In [12]:
```
import numpy as np
import matplotlib.pyplot as plt

from sklearn import metrics
from sklearn.model_selection import train_test_split

from sklearn.neural_network import MLPClassifier
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier
from sklearn import tree
from sklearn.linear_model import LogisticRegression
from sklearn.discriminant_analysis import QuadraticDiscriminantAnalysis
from sklearn.naive_bayes import GaussianNB
from sklearn.ensemble import BaggingClassifier
from sklearn.metrics import accuracy_score
from sklearn import datasets
from sklearn.ensemble import BaggingClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score, confusion_matrix, ConfusionMatrixDisplay
```

In [13]:
```
from scipy.io import loadmat
import pandas as pd

# Carga el archivo .mat
data = loadmat('hsefeatures.mat')

# Muestra las claves (variables) almacenadas en el archivo
print("Variables en el archivo:", data.keys())

# Explora todas las variables y sus shapes
for key in data:
    if not key.startswith('__'):
        print(f"{key}: {type(data[key])}, shape: {getattr(data[key], 'shape', 'N/A')}")

# Accede a la variable 'features' (ajusta el nombre si es diferente)
heart = data['heart']
print("Shape de heart:", heart.shape)



# Si quieres convertirlo a DataFrame (si es 2D)
df = pd.DataFrame(heart)
print(df.head())
```

```
Variables en el archivo: dict_keys(['__header__', '__version__', '__globals__', 'heart'])
heart: <class 'numpy.ndarray'>, shape: (13015, 28)
Shape de heart: (13015, 28)
         0         1         2         3         4         5         6   \
0  0.330670  0.339032 -0.942820 -0.707676  0.501767 -0.119639 -0.447719
1  0.331246  0.336737 -0.927206 -0.694687  0.508971 -0.120814 -0.453824
2  0.331770  0.344386 -0.923716 -0.682372  0.488986 -0.113470 -0.434460
3  0.329360  0.331383 -0.953241 -0.699698  0.492007 -0.112001 -0.435856
4  0.331467  0.347445 -0.898084 -0.699024  0.519661 -0.135503 -0.470572

         7         8         9   ...        18        19        20        21  \
0  1.783492  0.238308 -1.157191  ... -0.144814 -0.308339 -0.020249  0.654093
1  0.807546 -0.053670 -1.076089  ...  0.080666 -0.798582 -0.299248  1.655671
2  1.313518 -0.162544 -1.002464  ...  0.427350  0.263785 -0.124278  1.151582
3  1.026310 -0.231880 -1.094214  ...  0.372958 -0.640030 -0.061730  1.428643
4  1.593459  0.280987 -1.162752  ...  0.349549 -1.186166 -0.042134  1.306349

         22        23        24        25        26   27
0  0.529630  1.324806  0.243527 -0.360307 -0.604145  0.0
1  0.700076  1.906129 -0.162199  0.057421 -0.283001  0.0
2  0.466817  1.671573  1.312135 -0.573021 -0.209402  0.0
3  1.038850  1.715734  0.051105  0.244811 -0.728320  0.0
4  0.369234  2.357850  0.228454 -0.395140  0.325261  0.0

[5 rows x 28 columns]
```

In [14]:
```
print(df[27].unique())
```

```
[0. 1.]
```

In [15]:
```
from sklearn.model_selection import train_test_split

X = df.iloc[:, :-1]  # Todas las columnas menos la última
y = df.iloc[:, -1]   # Última columna (target)

print("Media de cada columna:")
print(X.mean())

print("\nDesviación estándar de cada columna:")
print(X.std())

print("\nMínimo y máximo de cada columna:")
print(X.min())
print(X.max())

Xtrain_flat, Xtest_flat, Ytrain, Ytest = train_test_split(X, y, test_size=1/3)
```

```
Media de cada columna:
0    -1.747012e-17
1    -1.310259e-17
2    -1.921714e-16
3    -2.183766e-16
4     3.057272e-17
5     6.551297e-18
6     1.091883e-17
7    -5.241037e-17
8     5.197362e-16
9    -6.332920e-16
10    1.747012e-17
11    2.271116e-16
12   -5.241037e-17
13   -7.424803e-17
14   -2.375937e-15
15   -6.988050e-17
16    6.988050e-17
17    1.747012e-17
18    9.608569e-17
19    7.861556e-17
20    1.834363e-16
21    5.241037e-17
22    2.096415e-16
23    2.140090e-16
24    1.747012e-16
25    1.747012e-17
26   -1.615987e-16
dtype: float64

Desviación estándar de cada columna:
0     1.0
1     1.0
2     1.0
3     1.0
4     1.0
5     1.0
6     1.0
7     1.0
8     1.0
9     1.0
10    1.0
11    1.0
12    1.0
13    1.0
14    1.0
15    1.0
16    1.0
17    1.0
18    1.0
19    1.0
20    1.0
21    1.0
22    1.0
23    1.0
24    1.0
25    1.0
26    1.0
dtype: float64

Mínimo y máximo de cada columna:
0    -11.604172
1    -11.555400
2     -1.219734
3     -0.931188
4     -8.099012
5     -7.726383
6     -0.637346
7     -7.015409
8     -0.995783
9     -6.334690
10    -2.970653
11    -1.032308
12    -0.655224
13    -1.588776
14    -3.574981
15    -5.088412
16    -4.556387
17    -3.300155
18    -4.392735
19    -3.976942
20    -5.345528
21    -5.136915
22    -4.612269
23    -5.745571
24    -4.956272
25    -8.237134
26    -5.774492
dtype: float64
0      4.613710
1      6.258905
2      8.048074
3      9.402231
4      2.475408
5     10.748313
6     11.811050
7     12.005144
8     46.353210
9      3.174464
10     2.619517
11     8.725121
12     4.078963
13     3.262879
14     3.879935
15     2.465319
16     3.413905
17     4.423456
18     5.145281
19     5.056655
20     5.970279
21     7.667865
22     4.806727
23     5.227834
24     4.643749
25     6.949182
26     4.600157
dtype: float64
```

In [16]:
```
from sklearn.preprocessing import MinMaxScaler

scaler = MinMaxScaler()
X_normalized = scaler.fit_transform(X)
print("Mínimo:", X_normalized.min(axis=0))
print("Máximo:", X_normalized.max(axis=0))
```

```
Mínimo: [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 0. 0. 0.]
Máximo: [1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
 1. 1. 1.]
```

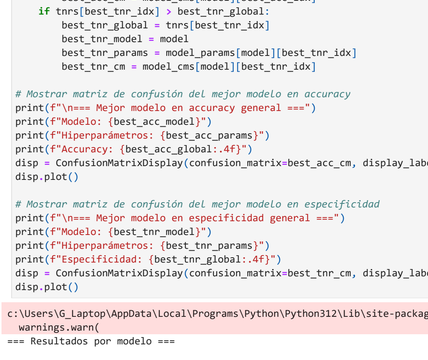
In [9]:
```
# ...existing code...

def LogisticRegressionTraining(Xtrain, Ytrain, Xtest, Ytest, max_iter=500):
    mdl = LogisticRegression(max_iter=max_iter, solver='lbfgs')
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)

def QDATraining(Xtrain, Ytrain, Xtest, Ytest):
    mdl = QuadraticDiscriminantAnalysis()
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)

def KNNTraining(Xtrain, Ytrain, Xtest, Ytest, n_neighbors=5):
    mdl = KNeighborsClassifier(n_neighbors=n_neighbors)
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)

def DecisionTreeTraining(Xtrain, Ytrain, Xtest, Ytest, max_depth=5):
    mdl = tree.DecisionTreeClassifier(max_depth=max_depth)
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)

def GaussianNBTraining(Xtrain, Ytrain, Xtest, Ytest):
    mdl = GaussianNB()
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)

def MLPTraining(Xtrain, Ytrain, Xtest, Ytest, hidden_layer_sizes=(50,), max_iter=300):
    mdl = MLPClassifier(hidden_layer_sizes=hidden_layer_sizes, max_iter=max_iter)
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)

def BaggingKNNTraining(Xtrain, Ytrain, Xtest, Ytest, n_neighbors=5, n_estimators=10):
    mdl = BaggingClassifier(
        estimator=KNeighborsClassifier(n_neighbors=n_neighbors),
        n_estimators=n_estimators,
        random_state=42
```

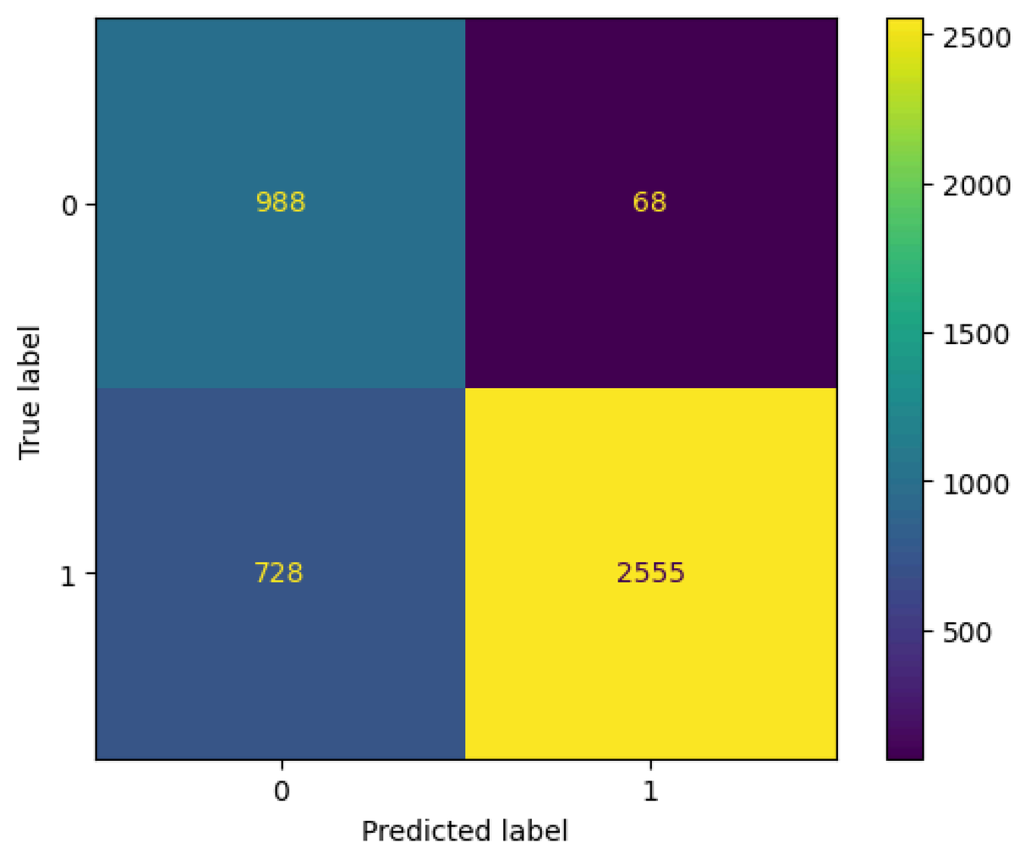
```
    )
    mdl.fit(Xtrain, Ytrain)
    Ypred = mdl.predict(Xtest)
    return accuracy_score(Ytest, Ypred)
# ...existing code...
```

In [ ]:
```
# ...existing code...
import numpy as np
from sklearn.linear_model import LogisticRegression
from sklearn.discriminant_analysis import QuadraticDiscriminantAnalysis
from sklearn.neighbors import KNeighborsClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.ensemble import BaggingClassifier
from sklearn.svm import SVC
from sklearn.metrics import accuracy_score, confusion_matrix, ConfusionMatrixDisplay

def get_metrics(y_true, y_pred):
    cm = confusion_matrix(y_true, y_pred, labels=[0, 1])
    tn, fp, fn, tp = cm.ravel()
    acc = (tp + tn) / (tp + tn + fp + fn)
    tnr = tn / (tn + fp) if (tn + fp) > 0 else 0  # Specificidad
    return acc, tnr, cm

n_iter = 10  # Puedes aumentar para mayor robustez

model_results = {
    "LogisticRegression": [],
    "QDA": [],
    "KNN": [],
    "MLP": [],
    "Bagging": [],
    "SVM": []
}
model_params = {
    "LogisticRegression": [],
    "QDA": [],
    "KNN": [],
    "MLP": [],
    "Bagging": [],
    "SVM": []
}
model_cms = {
    "LogisticRegression": [],
    "QDA": [],
    "KNN": [],
    "MLP": [],
    "Bagging": [],
    "SVM": []
}

# Entrenamiento
for i in range(n_iter):
    # Logistic Regression
    max_iter = np.random.randint(100, 2001)
    mdl = LogisticRegression(max_iter=max_iter, solver='lbfgs')
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["LogisticRegression"].append((acc, tnr))
    model_params["LogisticRegression"].append({"max_iter": max_iter})
    model_cms["LogisticRegression"].append(cm)

    # QDA
    reg_param = np.random.uniform(0, 0.2)
    mdl = QuadraticDiscriminantAnalysis(reg_param=reg_param)
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["QDA"].append((acc, tnr))
    model_params["QDA"].append({"reg_param": reg_param})
    model_cms["QDA"].append(cm)

    # KNN
    n_neighbors = np.random.randint(1, 21)
    mdl = KNeighborsClassifier(n_neighbors=n_neighbors)
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["KNN"].append((acc, tnr))
    model_params["KNN"].append({"n_neighbors": n_neighbors})
    model_cms["KNN"].append(cm)

    # MLP
    hidden_layer_sizes = tuple(np.random.randint(50, 200, size=np.random.randint(1, 3)))
    max_iter = np.random.randint(200, 1001)
    learning_rate_init = 10**np.random.uniform(-4, -1)
    mdl = MLPClassifier(hidden_layer_sizes=hidden_layer_sizes, max_iter=max_iter, learning_rate_init=learning_rate_init)
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["MLP"].append((acc, tnr))
    model_params["MLP"].append({"hidden_layer_sizes": hidden_layer_sizes, "max_iter": max_iter, "learning_rate_init": learning_rate_init})
    model_cms["MLP"].append(cm)

    # Bagging
    n_neighbors = np.random.randint(1, 11)
    n_estimators = np.random.randint(5, 21)
    mdl = BaggingClassifier(
        estimator=KNeighborsClassifier(n_neighbors=n_neighbors),
        n_estimators=n_estimators,
        max_samples=0.5,
        max_features=0.5,
        random_state=42
    )
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["Bagging"].append((acc, tnr))
    model_params["Bagging"].append({"n_neighbors": n_neighbors, "n_estimators": n_estimators})
    model_cms["Bagging"].append(cm)

    # SVM
    C = 10**np.random.uniform(-2, 2)
    gamma = 10**np.random.uniform(-3, 1)
    mdl = SVC(C=C, gamma=gamma, kernel='rbf')
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["SVM"].append((acc, tnr))
    model_params["SVM"].append({"C": C, "gamma": gamma, "kernel": "rbf"})
    model_cms["SVM"].append(cm)

# Mostrar resultados por modelo
print("=== Resultados por modelo ===")
best_acc_global = -1
best_tnr_global = -1
best_acc_model = None
best_tnr_model = None
best_acc_params = None
best_tnr_params = None
best_acc_cm = None
best_tnr_cm = None

for model in model_results:
    arr = np.array(model_results[model])
    accs = arr[:,0]
    tnrs = arr[:,1]
    best_acc_idx = np.argmax(accs)
    best_tnr_idx = np.argmax(tnrs)
    print(f"\nModelo: {model}")
    print(f"  Accuracy promedio: {accs.mean():.4f}")
    print(f"  Mejor accuracy: {accs[best_acc_idx]:.4f} con params {model_params[model][best_acc_idx]}")
    print(f"  Especificidad promedio (TNR): {tnrs.mean():.4f}")
    print(f"  Mejor especificidad: {tnrs[best_tnr_idx]:.4f} con params {model_params[model][best_tnr_idx]}")

    # Guardar mejor global
    if accs[best_acc_idx] > best_acc_global:
        best_acc_global = accs[best_acc_idx]
        best_acc_model = model
        best_acc_params = model_params[model][best_acc_idx]
        best_acc_cm = model_cms[model][best_acc_idx]
    if tnrs[best_tnr_idx] > best_tnr_global:
        best_tnr_global = tnrs[best_tnr_idx]
        best_tnr_model = model
        best_tnr_params = model_params[model][best_tnr_idx]
        best_tnr_cm = model_cms[model][best_tnr_idx]

# Mostrar matriz de confusión del mejor modelo en accuracy
print(f"\n=== Mejor modelo en accuracy general ===")
print(f"Modelo: {best_acc_model}")
print(f"Hiperparámetros: {best_acc_params}")
print(f"Accuracy: {best_acc_global:.4f}")
disp = ConfusionMatrixDisplay(confusion_matrix=best_acc_cm, display_labels=[0, 1])
disp.plot()

# Mostrar matriz de confusión del mejor modelo en especificidad
print(f"\n=== Mejor modelo en especificidad general ===")
print(f"Modelo: {best_tnr_model}")
print(f"Hiperparámetros: {best_tnr_params}")
print(f"Especificidad: {best_tnr_global:.4f}")
disp = ConfusionMatrixDisplay(confusion_matrix=best_tnr_cm, display_labels=[0, 1])
disp.plot()
```

```
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (978) reached and the optimization hasn't converged yet.
  warnings.warn(
=== Resultados por modelo ===

Modelo: LogisticRegression
  Accuracy promedio: 0.8615
  Mejor accuracy: 0.8615 con params {'max_iter': 582}
  Especificidad promedio (TNR): 0.6723
  Mejor especificidad: 0.6723 con params {'max_iter': 582}

Modelo: QDA
  Accuracy promedio: 0.8400
  Mejor accuracy: 0.8472 con params {'reg_param': 0.18901617968047776}
  Especificidad promedio (TNR): 0.9120
  Mejor especificidad: 0.9356 con params {'reg_param': 0.015942282030095112}

Modelo: KNN
  Accuracy promedio: 0.9122
  Mejor accuracy: 0.9265 con params {'n_neighbors': 4}
  Especificidad promedio (TNR): 0.8026
  Mejor especificidad: 0.8902 con params {'n_neighbors': 4}

Modelo: MLP
  Accuracy promedio: 0.9186
  Mejor accuracy: 0.9286 con params {'hidden_layer_sizes': (130, 173), 'max_iter': 486, 'learning_rate_init': 0.0018516696315852466}
  Especificidad promedio (TNR): 0.8244
  Mejor especificidad: 0.8712 con params {'hidden_layer_sizes': (166, 100), 'max_iter': 850, 'learning_rate_init': 0.00826068770973839}

Modelo: Bagging
  Accuracy promedio: 0.9130
  Mejor accuracy: 0.9290 con params {'n_neighbors': 1, 'n_estimators': 16}
  Especificidad promedio (TNR): 0.7734
  Mejor especificidad: 0.8390 con params {'n_neighbors': 1, 'n_estimators': 16}

=== Mejor modelo en accuracy general ===
Modelo: Bagging
Hiperparámetros: {'n_neighbors': 1, 'n_estimators': 16}
Accuracy: 0.9290

=== Mejor modelo en especificidad general ===
Modelo: QDA
Hiperparámetros: {'reg_param': 0.015942282030095112}
Especificidad: 0.9356
```

Out[ ]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1296a649a30>





La menor cantidad son enfermos

maximizar la especifidad

Cross validation

In [11]:
```python
from sklearn.model_selection import StratifiedKFold, cross_val_predict

cv = StratifiedKFold(n_splits=5, shuffle=True)
model_funcs = {
    "LogisticRegression": lambda hp: LogisticRegression(max_iter=hp["max_iter"], solver='lbfgs'),
    "QDA": lambda hp: QuadraticDiscriminantAnalysis(reg_param=hp["reg_param"]),
    "KNN": lambda hp: KNeighborsClassifier(n_neighbors=hp["n_neighbors"]),
    "MLP": lambda hp: MLPClassifier(hidden_layer_sizes=hp["hidden_layer_sizes"], max_iter=hp["max_iter"], learning_rate_init=hp["learning_rate_init"]),
    "Bagging": lambda hp: BaggingClassifier(
        estimator=KNeighborsClassifier(n_neighbors=hp["n_neighbors"]),
        n_estimators=hp["n_estimators"],
        max_samples=0.5,
        max_features=0.5,
        random_state=42
    )
}

n_iter = 10
metrics_results = {k: [] for k in model_funcs}
params_results = {k: [] for k in model_funcs}
best_tnr = -1
best_model = None
best_hp = None
best_cm = None

for model_name, build_model in model_funcs.items():
    for i in range(n_iter):
        # Hiperparámetros aleatorios
        if model_name == "LogisticRegression":
            hp = {"max_iter": np.random.randint(100, 2001)}
        elif model_name == "QDA":
            hp = {"reg_param": np.random.uniform(0, 0.2)}
        elif model_name == "KNN":
            hp = {"n_neighbors": np.random.randint(1, 21)}
        elif model_name == "MLP":
            hp = {
                "hidden_layer_sizes": tuple(np.random.randint(50, 200, size=np.random.randint(1, 3))),
                "max_iter": np.random.randint(200, 1001),
                "learning_rate_init": 10**np.random.uniform(-4, -1)
            }
        elif model_name == "Bagging":
            hp = {
                "n_neighbors": np.random.randint(1, 11),
                "n_estimators": np.random.randint(5, 21)
            }
        else:
            continue

        model = build_model(hp)
        # cross_val_predict para obtener predicciones de CV
        y_pred = cross_val_predict(model, X, y, cv=cv)
        acc, tnr, cm = get_metrics(y, y_pred)
        metrics_results[model_name].append((acc, tnr))
        params_results[model_name].append(hp)
        if tnr > best_tnr:
            best_tnr = tnr
            best_model = model_name
            best_hp = hp
            best_cm = cm

# Mostrar promedios
for model in metrics_results:
    arr = np.array(metrics_results[model])
    print(f"\nModelo: {model}")
    print(f"  Accuracy promedio: {arr[:,0].mean():.4f}")
    print(f"  Especificidad promedio (TNR): {arr[:,1].mean():.4f}")

# Mostrar el mejor modelo en especificidad y su matriz de confusión
print(f"\nMejor modelo en especificidad: {best_model}")
print(f"Hiperparámetros: {best_hp}")
print(f"Especificidad: {best_tnr:.4f}")
disp = ConfusionMatrixDisplay(confusion_matrix=best_cm, display_labels=[0, 1])
disp.plot()
```

```
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\linear_model\_logistic.py:1237: FutureWarning: 'multi_class' was deprecated in version 1.5 and will be removed in 1.7. From then on, binary problems will be fit as proper binary  logistic regression models (as if multi_class='ovr' were set). Leave it to its default value to avoid this warning.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\linear_model\_logistic.py:1237: FutureWarning: 'multi_class' was deprecated in version 1.5 and will be removed in 1.7. From then on, binary problems will be fit as proper binary  logistic regression models (as if multi_class='ovr' were set). Leave it to its default value to avoid this warning.
  warnings.warn(
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  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:698: UserWarning: Training interrupted by user.
  warnings.warn("Training interrupted by user.")
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (866) reached and the optimization hasn't converged yet.
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c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (238) reached and the optimization hasn't converged yet.
  warnings.warn(
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c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (360) reached and the optimization hasn't converged yet.
  warnings.warn(
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  warnings.warn(
```
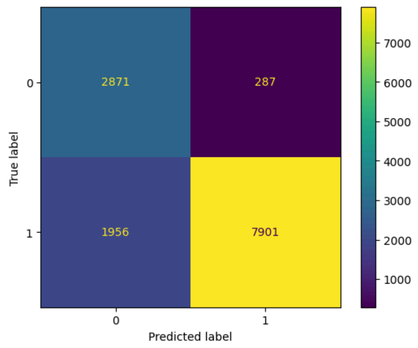

```
Modelo: LogisticRegression
  Accuracy promedio: 0.8610
  Especificidad promedio (TNR): 0.6447

Modelo: QDA
  Accuracy promedio: 0.8389
  Especificidad promedio (TNR): 0.8930

Modelo: KNN
  Accuracy promedio: 0.9259
  Especificidad promedio (TNR): 0.8225

Modelo: MLP
  Accuracy promedio: 0.9242
  Especificidad promedio (TNR): 0.8339

Modelo: Bagging
  Accuracy promedio: 0.9145
  Especificidad promedio (TNR): 0.7635

Mejor modelo en especificidad: QDA
Hiperparámetros: {'reg_param': 0.028878711370122146}
Especificidad: 0.9091
```

Out[11]:
```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1296a3af3e0>
```



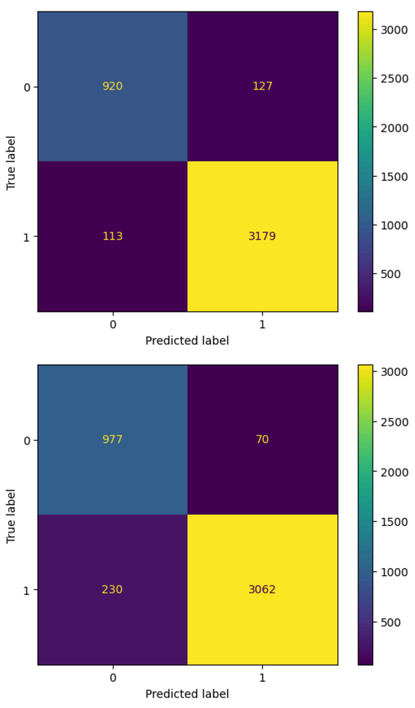
In [17]:

```python
# ...existing code...
import numpy as np
from sklearn.linear_model import LogisticRegression
from sklearn.discriminant_analysis import QuadraticDiscriminantAnalysis
from sklearn.neighbors import KNeighborsClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.ensemble import BaggingClassifier
from sklearn.svm import SVC
from sklearn.metrics import accuracy_score, confusion_matrix, ConfusionMatrixDisplay

def get_metrics(y_true, y_pred):
    cm = confusion_matrix(y_true, y_pred, labels=[0, 1])
    tn, fp, fn, tp = cm.ravel()
    acc = (tp + tn) / (tp + tn + fp + fn)
    tnr = tn / (tn + fp) if (tn + fp) > 0 else 0  # Specificidad
    return acc, tnr, cm

n_iter = 100  # Puedes aumentar para mayor robustez

model_results = {
    "LogisticRegression": [],
    "QDA": [],
    "KNN": [],
    "MLP": [],
    "Bagging": [],
    "SVM": []
}
model_params = {
    "LogisticRegression": [],
    "QDA": [],
    "KNN": [],
    "MLP": [],
    "Bagging": [],
    "SVM": []
}
model_cms = {
    "LogisticRegression": [],
    "QDA": [],
    "KNN": [],
    "MLP": [],
    "Bagging": [],
    "SVM": []
}

# Entrenamiento
for i in range(n_iter):
    # Logistic Regression
    max_iter = np.random.randint(100, 2001)
    mdl = LogisticRegression(max_iter=max_iter, solver='lbfgs')
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["LogisticRegression"].append((acc, tnr))
    model_params["LogisticRegression"].append({"max_iter": max_iter})
    model_cms["LogisticRegression"].append(cm)

    # QDA
    reg_param = np.random.uniform(0, 0.2)
    mdl = QuadraticDiscriminantAnalysis(reg_param=reg_param)
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["QDA"].append((acc, tnr))
    model_params["QDA"].append({"reg_param": reg_param})
    model_cms["QDA"].append(cm)

    # KNN
    n_neighbors = np.random.randint(1, 21)
    mdl = KNeighborsClassifier(n_neighbors=n_neighbors)
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["KNN"].append((acc, tnr))
    model_params["KNN"].append({"n_neighbors": n_neighbors})
    model_cms["KNN"].append(cm)

    # MLP
    hidden_layer_sizes = tuple(np.random.randint(50, 200, size=np.random.randint(1, 3)))
    max_iter = np.random.randint(200, 1001)
    learning_rate_init = 10**np.random.uniform(-4, -1)
    mdl = MLPClassifier(hidden_layer_sizes=hidden_layer_sizes, max_iter=max_iter, learning_rate_init=learning_rate_init)
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["MLP"].append((acc, tnr))
    model_params["MLP"].append({"hidden_layer_sizes": hidden_layer_sizes, "max_iter": max_iter, "learning_rate_init": learning_rate_init})
    model_cms["MLP"].append(cm)

    # Bagging
    n_neighbors = np.random.randint(1, 11)
    n_estimators = np.random.randint(5, 21)
    mdl = BaggingClassifier(
        estimator=KNeighborsClassifier(n_neighbors=n_neighbors),
        n_estimators=n_estimators,
        max_samples=0.5,
        max_features=0.5,
        random_state=42
    )
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["Bagging"].append((acc, tnr))
    model_params["Bagging"].append({"n_neighbors": n_neighbors, "n_estimators": n_estimators})
    model_cms["Bagging"].append(cm)

    # SVM
    C = 10**np.random.uniform(-2, 2)
    gamma = 10**np.random.uniform(-3, 1)
    mdl = SVC(C=C, gamma=gamma, kernel='rbf')
    mdl.fit(Xtrain_flat, Ytrain)
    Ypred = mdl.predict(Xtest_flat)
    acc, tnr, cm = get_metrics(Ytest, Ypred)
    model_results["SVM"].append((acc, tnr))
    model_params["SVM"].append({"C": C, "gamma": gamma, "kernel": "rbf"})
    model_cms["SVM"].append(cm)

# Mostrar resultados por modelo
print("=== Resultados por modelo ===")
best_acc_global = -1
best_tnr_global = -1
best_acc_model = None
best_tnr_model = None
best_acc_params = None
best_tnr_params = None
best_acc_cm = None
best_tnr_cm = None

for model in model_results:
    arr = np.array(model_results[model])
    accs = arr[:,0]
    tnrs = arr[:,1]
    best_acc_idx = np.argmax(accs)
    best_tnr_idx = np.argmax(tnrs)
    print(f"\nModelo: {model}")
    print(f"  Accuracy promedio: {accs.mean():.4f}")
    print(f"  Mejor accuracy: {accs[best_acc_idx]:.4f} con params {model_params[model][best_acc_idx]}")
    print(f"  Especificidad promedio (TNR): {tnrs.mean():.4f}")
    print(f"  Mejor especificidad: {tnrs[best_tnr_idx]:.4f} con params {model_params[model][best_tnr_idx]}")

    # Guardar mejor global
    if accs[best_acc_idx] > best_acc_global:
        best_acc_global = accs[best_acc_idx]
        best_acc_model = model
        best_acc_params = model_params[model][best_acc_idx]
        best_acc_cm = model_cms[model][best_acc_idx]
    if tnrs[best_tnr_idx] > best_tnr_global:
        best_tnr_global = tnrs[best_tnr_idx]
        best_tnr_model = model
        best_tnr_params = model_params[model][best_tnr_idx]
        best_tnr_cm = model_cms[model][best_tnr_idx]

# Mostrar matriz de confusión del mejor modelo en accuracy
print(f"\n=== Mejor modelo en accuracy general ===")
print(f"Modelo: {best_acc_model}")
print(f"Hiperparámetros: {best_acc_params}")
print(f"Accuracy: {best_acc_global:.4f}")
disp = ConfusionMatrixDisplay(confusion_matrix=best_acc_cm, display_labels=[0, 1])
disp.plot()

# Mostrar matriz de confusión del mejor modelo en especificidad
print(f"\n=== Mejor modelo en especificidad general ===")
print(f"Modelo: {best_tnr_model}")
print(f"Hiperparámetros: {best_tnr_params}")
print(f"Especificidad: {best_tnr_global:.4f}")
disp = ConfusionMatrixDisplay(confusion_matrix=best_tnr_cm, display_labels=[0, 1])
disp.plot()
```

```
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (413) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (672) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (473) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (206) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (220) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (347) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (826) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (414) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (247) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (555) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (812) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (378) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (825) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (448) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (603) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (797) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (509) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (296) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (794) reached and the optimization hasn't converged yet.
  warnings.warn(
c:\Users\G_Laptop\AppData\Local\Programs\Python\Python312\Lib\site-packages\sklearn\neural_network\_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (515) reached and the optimization hasn't converged yet.
  warnings.warn(
```

```
=== Resultados por modelo ===

Modelo: LogisticRegression
  Accuracy promedio: 0.8594
  Mejor accuracy: 0.8594 con params {'max_iter': 1268}
  Especificidad promedio (TNR): 0.6285
  Mejor especificidad: 0.6285 con params {'max_iter': 1268}

Modelo: QDA
  Accuracy promedio: 0.8290
  Mejor accuracy: 0.8366 con params {'reg_param': 0.14807051562378964}
  Especificidad promedio (TNR): 0.8928
  Mejor especificidad: 0.9207 con params {'reg_param': 0.003945502721216321}

Modelo: KNN
  Accuracy promedio: 0.9124
  Mejor accuracy: 0.9447 con params {'n_neighbors': 1}
  Especificidad promedio (TNR): 0.7895
  Mejor especificidad: 0.9331 con params {'n_neighbors': 2}

Modelo: MLP
  Accuracy promedio: 0.9129
  Mejor accuracy: 0.9299 con params {'hidden_layer_sizes': (180, 120), 'max_iter': 318, 'learning_rate_init': 0.0017768300862646847}
  Especificidad promedio (TNR): 0.7946
  Mejor especificidad: 0.8663 con params {'hidden_layer_sizes': (193, 64), 'max_iter': 782, 'learning_rate_init': 0.002024344626166948}

Modelo: Bagging
  Accuracy promedio: 0.9091
  Mejor accuracy: 0.9265 con params {'n_neighbors': 1, 'n_estimators': 12}
  Especificidad promedio (TNR): 0.7423
  Mejor especificidad: 0.8367 con params {'n_neighbors': 1, 'n_estimators': 6}

Modelo: SVM
  Accuracy promedio: 0.8476
  Mejor accuracy: 0.9336 con params {'C': 2.7656686440028526, 'gamma': 0.2712132263039592, 'kernel': 'rbf'}
  Especificidad promedio (TNR): 0.4544
  Mejor especificidad: 0.8558 con params {'C': 45.841954312918844, 'gamma': 0.058704729132111465, 'kernel': 'rbf'}

=== Mejor modelo en accuracy general ===
Modelo: KNN
Hiperparámetros: {'n_neighbors': 1}
Accuracy: 0.9447

=== Mejor modelo en especificidad general ===
Modelo: KNN
Hiperparámetros: {'n_neighbors': 2}
Especificidad: 0.9331
```

Out[17]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1296ad4d730>



In [ ]:
```
# Exportar solo a HTML
import os
notebook_path = os.path.abspath('GuevaraG-EvaluarModelosTaller.ipynb')
!jupyter nbconvert --to html "{notebook_path}"

# Mostrar la ruta del archivo HTML generado
html_path = notebook_path.replace('.ipynb', '.html')
print(f"HTML generado en: {html_path}")
```