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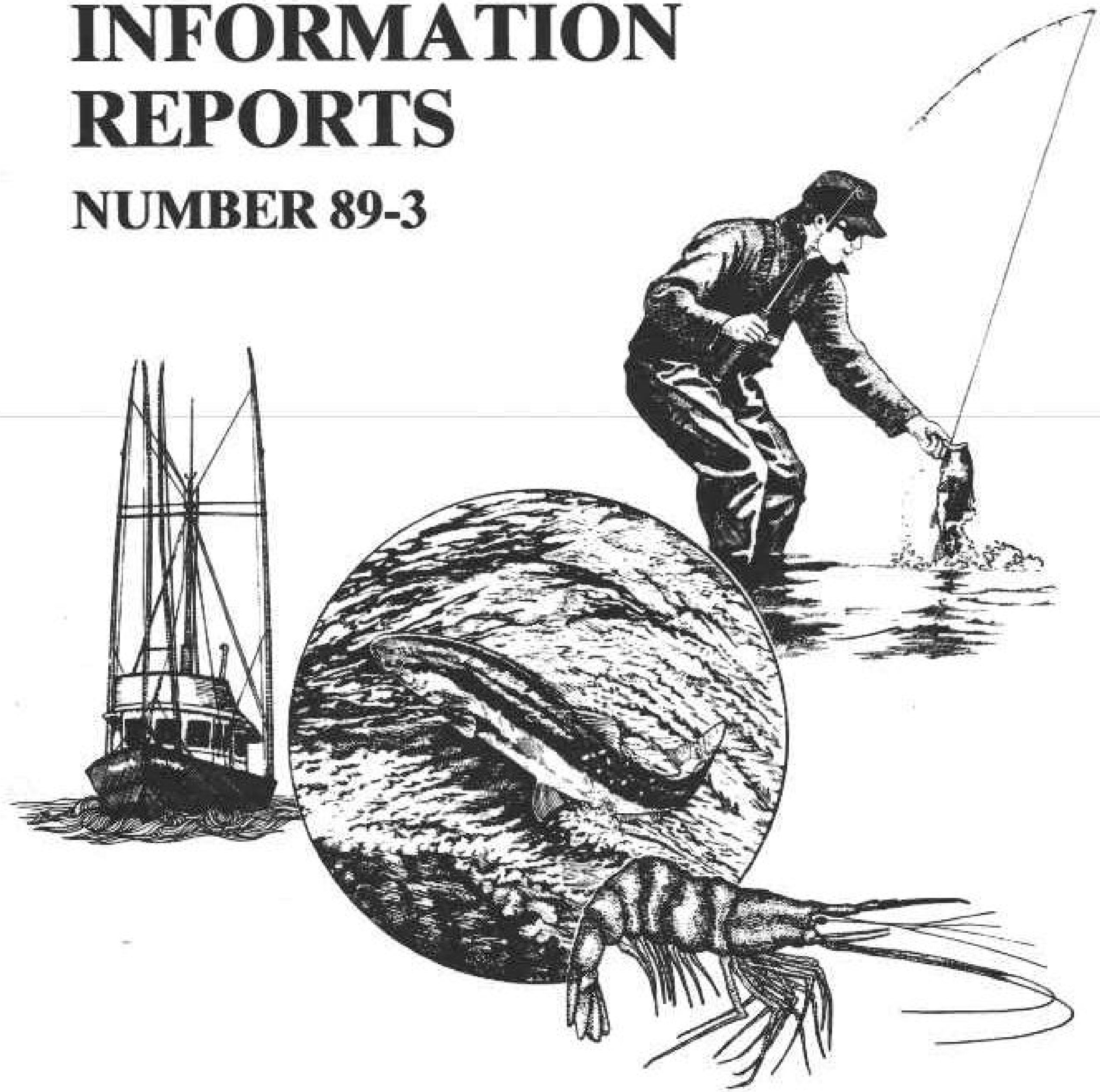

FISH DIVISION

Oregon Department of Fish and Wildlife

Use of Production Potential at 25 Inland Fish Propagation Facilities Operated by the Oregon Department of Fish and Wildlife

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Oregon Department of Fish and Wildlife
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INTRODUCTION

Haskell (1955) developed one of the first models for salmonid loading density. His basic premises were that capacity is limited by oxygen consumption and the accumulation of metabolic waste, and that these factors are proportional to the amount of food fed. Therefore, he developed a model based on the weight of food fed to fish.

Since Haskell (1955) developed his model, many additional models and guidelines have been developed. Piper (1967) updated Haskell's model by substituting fish length (inches) for weight of food fed daily, and developed a model to determine carrying capacity instead of loading density.

Burrows and Combs (1968) developed additional guidelines for carrying capacity and loading density. They stated that productivity of hatcheries is determined by water quality and quantity, temperature, disease, and hatchery location in relation to the fish runs. Their carrying capacity model was based on dissolved oxygen content of the water, dissolved oxygen requirements of the fish, and water temperature. They also determined maximum loading density for chinook salmon fingerling and noted that overcrowding caused reduced growth and poor food use.

Liao (1971) developed a carrying capacity model that is commonly applied today. He based his model on information that determined oxygen consumption for various sizes of salmonids at hatcheries in five states. Tests were conducted for eight species of salmonids under different operating conditions. He developed two separate models: one for Pacific salmon *Oncorhynchus* spp. and the other for Pacific trout *Oncorhynchus* spp. and charr *Salvelinus* spp. Data included in the models were temperature, fish weight, inflow dissolved oxygen, and allowable outflow dissolved oxygen. These data were used to determine oxygen uptake rate and carrying capacity.

Several additional carrying capacity models have been developed. Willoughby (1968) introduced a model using the same assumptions as Haskell (1955), and related oxygen consumption to quantity of food fed. Elliot (1969) developed a carrying capacity model for chinook salmon *O. tshawytscha* based on oxygen requirements and temperature. Westers (1970) and Westers and Pratt (1977) developed carrying capacity models based primarily on the number of water exchanges per hour. Piper et al. (1982) provide an overview of work on many carrying capacity and loading density models.

This report is an evaluation of the use of production potential at 25 inland fish propagation facilities operated by the Oregon Department of Fish and Wildlife (ODFW). Jeffrey and Associates (1987b) evaluated use of capacity at 14 coastal hatcheries. This report includes all other salmonid rearing facilities operated by ODFW except two large, seminatural rearing ponds. The objectives of the report are to compare theoretical flow requirements with minimum available water flow during the period April 1985 to April 1987, and to determine theoretical space requirements and compare them with available space during the same period. These comparisons will be the criteria to determine if fish propagation facilities are producing fish at theoretical production potential.

Additional limiting factors not included in the production models will also be discussed, and some opportunities for increased production will be suggested. I had many different carrying capacity and loading density models to choose from, and different results can be obtained by applying these models in identical situations. The models I chose for this evaluation were selected to make results comparable with those of Jeffrey and Associates (1987b).

METHODS

I used the carrying capacity model developed by Liao (1971) and the loading density graph developed by Burrows and Combs (1968) and translated mathematically by Jeffrey and Associates (1987a) to determine theoretical flow (gallons per minute) and space (cubic feet) required to rear fish at each of 25 inland fish propagation facilities operated by ODFW. I then compared actual available flow to theoretical flow required for the fish present, and available rearing space to theoretical space required for the fish present from April 1985 to April 1987.

The carrying capacity and loading density models used in this study are the same ones that Jeffrey and Associates (1987b), under contract to the Oregon Coastal Zone Management Association (OCZMA) with funding provided by ODFW, used in an evaluation of state-operated fish propagation facilities on the Oregon coast. Data on available space were first collected by Egna (1987) under contract to the OCZMA with funds provided by ODFW.

I (or an associate) visited each facility and collected or verified information concerning temperature (^{o}F), flow (gallons per minute), dissolved oxygen (parts per million), available rearing space (cubic feet), and other limiting factors. Temperature used in this evaluation was the mean monthly maximum value. Available flow was minimum gallons per minute available each month as determined by the limiting factor. This limiting factor could be stream flow, spring flow, pump capacity, delivery system capacity, water rights, etc. I assumed that the dissolved oxygen level at the hatchery inflow was 95% saturation unless hatchery personnel or data records indicated otherwise.

Theoretical flow and space required for each species and lot of fish were calculated every month. These values, which were summed to determine theoretical total flow and space required during that month, were compared with flow and space available at that facility. Additional factors that may restrict production were also noted, because the models used in evaluation of production potential consider only water flow and rearing space, and do not include factors such as water quality, pond condition, funding, or disease.

The quality of available data was variable. Information on species, number, and weight of fish was adequate. Temperature data were also usually complete. When they were incomplete, data from other years or sources were substituted. In general, accurate equipment to measure dissolved oxygen and flow was missing, and records were incomplete. Therefore, the values I present are the best estimates available.

Assumptions incorporated into the carrying capacity and loading density models were:

1. Loading density should never exceed 2 lb fish/cu ft water.

2. Outlet dissolved oxygen concentration is 6 ppm.

I found some disagreement in the literature concerning adequate level of dissolved oxygen. Westers and Pratt (1977) and Willoughby (1968) state that 5 ppm dissolved oxygen is adequate for trout, whereas Burrows and Combs (1968) note that a dissolved oxygen level below 6 ppm results in reduced growth rate. I assumed an outlet dissolved oxygen level of 6 ppm to make my results comparable with those of Jeffrey and Associates (1987b).

RESULTS AND DISCUSSION

Aumsville Rearing Ponds

Background

These earthen ponds, which are a satellite of South Santiam Fish Hatchery, are located near Stayton. Water is obtained from the North Santiam River through an irrigation canal. ODFW has purchased 2,244 gpm of water from the Santiam Water Control District for fish production. Currently, fall chinook salmon are produced at the facility.

Theoretical Flow and Space Requirements

Aumsville Rearing Ponds did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement occurred in February 1987 and represented 49% of the flow available for rearing (Figure 1). Maximum theoretical space requirement was 24,170 cu ft, or 45% of the 54,000 cu ft available for rearing (Figure 1).

Additional Factors

The facility is operated with Mitchell Act funds administered by the National Marine Fisheries Service (NMFS), and these funds regulate production level. Outbreaks of the protozoan *Myxobolus insidiosus* can be severe if fish remain in these ponds past the middle of February. Water availability during the irrigation season is questionable.

Opportunities for Increased Production

According to the production models, additional fish could be raised in Aumsville ponds. The protozoan disease problem must be corrected, and water availability during the irrigation season must be taken into account. Constructing concrete ponds might improve production. Any increase in production must be approved by NMFS.

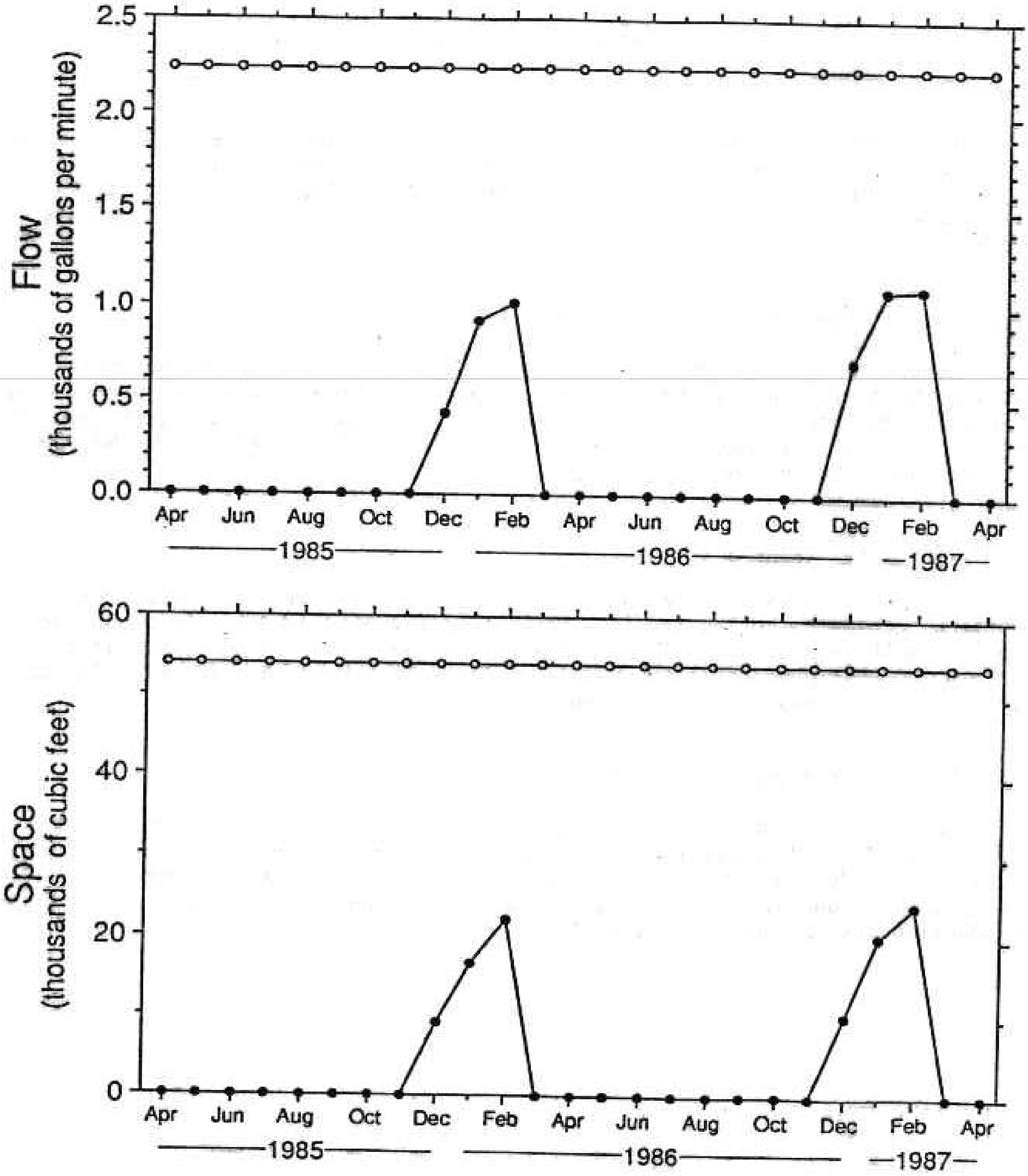


Figure 1. Flow and space use at Aumsville rearing ponds. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Bonneville Fish Hatchery

Background

Bonneville Fish Hatchery is located 3 miles west of Cascade Locks. It obtains water from Tanner Creek and a series of wells. Tanner Creek provides a minimum flow between 6,750 and 15,700 gpm from February through November, but water is not always available in December and January. The wells currently provide 12,000 gpm consistently, 2,000 gpm of which is used for incubation. New wells should be in operation during November 1988. Spring chinook salmon, fall chinook salmon, and coho salmon *O. kisutch* are currently produced at the hatchery.

Theoretical Flow and Space Requirements

This facility did not reach theoretical production potential during the period of evaluation. Maximum theoretical flow use occurred in December 1986 when 77% of available flow was required (Figure 2). Maximum theoretical space requirement consistently occurred in April and May each year when between 39% and 56% of the available space was required for rearing fish (Figure 2).

Additional Factors

Bonneville Fish Hatchery is operated with funds provided by the U.S. Army Corps of Engineers (USACE) and Mitchell Act funds administered by NMFS, and these funds regulate production level. Construction of a navigation lock for Bonneville Dam has restricted full use of the hatchery because of the possible disruption of water supply, and the well system is being rebuilt. One battery of ponds has no water available in the winter because Tanner Creek freezes and it has no well-water supply.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Bonneville Fish Hatchery. Increased production should probably be delayed until construction of the navigation lock is complete. Any increase in production must be approved by NMFS.

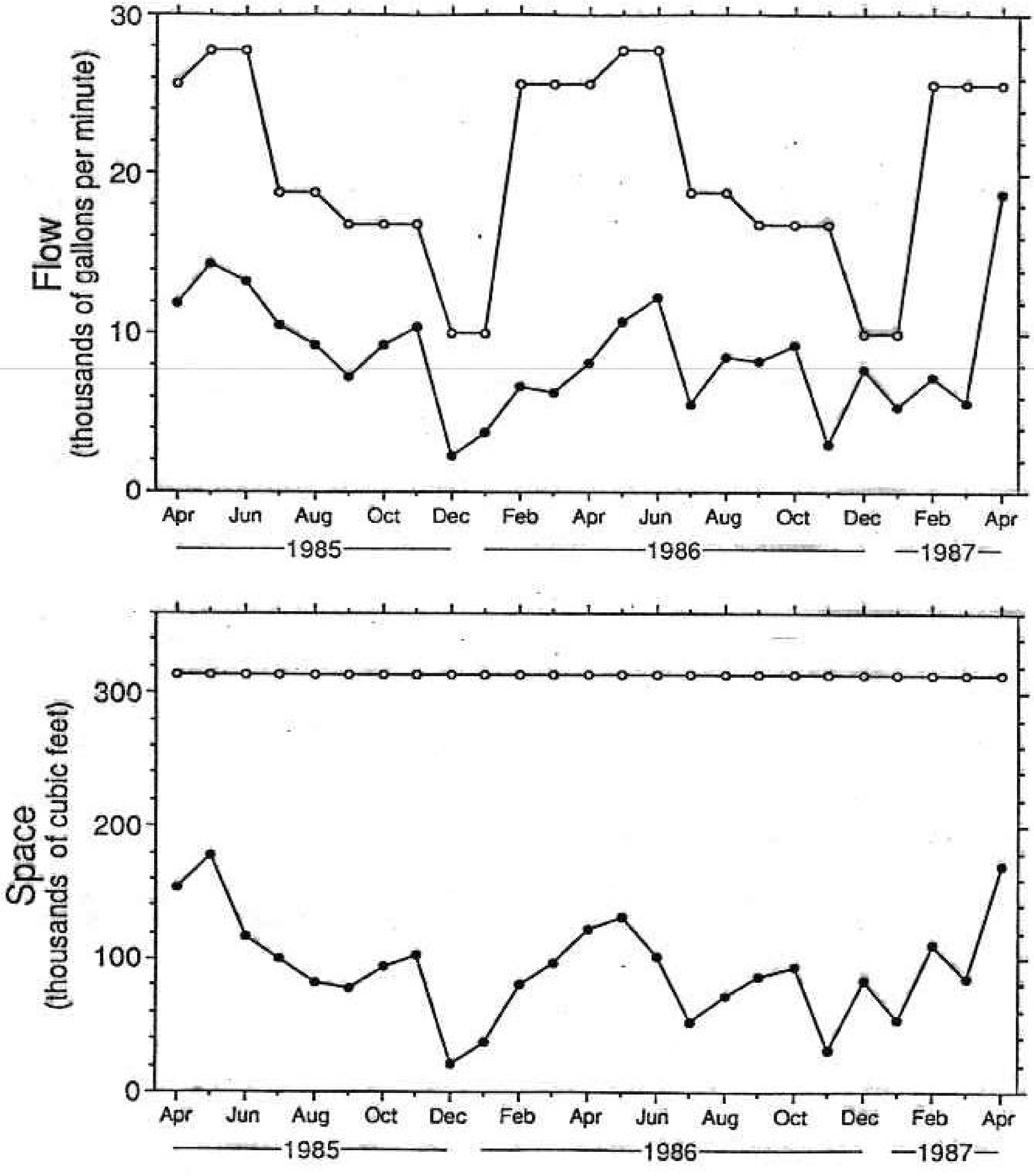


Figure 2. Flow and space use at Bonneville Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Cascade Fish Hatchery

Background

Cascade Fish Hatchery is located 1.5 miles west of Cascade Locks. It obtains water from Eagle Creek. Minimum available flow each month varies from 4,920 to 8,795 gpm. Coho salmon are produced at the hatchery.

Theoretical Flow and Space Requirements

This facility exceeded theoretical production potential during the evaluation period. Theoretical flow requirement reached 87% to 147% of minimum flow available from August to October (Figure 3). In September and October, when stream flow declined to 4,920 gpm, water was recirculated.

Rearing space was not a limiting factor at Cascade Fish Hatchery. Theoretical space requirement reached a maximum of 86% of the space available for fish rearing (Figure 3).

Additional Factors

Cascade Fish Hatchery is operated with Mitchell Act funds administered by NMFS, and these funds regulate production level. Ice and slush ice in the winter limit flow in the creek, and flow through the delivery system does not meet design criteria. According to engineering specifications, the delivery pipeline should provide 18,000 gpm, but at present it provides only about 50% of that flow.

Opportunities for Increased Production

New rearing technology (such as oxygen supplementation) appears to be the only feasible way to increase production. Improving the delivery system would increase flow in late fall, winter, and spring, but would have no effect on summer flow. Any increase in production must be approved by NMFS.

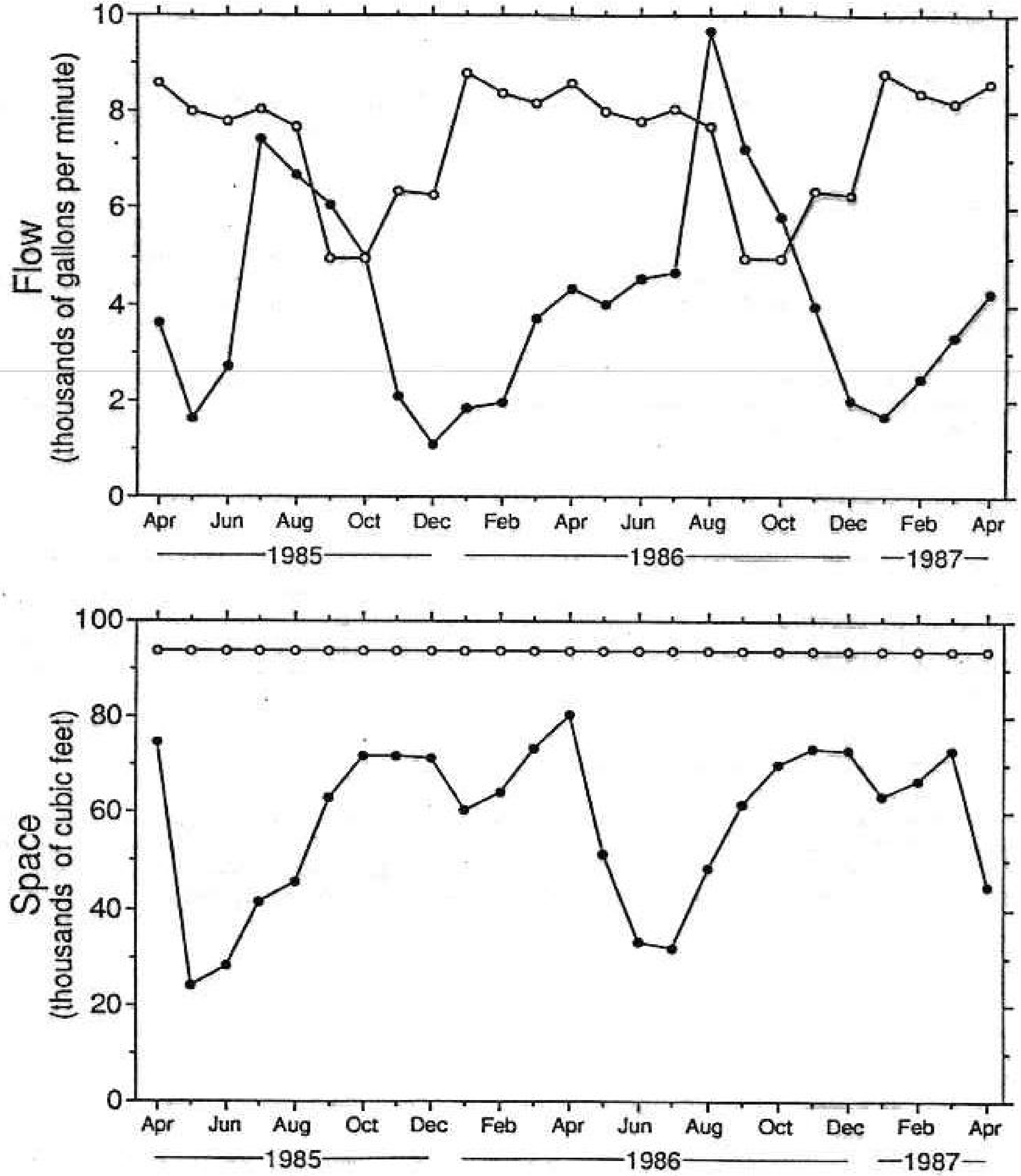


Figure 3. Flow and space use at Cascade Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Clackamas Fish Hatchery

Background

Clackamas Fish Hatchery is located off State Highway 224 in McIver State Park. Water is obtained primarily from the Clackamas River. Twenty thousand gallons per minute should be delivered by pump to the hatchery, but flow has gradually declined because of water delivery problems. An additional 150 gpm is provided by a well. Winter steelhead *O. mykiss* and spring chinook salmon are raised at this facility.

Theoretical Flow and Space Requirements

This hatchery did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement occurred in August 1986 at 94% of the available flow (Figure 4). Maximum theoretical space required during the period of evaluation, which consistently occurred from August to October, was 31% of the available rearing space (Figure 4).

Additional Factors

This hatchery is operated with funds provided by Portland General Electric Company, the City of Portland, ODFW, and Mitchell Act funds administered by NMFS, and these funds regulate production level. Poor summer water quality causes low dissolved oxygen concentration (about 85% saturation) and disease problems.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Clackamas Fish Hatchery under current conditions. However, other factors restrict production level. Diseases can be expected during the summer rearing period and should be considered. Current effort to improve the water delivery system should be completed in 1989, and this will increase production potential. Any increase in production must be approved by the agencies that provide funding.

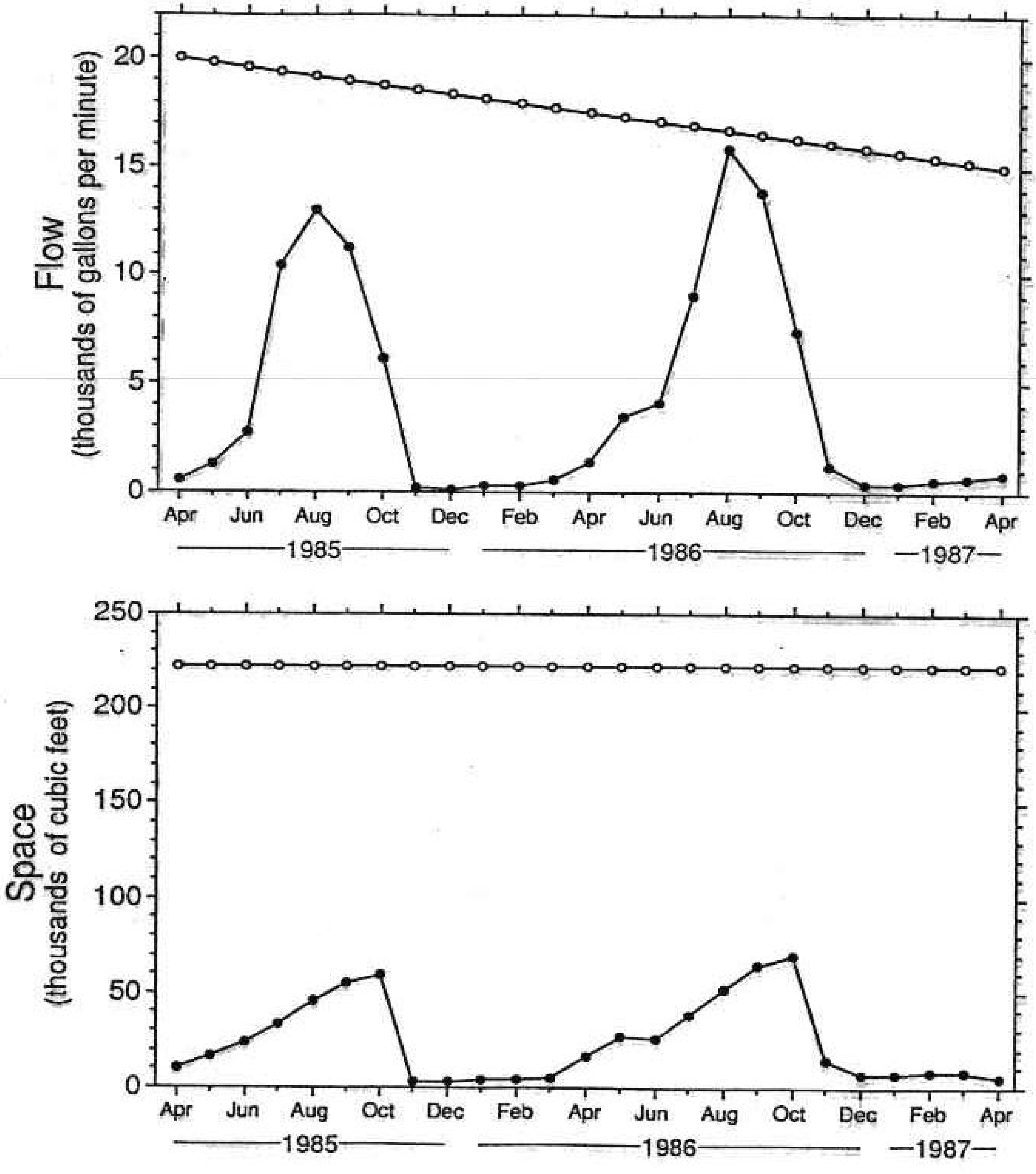


Figure 4. Flow and space use at Clackamas Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Dexter Rearing Ponds

Background

Dexter Rearing Ponds, a satellite of Willamette hatchery, are located 1 mile west of Lowell at the base of Dexter dam. They are supplied by 30,083 gpm of water from Dexter Reservoir to produce spring chinook salmon.

Theoretical Flow and Space Requirements

This facility did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement was 31% of the flow available (Figure 5). Maximum theoretical space requirement was 54% of the space available (Figure 5).

Additional Factors

Apparently, the only other factor that influences production at Dexter ponds is that funding is provided by ODFW and USACE, and these funds regulate production level.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Dexter ponds under present conditions. Modifications of the water delivery system and construction of additional ponds would increase production potential. Any increase in production level or modification of the facilities would require approval by USACE.

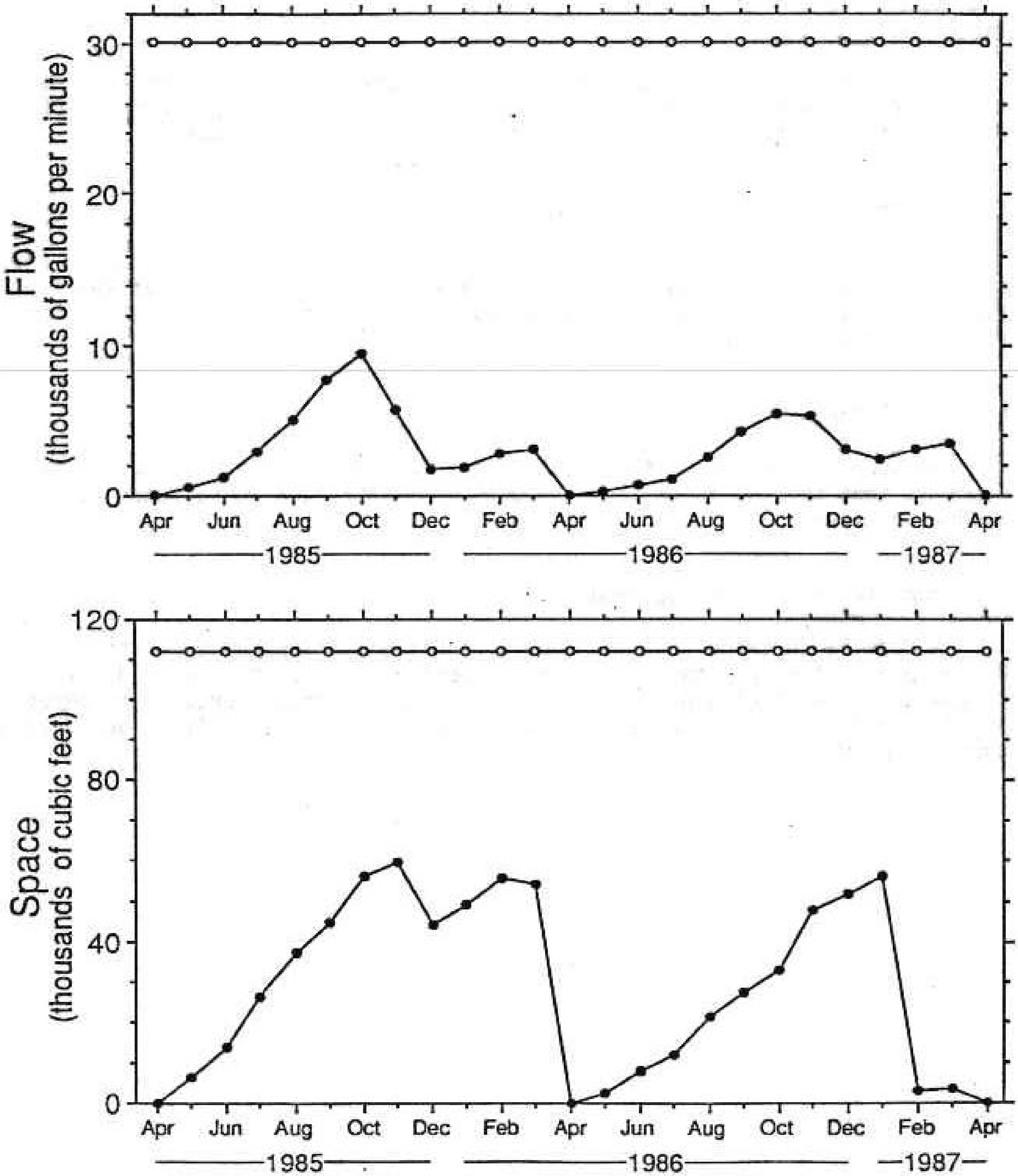


Figure 5. Flow and space use at Dexter Rearing Ponds. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Fall River Fish Hatchery

Background

Fall River Fish Hatchery is located 20 miles southwest of Bend off U.S. Highway 97. Water is obtained from Fall River, a spring-fed stream. Available flow is a constant 7,800 gpm. This facility produces rainbow trout *O. mykiss*, cutthroat trout *O. clarki*, and brook trout *S. fontinalis*.

Theoretical Flow and Space Requirements

This hatchery exceeded theoretical production potential during the evaluation period. Theoretical required flow in June 1985 was 104% of the flow available for fish rearing (Figure 6). Space did not limit production at Fall River hatchery. Maximum theoretical space requirement was only 33% of the space available (Figure 6).

Additional Factors

Funding is provided by ODFW, and these funds regulate production level.

Opportunities for Increased Production

Increasing production at Fall River hatchery would require hatchery modification or the application of new rearing technology such as oxygen supplementation. ODFW funds the hatchery, so increases in production do not need the approval of any other agency.

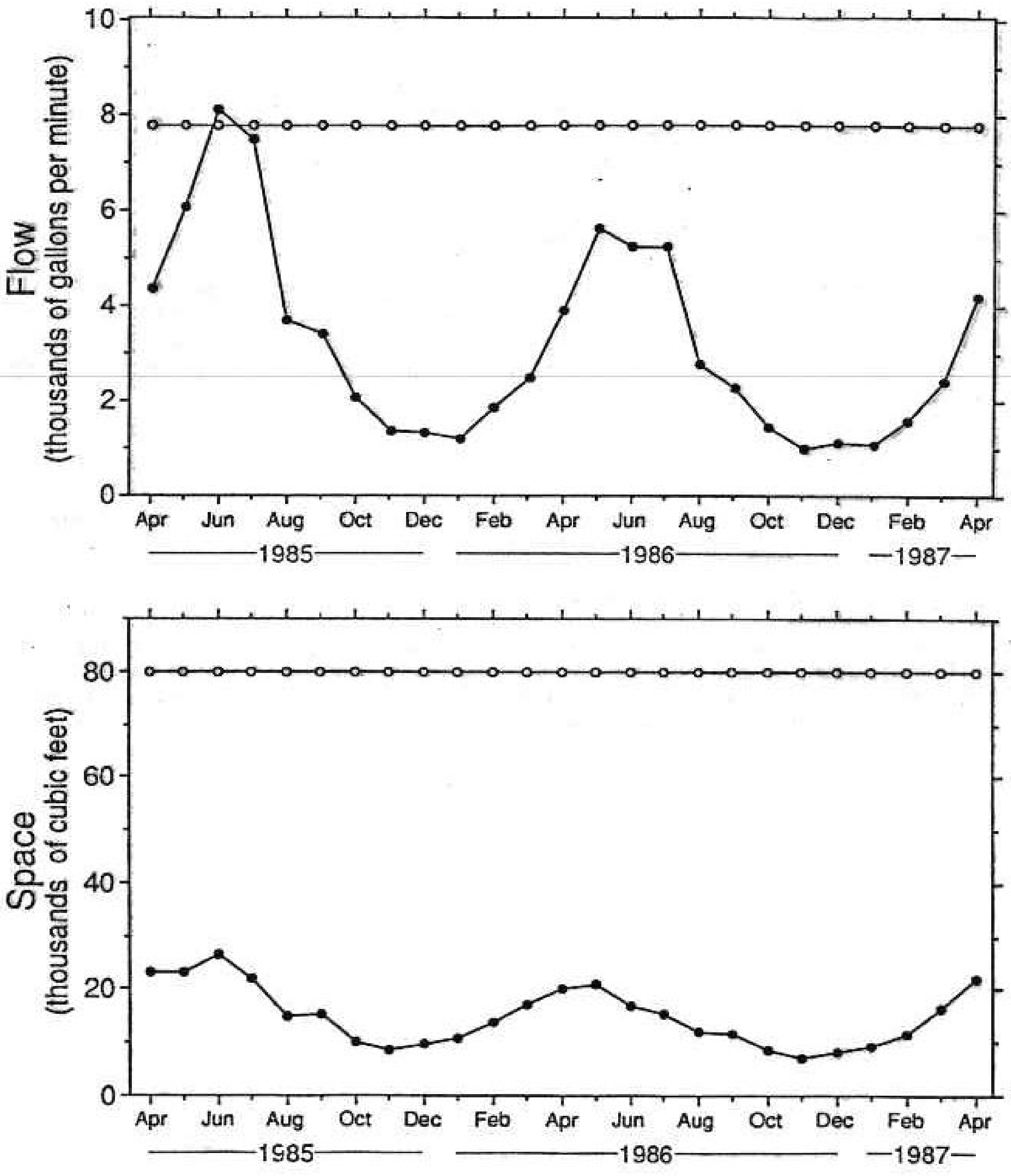


Figure 6. Flow and space use at Fall River Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Gnat Creek Fish Hatchery

Background

Gnat Creek Fish Hatchery is located 28 miles east of Astoria on U.S. Highway 30. Water is obtained from Gnat Creek. Minimum available flow each month varies between 1,200 and 8,000 gpm. Winter and summer steelhead are produced at the hatchery.

Theoretical Flow and Space Requirements

Theoretical production potential was exceeded during the evaluation period. Theoretical required flow exceeded minimum available flow from July to September by as much as 400% of available flow (Figure 7). At most, theoretical space requirements represented only 53% of the available space (Figure 7).

Additional Factors

This hatchery is operated with Mitchell Act funds administered by NMFS, and these funds regulate production level. During periods of low flow, water must be recirculated, and this can lead to disease problems.

Opportunities for Increased Production

Under present conditions, opportunities to increase production at this facility are limited. Application of new rearing technology such as oxygen supplementation, or development of a well-water supply appear to be the only options for increasing production. Any increase in production must be approved by NMFS.

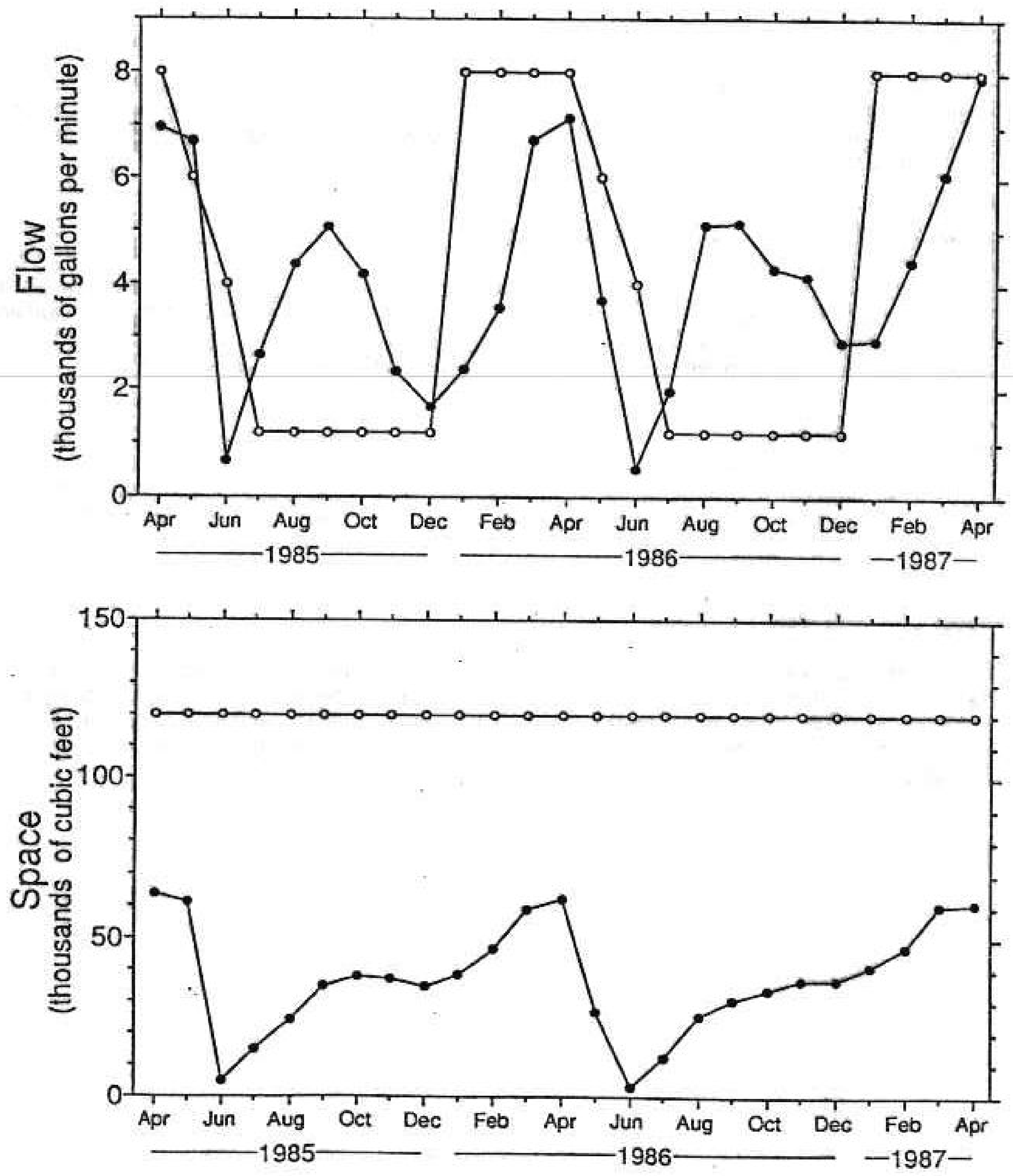


Figure 7. Flow and space use at Gnat Creek Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Herman Creek Rearing Ponds

Background

Herman Creek Rearing Ponds, a satellite of Oxbow Hatchery, are located approximately 1 mile east of Cascade Locks on I-80N. They obtain water from Herman Creek, and minimum available flow varies between 4,800 and 5,700 gpm. Coho salmon are produced at this facility.

Theoretical Flow and Space Requirements

Herman Creek Rearing Ponds did not reach theoretical production potential during the evaluation period. Maximum theoretically required flow occurred in June 1986 at 94% of the available flow (Figure 8). Maximum theoretical space requirement was 68% of the space available (Figure 8).

Additional Factors

The ponds are operated with Mitchell Act funds administered by NMFS, and these funds regulate production level. Inflow from Herman Creek is limited by small pipe size, lack of head pressure, and gravel in the intake. This facility has also had recurring disease problems.

Opportunities for Increased Production

The production models indicate that additional fish could be raised at Herman Creek Rearing Ponds with the available flow and space. Reconstruction of the water delivery system would add to production potential. Any increase in production level must be approved by NMFS.

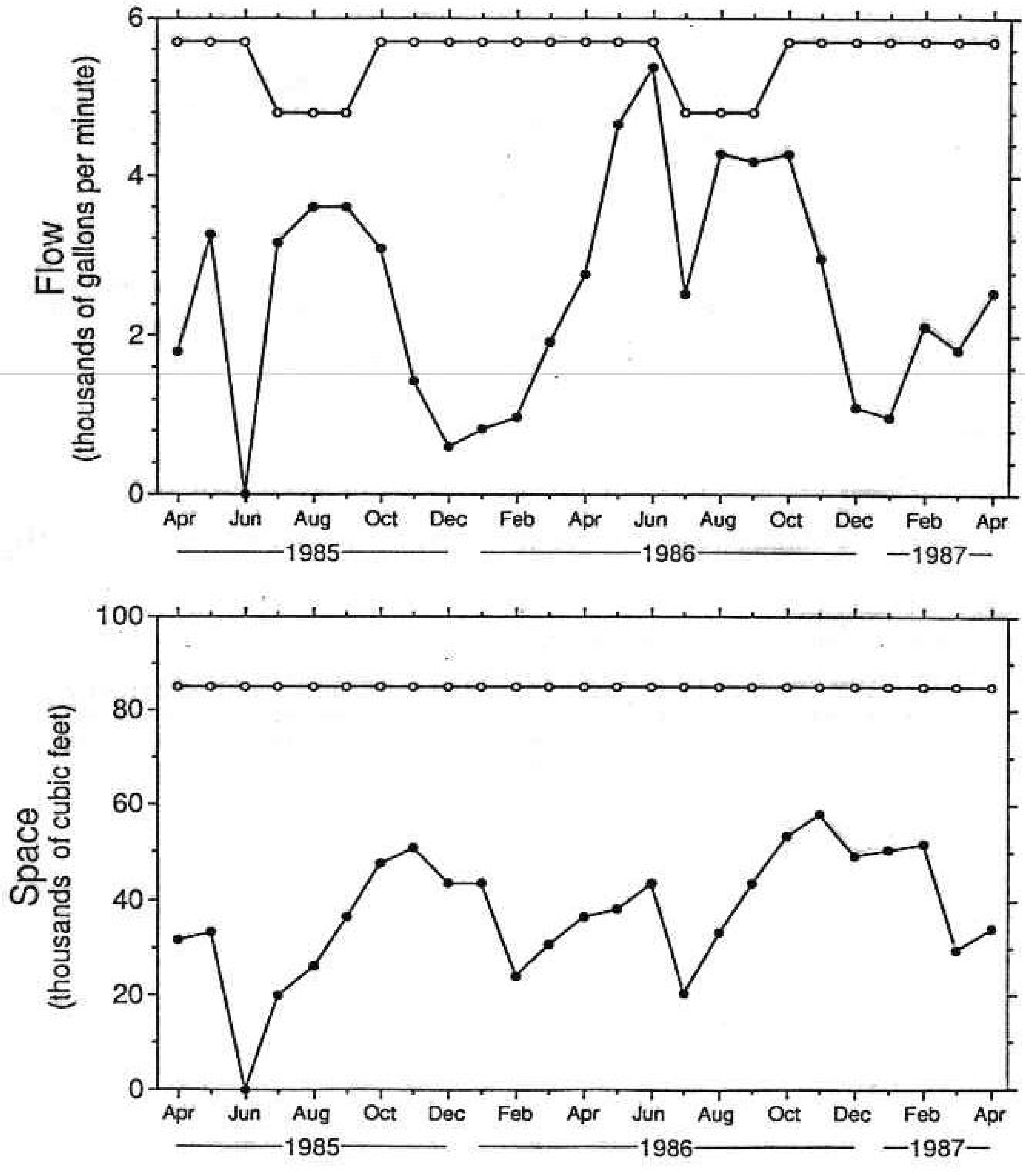


Figure 8. Flow and space use at Herman Creek Rearing Ponds. Open symbols indicate available flow and space; closed symbols indicate theoretically required flow and space.

Irrigon Fish Hatchery

Background

Irrigon Fish Hatchery is located 2 miles west of Irrigon. Water is obtained from two wells located near the Columbia River. Minimum available rearing flow varies between 19,592 and 20,900 gpm. Summer steelhead and fall and spring chinook salmon are produced at the hatchery.

Theoretical Flow and Space Requirements

Irrigon Fish Hatchery exceeded theoretical production potential during the period of evaluation. From October 1986 to April 1987 the theoretically required flow to rear fish at the hatchery ranged from 102% to 132% of the flow available for fish rearing (Figure 9). Theoretically required space reached a maximum of 57% of the space available for fish rearing (Figure 9).

Additional Factors

This hatchery is part of the Lower Snake River Compensation Plan. Funds are administered by the U.S. Fish and Wildlife Service (USFWS), and these funds regulate production level. The present water supply is limited by well design, and the pumps require periodic repair because of damage from sand. Problems with the water system are being corrected.

Opportunities for Increased Production

Investment in additional wells or application of new rearing technology such as oxygen supplementation could increase production at Irrigon Fish Hatchery. Any increase in production must be approved by USFWS.

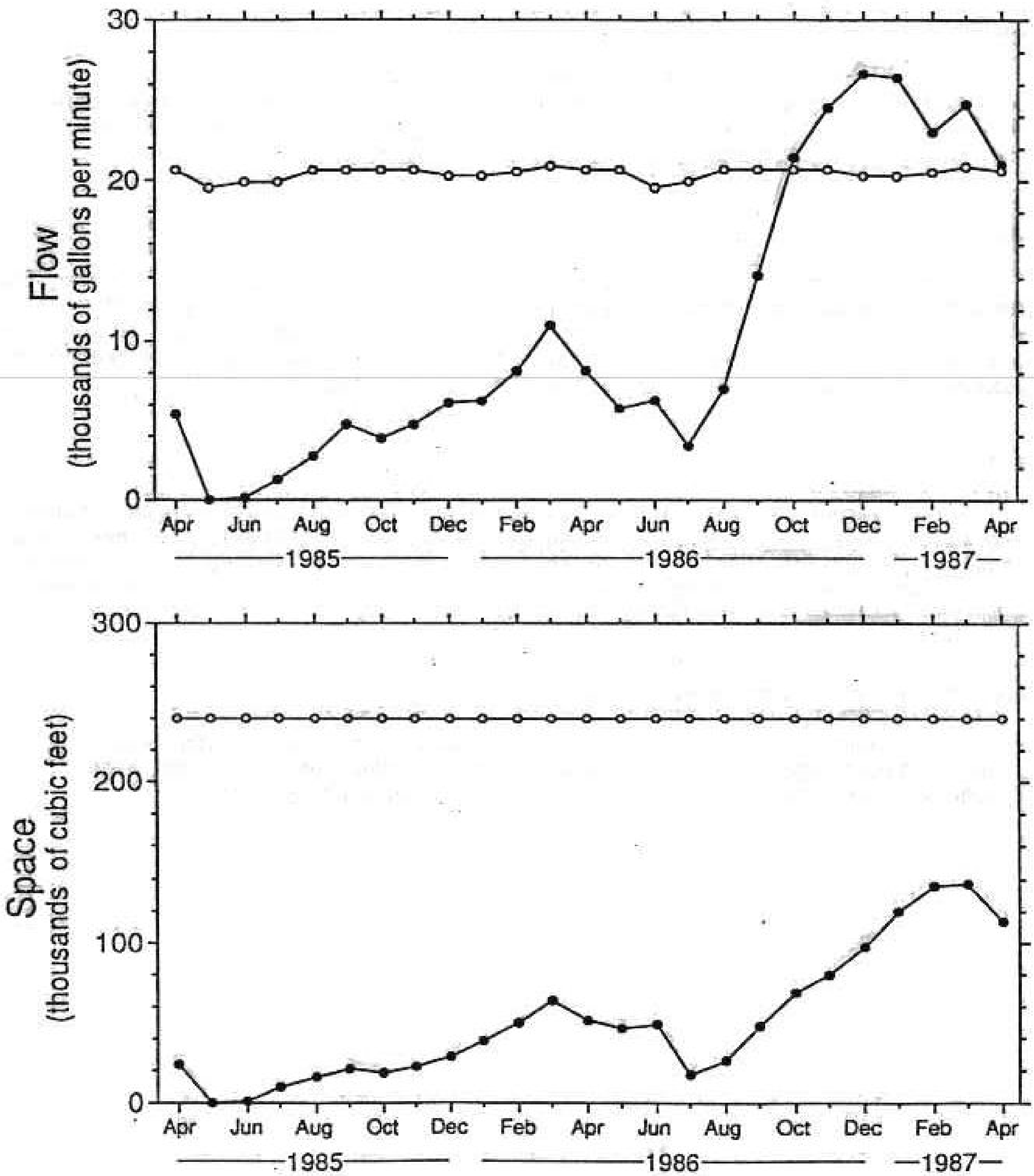


Figure 9. Flow and space use at Irrigon Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Klamath Fish Hatchery

Background

Klamath Fish Hatchery is located 3 miles west of U.S. Highway 97 at Klamath Agency. Water is obtained from several springs that provide at total of 9,025 gpm. Rainbow trout, cutthroat trout, brook trout, coho salmon, and kokanee *O. nerka* are produced at the hatchery.

Theoretical Flow and Space Requirements

Klamath Fish Hatchery did not reach theoretical production potential during the evaluation period. In April 1985 the theoretically required flow for fish rearing was 90% of the available flow (Figure 10). Maximum theoretical space requirement occurred in April 1985 and May 1986, when between 54% and 64% of the available space was required for fish propagation (Figure 10).

Additional Factors

Funding is provided entirely by ODFW, and these funds regulate production level. Approximately 2,000 gpm, which flows into a gravel-bottomed pond with 10,400 cu ft of rearing space, cannot be delivered to other ponds. Therefore the effective water supply is reduced to 7,025 gpm. The water collection and delivery system for all ponds is old and deteriorating and needs to be replaced.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Klamath Fish Hatchery. Substantial increase in production would require extensive repairs. Replacement of the water collection and delivery system would increase available flow. New pipelines could deliver water from each spring to more than one pond or series of ponds. Replacing gravel-bottomed ponds with concrete or asphalt bottoms could improve or increase rearing space.

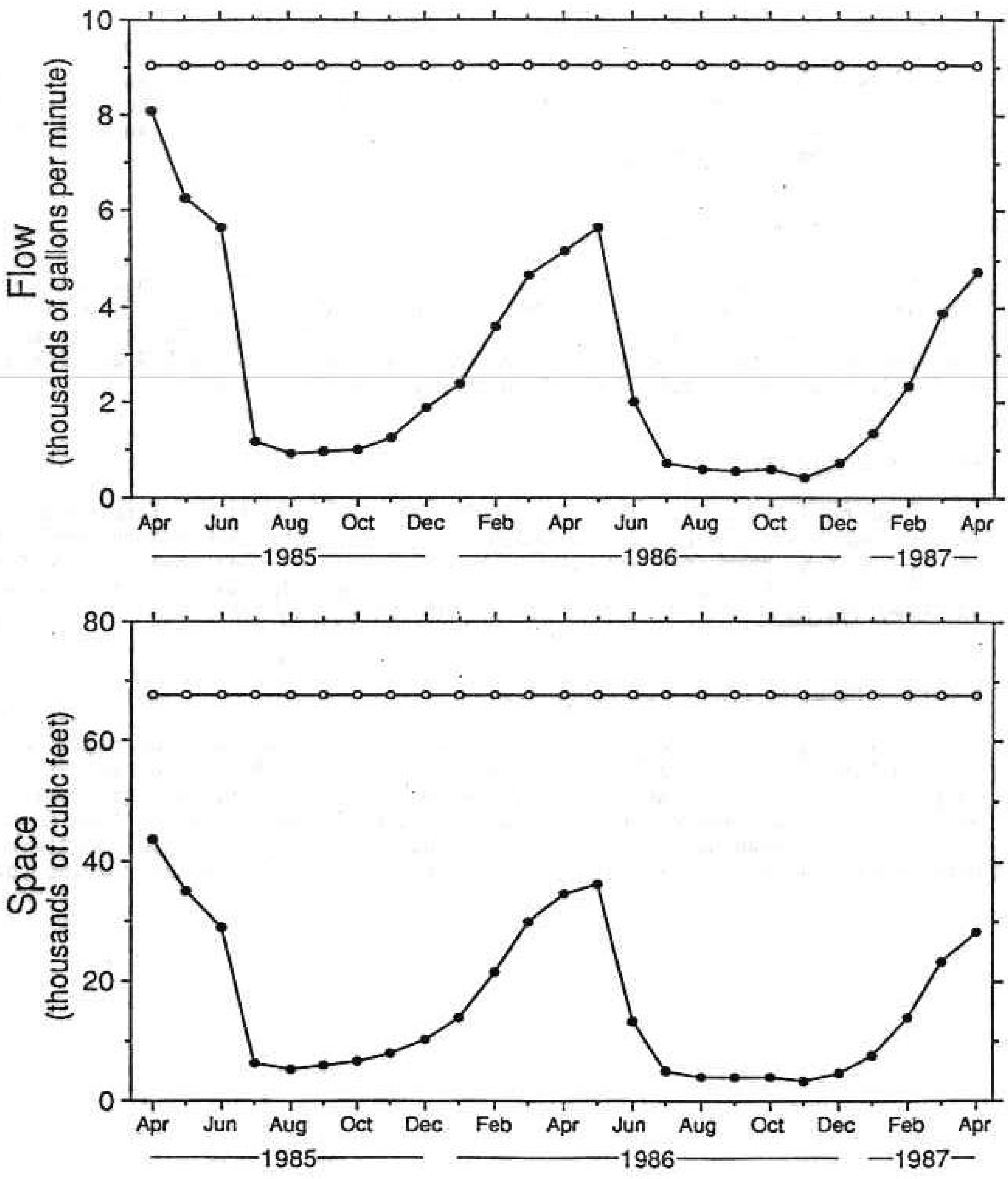


Figure 10. Flow and space use at Klamath Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Leaburg Fish Hatchery

Background

Leaburg Fish Hatchery is located 23 miles east of Springfield on State Highway 126. Water is obtained from Leaburg Dam, a small reservoir on the McKenzie River, which provides a constant 33,855 gpm for fish rearing. Presently the facility produces summer steelhead, rainbow trout, and cutthroat trout. Occasionally spring chinook salmon are also produced.

Theoretical Flow and Space Requirements

Leaburg Fish Hatchery did not reach theoretical production potential during the evaluation period. During periods of maximum use, theoretical flow requirement ranged between 57% to 59% of the flow available for rearing fish (Figure 11). Maximum theoretical space requirement occurred in the spring when it reached 42% of the available space (Figure 11).

Additional Factors

Funds are provided by USACE, and these funds regulate production level. Disease outbreaks have occurred at high production levels.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Leaburg Fish Hatchery. Solutions to disease problems should be found before production is increased. Any increase in production must be approved by USACE.

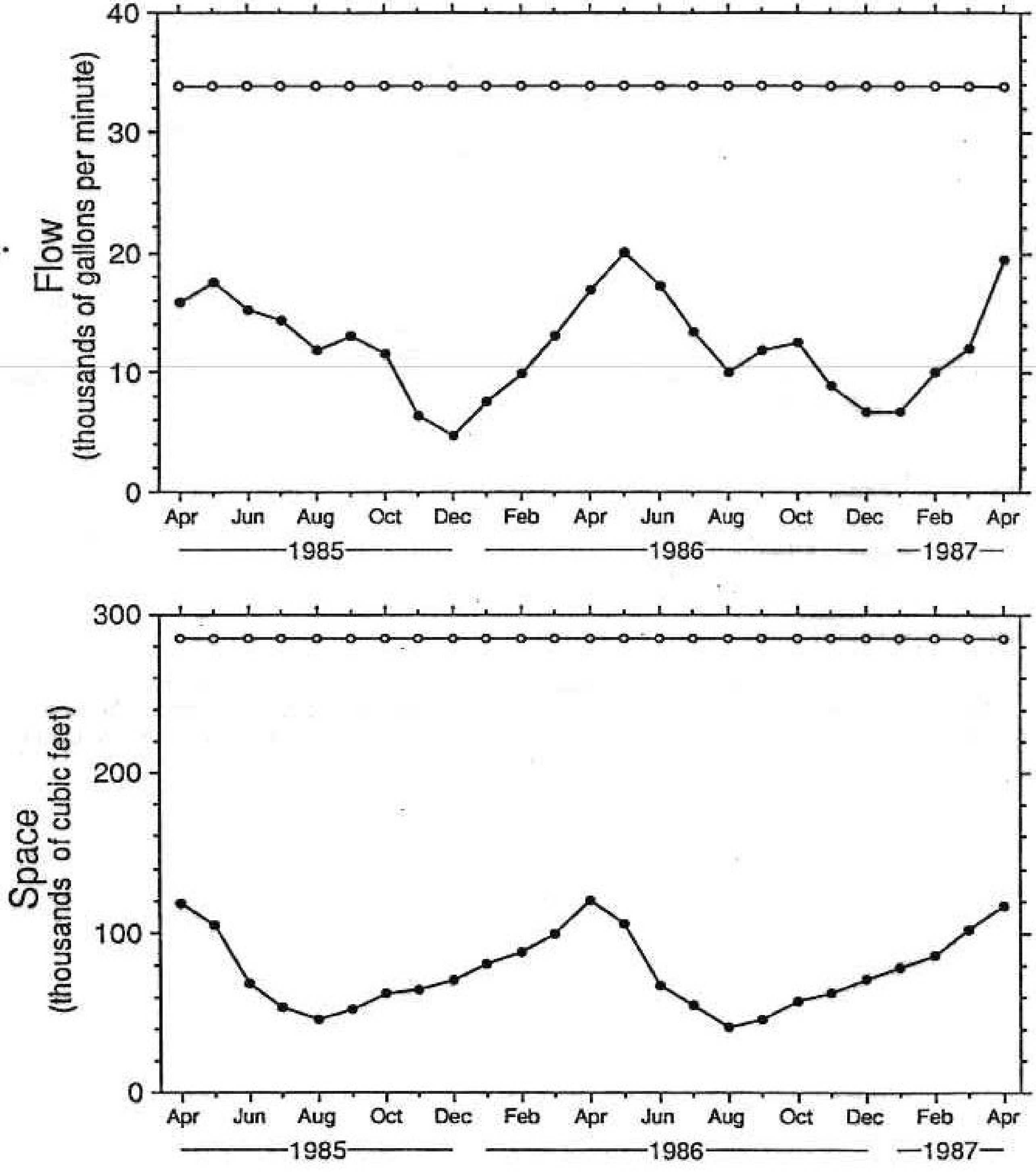


Figure 11. Flow and space use at Leaburg Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Lookingglass Fish Hatchery

Background

Lookingglass Fish Hatchery is located 20 miles north of Elgin off the Palmer Junction Road. Lookingglass Creek and two wells provide 12,600 gpm of water for fish rearing. Spring chinook salmon are produced at the hatchery.

Theoretical Flow and Space Requirements

Lookingglass Fish Hatchery exceeded theoretical production potential during the evaluation period. The theoretical maximum flow necessary to raise fish was only 72% of the available supply during July and August 1985 (Figure 12). From August 1985 to November 1985 between 94% and 120% of the available space was theoretically required for the fish present (Figure 12).

Additional Factors

This hatchery is part of the Lower Snake River Compensation Plan. Funds are administered by USFWS, and these funds regulate production level. Ice has restricted water supply in winter.

Opportunities for Increased Production

Because space restricts theoretical production potential, construction of additional ponds or raceways appears to be the only feasible option to increase production. Any construction or production increase must be approved by USFWS.

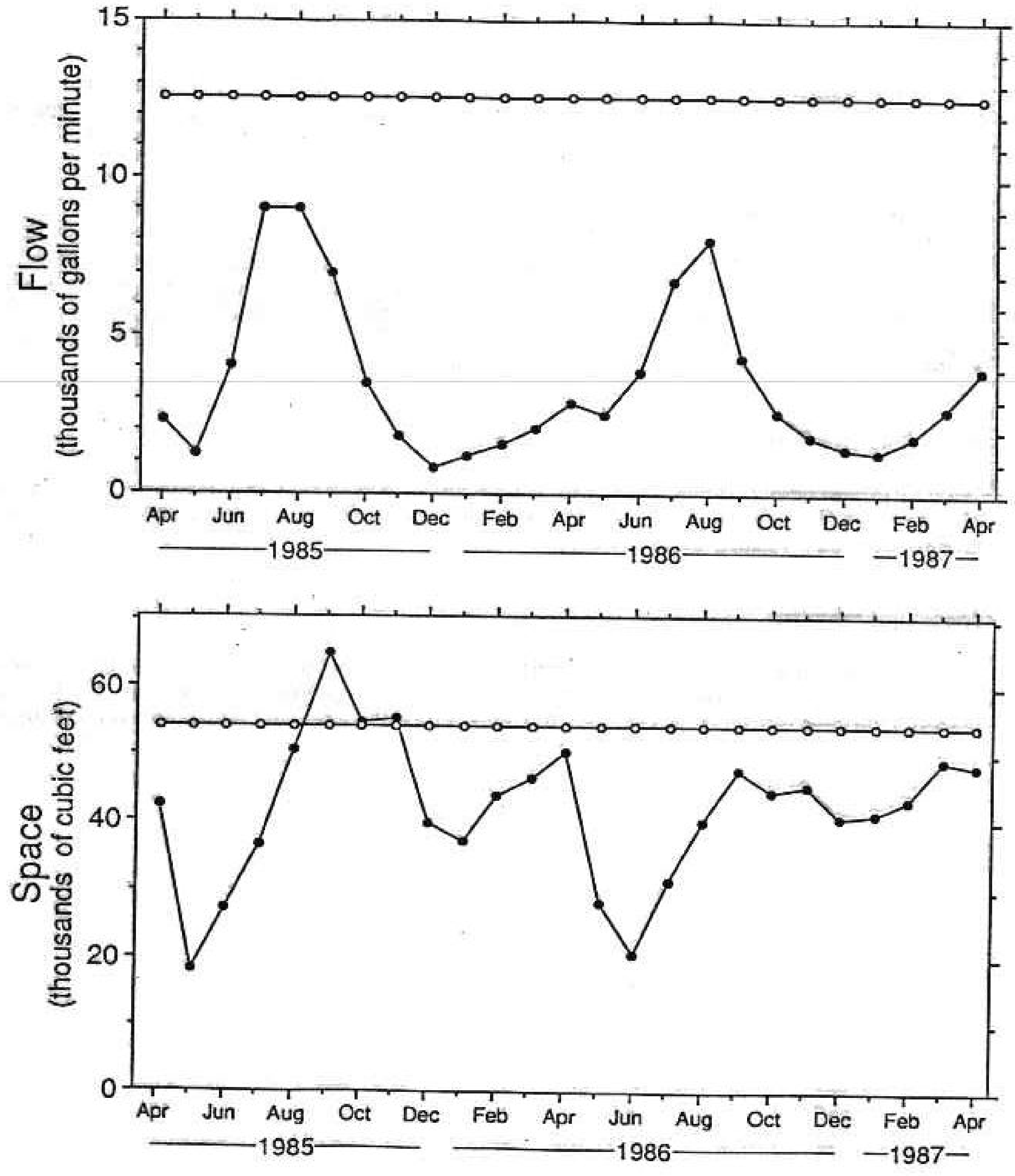


Figure 12. Flow and space use at Lookingglass Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Marion Forks Fish Hatchery

Background

Marion Forks Fish Hatchery is located 11 miles east of Idanha on State Highway 22. Marion Creek supplies water during the spring and summer, and Horn Creek supplies water during the winter when Marion Creek freezes. Minimum available flow varies from 6,000 to 15,266 gpm. Spring chinook salmon and winter steelhead are produced at the hatchery.

Theoretical Flow and Space Requirements

Marion Forks Fish Hatchery did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement was 57% of the available flow in October 1986 (Figure 13). Maximum theoretical space requirement occurred from September to March when 40% to 54% of the space available was necessary (Figure 13).

Additional Factors

The hatchery is operated with funds provided by ODFW and USACE, and these funds regulate production level. Low water temperature results in slow growth, and a 2-year rearing period for winter steelhead is required.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Marion Forks Hatchery. Because of cold water, rearing should focus on programs other than 2-year winter steelhead smolt production. Any increase in production must be approved by USACE.

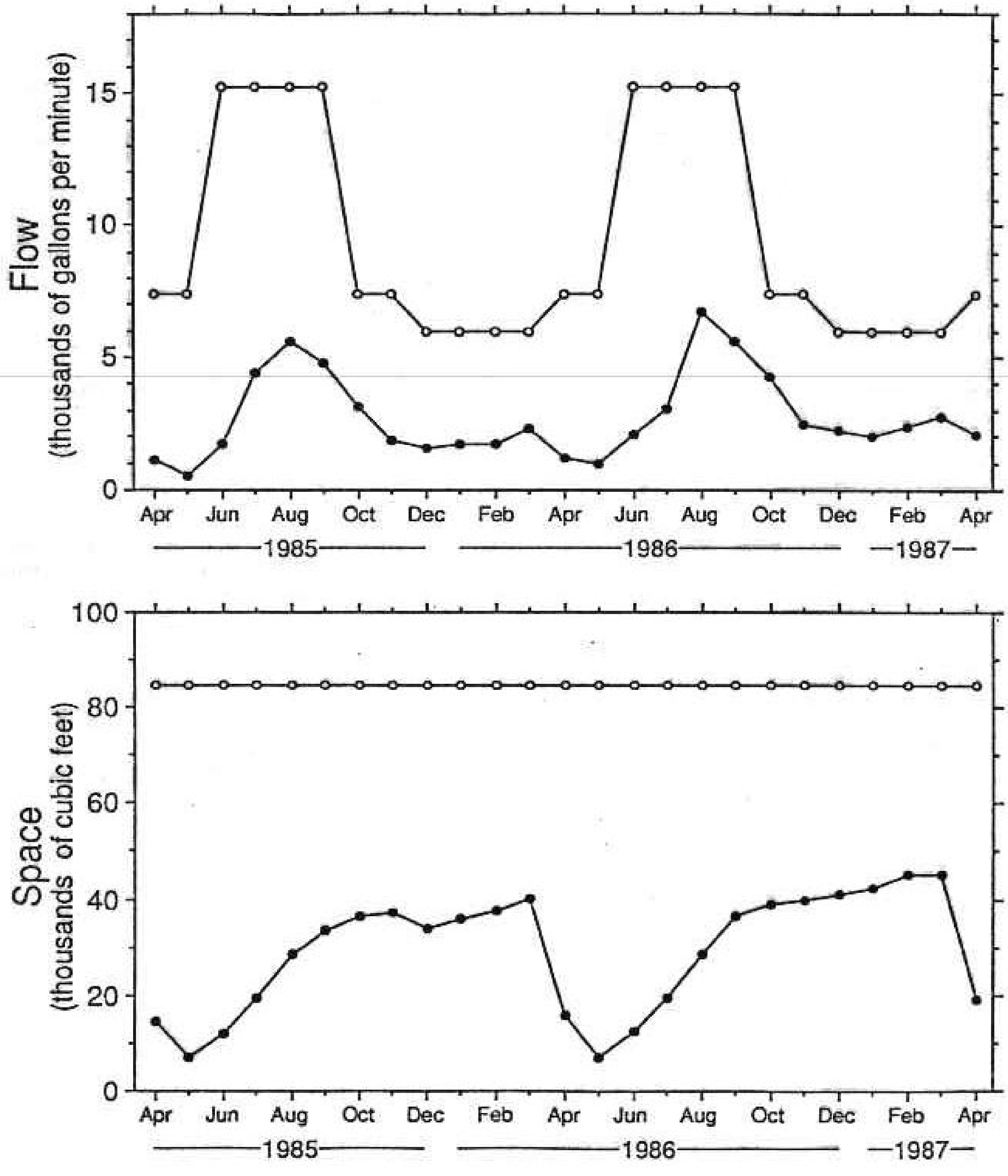


Figure 13. Flow and space use at Marion Forks Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

McKenzie River Fish Hatchery

Background

McKenzie River Fish Hatchery is located 22 miles east of Springfield on State Highway 126. Water comes from Cogswell Creek and the McKenzie River through Leaburg Canal. A constant 22,450 gpm of water is available for fish rearing. Currently, summer steelhead and spring chinook salmon are produced at the hatchery.

Theoretical Flow and Space Requirements

McKenzie River Fish Hatchery did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement was only 27% of the available flow (Figure 14). Maximum theoretical space requirement was 50% of the space available (Figure 14).

Additional Factors

Funding is provided by ODFW and USACE, and these funds regulate production level. The potential for disease problems is similar to that at Leaburg Fish Hatchery because both hatcheries use the same water source.

Opportunities for Increased Production

According to the production models, additional fish could be raised without modification to the present facilities. Pond construction or holding pond modification would add additional capacity. Any increase in production level or construction of ponds would require approval by USACE.

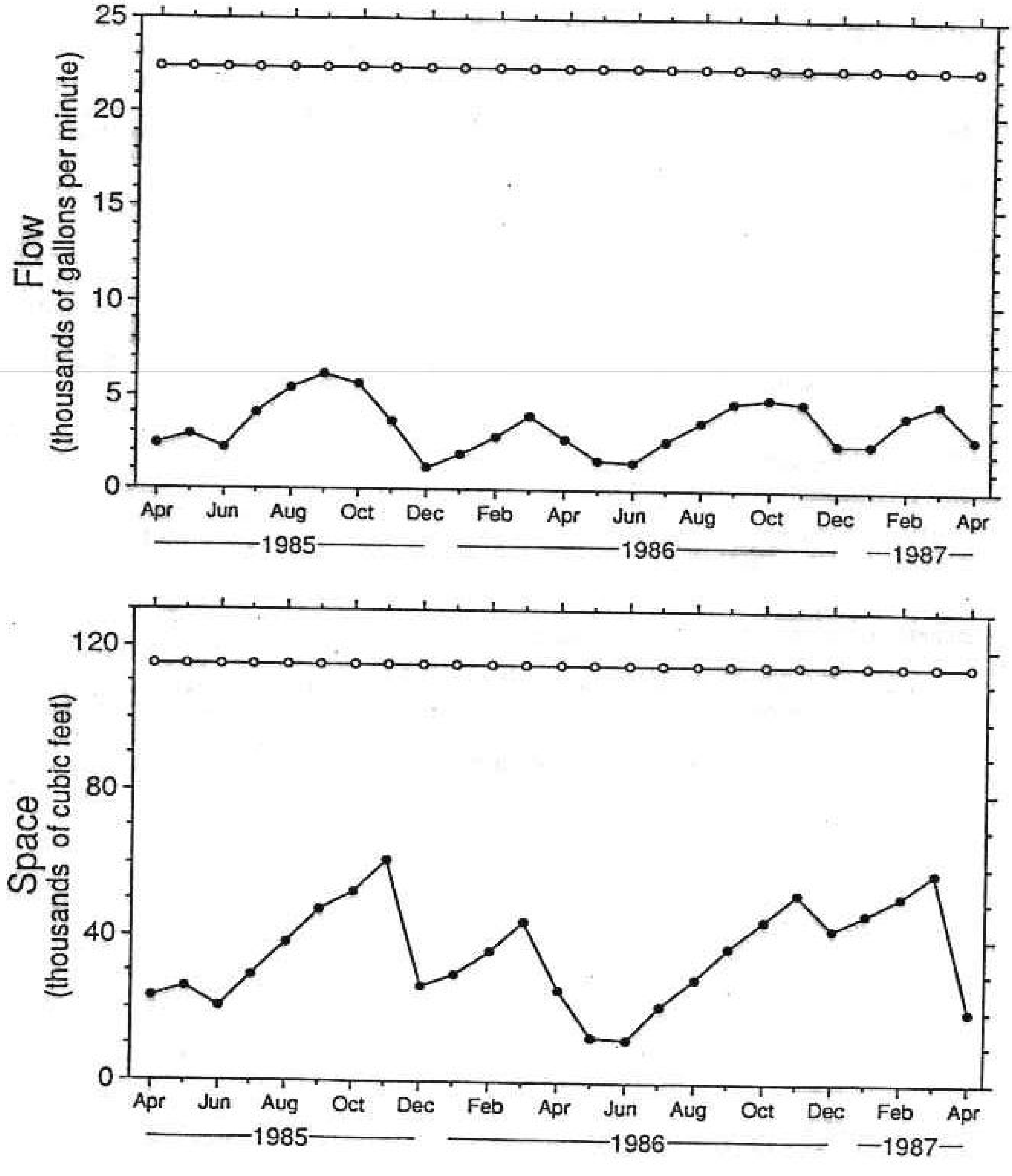


Figure 14. Flow and space use at McKenzie River Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Oak Springs Fish Hatchery

Background

Oak Springs Fish Hatchery is located 9 miles northeast of Maupin off U.S. Highway 197. Water comes from a series of springs. A constant 10,893 gpm is available for fish rearing. Currently, summer steelhead and rainbow trout are produced at the hatchery.

Theoretical Flow and Space Requirements

Oak Springs Fish Hatchery exceeded theoretical production potential during the period of evaluation. Theoretical flow requirements reached 197% of the available rearing flow (Figure 15). Some water is recycled in a series of rock-bottomed ponds, which may account for the facility exceeding production potential by such a high percentage. In this flow-through recirculation system, an unknown amount of reoxygenation occurs as water falls from pond to pond.

Maximum space requirement occurred in April and May 1985 when between 42% and 51% of the available space was theoretically necessary (Figure 15). The value for available rearing space is an estimate because of the series of ponds with rock bottoms. The bottom is uneven in these ponds, and depth ranges from 0 to 10 ft.

Additional Factors

Funds are provided by ODFW, and these funds regulate production level. Irrigation runoff contaminates the supply springs for the upper ponds and results in disease problems and fish mortality each year.

Opportunities for Increased Production

According to the production models, theoretical production potential has been exceeded at Oak Springs Fish Hatchery. Updating and expanding the water delivery system would substantially increase available flow. Diversion dams above the water supply springs could prevent contamination by irrigation runoff. Replacing the rock-bottomed ponds would ease treatment for disease, increase worker safety, and provide more control over flow.

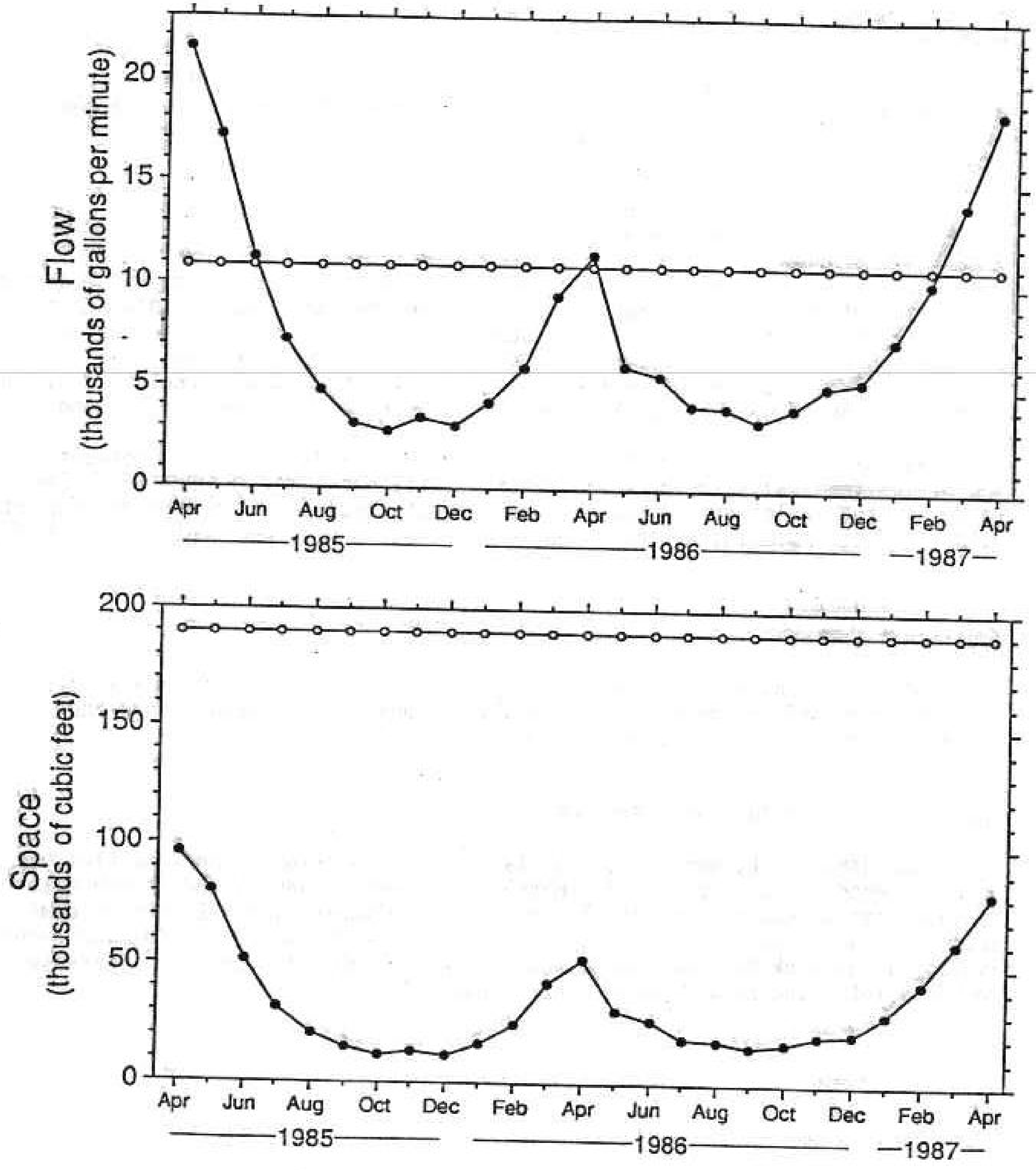


Figure 15. Flow and space use at Oak Springs Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Oxbow Fish Hatchery

Background

Oxbow Fish Hatchery is located 1 mile east of Cascade Locks along I-80N. Water is obtained from Oxbow Spring. Minimum available water flow varies between 300 and 2,400 gpm. Spring chinook salmon and coho salmon are raised at the hatchery.

Theoretical Flow and Space Requirements

This facility exceeded theoretical production potential during the evaluation period. Theoretical flow requirements in July 1985 and 1986 were 124% and 128%, respectively, of available flow (Figure 16). Maximum theoretical space requirement was 46% of the available space (Figure 16).

Additional Factors

This facility is operated with Mitchell Act Funds administered by NMFS, and these funds regulate production level. Flow from Oxbow Spring declines to as low as 300 gpm, and remains below 1,000 gpm from August through January.

Opportunities for Increased Production

According to the production models, Oxbow Hatchery has reached theoretical production potential. Potential could be increased by providing water from Herman Creek, although this may introduce diseases. Any increase in production must be approved by NMFS.

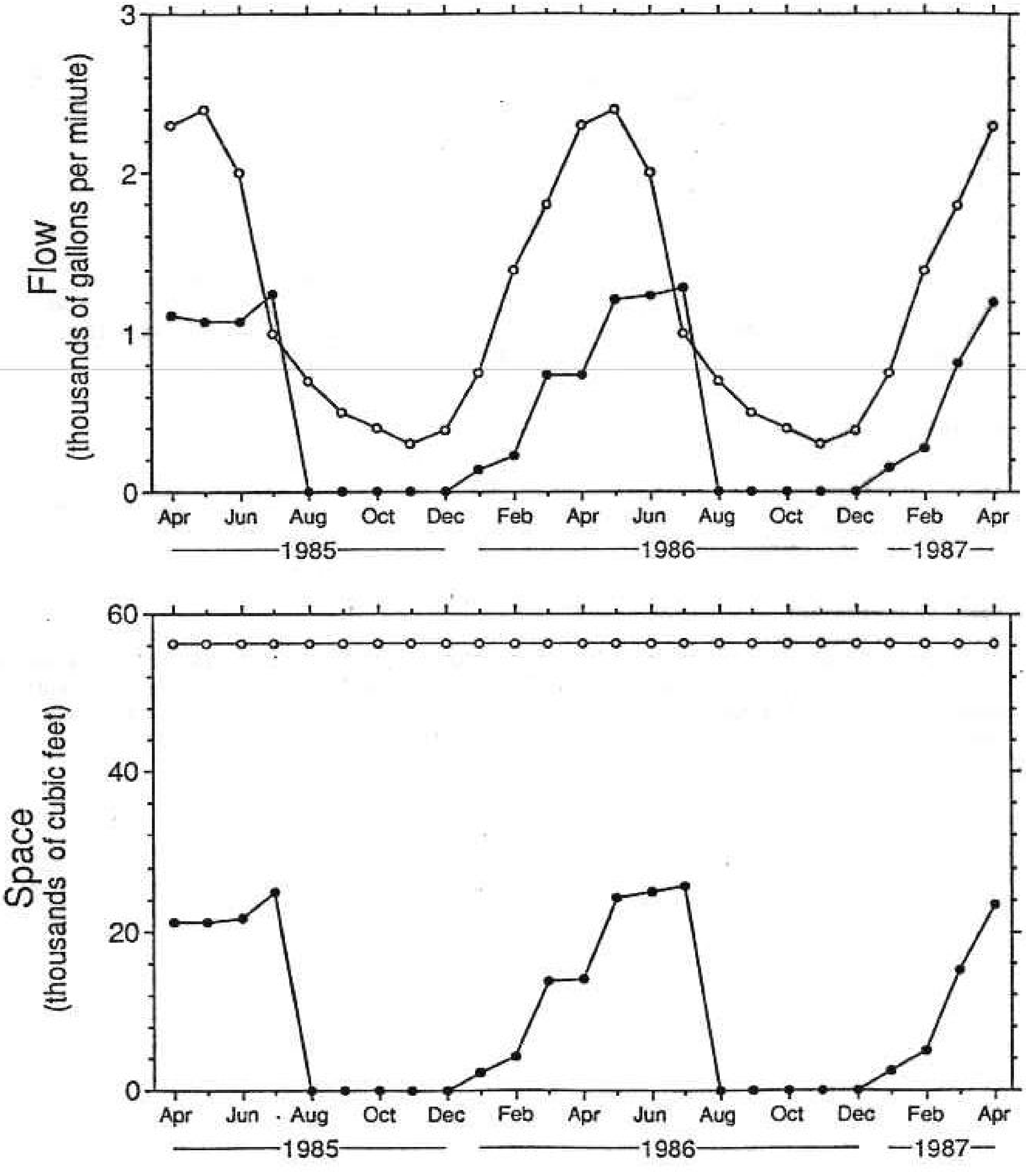


Figure 16. Flow and space use at Oxbow Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Pelton Ladder

Background

Pelton ladder, which is a satellite rearing facility for Round Butte Fish Hatchery, consists of a former fish passage ladder that has sections converted to rear spring chinook salmon. Water comes from Pelton Reservoir (Lake Simtustis), an impoundment of the Deschutes River. A constant 3,590 gpm is available for fish rearing. Spring chinook salmon are produced at the facility.

Theoretical Flow and Space Requirements

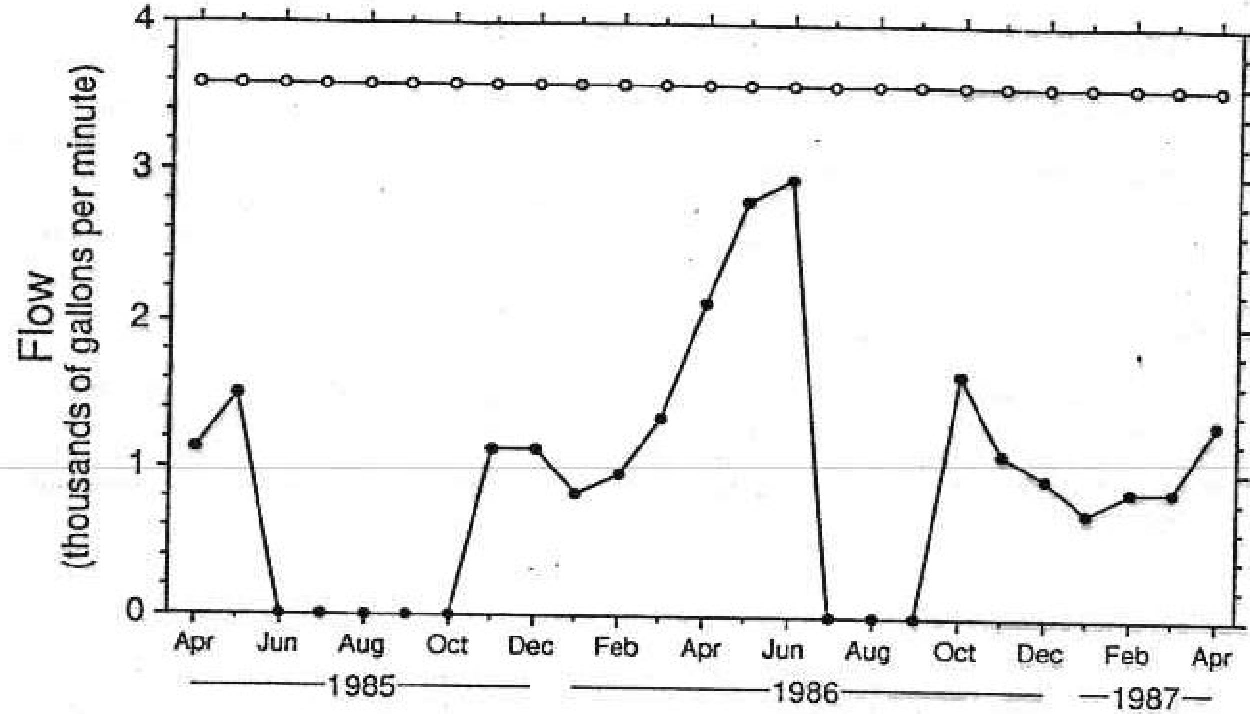
Pelton ladder did not reach theoretical production potential during the period of evaluation. Maximum theoretical flow requirement was only 82% of the flow available (Figure 17). Theoretical space requirements during the time Pelton ladder was used ranged between 11% and 20% of the available rearing space (Figure 17).

Additional Factors

The facility is operated with funds from Portland General Electric Company, and these funds regulate production level. Infectious hematopoetic necrosis (IHN) virus occurs at Round Butte Fish Hatchery, which provides the fish that are reared in Pelton ladder.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Pelton ladder under present conditions. To increase production potential, flow through the ladder could be increased following consulting engineers to determine velocity changes. More sections of the ladder could be converted to rearing space. Water could be delivered to downstream portions of the ladder through external pipelines in order to provide fresh water periodically and to reduce the proportion of recycled water in downstream sections of the ladder. Any increase in production must be approved by Portland General Electric Company.



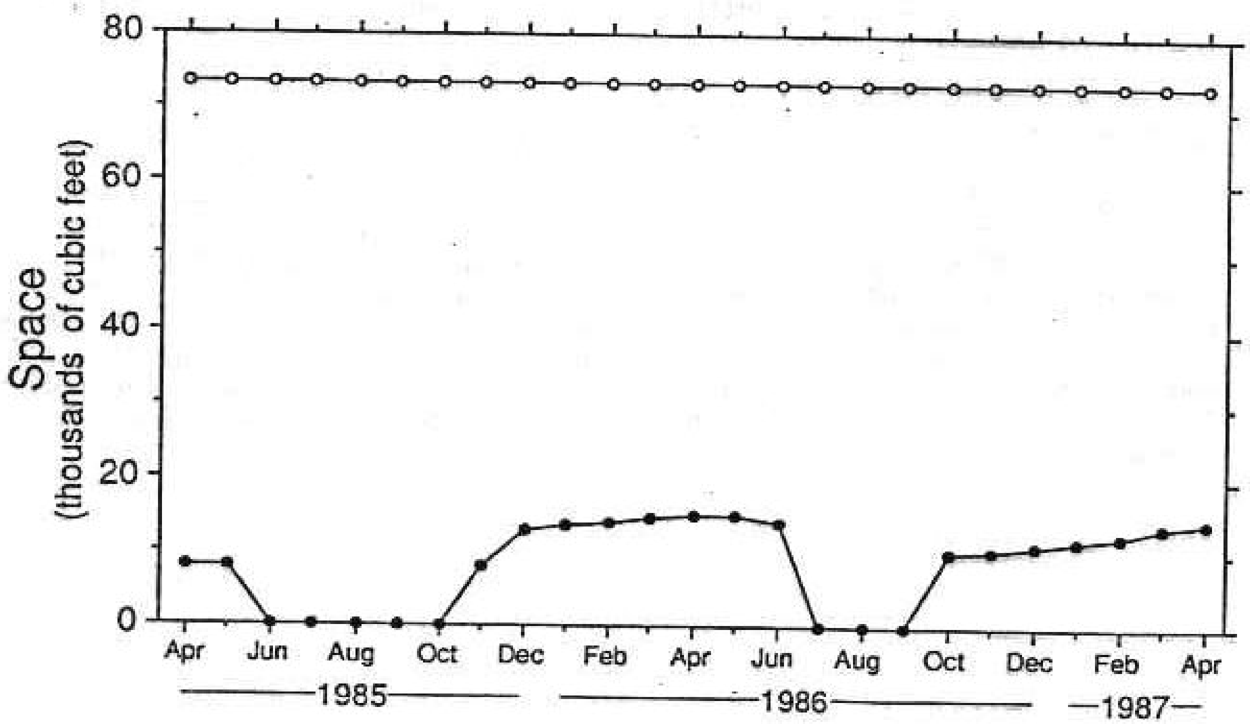


Figure 17. Flow and space use at Pelton ladder. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Roaring River Fish Hatchery

Background

Roaring River Fish Hatchery is located 11 miles southeast of Scio off State Highway 226. Water is obtained from Roaring River, a tributary of Crabtree Creek. Minimum available flow fluctuates from 2,166 gpm in October to 15,405 gpm during the winter. Winter steelhead, summer steelhead, rainbow trout, and cutthroat trout are produced at the hatchery.

Theoretical Space and Flow Requirements

This facility exceeded theoretical production potential during the period of evaluation. Theoretical flow requirements in October 1985 and 1986 were 117% and 139%, respectively, of the flow available during the first part of the month (Figure 18). Maximum theoretical space requirement was 54% of the available rearing space (Figure 18). Available rearing space increased in 1987 following the construction of new ponds and improvement of old ponds.

Additional Factors

Funds are provided entirely by ODFW, and these funds regulate production level. Diseases limit production in 12 older ponds.

Opportunities for Increased Production

According to the production models, this facility has exceeded theoretical production potential. Application of new rearing technology such as oxygen supplementation appears to be the only option to increase production. Space for additional pond construction is present, but this would have little value without additional water.

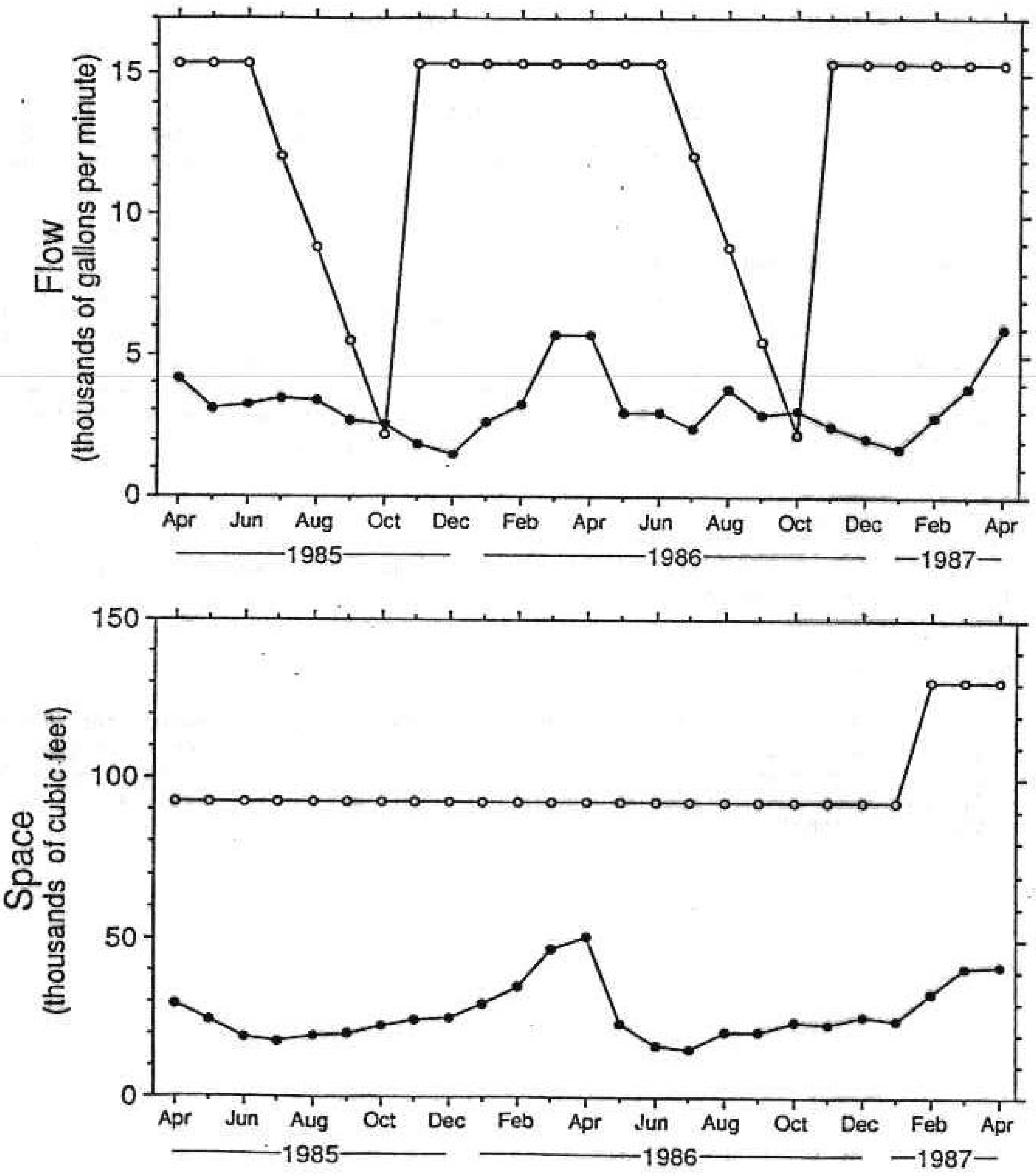


Figure 18. Flow and space use at Roaring River Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Round Butte Fish Hatchery

Background

Round Butte Fish Hatchery is located 10 miles west of Madras at the base of Round Butte Dam. Water is supplied by two springs. Between 8,590 and 8,965 gpm are available for fish rearing. Summer steelhead, spring chinook salmon, and brown trout *Salmo trutta* are produced at the hatchery.

Theoretical Flow and Space Requirements

Round Butte Fish Hatchery did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement occurred in March and April and represented between 46% and 56% of the flow available for rearing at that time (Figure 19). Maximum theoretical space requirement reached 73% of the available space (Figure 19).

Additional Factors

This hatchery is operated with funds provided by Portland General Electric Company, and these funds regulate production level. Problems with IHN virus have resulted in quarantine restrictions. Production has been shifted to Pelton ladder to increase survival of spring chinook salmon.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Round Butte Fish Hatchery under current conditions. Using one adult pond for rearing would provide 2,732 cu ft of additional rearing space. Modifying the water delivery system would provide an undetermined quantity of additional water. Any increase in production must be approved by Portland General Electric Company.

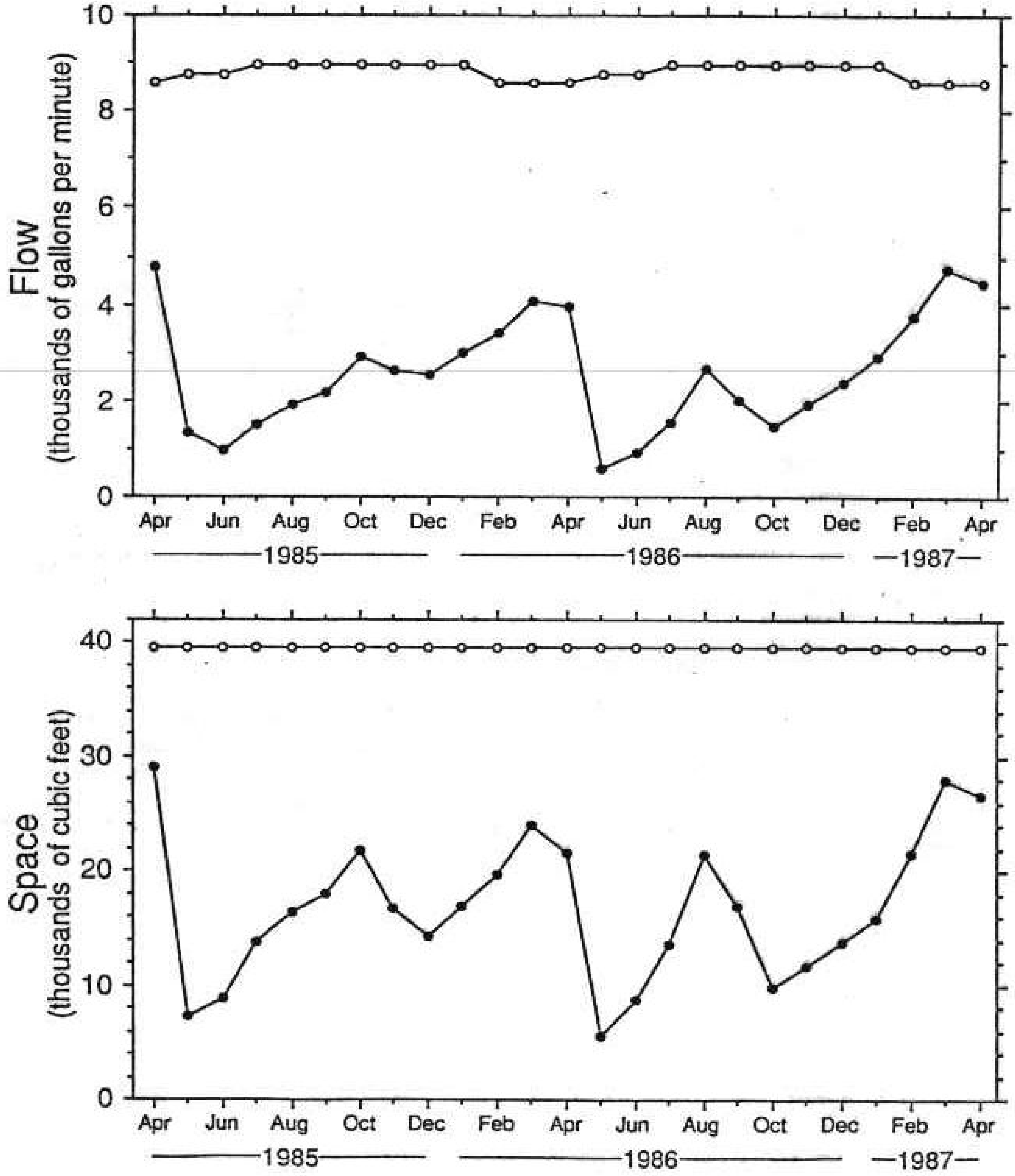


Figure 19. Flow and space use at Round Butte Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Sandy Fish Hatchery

Background

Sandy Fish Hatchery is located 1.5 miles north of Sandy off U.S. Highway 26. Water is obtained primarily from Cedar Creek, a tributary of the Sandy River. Available rearing flow varies between 1,800 gpm in summer and fall and 8,300 gpm in winter and spring. Coho salmon are reared at the hatchery.

Theoretical Flow and Space Requirements

Sandy hatchery exceeded theoretical production potential during the period of evaluation. During low flow periods in summer and early fall, theoretical flow requirement ranged between 112% and 244% of the available flow (Figure 20). Maximum theoretical space requirement was 40% of the space available for rearing (Figure 20).

Additional Factors

The facility is operated with Mitchell Act funds administered by NMFS, and these funds regulate production level. Disease can be a problem when water must be recirculated during low summer flow.

Opportunities for Increased Production

The only apparent option for increasing production is the application of new rearing technology, such as oxygen supplementation. Any increase in production must be approved by NMFS.

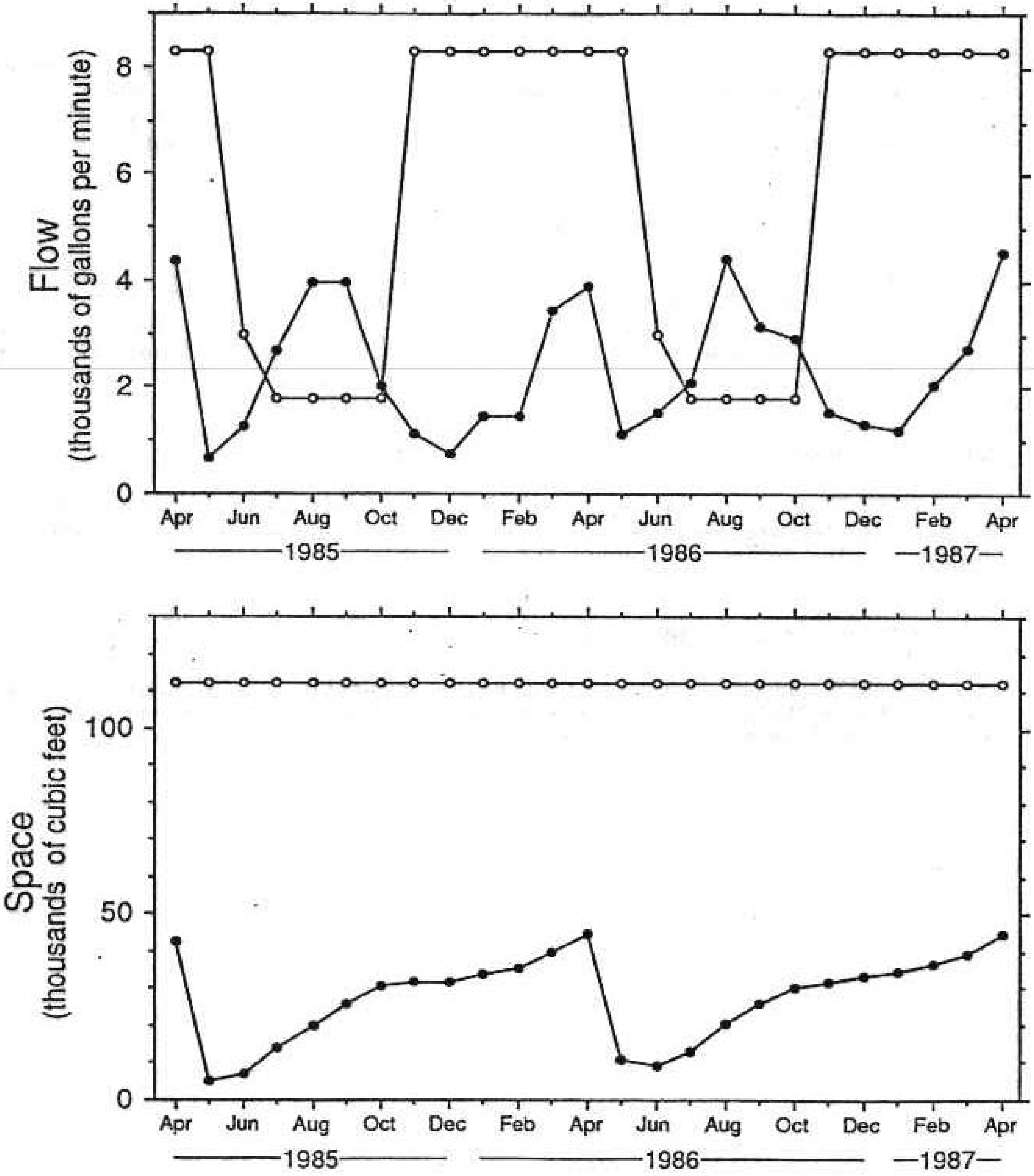


Figure 20. Flow and space use at Sandy Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

South Santiam Fish Hatchery

Background

South Santiam Fish Hatchery is located 0.5 mile from Foster off U.S. Highway 20. Water is obtained from Foster Reservoir, an impoundment of the South Santiam River. A constant 8,400 gpm is available for fish rearing. This water is collected from upper and lower levels of the reservoir and is delivered to an aeration tower before going through the rearing ponds. During the evaluation period summer steelhead, spring chinook salmon, and coho salmon were reared at the hatchery.

Theoretical Flow and Space Requirements

South Santiam hatchery did not reach theoretical production potential during the period of evaluation. Maximum theoretical flow requirement occurred in October 1986 when 69% of available flow was required for rearing (Figure 21). Maximum theoretical space requirement was 53% of the space available (Figure 21).

Additional Factors

Funding is provided by USACE and ODFW, and these funds regulate production level. Burrows ponds, which are known to have higher incidence of disease than standard raceways, are used. Production was higher in past years, but because of problems with disease and poor fish quality, production was reduced.

Opportunities for Increased Production

According to the production models, additional fish could be raised at South Santiam Fish hatchery. However, this facility has a history of problems with fish quality at a high rearing density. If these problems are solved and additional production is desired beyond the present potential, the water delivery system could be improved, an additional rearing pond could be constructed, the Burrows ponds could be replaced with standard raceways, and a settling basin could be constructed. New rearing technology such as oxygen supplementation could be applied. Increases in production must be approved by USACE.

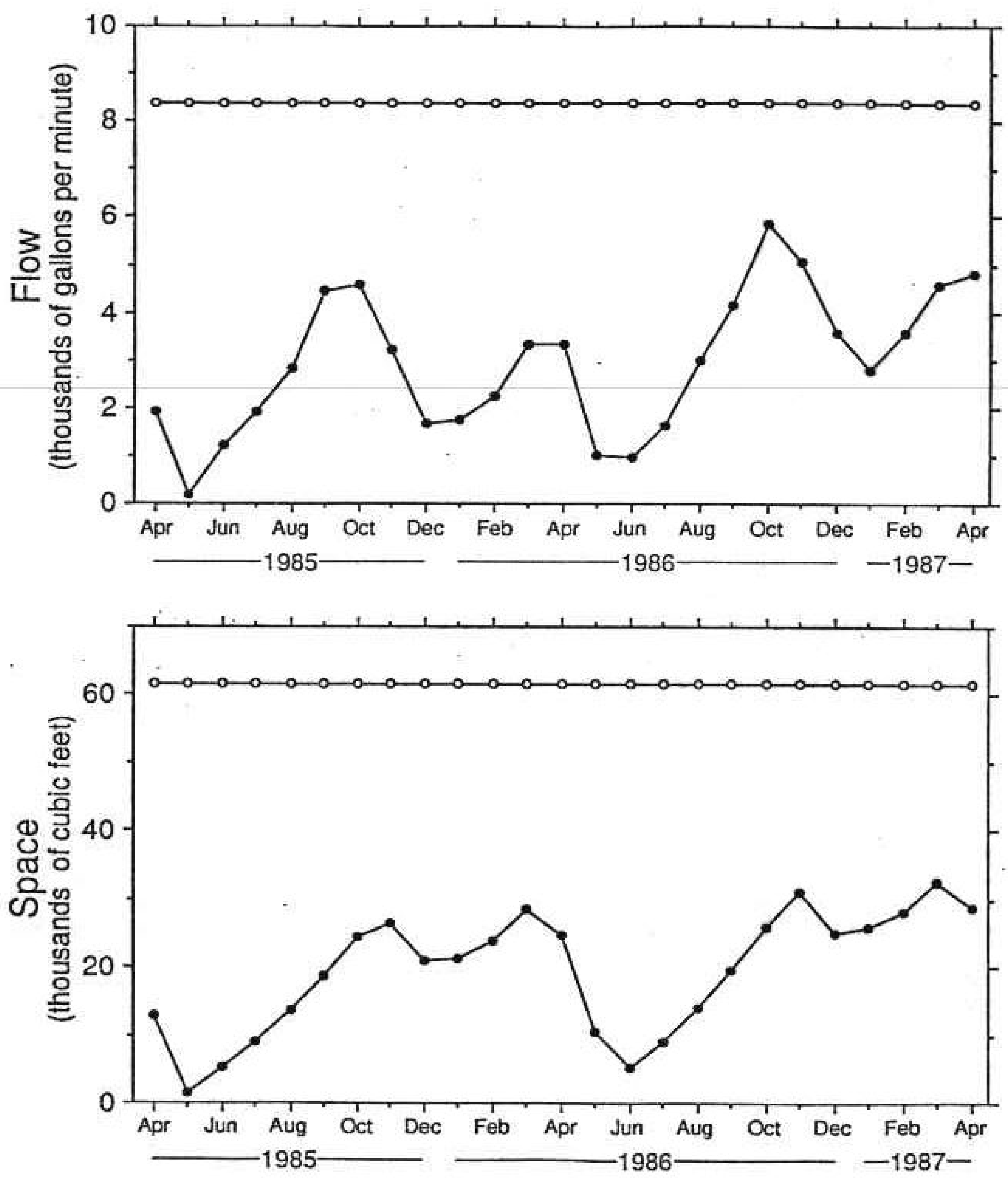


Figure 21. Flow and space use at South Santiam Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Trojan Rearing Ponds

Background

The Trojan Rearing Ponds, a satellite of Gnat Creek Fish Hatchery, are located at the Trojan Nuclear Power Plant near Rainier on U.S. Highway 30. The Trojan Rearing Ponds consist of two gravel-bottomed ponds that receive 6,900 gpm of heated water pumped from the Columbia River at Trojan Nuclear Power Plant. Winter steelhead and cutthroat trout are reared in the ponds.

Theoretical Flow and Space Requirements

Trojan Rearing Ponds did not reach theoretical production potential during the period of evaluation. Maximum theoretical flow requirement, which occurred in March 1987, represented 43% of the flow that the pumps can provide (Figure 22). The maximum theoretical space requirement was 21% of the available space (Figure 22).

Additional Factors

The facility is operated with Mitchell Act funds administered by NMFS, and these funds regulate production level. Because the water is collected from the lower Columbia River, water quality is poor and summer temperature is high. IHN virus at the facility limits the locations where fish may be stocked.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Trojan Rearing Ponds. Poor water quality, high summer water temperature, and IHN restrict opportunities to increase production. Any increase in production must be approved by NMFS.

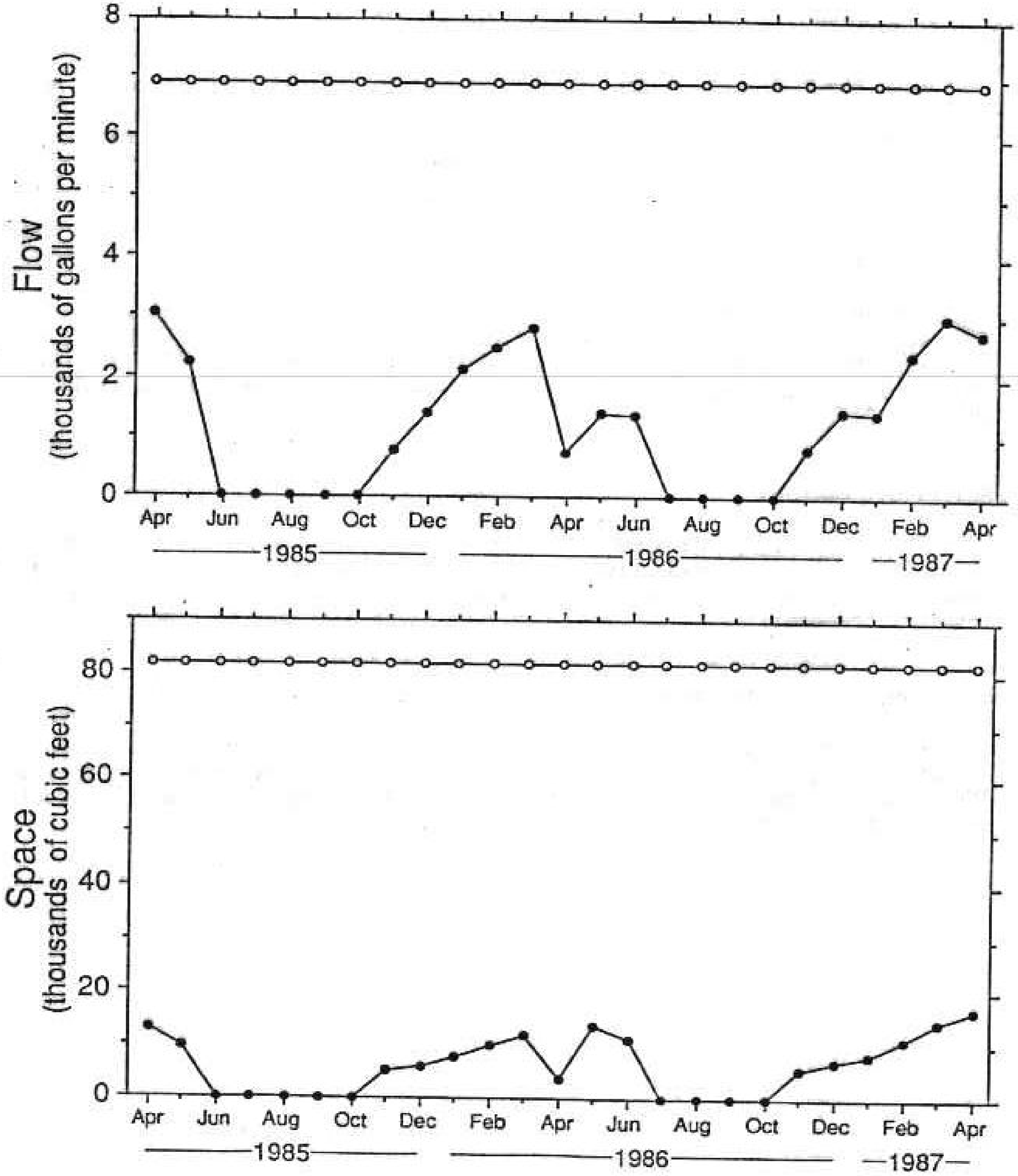


Figure 22. Flow and space use at Trojan Rearing Ponds. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Wallowa Fish Hatchery

Background

Wallowa Fish Hatchery is located 2 miles southwest of Enterprise off State Highway 82. Two unnamed springs, Spring Creek, Hurricane Creek, and Clear Creek provide water for the hatchery. Available flow for rearing and acclimation ponds varies between 3,140 and 15,970 gpm. Rainbow trout, coho salmon, and summer steelhead are reared at this hatchery.

Theoretical Flow and Space Requirements

This facility exceeded theoretical production potential during the evaluation period. Maximum theoretical flow requirements from April to August ranged between 111% and 343% of the available flow (Figure 23). Available rearing space is 81,000 cu ft, but if the acclimation ponds used for the Lower Snake River Compensation Plan are included, 169,200 cu ft are available. Maximum theoretical space requirement was 115% of the available rearing space excluding the acclimation ponds, or 55% of available space including the acclimation ponds (Figure 23).

Additional Factors

A portion of this facility is part of the Lower Snake River Compensation Plan, so some operational funds are provided by USFWS and some are provided by ODFW, and these funds regulate production level. Whirling disease *Myxosoma cerebralis*, which has occurred at the facility, has resulted in restrictions on stock transfer. Some ponds at the existing facility need to be replaced. Agricultural runoff in Spring Creek causes extremely poor water quality. Attempts to develop deep wells have been unsuccessful.

Opportunities for Increased Production

New rearing technology, such as oxygen supplementation, appears to be the only alternative for increasing production at Wallowa Fish Hatchery. In addition, poor water quality limits production. Development of shallow wells to supplement the water supply may be possible.

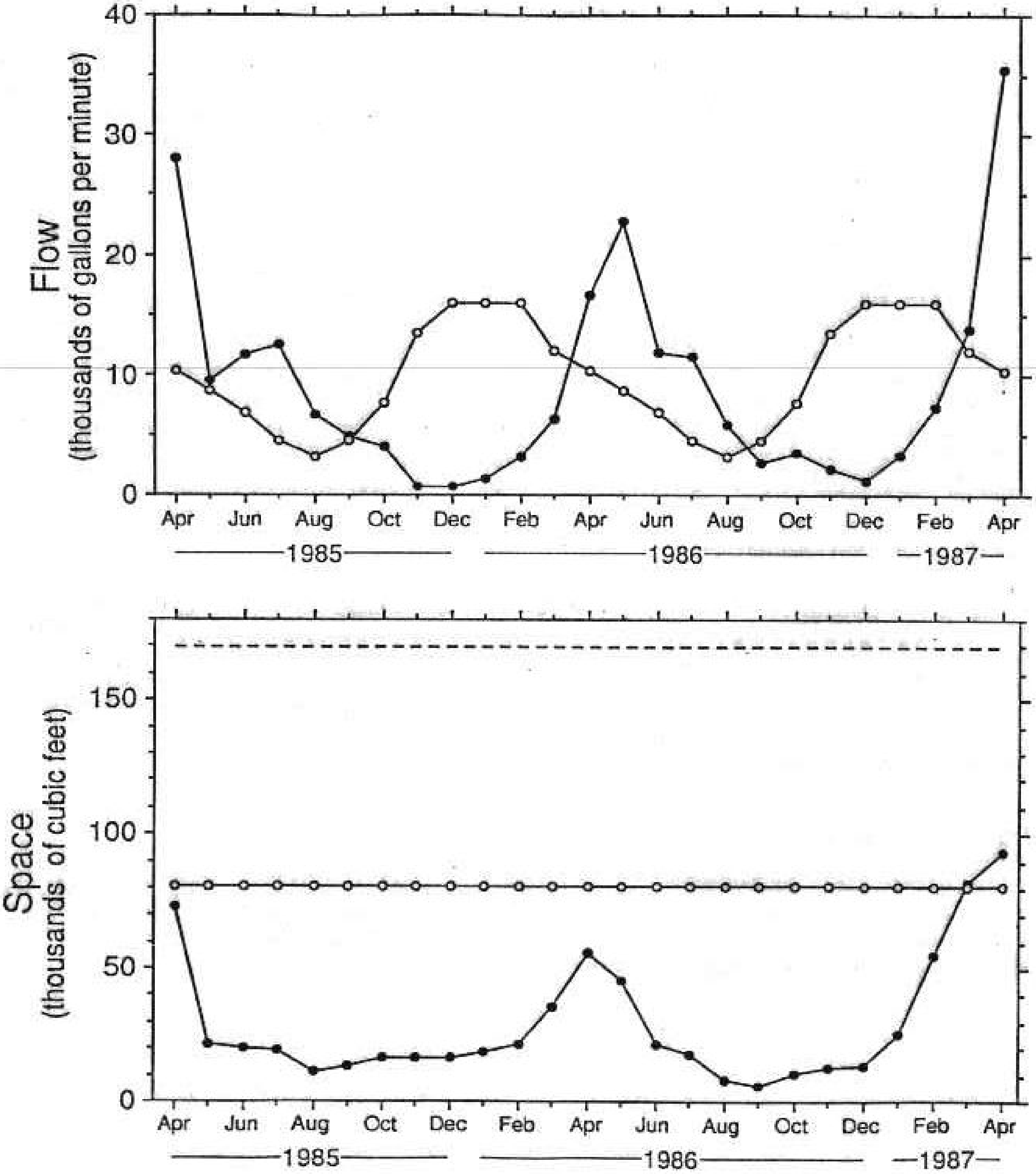


Figure 23. Flow and space use at Wallowa Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space. Dashed line indicates available space when acclimation ponds are included.

Willamette Fish Hatchery

Background

Willamette Fish Hatchery is located 1 mile northeast of Oakridge off State Highway 58. Water comes from Salmon Creek. Minimum available rearing flow each month varies between 33,784 and 36,594 gpm. Rainbow trout, winter steelhead, and spring chinook salmon are produced at the hatchery.

Theoretical Flow and Space Requirements

Willamette Fish Hatchery did not reach theoretical production potential during the evaluation period. Maximum theoretical flow requirement was reached in August 1986 at 55% of available flow (Figure 24). Total available rearing flow varied with operation of the adult holding pond (Figure 24). Maximum theoretical space requirement was 48% of the available space (Figure 24).

Additional Factors

Funds are provided by USACE and ODFW, and these funds regulate production level. Some wooden incubation troughs must be replaced.

Opportunities for Increased Production

According to the production models, additional fish could be raised at Willamette Fish Hatchery. Plans are proceeding to attempt to increase production at the hatchery with an experimental oxygen supplementation system. Production potential should be reevaluated after this is implemented.

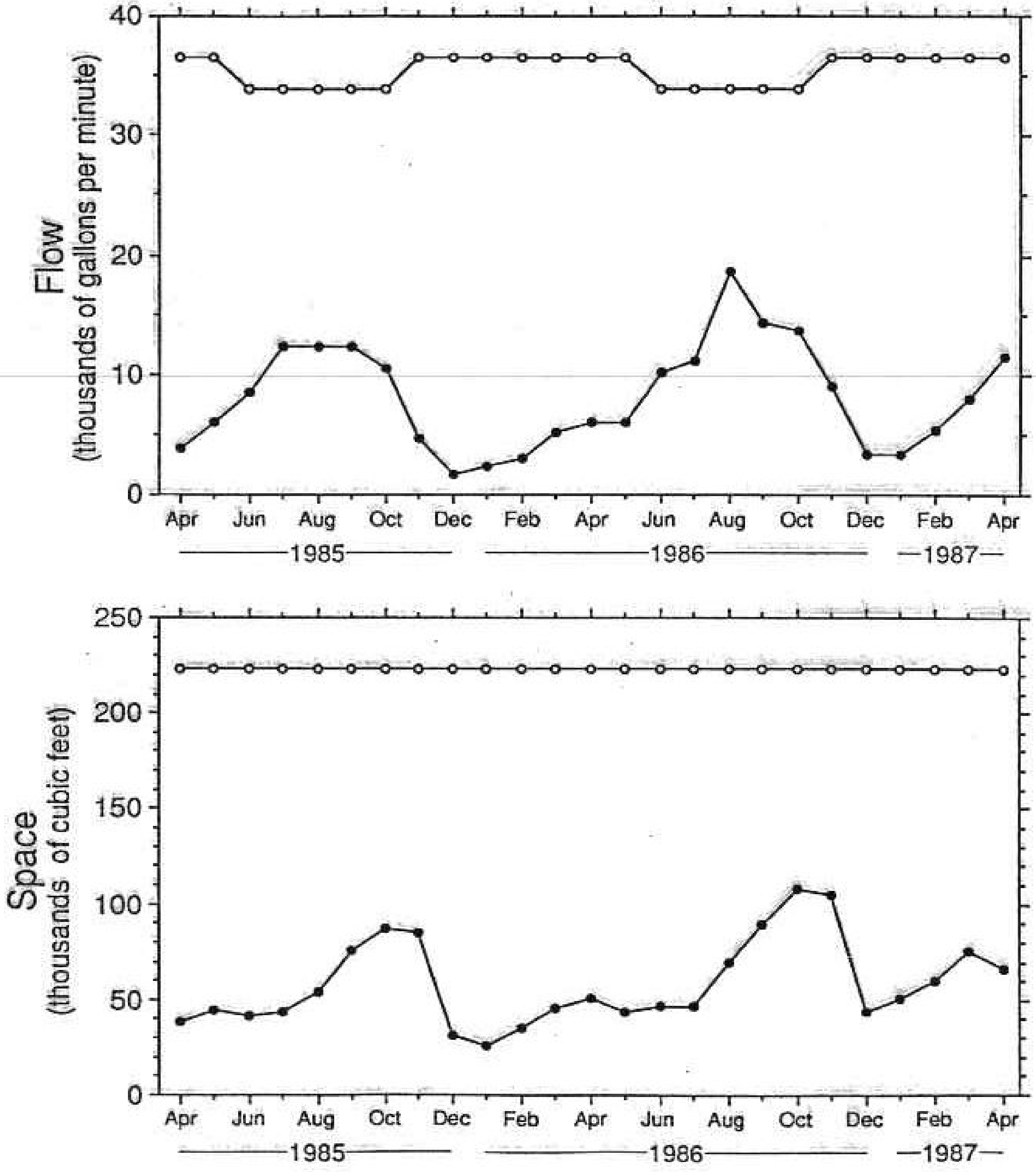


Figure 24. Flow and space use at Willamette Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

Wizard Falls Fish Hatchery

Background

Wizard Falls Fish Hatchery is located 5 miles downstream from Camp Sherman on the Metolius River. Water is obtained from Wizard Springs. A constant 4,500 gpm is available for fish rearing. ODFW owns water rights to the Metolius River, but this water is not used because of potential disease problems and pumping costs. Rainbow trout, brook trout, brown trout, cutthroat trout, kokanee, and Atlantic salmon *Salmo salar* are produced at the hatchery.

Theoretical Flow and Space Requirements

Wizard Falls Fish Hatchery exceeded theoretical production potential during the evaluation period. Maximum theoretical flow requirement from April to June each year ranged between 111% and 139% of the flow available for rearing (Figure 25). Maximum theoretical space requirement in May 1985 and 1986 was between 59% and 60% of the space available for rearing (Figure 25).

Additional Factors

Funding is provided by ODFW, and these funds regulate production level. Additional water and rearing space available at the hatchery is currently not used because of diseases.

Opportunities for Increased Production

Under present conditions, opportunities to increase production at this facility are limited. New rearing technology, such as oxygen supplementation, could be applied. Development of an additional spring could provide 1,500 to 2,500 gpm of additional water.

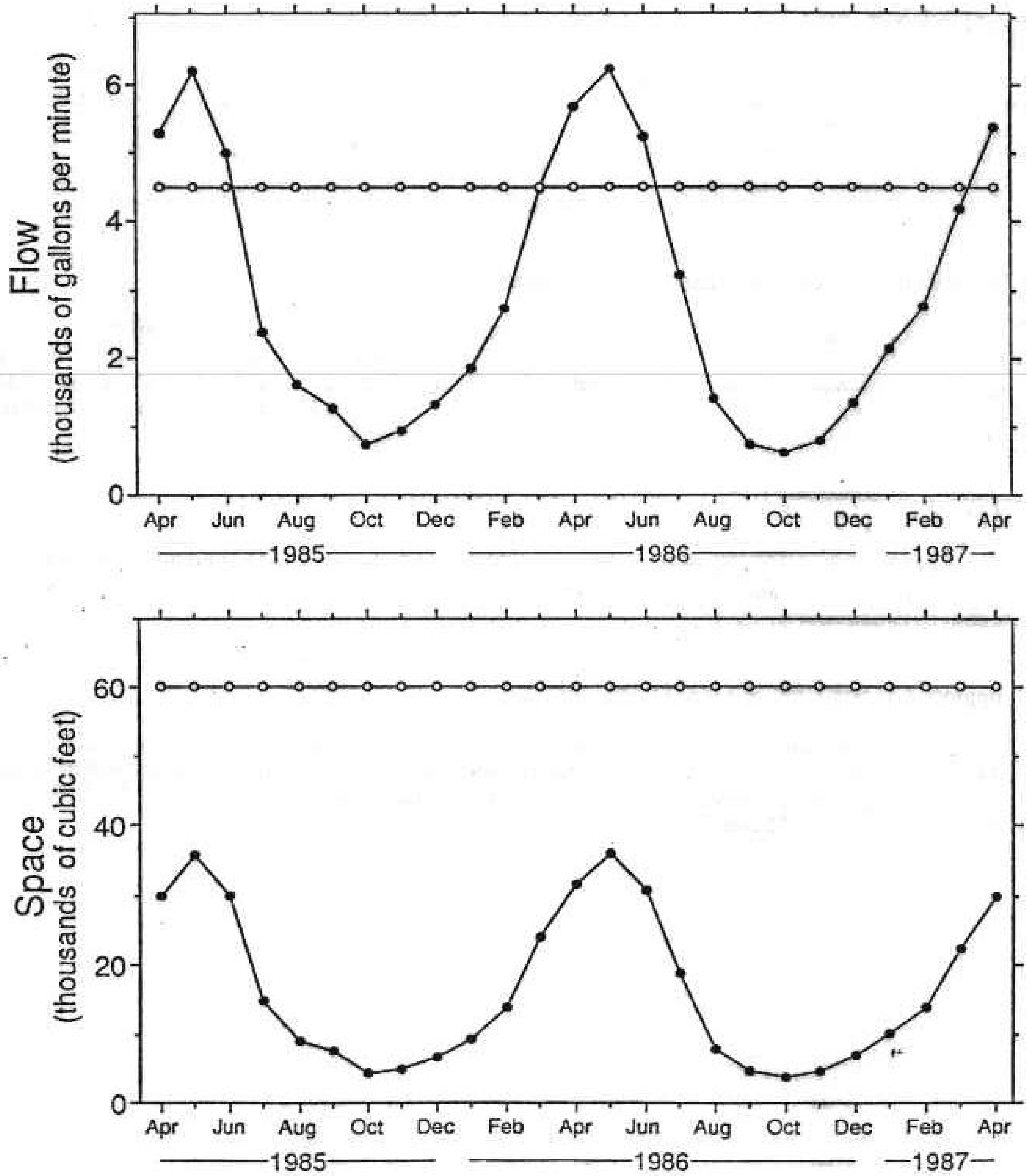


Figure 25. Flow and space use at Wizard Falls Fish Hatchery. Open symbols indicate available flow or space; closed symbols indicate theoretically required flow or space.

SUMMARY AND CONCLUSIONS

Twenty-five inland fish propagation facilities operated by ODFW were evaluated to determine whether they reached theoretical production potential (requiring all available flow or space) between April 1985 and April 1987. The carrying capacity model developed by Liao (1971) and the loading density graph produced by Burrows and Combs (1968) and transformed mathematically by Jeffrey and Associates (1987a) were used to determine total flow and space requirements at each facility each month. Eleven propagation facilities exceeded production potential, with production levels ranging between 104% and 429% of theoretical production potential. The remaining 14 facilities reached an average of 68% production potential. Available flow is (or would become) the limiting factor at 21 facilities, whereas available space is (or would become) the limiting factor at 4 facilities.

Caution must be used before attempting to increase production to the maximum levels indicated. Data on dissolved oxygen concentration and flow were often incomplete. Additional factors which are not addressed in this report influence production potential.

Liao (1971) noted that several factors not included in his model may affect carrying capacity. Burrows and Combs (1968) stated that their loading density graph depicted maximum loading density, and growth rate would decline at higher densities. Neither of these studies evaluated effects of carrying capacity or loading density on survival after release.

Increased production does not necessarily result in increased adult return. Banks (1986), who studied the effects of increased rearing density on adult return of coho salmon, reported a reduced survival rate, but an increase in the total number of adults that returned. His preliminary results with chinook salmon indicated that survival decreased and total number of returning adults did not increase with increased rearing density.

Factors in addition to hatchery conditions should be considered when determining production level. Even if increased additional production increased adult return, the benefit may be outweighed by the cost of producing additional smolts. More hatchery production may have a negative effect on wild populations. Any increase in production should occur gradually, and should include evaluation of hatchery conditions, the effect on adult survival and return, the effect on wild fish, and the cost of producing adults.

REFERENCES

Banks, J. 1986. Effects of raceway inflow and rearing density interactions on adult returns of coho and spring chinook salmon. Pages 47-52 *in* Chapter 6 of the Proceedings of the 37th Annual Northwest Fish Culture Conference. Oregon Department of Fish and Wildlife, Portland.

Burrows, R.E., and B.D. Combs. 1968. Controlled environments for salmon propagation. Progressive Fish-Culturist 30:123-126.

Egna, H.S. 1987. A review of salmonid hatcheries in Oregon. Oregon Department of Fish and Wildlife, Portland.

Elliot, J.W. 1969. The oxygen requirements of chinook salmon. Progressive Fish-Culturist 17:67-73.

Haskell, D.C. 1955. Weight of fish per cubic foot of water in hatchery troughs and ponds. Progressive Fish-Culturist 17:117-118.

Jeffrey and Associates. 1987a. Preliminary capacity utilization evaluation of the Oregon public hatchery facilities. Oregon Coastal Zone Management Association, Newport.

Jeffrey and Associates. 1987b. Evaluation of capacity utilization at fourteen public salmonid propagation facilities which serve the Oregon coast. Oregon Coastal Zone Management Association, Newport.

Liao, P.B. 1971. Water requirements of salmonids. Progressive Fish-Culturist 33:210-215.

Piper, R.G. 1967. An approach to establishing a loading capacity formula for trout hatcheries. Pages 12-13 *in* Proceedings of the 18th Annual Northwest Fish Culture Conference. University of Washington, Seattle.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish hatchery management. U.S. Fish and Wildlife Service, Washington, D.C.

Westers, H. 1970. Carrying capacity of salmonid hatcheries. Progressive Fish-Culturist 32:43-46.

Westers, H., and K.M. Pratt. 1977. Rational design of hatcheries for intensive salmon culture, based on metabolic characteristics. Progressive Fish-Culturist 39:157-165.

Willoughby, H. 1968. A method for calculating carrying capacities of hatchery troughs and ponds. Progressive Fish-Culturist 30:173-174.