1994. Larval development, distribution, and abundance of common dolphin, *Coryphaena hippurus*, and pompano dolphin, *C. equiselis* (family: Coryphaenidae), in the northern Gulf of Mexico. Fish. Bull. 92:275–291

El-Sayed, A. F. M.

1991. Protein requirements for optimum growth of *Liza ramada* fry (Mugilidae) at different water salinities. Aquat. Liv. Resour. 4:117–123.

Fabens, A. J.

1965. Properties and fitting of the von Bertalanffy growth curve. Growth 29:265–289

Fagundes Netto, E. B., and D. D. Benetti.
1984. Noções sobre o crescimento e perspectivas de cultivo da garoupa-verdadeira (*Epinephelus guaza* Linnaeus 1758, Pisces, Serranidae). *In* Anais III Simpósio Brasileiro de Aquicultura, São Paulo, Brazil, p. 124–132.

Florida Sportsman.
1979. In the wake. June, p. 123.

Gibbs, R. H., Jr., and B. B. Collette.
1959. On the identification, distribution, and biology of dolphins, *Coryphaena hippurus* and *C. equiselis*. Bull. Mar. Sci. Gulf Caribb. 9 (2):117–152.

Hagood, R. W., and G. N. Rothwell, M. Swafford, and M. Tosaki.
1981. Preliminary report on the aquaculture development of the dolphin fish, *Coryphaena hippurus* Linnaeus. J. World Maricult. Soc. 12(1):135–139.

Hassler, N. W., and M. T. Hogarth.
1977. The growth and culture of dolphin, *Coryphaena hippurus*, in North Carolina. Aquaculture 12:115–122.

Iwai, T., Jr., H. Ako, and L. E. Yasukochi.
1992. Use of beef liver in the diet of juvenile mahimahi, *Coryphaena hippurus* L. World Aquaculture 23(3):49–51.

Jobling, M.
1990. Fulfilling the impossible dream. Fish Farmer, July/Aug.:52–53.

Johnson, G. D.
1978. Development of fishes of the Mid-Atlantic Bight. An atlas of egg, larval and juvenile stages. Vol. 4: Carangidae-Ephippidae. U.S. Dep. Interior, Fish. Wild. Service, FWS/OBS 78/12:123–128.

Jones, R.
1976. Growth in fishes. *In* D. H. Cushing and J. J. Walsh (eds.), The ecology of the seas, Chap. 11, p. 251–279. W. B. Saunders Co.

Kim, B. G., S. Monahan, E. Schaleger, and A. C. Ostrowski.
1993. Intensive hatchery culture of mahimahi (*Coryphaena hippurus*) at the Oceanic Institute. '93 World Aquaculture, European Aquac. Soc. Special Publ. 19, p. 401.

Kraul, S.
1989. Review and current status of the aquaculture potential for the mahimahi, *Coryphaena hippurus*. Advances in tropical aquaculture, Tahiti. AQUACOP, IFREMER. Actes Colloq. Int. 9:445–459.
1991. Hatchery methods for the mahimahi, *Coryphaena hippurus*, at Waikiki Aquarium. *In* J. P. McVey (ed.), Handbook of mariculture, Vol. II: Finfish aquaculture, p. 241–250. CRC Press, FL.

Kraul, S., and H. Ako.
1993. Successful methods for mahimahi aquaculture. '93 World Aquaculture, European Aquacult. Soc. Spec. Publ. 19, p. 403.

Ostrowski, A. C., C. Brownell, and E. O. Duerr.
1989. Growth and feeding rates of juvenile dolphins (*Coryphaena hippurus*) fed a practical diet through growout. World Aquaculture 20(4):104–105.

Ostrowski, A. C., B. Kim, and E. O. Duerr.
1992. Preliminary studies on the dietary protein: energy needs of juvenile mahimahi (*Coryphaena hippurus*). Aquaculture 92. World Aquac. Soc. Abstract, No. 323, p. 176.

Oxenford, H. A., and W. Hunte.
1983. Age and growth of dolphin (*Coryphaena hippurus*) determined by growth rings in otoliths. Fish. Bull. 84:906–909.
1986. A preliminary investigation of the stock structure of the dolphin, *Coryphaena hippurus*, in the western central Atlantic. Fish. Bull. 84:451–460.

Palko, B. J., G. L. Beardsley, and W. J. Richards.
1982. Synopsis of the biological data on dolphin-fishes, *Coryphaena hippurus* Linnaeus and *Coryphaena equiselis* Linnaeus. U.S. Dep. Commer., NOAA Tech. Rep. NMFS Circ. 433, FAO Fish. Syn. 130, 28 p.

Prince, E. D., D. W. Lee, J. R. Zweifel, and E. B. Brothers.
1991. Estimating age and growth of young Atlantic blue marlin *Makaira nigricans* from otolith microstructure. Fish. Bull. 89:441–459.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. Spec. Publ. 191.
1979. Growth rates and models. *In* W. S. Hoar and D. J. Randall (eds.), Fish physiology, Vol 8, p. 677–743. Acad. Press, NY.

Rose, C. D., and W. W. Hassler.
1968. Age and growth of the dolphin, *Coryphaena hippurus* (Linnaeus), in North Carolina waters. Trans. Am. Fish. Soc. 97:271–276.

Schekter, R. C.
1983. Mariculture of dolphin (*Corypaena hippurus*): is it feasible? Proc. Gulf Caribb. Fish. Inst.:27–32

Szyper, J. P., R. Bourke, and L. D. Conquest.
1984. Growth of juvenile dolphin fish, *Coryphaena hippurus*, on test diets differing in fresh and prepared components. J. World Maricult. Soc. 15:219–221.

Tucker, J. W., Jr.
1989. Development of feeds for marine and brackishwater fish. World Aquaculture 20:106.

Uchiyama, J. H., R. K. Burch, and S. Kraul Jr.
1986. Growth of the dolphins, *Coryphaena hippurus* and *C. equiselis* in Hawaiian waters, as determined by daily increments on otoliths. Fish. Bull. 84:186–191.

Wang, C. H.
1979. A study of the population dynamics of dolphin fish (*Coryphaena hippurus*) in waters adjacent to eastern Taiwan. Acta Oceanogr. 10:233–251.